THE

SEWAGE QUESTION:

BEING A

GENERAL REVIEW OF ALL SYSTEMS AND

HITHERTO EMPLOYED IN VARIOUS COUNTRIES

FOR DRAINING CITIES AND UTILISING SEWAGE:

TREATED WITH REFERENCE TO

Public Health, Agriculture, and National Economy generally.

ALSO A DESCRIPTION

CAPTAIN LIERNUR'S SYSTEM

FOR DAILY INOFFENSIVE REMOVAL OF FÆCAL SOLIDS, FLUIDS, AND GASES BY PNEUMATIC FORCE, COMBINED WITH AN IMPROVED METHOD OF SEWAGE UTILISATION.

COMPILED FOR THE INFORMATION OF SANITARY AND MUNICIPAL AUTHORITIES, AND ALL INTERESTED IN AGRICULTURAL DEVELOPMENT.

BY

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FREIEN DEUTSCHEN HOCHSTIFT, AND OF THE SENCKENBERGISCHEN NATURFORSCHENDEN GESELLSCHAFT
AT FRANKFORT ON THE MAINE, ETC.

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To

HIS ROYAL HIGHNESS

PRINCE HENRY OF THE NETHERLANDS,

GOVERNOR OF THE GRAND-DUCHY OF LUXEMBURG,

VICE-ADMIRAL OF THE DUTCH NAVY,

PROTECTOR OF THE ACADEMY AT DELFT,

ETC. ETC. ETC.

THE GENEROUS AND ENLIGHTENED PROTECTOR OF A NEW INVENTION

DESTINED TO INAUGURATE

SANITARY, AGRICULTURAL, AND SOCIAL REFORMS,

This Work

IS MOST RESPECTFULLY DEDICATED

BY

THE AUTHOR.

PREFACE.

THE SEWAGE QUESTION resolves itself into this: What is the cheapest and most efficient technical process for rendering human excreta useful instead of dangerous?

To answer it we give, in the following pages, a succinct account of all the various systems hitherto employed for that purpose; and having drawn our information from the most reliable authorities, both English and foreign, leave the reader to form his own conclusions, not doubting but that, on the whole, they will coincide with our own.

Among the most valuable of these sources, of which we have principally availed ourselves, are the writings of Captain CHARLES T. LIERNUR, Civil and Military Engineer, who, during a number of years, has professedly had an extensive practice in various branches of engineering on both sides of the Atlantic. When we first contemplated to publish the result of our studies, he willingly placed at our disposal his own scientific and technical investigations on the subject in the shape of voluminous notes, with proper references for collating the facts mentioned.

Among these notes we found a description of a new plan invented by him, called the PNEUMATIC SEWERAGE SYSTEM, which, after a close and conscientious investigation, we herewith submit, as, in our opinion, the best solution thus far given to a really difficult problem.

In this view we are not only countenanced by the approval of eminent engineers and agriculturists, who have, like us, carefully examined the invention, and of several scientific periodicals giving a critical description of it, but also by HIS ROYAL HIGHNESS PRINCE HENRY OF THE NETHERLANDS, who, after mature deliberation, recommended it for adoption in the Grand Duchy of LUXEMBURG; and, further, by the now well-known fact, that the City of the HAGUE, after having submitted Captain LIERNUR'S plan to a committee of professional inquiry, resolved *at once* to give it a fair practical trial at the public expense. Finally, the new system commends itself to general attention, because it is not some 'untried scheme of uncertain issue,' but a combination of practical contrivances with the actual working of which we are all familiar.

There can be no doubt of the high importance of the subject. Apart from the sanitary considerations involved, it directly bears upon the agricultural development of the country. All mechanical skill and industry, and all commercial enterprise, avail but little in the end, unless we also stimulate the soil to yield the largest crops without impairing its permanent fertility.

Scientific demonstration and practical experience go far to show, that the best means to obtain such harvests consist in properly utilising the ashes of the food we consume and the fructifying gases contained therein; in adopting improved modes of tillage; and further, in securing an increased action of the sun and atmosphere, such as may be suggested by a higher knowledge of vegetable physiology.

Leaving these latter means to be developed by future inventive talent, and treated by abler pens, we have endeavoured to contribute our mite to the solution of the former, as those more immediately necessary.

These pages are principally prepared for the information of Municipal authorities and all others directly interested in Public Health, Agriculture, and National Progress; but in order to bring them also within the easy comprehension of other readers, we have thought proper here and there to explain certain elementary facts, generally within the compass only of strictly professional men, avoiding at the same time all technicalities wherever practicable.

May our labour not prove in vain, but assist in opening and smoothing the road to new fields of honourable and useful enterprise!

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I. CITY SEWERAGE BEARING ON NATIONAL ECONOMY.

It need hardly be stated that the removal of human excrements out of cities and towns has always been a question of the highest importance, both from considerations of public health and national economy. It is, however, in later years only that a more serious interest has been excited with regard to city sewerage, and this is mainly owing to three causes:—

In the first place, modern civilisation seems to mass the increase of population almost exclusively in large cities and towns, whilst that of the open country remains nearly stationary, thus rendering the necessity for effective municipal sanitary measures and reforms daily more urgent.

In the second place, the sciences bearing directly upon agriculture, namely chemistry and vegetable physiology, have during the present century made immense strides, proving conclusively the surpassing value of human excrements as a fertiliser, and pointing out new and improved modes of utilising them.

In the third place, notwithstanding these universally acknowledged facts, our daily experience teaches us, that the technical means hitherto employed have proved partially or wholly inadequate to meet the requirements in view; for it appears that in many cities, which were thought to be well drained, often at enormous cost—soil, water, and atmosphere are still contaminated by the decomposition of human excrements, resulting in endemic fevers and deadly epidemics; whilst, on the other hand, our present modes of using sewage matter for agricultural purposes, either yield only poor grass on sandy uninhabitable spots, or render, by their manipulations, human manure so expensive or worthless, that farmers cannot be induced to apply it on any extensive scale—all conclusively showing that the various problems before us are as yet far from being solved.

No wonder then that the city sewerage question so pre-eminently occupies the minds of all thinking men, but more especially of those to whom, by their official capacity, public health and welfare are entrusted. Luckily, the many able discussions of the subject, by parliamentary committees, municipal authorities, scientific and technical societies, agricultural clubs and colleges, and other public and private bodies, have resulted in such a mass of highly valuable materials, in the shape of committee reports, treatises, pamphlets, scientific accounts of experiments, &c., that we are now in a very favourable position for forming a conclusive opinion of the subject in nearly all its bearings.

As stated in our preface, the question resolves itself simply into this:—*What are the cheapest and most effective technical means for rendering human excrements useful instead of dangerous?*

Experience being the safest guide in all matters of practical detail, it is but policy to ascertain the results of all the various plans hitherto adopted.

But first we will cast a glance at the bearings of the subject upon *those general interests which form the salient points of* NATIONAL ECONOMY, *namely* PUBLIC HEALTH and AGRICULTURE, *having reference in doing so to the lessons taught us by the history of* the past and present times.

Of all the sciences we cultivate, surely there is none of higher importance to the prosperity and happiness of a nation than the *Science of Public Health*, which lies at the very root of all good government. Governments being instituted amongst men to secure them life, liberty, and happiness, and none of these being possible without public health, history teaches us, in numerous instances, the baneful consequences of this principle being ever lost sight of. Whenever a people were considered to exist merely for the support and benefit of a government or dynasty, public health and its fountain-head agriculture were invariably utterly neglected, and national prosperity destroyed.

Nor could any extension of empire, or warlike prowess and glory, or peculiar political theories, or diplomatic combinations, ever raise a people to that high standard of civilisation and happiness it would surely have reached, by peacefully developing the immense wealth infallibly secured by a rational, systematic culture of the soil, and consequent industry and commerce. All nations seeking to secure greatness by war and conquest have become more or less morally and politically debased; and so it will ever be to the end of time.

The reason of this is obvious. Whenever agriculture is reduced to a mere gathering of harvests, the soil will become exhausted in time, and will not any longer bear adequate crops; and the want of nourishing food constantly lessening physical development, moral debasement, vice, and crime necessarily follow. The ancient maxim, 'Mens sana in corpore sano,' was meant to express the important fact, that the general standard of public morals always corresponds with the state of public health, the latter depending again upon abundance of food combined with a pure atmosphere and an unlimited supply of undefiled water. All efforts at sound civil government must fail, unless they secure these primary conditions of human happiness.

According to all military experience, the strength of a fortress depends upon the number of barrels of bread and beef within, and the mightiest stronghold must at last surrender to hunger and want: even so it is with a nation!

Let it be subjected to ever so firm a rule, if agriculture is neglected, the voice of nature soon proves itself stronger than the greatest efforts of government; and the masses always ascribing their sufferings to misrule, a revolution is the inevitable result, unless the brewing storm is timely averted by war upon a neighbouring and more prosperous nation, to whom then the direful consequences of a neglect of agriculture are transferred.

Defining agriculture to be that treatment of the soil which perpetuates fertility, a most interesting illustration of the powerful influence of this important science upon the destinies of a nation is afforded by the history of France. Under the old Bourbon dynasty it was totally neglected, and at the same time, also, nearly all the other branches of national industry and commerce. Wars were undertaken to afford pleasure and glory to a Louis Quatorze, or to satisfy the whims of a minister or a mistress. A small centre of luxury and profligacy at Paris and Versailles was surrounded by an immense territory of hunger and want. Moral perceptions getting constantly more dimmed, no wonder that the people soon began to doubt the divine right of princes who ignored their very claims to existence, and that they extended their infidelity in time even to religion. The natural consequence was the great French Revolution, breaking down all political and social barriers, and sweeping away, like an angry torrent, all obstructions to national welfare.

The marvellous genius of a Napoleon soon restored order to the chaos, by a code of laws which seems almost the result of inspiration, reviving commercial and industrial enterprise, and bringing hundreds of thousands of acres under cultivation, which had been waste for centuries. The abundance of food and all the means of subsistence produced by this statesmanlike policy resulted in such an increase of population, that, notwithstanding the desolating wars from 1793 to 1815, which cost nearly three millions of men, the population of France was greater at the close of that period than it was twenty-three years before.

In nothing is the superior wisdom of the present Emperor of the French so manifest as in the undivided attention he, like the founder of his dynasty, pays to the sanitary, agricultural, industrial, and commercial interests of his people, which thus manifestly proves that true statesmanship finds its best allies in agriculture and public health.

By the glorious initiative of Napoleon III., an international sanitary commission is now labouring to stop the fountain-head of epidemics in the distant East, by enforcing certain sanitary measures on the immense annual caravans of Mussulman pilgrimage. Let us all share in this truly philanthropic work by contributing, each one in his sphere, towards sanitary reforms, especially in the sewerage of our cities and towns, and thereby gradually exterminate the hotbeds of pestilence festering in our midst.

We conclude these general introductory remarks by referring to the fundamental laws of national economy, so lucidly laid down by Professor Thudichum:[1]

1. The basis of human life, the very root of all human society, is the capacity to produce food in such quantities, that a surplus of it may be exchanged for commodities resulting from the labours of other people unable to produce food.
2. This capacity to produce food must be rendered permanent by a strict observance of the laws of nature regulating vegetable life, the knowledge of which is the basis of agricultural science.
3. The first and most important of these laws is, that we must return to the soil the mineral ingredients we take from it in

[1] Prof. Thudichum: 'Grundlagen der öffentlichen Gesundheitspflege in Städten.' Frankfurt a/M., 1865.

gathering our crops. The atmosphere furnishes the nutritive elements, and the soil the minerals, out of which vegetable fibres, vessels, and structures containing food are built up. Without these mineral ingredients, no harvest can possibly flourish.

4. These mineral ingredients are continually ejected from human beings and animals in their excrements, by returning which to the soil we furnish it with building materials for new crops; at the same time keeping pure the atmosphere we breathe and the water we drink, and thus preventing epidemics and death.

These laws of national economy are based on the sublime laws of nature, and their neglect is inevitably followed by national decay. The illustrious Liebig, who has devoted his mighty intellect and talents to the discovery of the laws of vegetable life, raising thereby agricultural chemistry to its present astounding eminence, very justly remarks, that *every law of nature is the ready servant of mankind; beneficent when rightly employed, but destructive when neglected.*

II. HISTORICAL NOTES ON SEWERAGE.

The removal of excreta out of human habitations is a matter, the origin of which may be traced to the very first dawn of civilisation. An innate abhorrence of matters so very offensive to the senses compels mankind to get rid of them in any way: a natural propensity, shared by many animals (the *carnivora*), which scrape their excrements into the ground, and cover them with earth, or otherwise remove them out of their sight and smell. And if instinct be that by which nature makes known its inviolable laws where reason could not discern them, it is here unmistakably pointed out that the excrements of all *carnivorous* animals at least, including to a certain extent human beings, *should at once be put into the ground.*

1. Sewerage amongst Ancient Nations.—A few items found in the records of antiquity relative to this subject may be found not altogether uninteresting. According to Benfey's Sanscrit Glossary the *ancient Hindoos* had particular houses for performing the offices of nature, called '*Avaskara-Mandira*' (literally 'filth-temple'), which stood separate from human habitations, and were no doubt kept scrupulously clean, as may be inferred from the excessively strict Hindoo laws respecting ablutions and personal cleanliness.

The extensive and complicated canal systems of ancient *Egypt*, executed under Rameses I. and some of his successors, served no doubt also for sewerage purposes, owing to the intense aversion of the ancient Egyptians to all kinds of impurities. *Assyria* and *Babylon* were, according to Herodotus, likewise possessed of most magnificent canals for irrigating the country districts, which were supplied by the rivers Tigris and Euphrates, and which doubtless also carried away the sewage of their cities: the same as in *Phœnicia*, where the art of making canals and harbours was so well known, where drains were first excavated, and asphalt was a regular article of commerce.

2. Mosaic Sanitary Law.—We gain a still clearer insight into the customs of the ancient *Hebrews*, by referring to the ordinance of their great legislator: Deut. xxiii. 12, 13: '*Thou shalt have a place also without the camp, whither thou shalt go forth abroad: And thou shalt have a paddle upon thy weapon; and it shall be, when thou wilt ease thyself abroad, thou shalt dig therewith, and shalt turn back and cover that which cometh from thee.*'

However primitive this mode of disposing of human excrements, it certainly shows plainly enough that the Hebrew lawgiver was fully alive to the necessity of sanitary regulations. The use of fæcal matters as a fertiliser could not yet enter into the consider-

ation of Moses, as he had to deal with a nomadic people just coming out of Egypt, where the annual inundation of the Nile covers the soil with the 'chemi,' or 'black sediment,' as the ancient Egyptians called it. During the period of the kings, when the attention of the Hebrews was almost exclusively devoted to a cruel warfare between contending tribes and dynasties, which struggled for the mastery, and their religion had degenerated into the worship of idols, the sanitary arrangements of the towns were of the rudest kind. So we find that the filth of Jerusalem was burnt in an oven in the valley of Hinnom; which also served for human sacrifices, and was called '*tophet*,' from *toph*, a drum, used on such occasions to drown the cries of the victims. At a later period, however, when the Mosaic religion was restored, the temple purified and rebuilt, and the country began to prosper under the protectorate of powerful neighbouring nations, large sewers and aqueducts were constructed, which still exist, owing to the fact of their being cut in the solid rock upon which the city is built. Eusebius, who was a native of that country, and died about the year 340, mentions Timocrates, the surveyor of Syria, by whom the city was throughout provided with water. The water used for flooding the court of the temple, to wash away the offal and blood of the sacrifices, drained into a pit now called 'the fountain of the Virgin;' from whence, after mingling with the town sewage, it was conducted to a second one, and thence to the King's Garden, for purposes of irrigation. These pits served, no doubt, as settling tanks to collect the solid matter; and thus, in their general arrangement, we can perhaps trace the earliest attempts at utilising sewage.

3. ROMAN CLOACA MAXIMA.—The most interesting monument of antiquity, however, as regards city sewerage, is the famous *Cloaca Maxima* of *Rome*, of which extensive remnants have been preserved to our days, still serving the original purpose, and offering the great advantage of historical certainty to the student. This immense city-sewer, begun under king Tarquinius Priscus about 600 B.C., and finished under his successor, Tarquinius Superbus, was built for the avowed purpose of cleaning the metropolis of human excrements and all other sewage matter, by underground drainage into the Tiber. At street crossings, or wherever one street intercepted another, so called 'trivia' (three ways), urinals were placed, which afterwards from their location were called 'triviæ.'* This work was placed under the superintendence of the 'curatores cloacarum,' who levied a special tax, 'cloacarium,' to keep it in constant repair. It had also a goddess of its own, 'Cloacina,' who, with her sister 'Mephitis,' was meant to protect the Romans against the deadly exhalations of their sewage. In spite of these precautionary measures, and notwithstanding repeated thorough cleansings,—Agrippa enlarged and cleaned the work during the reign of the Emperor Augustus, by leading the waters of the aqueducts through this great drain,—the Cloaca Maxima became gradually filled and choked with mud and rubbish

* It is said that, to the foolish scribblings with which these places, in these ancient times, were covered by the vulgar, the words 'trivial' and 'trifle' owe their origin.

to such a degree, that of the original height of 10½ feet (some writers give the dimensions as 17 feet high and 14 feet wide) at last only 6 to 7 feet were left, as may be seen by the remains still in existence. The immense sums spent on building this work, and the unmistakable skill and genius employed in connecting the main sewer with lateral conduits leading to all parts of the metropolis—all this was not sufficient to attain the purposes in view, but only served to poison the Tiber, and deprive agriculture of a material, the immense importance of which for manuring an exhausted soil was not at all understood in those times.

These well known and indisputable historical facts show that the advocates of the sewerage by water system, chiefly adopted in England, commit a most serious mistake by pointing to the example of ancient Rome as a successful precedent!

4. SEWERAGE IN THE MIDDLE AGES.—Carthage and Alexandria had also well-constructed sewers; and not only were almost all the cities founded by the Romans similarly provided, but, on the downfall of their mighty empire, her pernicious example of wasting sewage, by discharging it into rivers, spread gradually like a slow poison all over Europe; many ambitious founders or rulers of cities employing for the purpose foreign architects, who were either natives of Italy, or had at least pursued their studies in that country, and therefore had naturally the famous Cloaca Maxima constantly as a precedent before their mind's eye. Europe, however, being no longer under the influence of one centralising ruling power, nations and tribes soon entered upon deadly struggles for supremacy; and the sanguinary feudal wars between rival dynasties speedily resulted in the most galling political oppression, and moral and mental degradation.

The architecture of those periods was exclusively devoted to the ruling principles of the age, religion and warfare. Hence arose those majestic domes and spires, monasteries and feudal castles, many of which are still the admiration of mankind; whilst, at the same time, domestic comforts and sanitary requirements were utterly disregarded, religious superstition ascribing, in cases of pestilence, the direct consequences of human folly to the mysterious visitations of higher powers.

The city sewerage of those days was, in the first instance, simply borrowed from the practice of the peasant collecting excremental matters in common pits for manuring purposes. But the nobility and clergy soon began unceremoniously to use the narrow winding streets of crowded cities as open gutters; the citizens followed the example of their betters, and allowed their private pits to overflow in the same direction. Another abomination soon came into practice; fæcal matters were thrown at night from the windows out into the street, passers-by being simply warned by a peculiar call to guard themselves against pollution. Edinburgh, amongst many other cities, was long notorious for this disgusting practice.*

The streets of London, according to Macaulay, at the close of the seventeenth century, were in a similar disgraceful condition; and Sir Walter Scott, in his 'Fair Maid of Perth,' affords us some

* In that city the call was corrupt French, '*Gardez l'eau!*' Paris, and many other continental cities, were likewise conspicuous in that respect.

curious glimpses into the state of sanitary affairs in the Scotch towns of those days. Nor was the aspect of mediæval towns on the Continent any the less disgusting, as may be learned from the minute statements of many historical writers of Germany, France, the Netherlands, Italy, and other countries.

In Holland, the cities being nearly all cut up and divided by concentric canals, the sewage matter was, and, strange to say, in many cases still is, allowed to run into them, continually producing exhalations of the most offensive kind. Even in our days, notwithstanding the superior personal cleanliness of the Dutch people, Holland is continually subject to endemic fevers, and regularly scourged by cholera, typhus, and similar epidemics, the origin of which is now generally ascribed to the horrible effluvia arising from the canals.

The erroneous notion that the noxious elements of fæcal matter can be neutralised by dilution and dissipation in canals, rivers, or harbours, was almost universally entertained; and that the repeated, awful visitations of 'black death,' or plague and pestilence, were never traced to their true origin, can only be ascribed to the strange perversity of the people in regarding their afflictions only from a religious point of view, without endeavouring to study the laws of nature with regard to public health. We need only refer to the many harrowing accounts by various authors of the plague and pestilence, both of ancient and mediæval times, at Athens (430 B.C.), Jerusalem (72 A.D.), Rome (77, 170, 189, 262 A.D.), Constantinople (544), Marseilles (588, 1720), Florence (1348), Milan (1628), London (1563, 1603, 1625, 1636, 1665), and other cities all over the world.

5. NEGLECT OF AGRICULTURE THE RUIN OF NATIONS.—History shows, not less plainly, the baneful consequences of not returning to the soil the minerals extracted from it in gathering harvests. Liebig very justly says: 'The Cloaca Maxima engulphed for centuries the Roman peasant's prosperity; and when his exhausted fields could no longer produce food, the great sewer became equally the ruin of the islands of Sardinia and Sicily, and of the fertile coast of Africa.' *

However this may be, it is evident that, if the strength of a nation or its weakness is to be measured by its populousness, its growth or decay depends also upon the quantity of food to be had within the territory it occupies; for it is an ascertained fact, that the increase or decrease of a population keeps pace not only with the

* Dr. Schultz-Schultzenstein, who disagrees with Liebig's theory of mineral fertilisers, &c., also contradicts in his book on 'Exhaustion of Soils,' the entire correctness of the above quotation, alleging that Liebig has only taken the portion which supports his peculiar ideas, omitting the other; and, in proof of this, gives the whole passage as found in Columella's work, 'De Re Rusticâ,' part 1, p. 19, as follows:—Sæpenumero civitatis nostræ principes audio culpantes modo agrorum infæcunditatem, modo cœli per multa jam tempora noxiam frugibus intemperiem. Existimant ubertate nimia prioris ævi defatigatum et effœtum solum nequire pristina benignitate præbere mortalibus alimenta.

'Quas ego causas procul a veritate abesse certum habeo. Quod neque fas existimare, humi naturam, quam primus ille mundi genitor perpetua fœcundidate donavit, quasi quodam morbo sterilitate affectam: neque prudentis credere, tellurem, quæ divinam et æternam juventam sortita, communis omnium parens dicta sit, quia cuncta peperit semper, et deinceps paritura sit, velut hominem consenuisse,' &c.

average plenty or scarcity of long periods, but even of a few consecutive years, nay, sometimes, of a single harvest, in case of excessive abundance or its opposite. Thus, it appears, times of great scarcity correspond with a lesser number of births and an increased mortality of infants and of the old and decrepit among the poorer classes, which preponderating, as they do, largely in all communities, cannot but affect to a great extent the total number.

Though that most powerful and reliable instrument ever brought to bear in aid of science and the discovery of nature's laws, namely Statistical Record, has in our own times placed this matter beyond dispute, and shown that the annual human increase produced within a country depends as much upon the nourishment to be had within it, as the vegetable crop of a farm depends upon the amount of manure given to the soil, still an attentive reader of ancient history can even there trace the same immutable and invariable law.*

Thus, for instance, it is interesting to mark how the scarcity of food affected the population of the Roman empire. Its decrease before the last Punic war conclusively showed the inability of the soil to support the former numbers; and as the wars themselves could have had only a passing influence, the true cause must be found in the fact that, by the exhaustive process of tilling the soil then in practice (justly called by Liebig 'Raubbau,' robbing culture, or agriculture without manuring), the earth at length lost its power to produce.

The entire Campagna, ancient Latium, extending from Rome to the Pontine Marshes, once the seat of a most populous race, is now a melancholy, barren territory. Already under Pompey, Rome was depending upon imports of foreign breadstuffs, and suffered repeatedly from famine. The census taken by Julius Cæsar proves the decrease of population, the cause of which was not unknown to him; but his laws upon the subject could of course not restore fertility to the exhausted domains in the Campagna; as little as the communistic scheme of Caius Gracchus before him, of citizens having all property in common, could make up for the deficit in the supply of food compared to the ever-increasing demand. Hence both these rulers were driven to the conquest and plunder of neighbouring countries, to provide for the wants of their ravenous people.

Scipio (196 B.C.) began already to feed the poor citizens of Rome from government corn-stores procured by conquest. Caius Gracchus rated the quantity given to each recipient at sixty modii. Under Cæsar, no less than 350,000 poor citizens were thus fed at the public expense.

Sicily, Sardinia, and the coasts of Africa, yielding the most corn, had to give one-tenth of their harvests as a tribute to Rome; and Asia, not less fertile, was declared its public domain. Under the later emperors, not only Rome but half Italy received its sustenance

* So well are these laws established and acknowledged, that in countries where the army is made up by the conscription of a certain proportion of the population, it has been found that not only the number to be had can with a fair chance of accuracy be estimated from the state of the markets eighteen to twenty years previously, but even the average standard height of the men furnished.

from abroad, thus becoming entirely dependent upon their rulers for their daily bread. And from this time principally dates the rapid decadence of the mighty Roman people! The virtues resulting from conscious inherent strength and independence were soon *changed into the meanest egoism, lax morals, cringing slavery, and absence of all military genius. In the time of Diocletian the free peasantry disappeared altogether, being supplanted by colonies of slaves, farmers becoming 'peasants;'* * and this completed the fearful national decay, the last remnant of strength being consumed by large standing armies, who only destroyed but never produced; so much so that Constantine the Great, like a rat leaving a sinking ship, was compelled to abandon Rome and found a new capital in the East, there only to renew the same exhausting process.

The history of the decay of Spain reads nearly in the same strain. In the time of the Roman emperors she was one of the most populous and prosperous countries on the face of the earth. Livy and Strabo extol the great fertility of Spain, describing the hundredfold harvests of the plains of Andalusia. Under Abderrahman III. (912), Moorish Spain counted no less than 30,000,000 of people. The city of Granada alone could bring an army of 50,000 men into the field! The city of Tarragona, in the time of the Romans, had a population of 1,000,000; under Abderrahman III., about 350,000; whilst in our days it has not more than 15,000! Herrera, in his work about Spanish agriculture (1598), asks: 'What is the reason that food is now so scarce, and that now a pound of meat costs more than a whole sheep formerly?' The later laws enacted by the Catholic kings of Spain further prove the sterility of the soil, which in present times is so great, that Catalonia yields but one harvest in two years, and Andalusia, formerly so fertile, but one in three. Was there ever a more awful example of the ruin of a country by neglect of agriculture?

One of the most remarkable proofs, however, that the decline of fertility is not necessarily a process extending over centuries, is strikingly shown *by the decrease of yield in the harvests of the United States.* Carefully collated statistics prove that, in ten years, from 1840 to 1850, in the states of Connecticut, Massachusetts, Rhode Island, New Hampshire, Vermont, Kentucky, Georgia, Alabama, and others, the wheat harvest has diminished to one-half, and the potato crop to one-third of former quantities. Cassius Clay of Alabama says, in his ten letters to the President:—'In the state of New York the harvest was, eighty years ago, twenty-five to thirty fold; now it is but twelve. In the state of Ohio, then a teeming wilderness, the yield of wheat is now but twelve bushels per acre, and is constantly diminishing. In Virginia, once the most fertile region of the earth, thousands of acres have become so barren that they are abandoned, and the cotton regions are in a condition of exhaustion, which, considering the short period in which it has happened, is without example.'

Nothing is more melancholy and sorrowful, in travelling through

* Peasants, from *pagani*, that is, heathens, barbarians, or inferior caste of human beings. Here a change of meaning is seen from the original to the modern, resembling somewhat, in an inverted sense, our word '*villain*,' which, from originally signifying simply a 'villager,' or 'cottager,' that is, a farm labourer, now stands for something worse than a rogue.

many parts of the United States, than to see regions, extending many miles in every direction, where none but ruined farmhouses are met with, surrounded by exhausted fields, with fences thrown down, and a scanty *growth of noxious weeds explaining the cause of this utter desolation. The roads leading past and through such abandoned territories amply testify, by their washed-out and gutted condition, how seldom a human being now travels that way, and how* completely the land has become unfit for habitation. The astounding rapidity of decay, we here notice, compared to the long periods required thereto in the old world, is mainly due to the superior agricultural implements used by American farmers, whereby the resources of the soil are at once taxed to the utmost degree. But, slow or swift, the result is always the same to the public prosperity of a country!

On the other hand, look at China, with a teeming population of some 450,000,000, or above one-third of the whole human family, crowded together on a comparatively smaller area than any other country, except perhaps Japan. Mr. Thorwirth says, in his 'Canalisirung grosser Städte,' with respect to China:—

'We cannot but be surprised, on comparing the mournful experience of European states, and the exhaustion of their soil, with this over-populated empire, which, cut off as it was during thousands of years from all intercourse with other nations, and consequently from all importation of foreign breadstuffs, always produced its own food, and yet preserved the fertility of its soil. The only explanation to be given is, that the Chinese, like the Japanese, by observation and experience, ever knew the high value of human excrements and animal offal; and by carefully restoring both to their fields, followed the only true course to afford complete compensation to the soil, and maintain its fertility unimpaired for all times to come.'

Dr. Maron, member of the late Prussian expedition to Eastern Asia, reports that Japan, a country of about the size of Great Britain, but owing to its mountainous formation only half of it fit for cultivation, comfortably supports a larger population than Great Britain, without even using animal dung, or importing guano, bones, or other fertilisers, the only manure applied by the Japanese being human excrements, which, most carefully collected and utilised, has produced never-failing crops from time immemorial; and, since the opening of her harbours, enables Japan even to export breadstuffs in considerable quantities, whilst Great Britain is annually drained of millions and millions of money by importing food and fertilisers from abroad.

III. SEWERAGE BY WATER-CARRIAGE.

After these introductory remarks we proceed to glance at the various efforts made in more modern times to remove excremental matters out of cities, and begin with the so-called 'sewerage by water-carriage system,' this being the first attempt, on a large scale, to effect the purpose by means of subterranean conduits.

1. Old London Sewerage Works.—As many English cities now provided with the modern sewerage system took, as in all matters of science and art, their cue from the metropolis, we cannot do better than describe the London sewerage works as a general type of all the others, giving first a short account of their gradual development.

The site of the city of London is an undulating plain, formerly intersected by various brooks or creeks, each of which had a separate valley, some with springs or wells. The Fleet River, or River of Wells, called also the Old Bourne, now pronounced Holborn, was formerly navigated up to Holborn Bridge. It had several fine springs or wells, such as Saddler's Wells, Bagnigge Wells, Lamb's Conduit, Chad's Well, Clerkenwell (now all names of London districts), and which in 1218 supplied drinking water even to the people living west of Chancery Lane. There were also the Tye Bourne, the Bayswater (now called Ranelagh Sewer), and the King's Scholars Pond Brook, and other main valley drains, all formerly open streams, ponded up at various places for ornamental waters in the gardens of the nobility. The Fleet ditch or sewer was, by Act of Parliament in 1732, arched over from Holborn to Fleet Bridge.

In those days cesspools were looked upon as the proper receptacles for excrements, and sewers only as channels for surface water. The latter were at first open gutters, and only afterwards closed to gain more room in the streets. Up to 1815 it was penal to throw any excremental or any other offensive matter into them.

These cesspits were built of brick or stone, often without mortar, leaving the walls quite porous, and hence they seldom overflowed, the liquids percolating continually into the ground. In course of time, as the population increased, the subsoil became studded with these barbarous contrivances. When improved closet fixtures came into use, and superior cleanly habits caused much water to enter these pits, they began to overflow, often thoroughly saturating the whole site with most offensive fluid; it was therefore, from 1815 to 1847, permitted to build overflow-drains from the cesspools into the sewers, which by sheer necessity were changed from open streams into covered brick conduits.

In the year 1847 an Act of Parliament made it compulsory to drain all privy contents into the sewers. Prior to that time, these were under the control of eight different commissions, viz. the City, Holborn and Finsbury, Westminster, Poplar and Blackwall, Tower Hamlets, Surrey and Kent, Greenwich, and St. Katherine, all independent of each other, and appointing each their own officers, who constructed their works without a regular plan, and without regard to the drainage of adjoining districts. The sewers were consequently of all sorts of sizes and shapes, often leading to confusion, absurdity, and direct counteraction of purpose, large sewers emptying into smaller ones, lower into higher, egg-shaped into round or square sections, and so on.

The serious evils to public health arising from so disgraceful a state of affairs, which existed also in nearly every English town, led to the appointment of a commission in 1844, composed of scientific and practical men of the first class, who were to inquire into the whole matter and state their remedial measures. In 1844 and 1845, this commission memorialised Parliament by two extended reports, *summing up circumstantially how much sickness and how many deaths had resulted from the existing defective* arrangements, and proving the great and immediate necessity of having pure air to breathe, and uncontaminated water to drink; to secure which it was considered indispensable to remove all filth from streets and houses, to provide abundance of water, and to build well-ventilated houses.

2. METROPOLITAN COMMISSION OF SEWERS.—What was thus done for England in general was followed up for London in particular, the former eight commissions being, in 1847, superseded by a single one, called the Metropolitan Commission of Sewers, the members of which were appointed by government. This new commission submitted, in the same and the following year, three different reports to Her Majesty and Parliament. They recommended the same sanitary measures as mentioned before, insisting very properly upon one uniform and systematic plan for the entire drainage of London. But with regard to sewers they entertained views very different from those formerly held. The Metropolitan Commission insisted upon pipe sewers of small size taking the place of the large brick structures, upon the entire abolition of cesspools, upon leading all house-drains into these pipes, and making these changes compulsory.

During the six years that this scheme was followed, over 30,000 cesspools were abolished, the entire filth of London being conducted directly into the Thames. This example was unfortunately followed by a great many towns, in consequence of which the drainage was considerably improved, whilst the rivers were completely polluted.

The Metropolitan Commission was no less than six times superseded, being each time entirely new and differently constituted. The second reconstitution took place in 1849, when matters looked very critical indeed. The Thames was loaded with sewage, when the cholera (the first visit of which was in 1831-2) broke out, taking the lives of no less than 18,036 people. This fatality spurred the commission to increased activity. The public press agitated the question in a most energetic manner, in consequence of which the commission advertised for plans and designs, and received as many as 116 different schemes. In the midst of this excitement and confusion this commission was superseded by a third, who reported Mr. McLean's plan as the best, but could not recommend its execution. Mr. Frank Forster, the chief engineer, assisted by Messrs. Grant, Cresy, and Haywood, proposed a plan of their own for the interception of sewage, without, however, succeeding in getting it adopted.

In 1851 the fourth commission was issued, and brought forth a new scheme. Mr. Forster's health giving way under the excitement of the struggle, he resigned and died; and, in 1852, the commission was again superseded by a fifth, of which Mr. Bazalgette was chief engineer. During this and the following year more sewers were built, all leading into the Thames, and various fresh plans for intercepting the sewage were proposed, reported upon, and laid aside like all preceding ones. In 1854 Mr. Bazalgette, assisted by Mr. Haywood, prepared a new plan, which was at last approved of and recommended for immediate execution.

A sixth commission, appointed in 1855, merely discussed the subject, coming to no practical result. But sanitary matters had in the meantime arrived at such a fearful crisis, that the public lost all patience! The journals of the day teemed with stirring articles; pamphlets and lampoons abounded. The cholera, which had again appeared in 1854, and swept away over 20,000 fresh victims, proved at last to the plainest understanding, that mere talking did not mend the state of affairs, but that something must be done. All this violent agitation finally led to the total dissolution of the Metropolitan Commission of Sewers and the appointment of the present Metropolitan Board of Works, principally by the efforts of the late Lord Llanover, who, having first officiated as President of the Board of Health, was in 1858 appointed First Commissioner of Works.

3. METROPOLITAN BOARD OF WORKS.—This important body is entirely based upon the principle of self-government. Under it London became divided into thirty-nine districts, the city proper and the larger parishes each forming one, whilst some of the minor ones are united into one district. The ratepayers of each district elect amongst themselves a prescribed number of representatives, who form a board charged with paving, draining, lighting, and other municipal interests. These district boards elect from their body one or more members, in proportion to the extent and population of their respective districts, who then constitute the Metropolitan Board of Works, counting forty-five members, and presided over by a chairman.

This board in its turn controls all the main-sewers, the Thames embankment, together with all new streets and city improvements, making also rules and bye-laws for the direction and supervision of the various district boards.

Mr. Bazalgette, appointed engineer to the Metropolitan Board, was instructed to prepare a new plan for drainage and interception of sewage, which was approved by the board, but rejected by the veto of the chairman. On this being overruled, the plan was submitted to a commission of engineers, who instead thereof proposed a scheme of their own. The board however, in its turn, rejected the latter, adhering to Mr. Bazalgette's original plan; *according to which, in 1859, the works were finally commenced.*

This brief account shows that the delay caused by the bickerings and contentions of the various commissions and boards, from 1847 to 1859, has cost the city of London over 40,000 lives by epidemical visitations during this protracted struggle, not reckoning the thousands and thousands swept away by endemic fevers and other local diseases, all more or less traceable to defective sanitary arrangements, which had been so long submitted to by an impatient public. Besides this, immense wealth was sacrificed during this period by casting into the river a material which should have been used in agriculture as an invaluable fertiliser.

4. GENERAL BOARD OF HEALTH.—Long before this time the most perplexing state of sanitary affairs had called another body into existence. By Act of Parliament of August 31, 1848, for the promotion of Public Health it was enacted, that a General Board should be appointed to control the measures of all local boards.

This act provides rules for the election of local boards, the levying of taxes, making of laws and other regulations, by which all sorts of works referring to sanitary measures may be executed, without the costly and time-consuming interference of Parliament. The act also furnishes various technical instructions, for compliance with which the board is held responsible. Thus, for instance, every new building must have a subterranean drain emptying itself into a public sewer, if one is to be found within a hundred feet from the house; if not, then into a closed cesspool. The act also compels the use of waterclosets.

The powers conferred upon this most important body, the reports they published, and the measures they enacted, of course met with a very lively opposition from the advocates of various plans and systems, a contention resulting in good so far that the advantages and disadvantages of each particular scheme were thoroughly discussed, and most carefully pointed out.

Of the various reports issued by the General Board of Health none, however, created a greater sensation and met with a stronger opposition from eminent engineers and other professional men, than the 'Minutes of Information collected with reference to Works for the Removal of Soilwater or Drainage of Dwelling-houses and Public Edifices, and for the Sewerage and Cleansing of the Sites of Towns,' published July, 1852.

This report enjoined upon local authorities rules for the sewerage of towns which were totally subversive of all experience and the practice of eminent engineers, and openly violated many a theory. Not content with this, the report went even so far as to pass strictures upon and condemn certain works altogether, all which led to a long and irritating controversy between the parties interested, called the 'Pipe-and-Brick-Sewers War.'

The various erroneous hydraulic data adopted in this report were highly detrimental to the public interest, as the General Board had the legal power to reject all sewerage plans not in accordance with their peculiar notions, and to withhold their consent to the borrowing of money for executing the works. Thus many a good English town has to thank its imperfect and still costly drainage to the ill-advised course so long pursued by this commission.*

It would, however, be unfair to state that the Board confined their views to merely sanitary purposes, as is often alleged. On the contrary, their favourite system united sewerage with the providing of good water, and the application of the excrements to agriculture by means of steam power. In this respect it conforms to the theory propounded in the 'Congrès général d'Hygiène,' held at Brussels in 1852, which theory was based upon the continuous circulation of water, as follows:—

The water falling from the clouds and absorbed by the soil is collected, and by means of aqueducts sent to all dwellings in a town, there to serve all sorts of domestic purposes; after which the water, enriched by fertilising ingredients, is poured into sewers before diseases can arise out of fermentation; and finally, by means of a special set of pipes, it is distributed over fields, which absorb the fertilising ingredients, and allow the water to run off, clear as crystal, into ditches conveying it to rivers and to the ocean, whence it is again taken up by evaporation into the clouds, to travel the same way over and over again. A very fine theory indeed, but though, perhaps, true in the abstract, not at all practicable in the manner in which it was proposed to be put in operation.

The regulations and instructions of the General Board of Health are based upon the sweeping assertion, that the removal of excrements can best be effected by mixing them with large masses of water, and that this kind of water-carriage is the cheapest mode of conveyance; that even if by this means agriculture should eventually be deprived of a valuable material, the loss would be small indeed compared with that entailed upon a community by retaining sewage matter in cesspools, there to ferment and breed pestilence and death.

The board further insists that waterclosets are cheaper and more convenient and healthy than cesspools, and consequently instructs all local authorities to abolish the latter altogether. It rejects also the former large brick sewers, which are stated to give low velocities to sewage so as to form deposits, and recommends instead pipe sewers of the smallest practicable diameter, which, with their smooth interior and contracted area, give high velocities, and thus keep themselves clean, allowing oval-shaped brick sewers only in cases where the quantity of sewage matter requires conduits of larger size than can be made of pottery-ware.

This system of pipe sewers requires carefully constructed street-cesses or gullies, so arranged that no grit, sand, silt, or other refuse gets into the pipes, but that all such matter is gathered in receptacles, whence it is periodically removed. It further requires not less imperiously waterclosets with abundance of water, in order to render the sewage matter fluid enough for easy and uninterrupted passage through the pipes. Inasmuch as most privies are situated in the rear of dwellings, this system advocates what is called 'back-drainage,' by which means a lesser length of pipe traversing the middle between two rows of houses is sufficient, giving at the

* See Remarks on the Dictatorial Interference of the General Board of Health. London, 1852. Also, Letter relative to the Extraordinary Powers assumed by the General Board of Health. By T. Hawkesley. London,

same time a steeper gradient. In case a site is so low that no sufficient fall can be obtained, steam-power must be employed to pump the sewage matter up to the requisite height of a new gradient.

The opposition of the most eminent engineering talent to these laws of the board, for laws they were to which all had to submit, was of the most violent kind, especially after the outbreak of a most virulent epidemic at Croydon, shortly after that town had been provided with sewerage works in accordance with these instructions.

In a report by Neil Arnott, M.D., and Thomas Page, C.E.,* upon this subject, it is said?—'We regret to state the result of our investigation is a conviction, that the operations of the plan for the sewerage have been influential in producing the disease; and that the absence of proper provisions in that plan for some of the general requirements in town drainage, and the especial requirements of Croydon, has been productive of misfortune to the inhabitants.'

Mr. Bazalgette, engineer to the Metropolitan Board of Works, also condemned the theory of the General Board, and pointed out several remarkable instances of failure of the so-called pipe-system.†

In a discussion at the Institution of Civil Engineers, Nov. 23rd, 1852, held after reading a paper on the drainage of towns by Mr. Robert Rawlinson, the debate was very animated; and, in a most able summing up by the president, Mr. F. M. Rendal, it appears that the sense of the meeting, including the most eminent engineering talent of England, was most decidedly against the pipe-sewerage system.

The Board, however, made numerous attempts to defend itself,‡ ascribing the mischance at Croydon above-mentioned, along with other causes, to bad execution, defective material, and general influence of climate. And that these statements and the activity displayed resulted in something is evident from the fact, that, according to the board's official account of 1854, their system had already been applied to no less than 182 towns, counting a total population of over two millions, whilst applications for power to execute it had come in from over 100 towns more!

The preceding account of the great difference of opinion existing amongst professional men, and the many serious objections the majority of them raised against the rules and regulations of the government authorities, serves to explain the difficulties Mr. Bazalgette, the engineer to the London Maindrainage Works, had to contend with in executing his grand scheme of intercepting sewers, which we now proceed to describe.

* See their Report on an Inquiry relative to the Prevalence of Disease at Croydon. 1853. Also Report of Thomas Wickstead, on the State of the Works of Drainage and Sewerage in the Town of Croydon.

† See his Report, relative to the Application, State, and Examination of Tubular Pipe Drains and Sewers. 1853.

‡ See Reports by R. D. Grainger and Henry Austin on the Epidemic at Croydon. 1853. Report to Metropolitan Commission of Sewers on the Working of Pipe Sewers, May 25, 1856. Communications from the General Board of Health in respect to the Operation of Pipe Sewers. 1855. Reports on the Administration of the Public Health Act from 1848 to 1854.

5. **LONDON MAINDRAINAGE WORKS.**—The objects aimed at by Mr. Bazalgette in the planning of his great works were the following:*—

a. To intercept, by means of large conduits, the sewage of all the various main sewers hitherto emptying directly into the Thames, together with as much rainfall as could reasonably be dealt with; to divert these fluids by means of the said conduits from the river near London, discharging them into the Thames at such a point, that the return tides could not carry the sewage back to the metropolis.

b. To abolish all stagnant and tide-locked sewers with their accumulation of deposits, and thus to obtain a constant, instead of an intermittent, flow or discharge of sewage.

c. To provide sewerage also for districts hitherto imperfectly, or not at all, drained.

It must here be stated that the old London main sewers all passed under the low margin of the Thames before they reached it, discharging their contents at the level, and at the time of low water only. The outlets of these sewers were of course closed by the rising of the tide, the sewage being then always forced back into the lower portions of the conduits. Eighteen out of every twenty-four hours the sewage remained thus stagnant, during which time the heavier ingredients were deposited, forming constantly increasing accumulations of filth of the worst description. On heavy rains falling during times of high water, the closed sewers could no longer store the immense volumes of sewage fluids, which consequently rose through the house pipes, inundating the cellars and basements of many buildings.

The effect of such arrangements upon the Thames can be better imagined than described. The water coming from the uplands, already to such a degree polluted by various towns and manufactories that it had lost the last trace of its original transparency (notwithstanding which different water companies continued to furnish it to London for drinking!), day by day received at the city the excrements of its three millions, just at the time of low tide. This sewage could of course not be carried down out of harm's way, but continually returned to London with the rising tide, swaying down again with the following ebb, after mixing with another day's supply of pollution.

The progress towards the sea of many days' accumulation of sewage being almost imperceptible, ample time was given for the evolving of immense volumes of gases of the most deadly kind. The fearful condition of the Thames, just in front of the city, obtained a world-wide renown by innumerable most violent attacks of the public press, and was the object of many a biting but well deserved satire of Punch and various other periodicals.†

* See his paper upon the subject read before the Institution of Civil Engineers, from which this account is taken.

† Thus, for instance, we read in an English journal of May, 1858: 'Yesterday appeared before the Lord Mayor of London two supplicants with three bottles, respectively labelled, *Fleur de la Tamise*, *Extrait de London Docks*, and *Eau de Sainte* . . . . which his lordship was respectfully requested to smell. His lordship did smell, and, with many a hideous grimace, forthwith enjoined these gentlemen to treat in a like manner the members of the recently appointed General Board of Health and

It was to remedy the enormous evils arising from this awful state of affairs, that those stupendous works, called the 'Maindrainage of London,' were planned and executed by Mr. Bazalgette and his assistant Mr. Haywood, whose talent and skill cannot be sufficiently praised.

This maindrainage and the principles it involves give the distinctive feature to the so-called 'sewerage by water-carriage,' which must not be confounded with the various sub-main sewers and house-drains already in existence before Mr. Bazalgette's works.

6. PRINCIPLES OF LONDON MAINDRAINAGE.—The principles of the present London drainage consisted simply in constructing new lines of sewers at right angles with the existing ones, and a little below their level, so as to intercept their sewage, and convey it to an outfall fourteen miles below London Bridge; the largest possible proportion of sewage being carried away by mere gravitation, the remainder pumped up to the requisite height for a constant discharge.

At the outlets, the sewage is emptied into reservoirs situated on the banks of the Thames, at such a level as to effect a regular discharge into the river at or about the time of high water. By this arrangement the sewage is not only at once diluted by the immense volume of water in the Thames at high tide, but is also carried by the ebb to a point some twenty-six miles below London Bridge, and its return by the following flood to the metropolis is thus effectually prevented.*

To carry out this scheme the following main points turned up for consideration, which fairly represent the difficulties to be overcome in effecting the drainage of towns on tidal rivers, viz.

a. At what state of the tide, and at what point of the river, can sewage be discharged, so as not to return to the town by the next flood?

b. What is the minimum fall intercepting sewers should have to secure a constant flow, without leaving deposits?

c. What is the quantity of sewage, including all household fluids, to be discharged from the town every twenty-four hours?

d. Is the rainfall to pass off also into the intercepting sewers; and, if so, what is the average quantity to be provided for?

e. The above quantities having determined the total volume of sewage to be carried off, what is the proper size and form of the sewers?

f. What is the best kind of engine for pumping up the sewage

Commission of Sewers. It is difficult to give an idea of the effect of these waters upon the nasal and respiratory organs, but it appears to be more overpowering than chloroform. The preparation of these essences is as follows: London receives daily coming down the Thames all the fæcal matters, dirty water, house-drainage and refuse liquids of all the various towns along its banks and those of its branches. At low tide the city adds thereto the excrements of about 3,000,000 persons, and all the filth, garbage, offal, and nastiness collected from the streets mixed with the poisons proceeding from its numerous manufactories. When at the rising flood this mixture returns to the city, it is carefully stirred up by the paddle-wheels of some 200 to 300 steamers and left a few hours to ferment in the sun, after which it is ready for use.'

* See a paper read by Mr. Bazalgette before the Institution of Civil Engineers, March 14, 1865, on the 'Metropolitan System of Drainage and the Interception of the Sewage from the River Thames,' p. 11.

from the inevitably low levels to such a height as will secure a certain discharge?

In order to gain a much clearer idea of the whole question before us, let us cast a cursory glance at each of the above points separately.

a. State of Tide and Point of Discharge.—It appears that, at whatever point of a tidal river sewage may be discharged, the solid matters will again work their way up the stream, and deposit on the banks for speedy decomposition.

This is simply due to the greater power of the rising tide-water over the ebb, in conveying deposits of but little specific gravity. Now the specific gravity of human excrements is but little more than that of sweet or river water; and, consequently, a very slow current is capable of holding it in suspense. When such water meets the specific heavier salt or brackish water of a rising tide, the sweet water slides or runs over the latter in the middle of the stream, whilst the salt water creeps up along the bottom and the banks. The matters held in suspense by the sweet water will, when coming into contact with the salt tide, at once mingle with it or float on the surface, and thus be carried along upwards, but only to be deposited on the shore when the ebb sets in. This explains also why alluvial matters, brought down a river, are afterwards often found high up in the estuaries near its mouth.

This theory was verified by Mr. Robert Stephenson and Sir William Cubitt, and subsequently confirmed by Mr. Bazalgette by the following experiment:

Opposite Barking Creek a float was placed in the middle of the Thames, two hours after high water, at the period of spring-tides. This float went down with the tide 11¾ miles, and returned with the flood 12¾ miles, or actually one mile above the starting-point. It continued to float backwards and forwards until, fourteen days later, it was found at the corresponding time in highwater neap-tides but five miles below the original starting-point. Another experiment showed a total downward movement by the rising and falling tide of seven miles in fourteen days, the float having sometimes reached 6½ miles above the starting-point.

Much depends of course upon winds, freshets, and other causes; but it seems that, regarding the Thames, it may be assumed with certainty, that any substance held in suspense by the water will work its way up with the tides at the rate of about a mile a day, so long as the spring-tides increase, and work down stream at the rate of two miles a day, when they again fall off. The above experiments clearly showed that the London sewage should be discharged at least not higher up than Barking Creek, and always at times of high water.

b. Minimum Fall of Sewers.—The minimum fall of sewers should depend of course chiefly upon the quantity of sewage in proportion to the water holding it in suspense; or, in other words, upon the degree of consistency of the mass. The greater the quantity of water supplied to a town for household purposes, the greater will be the velocity imparted by it to the sewage, and the less the latter's tendency to leave deposits.

In rivers the motive power of velocity is as follows:—

3 inches per second will move			clay and work it up.
6	"	"	fine sand.
8	"	"	coarse sand.
12	"	"	fine gravel.
24	"	"	coarse gravel, one inch diameter.
36	"	"	stones size of an egg.

Now, assuming the quantity of water daily supplied to the inhabitants of a town to be five cubic feet per head, and that all this water is to pass into the sewers for holding the excrements in suspense, then experience proves that conduits should have the following velocities:—

Conduits of 36 inches diameter	require	30	inches	per second	velocity.*
" 18 " to 36 "	"	36	"	"	"
" 6 " to 18 "	"	40	"	"	"

c. Quantity of Sewage.—Experience shows that excrements add no perceptible or measurable quantity to the volume of the water supplied to the inhabitants of a town. In London the daily supply of water is calculated at five cubic feet per head, half of which passes off in six hours, the remainder in eighteen, owing to the domestic habits of the people. The maximum flow in the wealthier parts of London is always two to three hours later than in the quarters inhabited by the poorer classes.

d. Rainfall.—When sewers are built to carry off excrements and house-drainage, it is by most engineers preferred that rainwater should pass the same way, as the greater the quantity of water the easier the removal of sewage. The fact of rain being intermittent (from 150 to 160 days in the year), and falling sometimes suddenly in large quantities, only adds to its value as a motive power, by effecting that 'flushing' so necessary for clearing stoppages. The London maindrainage sewers were calculated to carry off $\frac{1}{4}$ of an inch of rain water in 24 hours, corresponding to a rainfall of about $\frac{1}{10}$ of an inch in depth, the remainder being absorbed by the soil or taken up by evaporation.

e, f. Sewers and Engines.—Having stated the ruling principles, we now proceed to give a short account of the sewers and engines of the London Maindrainage Works as constructed by Mr. Bazalgette, for effecting the various purposes in view. There are, on each side of the Thames, three lines of intercepting sewers, lying on different levels, and crossing the street main-drains at right angles.

7. NORTH LONDON MAINDRAINAGE WORKS.—On the north side of the Thames, the high-level main-sewer serves for collecting

* Let us suppose V to be speed of fluid in feet per second;
A = area of fluid in square feet in sewer;
P = length of immersed circumference;
F = feet of fall in 1000:

then English engineers use the following formula:—

$$V = \sqrt{8,5\ F\ \frac{A}{P}}$$

In the 'Service des Eaux et des Egouts' at Paris, on the other hand, the formula used is as follows:—

the drainage from the various sewers of the upper districts, in all about 10 square miles. It is 7 miles long; in form, mostly circular; and varies in size from 4 feet in diameter to 9½ by 12 feet. Its fall is from 1 foot in 200 at the upper end, to 1 foot in 1,000 at the lower. Many tunnels were required, one from Maiden Lane to Hampstead, ½ mile long. There were also many houses tunnelled at Hackney, and one building near the railway station had to be underpinned and placed upon iron girders, the sewer being carried right through the cellar.

The middle-level main-sewer drains the area situated below the high-level, in all about 17½ square miles of a densely populated city. Its length is about 9½ miles, and two miles running under Piccadilly as a branch. The size varies from 4 feet 6 inches by 3 feet 10 inches to 9 feet 6 inches by 12 feet.

Four miles of the main-sewer and Piccadilly branch were tunnelled under the streets at a depth varying from 20 to 60 feet. Over the Metropolitan Railroad the sewer is carried by a wrought iron aqueduct 150 feet span. The middle-level joins the high-level at Old Ford, Bow, by means of Penstock chambers so arranged that, in case of a great storm, part or all of the sewage can be discharged into the river Lea.

The low-level main-sewer intercepts the drainage running below high water-mark, of about 25½ square miles. Part of this area forming the western suburb, 14½ square miles, is so low that the sewage has to be pumped up 17½ feet high by a steam-engine at Chelsea. From Westminster Bridge to Blackfriars this sewer forms part of the Thames Embankment. Much tunnelling was also here required, the main tunnel running under the River Lea on its way to the Abbey Mills Pumping Station. Here the whole mass of sewage is raised 36 feet to the level of the outfall-sewer, which, as a continuation of the high-level, unites the drainage of the whole northern part of London.

The Abbey Mills Pumping Station has 8 steam-engines of 142 horsepower each, or 1,136 horsepower in all, lifting together a maximum of sewage and rainfall of 15,000 cubic feet per minute 36 feet high, by means of 16 pumps, each of 3 feet 10½ inches diameter and 4½ feet stroke, and consuming about 10,000 tons of coal a year.

The north outfall-sewer begins at Bow, and consists of two massive brick conduits, 9 feet high and wide with circular tops and segmental inverts, constructed side by side up to Abbey Mills Pumping Station, where they are joined by a third conduit of the same size, continuing parallel with them to Barking Creek. The whole of these outfall-sewers, 5½ miles in length, is raised above the surrounding country on an embankment, and is carried over various rivers, railways, roads, and streets, by means of wrought iron aqueducts, some of which are quite stupendous and very costly structures!

The sewer embankment is 40 feet wide at the top, and, in some places, 25 feet above the level of the country, its general appearance being that of a railway bank.

The fall of these sewers is but 2 feet a mile, or 1 in 2,640 feet; and as their gradient could not of course be raised or depressed to suit pre-existing works, the North Woolwich and the Bow and Barking Railways had to be lowered, so as to allow the sewers to pass over them, causing a further increase of the already enormous expenditure.

The Barking Creek reservoir, into which these three conduits discharge their sewage, has an area of 412,384 square feet, or about 9½ acres, divided by walls into four compartments, with an average depth of 16¾ feet, forming a total capacity of about 7 million cubic feet. The external and partition walls are of brickwork, the floor is paved with York flagging, and the whole is covered with brick arches resting on brick piers and overlaid with 2 feet of earth. By a culvert communicating with the river, either of the compartments may at high-tide be filled with water, whilst the gates of the three sewers are shut. By this arrangement the reservoir is periodically cleaned by flushing at low tide.

8. South London Maindrainage Works.—The maindrainage works on the south side of the Thames are similar. There is first the high-level sewer, with its southern branch, draining about 20 square miles. Some 1,000 feet of this branch are tunnelled in depths from 30 to 50 feet, the size varying from 7 to 10½ feet diameter. The low-level sewer, some 10 miles long, drains about 20 square miles, lying mostly below the level of high water; its size varies from a single sewer of 4 feet diameter to two culverts of 7 x 7 feet section each.

The old city sewers discharging into this low-level sewer have but little fall, and were, except at low water, always tide-locked and stagnant. In times of excessive rains they became soon overcharged, and days often elapsed before they could be relieved of their accumulated sewage, which in the meantime found its way into cellars and basements. This was, in consequence, the unhealthiest district of London!

At Deptford Creek, the sewage is lifted 18 feet high by means of 4 steam engines of 125 horsepower, capable together of pumping up 10,000 cubic feet per minute. The chimney is 150 feet high, the furnaces drawing air from the sewers and the engine-well for ventilation. The sewage is pumped up to the level of the high-level into the southern outfall sewer, conducting it to the Thames at Crossness Point in the Erith Marshes, a distance of 7¾ miles.

This outfall sewer is entirely built underground, being a brick culvert of 11 feet 6 inches diameter with a fall of 2 feet per mile. At its outlet into the river the sewer-bottom is 9 feet below low water, leaving but 2½ feet above. This outlet can be closed by penstocks, and the sewage pumped up into Crossness reservoir, which is done at high water by means of four engines of 125 horsepower each, the lift varying from 10 to 30 feet, according to the difference of sewage levels in the sewer and reservoir. The latter is similar in construction to that at Barking Creek described before, but is only 6½ acres in extent, with a capacity of about 4 million cubic feet.

9. Cost of London Sewerage Works.—The preceding description has been mainly derived from Mr. Bazalgette's 'Main-Drainage of London,' published in 1865. The whole of these gigantic

works is throughout a masterpiece of skill, and, considering the enormous difficulties to be overcome in the course of its construction, confers the highest credit and honour on the eminent engineer* who designed and executed it.

The cost of the maindrainage, or intercepting sewers alone, some 82 miles in length, is about 4,250,000*l.* sterling, which was raised by a 3*d.* rate levied on the metropolis, yielding 180,262*l.* per annum; principal and interest to be paid off in 40 years.

To this must be added the expenditure lavished before on the immense network, some 1,300 miles in length, of main-street sewers emptying into the intercepting conduits; also the enormous mileage of house or side-drains, the latter consisting nearly all of 6 inch earthen pipe, whilst the main-street sewers exhibit such a variety of sections and dimensions, as resulted from the conflicting opinions so long held by the General Board of Health and the various commissioners and engineers engaged in the construction of these works.

Thus, some of these sewers are of an oval section and large enough to admit the entrance of labourers, whilst others are pipes in conformity with the rules of the General Board of Health. In the city proper sewers are all of the former class, provided with street-gullies for cleaning and ventilation. The depth of these street-gullies, or ventilating shafts, is seldom less than ten feet, and often over thirty. These shafts, and a variety of costly contrivances for removing stoppages and effecting periodically thorough cleanings by flushing, form of course also no small item in the capital spent on sewerage purposes.

It is most difficult to get at anything like a correct estimate of the total cost of all the London sewerage works; but considering their enormous extent, the astounding depth of many excavations, the many difficulties always encountered in subterranean works on account of water springs, shoring up of defective foundations and houses, of removing or even rebuilding them,—considering further the frequency of deep ventilating shafts, tunnels, and other expensive structures, the erection and maintenance of most extensive pumping stations, it is estimated that *the total cost of all these sewerage works cannot be far from thirty million pounds sterling!*

10. TUBULAR DRAINAGE WORKS.—From such a patchwork arrangement as the London drainage works, in spite of their enormous cost, really are, let us now cast a glance at other cities, where so-called 'sewerage by water carriage' has been entirely carried out on the pipe-sewer plan.

An interesting instance is to be found in the borough of Dundee, on the estuary of the river Tay. This town has a population of about 100,000, and its police boundaries enclose some six square miles. The sewerage works were executed under the General Police Act of Scotland, which much resembles the English Health of Towns Act. The streets, at right angles with the river, have all tubular drains of salt-glazed fire-clay socket-pipes, varying from 9 inches, 12 inches, 15 inches, and 18 inches diameter, which the acting engineer deemed sufficient to carry off both house drainage and rainfall. The intercepting sewers, running parallel with the river, are brick sewers of oval section from 3 feet × 1 foot 10 inches to 4 feet 6 inches × 3 feet diameter.

The surface levels of the town being very irregular, the depth to which the sewers had to be sunk ranges from 7 to 21 feet; the deepest cutting in trap-rock was 19 feet. Manholes of 9 inch brick walls descend perpendicularly at all the junctions of the main and lateral sewers, and also at intervals of 120 feet. These holes are closed with iron covers level with the streets, and have steps in them for descent. The gully-drains conducting the street water into the sewers are placed from 30 to 60 yards apart, being closest together in the steepest streets.

To prevent the rising of sewer gases, a stone valve hung on a copper hinge closes the communication with the pipe leading into the sewer, and opens outwardly when pressed by the overflow of street water in the cess or sink where the detritus accumulates.

To keep the sewers clean, gates are at suitable points fitted in, by opening which a flushing may be effected. Scrapers and other cleansing tools for removing silt and sand are worked from the manholes by means of chains and hollow iron rods.*

The whole of this sewerage system is unprovided with ventilating arrangements, the engineer not deeming them necessary at the time. But although these works have barely existed half-a-dozen years, Dundee has already become one of the unhealthiest places known, just through this want of ventilation, which forces the sewer gases back into the houses in a concentrated form. The works were five years in progress, and cost about 52,000*l*.

The sewage is still allowed to run into the river about a quarter of a mile below the town, and is consequently lost to agriculture; but it is intended eventually to pump it up from its present outlet by a steam engine, and to force it through 12 inch cast iron pipes to the Sands of Barry, a district of barren land of some 2,000 acres, about seven miles below Dundee.

Leamington, a watering-place of some 16,000 inhabitants, is another instance of the tubular drainage system, enforced by the rules of the General Board of Health. So is Carlisle, which in 1854–5 was provided with sewerage-works under the direction of Mr. Robert Rawlinson. Besides 42,500 feet of earthenware, it has over 3,000 feet of cast-iron pipe-sewers, both of which are especially remarkable for their little fall. Wherever the sewers change either their gradient or alignement, brick shafts are built; and also everywhere else, some 300 feet apart, both for descending into them, or lowering a lamp for examination. In Salisbury, Sherborne, Southampton, Gloucester, Woolwich, Rugby, and various other towns, the pipe or tubular system is likewise carried out.

Newton, a town of some 24,000 inhabitants, on the river Usk, where the ordinary rise of tide is about 35 feet, has been very neatly drained by Mr. Alfred Williams upon the tubular plan. But the sewers can be discharged into the river only at low water by means of four outlets, two of which only, the new ones, are arranged for eventual utilisation of the sewage. The outlets are closed by iron disc-valves by the action of the rising tide, during which time the sewage of course accumulates. To counteract the evil effects of such stagnation, carefully built ventilating shafts and manholes have been everywhere provided.

Manchester is remarkable for the fact that the sewerage works serve only for rain and street water, excluding excrements and house-drainage. This is principally owing to Mr. Heron, who most energetically opposed the introduction of waterclosets, so that of 66,000 houses only about 12,000 are provided with them. The fæcal matters are collected in cesspits and daily mixed with the cinders and ashes of stone-coal, nearly the only fuel used there. These cinders are supposed to act as a deodoriser,* and form with the excrements a sort of compost-manure afterwards sold by the city, yielding some 8,700*l.* per annum. This manure is carried principally by railway to Lincolnshire, about 60 miles distant, the purchasers paying the expense of transport. The city empties each cesspool twice a year, employing some 120 men and 43 horses, the maintenance of which amounts to 18,300*l.* Deducting the above proceeds of sale of manure, this method of sewerage costs the city of Manchester nearly 10,000*l.* a year.

Richmond, on the other hand, has a tubular sewerage system for the excrements and house-drainage only, rain and street water being carefully excluded and discharged separately through the old conduits into the Thames. The town is supplied with water at the daily rate of about 5 cubic feet a head, half of which finds its way into the sewers, between morning and noon. There are nearly 53,000 feet of pipe-sewers, varying from 9 to 20 inches in diameter, and also some 13,500 feet of oval brick-sewers from 3 ft. 9 in. by 2 ft. 6 in. to 4 ft. by 2 ft. 9 in.

11. Sewerage by Water-carriage.—We have now, we think, quoted examples enough of so-called 'sewerage by water-carriage,' to show clearly what it is; and the reader will no doubt wonder with us, how arrangements, abounding so much in technical uncertainties and contradictions of all sorts, ever came to be dignified with the name of a 'system.'

This sewerage scheme may generally be stated to be nothing more nor less than a variety of conflicting methods, by which excremental matters are mixed with copious volumes of water, brought often from long distances at an immense cost, and thus removed from dwellings by means of most expensive subterranean conduits, of all sizes and forms, with or without ventilation, laid to all sorts of gradients, to some place or other outside a town for discharge into a river or elsewhere, the question of '*what to do with the sewage*' being as far from an acknowledged correct solution, as the primary question of removal itself. It is now with regard to utilisation of sewage that we shall have a few words to say.

* We say 'supposed to act,' for it is well known that these ashes are no disinfectants. In many places this error has led to much sickness. The 'Lancet,' speaking of the late epidemic in Wales, mentions the parish of Merthyr-Tydvil, where in a population of 54,750, 275 persons have been attacked with a severe form of cholera, of which number 115 have died; while of diarrhœa, 1819 cases have been treated, of whom 12 died. According to the reports of the officers of the Board of Health it has been clearly shown, 'that the disease found most of its victims in neighbourhoods where overflowing cesspools and *ash heaps charged with house refuse* existed.'

IV. UTILISATION OF SEWAGE DILUTED BY WATER.

1. Dilution of Sewage.—To understand fully the enormous difficulties involved in the utilisation of sewage diluted by water, we must have first a clear idea of the comparative volumes to be dealt with, which may be gained by taking a town of an area of one square mile with a population of 25,000, this being about an average density of population in Europe.

The fæcal matter yearly produced in such a town, at ten cubic feet per head, the annual average given by many exact measurements, would amount to . .	250,000	cubic feet.
The water used at the daily rate of 5 cubic feet per head, gives	45,625,000	,,
Rainfall $\frac{1}{8}$th of an inch during 150 days in the year, or say 18 inches on a square mile	41,817,600	,,
Total	87,692,600	,,

of which only 250,000 are fertilising matters, the remainder of 87,442,600 cubic feet being mere water. That is to say, to remove one part of excrements not less than 350 parts of water are used, which must of course afterwards be again got rid of.

In America and other new countries, a city population of 25,000 would perhaps be spread over an area of say nine or ten square miles, in houses containing but one family each, surrounded by spacious gardens, and approached by wide streets; there of course the proportion of water to excrements would be immeasurably increased by the larger quantity of rainfall.

The methods hitherto employed for disposing of sewage liquid may be classified as follows:—

a. *Casting them simply into rivers or harbours*, a method in the highest degree objectionable on sanitary and agricultural grounds, but nevertheless, strange to say, followed by about nineteen out of every twenty towns; or, as Mr. Robert Rawlinson said two years ago, ninety-nine out of every hundred towns in the United Kingdom, including the metropolis.

b. *Utilising the sewage in a liquid form* on level lands, either by surface-channels, or underground pipes and hose-and-jet distribution, or subsoil irrigation, or total submersion.

c. *Utilising the sewage by separating solids from fluids* and manufacturing artificial manure of some kind or other.

As regards the first method, we refer to what we have previously said, and proceed at once to describe the second mode of utilising sewage.

2. SURFACE SEWAGE CHANNELS.—By this method the land is first carefully and evenly graded down a gentle incline, no holes or uneven places being allowed, as the former would cause stagnation, and the latter interrupt the flow of the liquid. The land is then laid out in what is called the 'pane-and-gutter system,' which simply consists in conducting the sewage along the head of the field in an open ditch, running level or in the direction of the least fall of the ground. From this ditch trenches, called 'carriers,' or 'grips,' are dug in the direction of the greatest fall of the land, and stops are placed in them, causing the fluid to pond up and flow right and left over the field, which stops are removed or shifted during the day to suit requirements.

In case the land has but a very slight fall, it is laid out in a series of ridges and furrows, the sewage being conducted by an open ditch into the furrow on the highest part of the field, and allowed to overflow the little ridges in succession. In case of a steeper incline or a side hill, the land is sewaged by catchwork-trenches running as horizontals along the contour of the hill, thus making a set of carriers one above the other. The liquid is of course first brought to the highest one, falls then over the intervening land to the next, and so on to the bottom of the field.

In all these kinds of surface channels the sewage is allowed to flow slowly, or with a gentle ripple, over the whole of the grounds, washing around the lower part of the stems of the plants, the soil absorbing part of the fertilising ingredients, which thus eventually reach also the roots. At the bottom of the field the liquid falls again into another ditch in a comparatively purified condition, and is carried off towards the next river, or the ocean.

The meadows of Beddington, near Croydon, give a fair example of this irrigation system. The town has a population of some 35,000, producing daily without rainfall about five cubic feet per head of sewage (excrements diluted by water), or eight cubic feet including rain. These quantities correspond to sixty-five tons without rainfall, or ninety-eight tons including the same, per head during the year. The local board of health has rented 400 acres at 4*l.* per acre, of which 312 are irrigated with sewage, the other 80 being situated too high to be reached by the gravitation of the liquid. The sewaged acres are subrented again to a farmer for 5*l.* per acre, including the sewage, which is allowed to overflow twenty to thirty acres at a time for four consecutive days and nights, three times between the cuttings of the crops of Itàlian rye and meadow grass.

The farm is about three miles from Croydon. At the outfall of the sewers, a considerable distance from the town, the sewage is received in two large brick basins some three feet deep, in which the solid matter is retained by means of strainers. Upon clearing this matter out, it is mixed with street sweepings, &c., and sold to farmers at 2*s.* per ton. This part of the works is excessively offensive. From the tank the liquid is conducted to the farm by an open channel about four feet wide, which also exhales an unbearable stench. The rye-grass grows there very luxuriantly, and is continued for three consecutive years, after which it becomes necessary to plough the sods in and plant mangel-wurzel, or some other root crop, after which rye-grass is sown again.

It appears that the soil does not take the fertilising matter up by a process of percolation, but that the fibres of the plant absorb the nourishment direct from the fluid, and do this in so far that, after it has run its course over the fields, it is comparatively purified: in this condition it is discharged into the river Wandle. It will be shown hereafter that this fluid is, however, anything but fit for use, holding still as it does in suspense or solution many organic and inorganic substances. In either case, it is evident that a great waste of fertilising matter is incurred; for, according to a paper read by Mr. Latham, the able engineer of the works, before the Institute of Civil Engineers, the ammonia alone furnished by that sewage per head of population is worth annually 8*s.* and 6*d.*; and as he applies the sewage at the rate of one acre for every 100 inhabitants, it follows that each acre, which pays but 5*l.* rent, receives by this process annually 42*l.* 10*s.* worth of ammonia. In other words, he furnishes the farmer on those 312 acres actually with 13,260*l.* worth of ammonia, and obtains in payment 312*l.* in all, deducting the 4*l.* per acre paid by the town from the 5*l.* received. Truly a tremendous sacrifice.*

3. UNDERGROUND PIPES AND DISTRIBUTION BY HOSE AND JET.—This method brings the sewage into the field by means of underground pipes, laid in a sort of network over the whole grounds to be manured. Pipes with couplings or hydrants for attaching a hose are fixed at certain points, and a pressure or head of the sewage is kept up in the pipes, either by pumping, or by the fall of the land keeping it ponded up in a tank. Ten feet head is the least that will serve. The sewage is thrown over the fields in a sort of a shower from the nozzle of the hose. This process is, however, not capable of application in all seasons. Another great objection is the dragging of the hose to and fro over the growing crops. Besides, the fertilising ingredients are applied to the leaves, and not to the roots, which results in a positive injury to the plants, and is an unnecessary waste of manure. This system has been repeatedly tried, but always with discouraging effects.

4. SUBSOIL IRRIGATION.—For this process porous pipes, or tubes perforated with small holes, are laid under the ground, through which the sewage liquids are forced. On fields with subsoil drainage pipes this can sometimes be done by temporarily stopping up their outlets and putting on sewage connections. This plan has been variously tried, especially in Switzerland, but proves rather expensive and unsuccessful besides.

5. TOTAL SUBMERSION.—This method differs from the surface channel plan so far, that the sewage liquid submersing the field is not allowed to flow off over it, but remains at rest, and thus stagnates, as is extensively practised in Piedmont and Lombardy for the growth of rice and rye-grass. The following table, taken from Mr. Latham's paper, 'On the Utilisation of Sewage,' gives a

* See Appendix, No. 3, by Robert Rawlinson, C.E., in Third Report of Royal Commission appointed to inquire into the best Mode of Utilising Sewage. London, 1865. Also a Paper read by B. Latham, C.E., before the Society of Engineers, April 9, 1866, published in 'Engineering,' April 27, 1866.

schedule of towns where the liquid application is more or less followed:—

Towns	Population	Number of Gallons per Day	Acres under Irrigation
Aldershot Camp . .	14,000	. . . . .	250
Alwick, Cannongate . .	6,000	300,000	350 to 400
Bingley, Yorkshire . .	"	"	30 to 40
Birmingham . . .	300,000	15,000,000	130
Braintree	50,000	"	20
Bury St. Edmunds . .	"	Experimenting	"
Carlisle	21,000	843,000	80
Cheltenham . . .	36,000	1,000,000	120
Croydon	"	2 to 5 millions	360
Edinburgh	180,000	"	"
Hopwood	2,200	"	6
Leek	10,500	400,000	130
Mansfield	10,000	"	400
Melton Mowbray . .	..	Experimenting	"
Milverton	1,400	4,000	4
Mold	4,000	6,000	6
Nottingham	"	Experimenting	"
Oswestry	"	Proposed to irrigate	300
Rugby	8,000	80,000 to 200,000	400 to 500
St. Thomas, Exeter . .	"	Proposed to irrigate	150
Swaffham	2,000	"	5
Tavistock	8,000	"	90
Uckfield	1,200	"	4
Worthing	6,000	700,000	40

In order to estimate the true merits of the application of liquid sewage to lands it must be remembered that, of the small proportion of useful fertilising matter it contains, fully seven-eighths are in a state of solution. There is no question but that in hot, dry, and arid countries, irrigation itself cannot but produce useful results; and if the moisture applied contains, at the same time, fertilising ingredients, the beneficial effects will of course be considerably increased.

Thus in Spain, Northern Italy, and British India, irrigation on a large scale has proved highly useful. In Piedmont about one and a half million of acres are so treated; and in Lombardy nearly six millions. The soil in both these countries is composed of deep beds of gravel overlaid with light sand. The volume of water annually used amounts to from 5,000 to 12,000 tons per acre. The mean temperature is about 75° Fahr., the maximum 90°; and in some places, as Mantua and Milan for instance, even 98°. Those regions have, on an average, 200 clear days of burning sunshine, 125 cloudy days, and but 40 of rain. At Brescia, two-thirds of the entire year, the rays of a fierce sun are unchecked by clouds.

These facts, namely a torrid climate and a light sandy soil, go far to explain the splendid results obtained by the application of large volumes of fertilising water in those countries. In England, however, these conditions are wanting; nor is there any evidence that, except under fortunate circumstances but rarely met with, this method would be found to pay at all, many lands, indeed, requiring constant drainage instead of additional moisture.

The success of the irrigation scheme, as far as it goes, at Edinburgh and Croydon, is mainly due to causes of very rare occurrence. There, sewage is applied without stint and with little expense by mere gravitation; and produces, it is true, heavy crops of grass. But if the sewage had to be pumped up, as at Carlisle, Rugby, Watford, Worthing, and elsewhere, the balance would also there soon be found on the wrong side of the account.

The Edinburgh sewage meadows, so often quoted by zealous advocates of the irrigation scheme, are as follows:—

a. The Lochend and Spring Gardens comprise about 35 acres, laid out in ditches conducting the sewage, and allowing it to overflow right and left from the beginning of March to the end of November, each acre getting the flow of a 12 in. × 8 in. stream at the rate of 2 miles per hour for 10 days of 16 hours annually, equal to about 31,000 tons per acre per annum. The crops raised are chiefly coarse meadow-grass (Poa trivialis) and couch-grass (Triticum repens). On the higher lands, Italian rye-grass (Lolium perenne) is grown alternately every two years with potatoes.

b. Craigentinny Meadows consist of 190 acres under sewage irrigation by gravitation. The land was originally barren sand, but is now covered with a coating of loamy soil. The stops in the ditches are so arranged that the whole of the water flows, once in about 3 weeks, over 2 to 2½ acres at a time, changing every 3 or 4 hours during the day, the process going on during the entire summer and part of the winter, the immersion being some 70 to 80 days. Four or five crops are produced in the year of the same kind as in Spring Gardens.

c. Roseburn and Western Dairy Meadows, west of Edinburgh, contained about 100 acres, but are now reduced to 80 through the passage of railways, which had to pay a compensation of 1000*l.* per acre. The soil is gravelly sand and part loamy, with a subsoil of clay. The treatment is substantially the same as above described. The manager, Mr. Thompson, has in course of time tried the growth of some twenty different kinds of grass, but all died out with the exception of those first named.

d. Quarry Holes Meadows consist only of 8 acres of permanent meadows, and are chiefly remarkable for the large quantity of sewage applied to them, being not less than 65,000 tons per annum. The process goes on day and night, including Sundays, all the year round, except only during frost.

e. Grange and Rosebank (Broughton Road) Meadows.—The two remaining ones, of respectively 16½ and 6 acres, are managed much in the same way as the preceding.

This mode of utilisation has been applied to some portions of the Edinburgh meadows for over two centuries. The distribution is entirely by open carriers, and the quantity of liquid manure applied excessive.

Regarding the application of sewage liquid to corn and other rotation crops, the trials at Rugby, Watford, and Alnwick are illustrative. At Rugby, which has some 7000 inhabitants, the sewage was collected in a receiving tank, and thence pumped with a 12-horsepower engine through iron pipes laid over 470 acres of mixed grass and arable land, an arrangement in existence some 13 years. One tenant, who began with 190 acres, has gradually reduced the area of application, until he finally abandoned the use *of hose and jet altogether, confining himself to 20 acres of rye-grass and meadow land.* Before 1861, a tract of 280 acres was worked by another tenant who, after trying sewage both on arable and grass-land, had to give it up through the losses he sustained.

The present tenant had the same farm arranged for pipe, hose, *and jet application, to all sorts of crops, but has now reduced his operations to* 100 acres of grass land manured by open runs.

At Watford, the Earl of Essex prepared 210 acres of arable and grass land for pipe, hose, and jet distribution, but had also gradually to contract his operations, experience proving that one acre of rye-grass yields a better return to this kind of treatment than 40 acres of wheat.

Near Alnwick, the Duke of Northumberland put down machinery and pipes over some 270 acres of mixed land, and applied sewage in various quantities to all kinds of crops; but although the tenants got the sewage free of cost, the whole arrangement has been abandoned, the bailiff of the district reporting unfavourably against the use of sewage liquid for corn or any rotation crops whatever.

The royal commissioners, Professor J. Thomas Way and Mr. J. B. Lawes, charged with an inquiry into the best mode of utilising sewage, &c., give the following interesting items as a summary of their most carefully conducted experiments relative to the comparative value of sewaged and unsewaged grass:

When cut and given to fattening oxen tied up under cover, more sewaged than unsewaged fresh grass and hay was consumed by the animals, in order to produce a given weight of increase. When oil cake was used in addition to sewage food, the results were better.

Milking cows proved more productive both in milk and increase, when fed on unsewaged than on sewaged grass. But, considering that more crops can be cut with the sewage process from a given field, a sewaged acre will keep a cow a longer time, increasing thus the amount of milk three to fourfold. There is comparatively little difference in the composition of the milk produced from the two kinds of grasses; only that from sewaged grass is less rich, containing not so much casein, butter, sugar, and total solid matter than that from unsewaged grass: it has, however, more mineral ingredients.

The commissioners sum up the result of their scientific observations, extended over eight years, as follows:—

a. The proper way to dispose of sewage liquids is by applying them continuously to land, by which alone the most dangerous pollution of rivers can be avoided.

b. The financial results of such sewage applications depend mainly upon local circumstances, pumping being required on some lands, whilst on others mere gravitation effects the purpose; heavy soils, which are often alone available, are less fit for the process than light lands.

c. All local circumstances being favourable, profits may perhaps accrue; otherwise this system merely serves to aid in defraying the expenses connected with the removal of sewage.

6. **SEPARATING SOLIDS FROM FLUIDS.**—By 'sewage liquid' we mean, of course, the thin watery mass produced in sewerage by water-carriage, by employing some 350 parts of water to carry off one part of excrements (see p. 27). As many towns are not situated in the vicinity of fields combining all the adventitious circumstances needed for a system of utilisation, which requires pouring the sewage wholesale over them, many attempts have been made to extract the fertilising ingredients from the immense quantity of water that is used. This interesting process may not inaptly be compared to *mixing one atom of wheat-flour with a bushel of chaff-dust* for purposes of transportation, and then getting up a complicated and costly arrangement of chemicals and machinery for separating the flour from the chaff, in the hope of using it afterwards for food. No exaggeration, but plain simple truth, as the case stands.

To make the difficulty of recovering the useful part of sewage fluids still more plain, we have only to bear in mind that the proportion of value of the fertilising ingredients held in solution in urine to that contained in the fæces is as six to one.* The average estimates made by Messrs. Lawes, Way, Hofmann, Witt, and many others, as the mean annual produce of ammonia by a single individual of a mixed population of both sexes and all ages is as follows:—

Average Produce per Annum of both Sexes and all Ages per Head:

	Ammonia. lbs.	Value. s. d.
Urine	9·38	6 3
Fæces	1·19	1 0
Total	10·87	7 3*

There are also of course other ingredients contained in human excrements equally important; but ammonia being the most preponderating, it may be safely taken as a gauge of the comparative value of urine and fæces.

Now ammonia is a gas composed of one atom of nitrogen (14·20), to three of hydrogen (1), and is readily absorbed by water in large quantities; a pint of cold water can take up 600 to 700 pints of ammonia before it is saturated (see page 66).

In the sewage liquid the best part of the manure, ammonia, is therefore afloat, and a residue of solids obtained by filtration or straining cannot possibly have any great agricultural value. Ignorant or distrustful of the truth of these deductions, many people preferred practical tests to find the manure value of the solid residue of sewage fluids, sparing neither expense nor trouble for that purpose. These experiments were perhaps promoted by an opinion very generally entertained, that the excremental solids alone were polluting the rivers, whilst the fluids were held to be comparatively innocuous; others again considering the whole of the fæces a nuisance only fit to be thrown away, or got rid of at any cost.

For the information of our readers we will now shortly describe a few instances of such sewerage works, obtained principally from the report of Henry Austin, Esq., in the Second Report of the Royal Commission.

* Third Report of Royal Commission, p. 4[illegible], gives 8s. 6¾d.

a. Coventry Sewerage Works.—This town has some 42,000 inhabitants. The sewage is received in a depositing tank, whence it passes laterally through a coarse gravel two feet thick, confined between perforated boards, into a second and smaller tank, and thence through a second strainer into a third tank, from which it flows into the little river Soar, a branch of the Avon. These works are constructed in duplicate, so that the precipitated solids out of one set of tanks can be removed whilst the process is in operation in the other. The tanks are arched over and paved level with the ground, tramways leading over them, along which a movable crane travels for hoisting the residue up through manholes left in the pavement. After removal, the excremental matter is mixed with dry rubbish and thus converted into manure. The account of these works stands as follows:—

Cost of the

	£	s.	d.
Purchase of land (4½ acres) and road	555	4	0
Construction of sewerage works	3,764	16	11
Total	4,320	0	11

Working Expenses and Returns.

	£	s.	d.
Average annual working expenses	172	4	10
Interest upon cost of works at 6%	259	4	0
Total	431	8	10
Proceeds of sale of manure: 1,122 tons per annum	112	4	8
Annual loss incurred	319	4	2

b. Ashby-de-la-Zouch Sewerage Works.—A small town on the river Mease, a branch of the Trent: population about 4,000. The sewage is run in open brick tanks, 70 feet long and 10 feet wide, built in duplicate, and divided into three compartments each, between which strainers are placed, composed of perforated boards 3 feet apart. The upper strainer is filled in with coarse pebbles, the lower ones progressively with finer, and the last with fine gravel. The principal deposit takes place in the first tank, and is removed once in 6 to 8 weeks at an expense of 13*s.* for labour. The second tank need only be emptied once a year, and the third of course still seldomer. These works are extremely simple, require no attendance, and are not even surrounded with a fence. The total cost was but 80*l.*, which money the local board borrowed, payable in thirty years. The annual account stands as follows:—

	£	s.	d.
Rent of land	5	0	0
Capital, instalment, and interest	5	1	5
Working expenses	7	16	0
Total	17	17	5
Annual sale of manure	10	0	0
Annual loss incurred	7	17	5

c. Birmingham Sewerage Works.—This city, with nearly 300,000 inhabitants, is situated on the rivers Rea and Tame. The sewage is or was received in a settling tank, from which it could be passed into a second over a weir of floating planks, and even into a third before passing to the outfall.

Originally there were to the right and left filtering beds between the second and third tank, one for upward, the other for downward filtering. The downward filter soon became choked and useless; the upward was continued some time longer, but afterwards also abandoned. The filtering media were composed of three inches of 'nut gravel,' laid upon cast-iron grates and covered with nine inches of coarse sand. The sewage-sludge deposited in the tanks accumulated at the rate of 25,000 tons per annum, without any market to sell it even at 6*d.* a ton. Nobody wanted it. This sludge, composed of road and street-grit mixed with sewage, cannot readily be dried so as to become portable. The cost of the whole arrangement to the corporation of Birmingham is or was some thousands of pounds per annum, which of course were utterly thrown away, as the rivers were still polluted and the land was more injured than benefited by the application of a stuff, which is only the husk and not the nourishing kernel of the sewage.

These examples may be sufficient to show that filtering, the most inexpensive mode of collecting the insoluble parts of excrements, certainly does not pay; but represents only a sort of round-about way for throwing the far more valuable ingredients of the sewage into rivers, there to become highly detrimental to public health.

7. MANUFACTURING ARTIFICIAL MANURE.—The following attempts have been made to retain some of the fertilising ingredients held in solution in sewage liquids, and at the same time to deodorise them.

a. Uxbridge, a little town of about 3,500 inhabitants, in Middlesex, collected its sewage in tanks and passed it through boxes filled with charcoal, a material costing, at 5*l.* per ton, some 70*l.* per annum. The boxes were emptied about every six weeks at an expense, including other items, of about 60*l.* a year. The deposits, when partially dried, were mixed with town ashes, and put up for sale at 5*s.* a ton; and were even then only got rid of with great difficulty. Charcoal does not answer as a continuous filter, for, when saturated, its peculiar oxygenating power ceases.

b. St. Thomas, near Exeter, possesses sewerage works originally laid out for working Mr. Herapath's Patent Deodoriser, in which sulphate of iron and burnt magnesian limestone were used. The process proved of no avail, and was abandoned. The local board then resorted to the use of lime and basket-work, which also turned out a failure, and the works were discontinued in consequence of an indictment for a nuisance.

c. Clifton treated its sewage first with sulphate of iron and lime for deodorisation; but as the manure thus obtained did more harm than good to the land, the sulphate was abandoned, and lime only employed. This compound was, however, but of little agricultural value.

d. Leicester, on the Soar, with about 68,000 inhabitants, deodorised its sewage upon Mr. Wicksteed's patent, the process proving commercially an entire failure. The works were erected for the manufacture of a dry portable manure, which it was hoped would sell for about 4*l.* per ton, whilst in reality it hardly brought 4*s.* This part of the works has been abandoned, nothing else being now aimed at but to disinfect the sewage-fluid before throwing it into the river.

e. Tottenham, on the river Lea, with a population of some 14,000,* treated its sewage under Mr. Higg's patent, in works specially erected at a cost of several thousand pounds. The object was the manufacture of dry sewage manure, which resulted, as at Leicester, in utter loss to the proprietors.*

f. Ely, a small town of some 7,300 people, has also attempted the manufacture of dry manure out of deposits of sewage-liquid. The works were skilfully conducted by Mr. W. Burns, C.E. The process was as follows: At the end of the main sewer, on the top of it, a tank was placed, in which clay and lime were mixed with water and allowed to run down through a pipe into the sewage. This mixture fell into a movable strainer, which when full was hoisted up, being immediately replaced by another empty one. The full strainer was now emptied on a floor higher up, where the deposits were mixed with charcoal and gypsum, at the rate of four parts deposits, two of charcoal, and one of gypsum, and then left to dry. The floor was ventilated by a chimney, which served also as a channel for the strainers to move in. The liquid portion falling below was filtered upwards through a perforated floor, overlaid with twelve inches of charcoal and six of ground gypsum. In this elaborate manner a manure was manufactured, which farmers declined buying, because, they said, 'it had no strong scent,' which is nothing but the unscientific expression of unsophisticated countrymen, whose practical experience supplies the want of a chemical education, at least so far as to teach them that the presence of *ammonia* and *nitrogenous compounds*—to them known only by their 'scent'—indicates the main value of a fertiliser. Considering that at least three parts of the seven (charcoal and gypsum) are good fertilisers for many soils, the compound, notwithstanding the unfounded prejudice of the farmers, may have been well worth the price asked, viz. 10s. per ton.

These instances are enough to prove that solids extracted from fluid sewage cannot be manufactured into dry manure, so as to pay for the trouble. Apart from this, chemical analyses, most carefully conducted, of the results of various processes of deodorisation prove, that none of them have thus far succeeded in precipitating or retaining fertilising parts held in solution, the only substances precipitated being those which are held only in suspense, and which would just as well have been retained by the mere mechanical process of filtering.

* During the past season (fall of 1866) diarrhœa and typhus have prevailed at Page-green, a detached hamlet in the parish of Tottenham, numbering some ninety houses, which, according to Dr. Seaton, who was instructed by the council to make a sanitary investigation, was owing to the land in the immediate vicinity being treated with the sewage of Tottenham, and also to the inhabitants drinking water from wells dug just beneath the surface of that land. Thus, of twenty-four houses having such wells, not less than nineteen had either one or more cases of sickness. Mr. Morgan, C.E., who was specially instructed by the Privy Council to report on the sewerage works of Page-green, states that all the houses in the hamlet, with the exception of three, drain into the sewers; and hence it was probable, according to Mr. Arthur Priest, M.R.C.P., that the malignant fevers resulted from the poisonous exhalations ascending from the sewers into the houses, while the intestinal diseases arose from drinking water contaminated with sewage.

8. **PRECIPITATION OF SEWAGE BY LIME.**—Professor J. T. Way* gives the following analysis of sewage precipitated by lime:—

Precipitation of Sewage by Lime fifteen to sixteen grains per Gallon.

Ingredients	Grains per Gallon Before Treatment	After Treatment	Precipitate
Organic matter, soluble	19·40	19·35	- .
„ „ insoluble (suspended)	39·10	—	35·41
Lime	10·13	9·28	14·80
Magnesia	1·42	0·94	0·22
Soda	4·01	2·26 }	
Potash	3·66	3·80 }	1·02
Chloride of sodium	26·40	24·49 }	
Sulphuric acid	5·34	5·99	1·11
Phosphoric acid	2·63	0·45	2·06
Carbonic acid	9·01	5·19	8·92
Silica, sand, oxide of iron, &c.	6·20	0·23	5·96
Total	127·30	71·98	69·50
Ammonia	7·48*	7·50*	2·80

* This is in solution only.

From this table we deduce the following highly important facts:

a. No *Organic Matter* is precipitated, except such as was present in an insoluble or suspended form, and which might just as well have been retained by mechanical filtration.

b. None of the *Ammonia* of the sewage fluid is saved by precipitating, which ingredient is of the utmost value for vegetation and agriculture, but is here entirely lost, being allowed to pass off into the rivers. The small amount of ammonia retained in the precipitate is entirely due to insoluble matter.

c. Potash, another valuable agricultural ingredient, at least to some soils, being soluble, is likewise carried away by the waste liquid thrown into the rivers.

d. Phosphoric Acid is precipitated (five-sixths), and would form a most valuable fertiliser for cereals, if by this process the lime did not unite with it, forming as it does, with carbonic acid, an insoluble compound, absorbing also other suspended substances; and as, at the same time, ammonia is more or less set free and ready to escape, the use of lime is certainly so far injurious. What is required is to arrest the ammonia, and it is to this property that some acids, such as carbolic acid, owe their antiseptic qualities.

9. **PRECIPITATION OF SEWAGE BY SULPHATE OF ALUMINA.**—According to Mr. Stothert's process to a gallon of liquid from the Northumberland sewer was added:—

	Grains
Sulphate of alumina	73½
Sulphate of zinc	3½
Fine charcoal	73½
Total	150½

* Second Report of Royal Commission, 1861, p. 69.

to which after incorporation were further joined 22 grains of slacked lime, equal to 16¾ grains of quicklime. When the precipitation was complete, the following were the results :—

Ingredients of Sewage	Grains per Gallon		
	Before Treatment	After Treatment	Precipitate
Organic matter, suspended	17·00 }	21·58	121·63
„ „ in solution	41·03 }		
Lime	14·71	21·21	13·46
Magnesia	1·82	1·81	0·82
Alumina	—	0·77	9·94
Oxides of zinc and iron	2·64	1·05	8·88
Soda	2·40	2·26 }	0·50
Potash	3·57	3·74 }	
Chloride of sodium	22·61	22·50 }	
Sulphuric acid	5·31	32·08 }	
Phosphoric acid	5·76	trace	3·87
Carbonic acid	8·92	—	8·47
Silica, sand, &c.	10·91	0·25	10·53
Total	136·68	107·25	178·10
Ammonia	8·43*	8·41*	3·37

* In solution only.

This table proves that also by Mr. Stothert's process the ammonia in solution is lost to agriculture.

10. PRECIPITATION OF SEWAGE BY SOLUBLE PHOSPHATE OF MAGNESIA.—A third trial was made in accordance with the specifications of Mr. Blyth. To a gallon of sewage were added a quantity of superphosphate of lime, equal to 31¾ grains of phosphoric acid, and a quantity of sulphate of magnesia, equal to 18¾ grains of magnesia; and lime-water was afterwards added to precipitate the whole. The object of this process was to retain the ammonia in the precipitate in the shape of ammonia-phosphate of magnesia. To give the trial every chance, the quantities above stated were larger than prescribed, and this was the result :—

Ingredients of Sewage	Grains per Gallon		
	Before Treatment		
Organic matter, suspended	24·37 }	33·84	40·27
„ „ in solution	12·30 }		
Lime	12·52	21·16	25·71
	1·59	18·60	2·36
Soda	2·41	5·07 }	[illegible]
Potash	3·31	[illegible] }	
Chloride of sodium	34·30	[illegible] }	
Sulphuric acid	6·40	46·59 }	
Phosphoric acid	2·48	12·59	21·62
Carbonic acid	11·76	5·00	6·12
Oxide of iron, sand, silica, &c.	6·46	1·50	8·13
Total	117·90	181·00	105·70
Ammonia	7·88*	7·81*	2·37

* In solution only.

The ammonia separated here is, as in the other processes, due to the organic matters of the sewage. On the other hand, fully a third of the phosphoric acid added in the process was left in solution, and passing off in the liquid was of course lost.

11. PRECIPITATION OF SEWAGE BY PERCHLORIDE OF IRON.—A fourth trial was made with perchloride of iron (persalts), containing 25 per cent. of real perchloride, equal to 8·60 per cent. of metallic iron, used in the proportion of 6 grains metallic iron to one gallon of sewage.

The results were as follows:—

Ingredients of Sewage	Grains per Gallon	
	Before Precipitation	After Precipitation
Organic matter	9·20	9·80
Lime	11·25	8·58
Magnesia	1·35	—
Soda	1·89	—
Potash	1·09	—
Chloride of calcium	—	4·30
„ „ magnesium	—	3·03
„ „ sodium	5·58	9·26
„ „ potassium	—	1·74
Phosphoric acid	0·64	trace
Sulphuric „	3·43	3·57
Carbonic „	4·77	1·72
Total	39·20	42·00
Ammonia	2·32	2·33

This process, therefore, seems also unable to separate and retain the ammonia or any other manuring ingredient. The only useful effect it has, is that a precipitate is formed, which, after leaving above it a clear liquid, contained all the suspended matter of the sewage, both organic and inorganic, and also the phosphoric acid, which was held in solution; finally, and this is a considerable advantage, the sulphureted hydrogen is removed.

12. HIDING A TREASURE.—If in the treatment of sewage nothing else was to be accomplished than to render it inoffensive, this last process, costly as it is, would go far towards fulfilling its object. But is that really the question to be solved? Nobody doubts that means may be found to *hide a treasure* so as to make it quite inaccessible; but is it not, to use a mild term, the height of folly to do so, and to employ the most costly means for such a purpose?

The word *treasure* we use advisedly, because Baron Liebig, Professors Thudichum and Voelcker, Alderman Mechi, Messrs. Lawes, Hofmann, Witt, and many other high authorities, have repeatedly shown the great agricultural value of the ingredients contained in fæcal matters, proving satisfactorily, by history, analysis, and innumerable experiments, how absolutely indispensable it is to national welfare, and to the highest condition of health and life, that this great agricultural *treasure* should *not be lost*, nor hidden either. These scientific expounders of Nature's laws have further pointed out that human excrements are '*offensive*' only as long as they remain 'in the wrong place,' a definition which Lord Palmerston pronounced the only correct one he ever heard on the subject.

This peculiar characteristic of the fæces, their offensiveness when in the wrong place, and the utter impossibility of rendering them harmless except by putting them in the right one, that is *underground*, as enjoined by Moses thousands of years ago: this offensive peculiarity is but one of the unerring modes by which Nature herself teaches her laws, and seeks to enforce obedience, punishing without mercy any attempts to neglect or evade them.

Professor Way justly and graphically calls the sewage liquid '*a grain of gold* contained in a *mass of gold quartz*.' We have seen that the 'quartz,' as produced by sewerage by water-carriage, is of such a stubborn nature, that all chemical and mechanical processes hitherto employed have failed in bringing the 'grain of gold' back again.

V. DISADVANTAGES OF SEWERAGE BY WATER-CARRIAGE.

To RENDER a just criticism of sewerage by water-carriage, it is but fair to keep in view the purpose first sought to be accomplished. This was manifestly *to get rid of a nuisance* in as respectable, decorous, and inoffensive a manner as possible. Even as late as 1858 this was distinctly expressed by the Royal Commission 'appointed to inquire into the best mode of distributing the sewage of towns, and applying it to beneficial and profitable uses.' Their Report says (pp. 21, 22):—

'The great problem is to get rid of sewage, advantageously to agriculture if it may be; if not, at the least expense to the community at large. Throughout the discussions that have hitherto occurred upon this question, the real issue has been left comparatively in abeyance. The primary consideration is, not whether the sewage can be made serviceable to agriculture, but whether or not there exists any method which, consistently with a fair expenditure of money, falling on those who ought in justice to bear it, will practically rid us of the nuisance and danger attendant upon town sewage. The object must be accomplished; and the question is, simply, how its accomplishment can most satisfactorily be attained. All other considerations are secondary to this.'

This Royal Commission, and none ever worked more conscientiously, or brought greater talents to bear upon a subject, in their openly avowed expression of purpose, are evidently making a retrograde step from the great fact so well established and zealously advocated by the most eminent men of science and national economy, viz. that the question of sewage implies also one of food. They persistently look at the matter from a sanitary point of view only, forgetting altogether what the poor man but too well knows, that life suffers as much from scarcity of nourishment as from disease, and that famine is as unhealthy as pestilence. The error committed by these gentlemen was, in a great measure, due to the singularly contracted view of the nature of the remains of the food consumed by our bodies, entertained by medical men and members of the Board of Health, whose professional opinions on the subject were, that this material was filth, the ingredients composing it poison, and the whole a nuisance, to be got rid of 'somehow.' They admitted that *perhaps* there might be a way to make it useful to vegetable life; but to do so was to injure health, which should not be exposed to such risks. Hence they advocated what seemed to them the simplest mode of effecting the purpose, namely, to remove it out of the immediate neighbourhood of human habitations to some other place, no matter where, if only they and their friends were no longer annoyed by its immediate presence. And so they emptied it into the nearest watercourse, indifferent as to where the polluted stream went, upon the old principle, perhaps, of '*Vivons nous-mêmes, à bas les*' and no doubt thinking that, if every one did the same, public health would be secured to all, and all would be right.

Of course the measures thus advocated were not more effectual in preventing the contamination of the atmosphere by fæcal gases, than those of an ostrich making itself invisible by hiding its head in the sand; notwithstanding, however, such notions yet prevail among many men who, in these enlightened times, ought to know better. Thus Captain Liernur states in his notes, that a certain distinguished chemist, and member of the Royal Agricultural Society, at a conference he had with him in the latter part of last year, vehemently insisted upon the impossibility of drawing from sewage any pecuniary profit as manure, for the reason that the cost of collecting and transporting it was always much greater than its value as a fertiliser; and that hence such material never should be considered in any other light than a nuisance, to be hurried out of sight and smell with the least possible delay; and he only saw how untenable his assertion was, when reminded of the known fact, that, in a great number of continental towns, the neighbouring farmers purchase annually from the citizens their cesspool matter, at from three to five shillings per head in the family, which generally was given as a customary emolument to the servants; a price which these farmers certainly would not have given (they having besides the trouble and expense of collecting and transporting), unless they realised a profit.

But even supposing this gentleman's estimate of the comparative cost of removal, and value of the sewage, to be correct, and that a town, undertaking the removal and sale of the manure, paid for the first a sum represented by the figure 10, and received from the farmers a sum represented by the figure 7, it surely is evident that the ultimate cost of removal would be proportionally reduced to the figure 3, resulting in a saving represented by the figure 7 (equal to a clear profit to that amount), instead of having had to suffer a loss of the whole 10, which would have been the case if this foolish advice had been followed, and the sewage thrown into the nearest harbour or river.

Considering the fact, however, that by proper management the value of the manure is a great deal more than the cost of removal, the reader may understand how much is lost, not only to the towns, but to agricultural interests. Unfortunately, just such men as the one here alluded to, having no practical mechanical knowledge or business skill, exert still a considerable influence on account of their undoubted learning and scientific attainments; and when consulted prevent (by giving adverse judgments based upon abstract theories or certain obsolete methods of manipulation) the execution of works of public utility, which really are practicable by means of new and improved mechanical contrivances, but which, being out of or beneath their scope of investigation, they seldom know anything about.

But, in truth, the absence of this practical mechanical knowledge is no valid excuse for such singular and erroneous opinions in men thoroughly acquainted with chemical analysis and its kindred sciences. They should know better than pronounce any matter, organic or inorganic, decomposing and offensive to the senses or not, 'a nuisance to be got rid of;' they should remember that, in the sublime arrangements of Nature, not a single law is made in vain—that not a single atom is superfluous, but has its properly assigned function and place, for some good and wise purpose; that, in fact, no matter can be a 'nuisance,' unless the law of Nature is violated, or its intention frustrated; and that hence, when any matter is found to be such to our senses or organism in any way (as, for instance, sewage in leaky subterranean conduits, or in rivers and harbours), it may be taken as an unerring criterion that it is not in the right place.

Such violations of Nature's laws are the more dangerous, as not one of these serves for only a single purpose, but for several important ones at the same time, all mutually depending on each other; in consequence of which the evil effects of disobedience are never felt in only one direction, but in several simultaneously.

After the above review of the erroneous opinions alluded to, we proceed to give a detailed account of the disadvantages of sewerage by water-carriage, which, independent of the *principles involved*, was in its execution more the result of development than of design. One erroneous step always necessitated another: first, the saturation of the soil with urine, &c., caused the overflow of the cesspools; their abolition led to the use of waterclosets and house drainage in some shape or other, requiring in its turn a far more copious supply of water to flush away the sediment in the drains, thereby vastly increasing the quantity of sewage to be disposed of. The main sewers were first arched over, partly to gain room in the streets, and partly in the hope to prevent the escape of their exhalations; then they were greatly enlarged and sunk deeper, for the purpose of intercepting tributaries; and it was then only their builders became aware of the disagreeable fact, that their outfalls delivered such a volume of most noisome matter, that the wisest heads were completely puzzled what to do with it! As the readiest means at hand, the sewage was unceremoniously delivered into rivers and harbours, creating such deadly pollution as soon led to the most alarming consequences in regard to public health.

Then the great irrigation scheme started into life, for throwing sewage liquid upon lands, wherever they could be found at all suitable for the purpose; with what poor results has been partially shown in the preceding pages. Other 'systems' again took the noisome stuff and filtered it, strained it, precipitated it, concentrated it, and analysed it, throwing the valuable ingredients away, and retaining the worthless; then doctoring it with lime, charcoal, ashes, street-dirt, and all sorts of abominations, compounded it into various chemical messes, dried it again with hot air or steam, whirled it about in costly desiccating machines, cooked it, nay even baked it, and afterwards offered it for sale in all sorts of disguises, —as a liquid, as a lotion, as a powder, as cakes, as chunks,—to attract customers; most farmers, however, stoutly refusing to buy it at any price, until at last all sensible people agreed that sewage was as much a nuisance as ever! *

* We cannot help remarking that these roundabout ways of treating fæcal matters to no purpose whatever strongly reminds us of Dr. Franklin's prescription for cucumber salad: 'After carefully preparing the vegetable, mix it with pepper and salt and oil and vinegar, and various other condiments, and then,' quoth the great Yankee philosopher, 'pitch it out of the window.'

But one thing at least, it was confidently hoped, would be gained by sewerage by water-carriage, namely, the effectual removal of a most deadly nuisance out of cities and towns, or at least from the immediate olfactory and respiratory organs of their inhabitants. We shall afterwards see how far this has been accomplished; but as the only proper method of judging of the comparative value of a result is to consider also the cost and trouble incurred in accomplishing it, we must first glance, for a moment, at the enormous difficulties generally to be overcome, in executing the various works appertaining to this particular sewage system.

1. TECHNICAL DISADVANTAGES.—First and foremost stands the necessity for waterworks, the whole scheme of sewerage by water-carriage being based upon a plentiful supply of that element, not only to promote the transit of the sewage through narrow subterranean channels without sticking or forming deposits, but also enough to keep the interior of these conduits well flushed.

To build such sewerage works without providing, at the same time, for a copious supply of water, would be like sending a man-of-war to sea without ammunition. In fact, a great point with the advocates of this system has always been, that it was this very profusion of water which operated so favourably on the health of a town, because it induced more cleanly habits amongst the population. And far be it from us to deprecate this. We would rather recommend to double the quantity of water hitherto provided, wherever it was possible to get it; for, next to well-ventilated dwellings, there is nothing that promotes public health so powerfully as a supply of pure water in quantities enough to furnish it to every individual, old and young, rich and poor, not only for drinking and culinary purposes, but also for a regular daily bath. Nor do we believe that rates of mortality will ever be reduced to their minimum until, even in the humblest and poorest dwellings, some nook be appropriated for thorough daily ablutions. Eight cubic feet per head seems to be nearer the proper daily allowance than the five feet hitherto deemed sufficient.

But our question now is, should the immense volume of water daily flowing from a city, increased further by large quantities of rainfall, really be used for carrying off excremental matters, amounting annually to only about *ten cubic feet* per head, thereby obtaining a mixture utterly unavailable for any purpose whatever, in ninety-nine cases out of a hundred, both constituent parts being thoroughly spoiled?

Now, there are many towns, perhaps half the number in the world, so geologically and topographically situated, that a supply of water by means of waterworks requires either conduits of great length, sometimes hundreds of miles, or the erection of powerful machinery to pump it up from a great depth, out of copious wells found in the lower strata of the surrounding country, out of reach of the filtration of the polluted soil upon which the town stands. Such conduits, or pumping machinery, often involve an enormous outlay of capital, which surely must be put down, if not all, at least to a great extent, to the account of the sewerage works which absorb so great a proportion of the water provided in this costly manner. Thus, for instance, the minimum quantity used in waterclosets, and which is really necessary thoroughly to wash and rinse the basin and pipes, may be estimated at two cubic feet daily per head of population. Supposing the whole town to be provided with this arrangement, the waste of water for this item alone would, for a city of 100,000 inhabitants, amount of course to 1,500,000 gallons per day; and supposing further the pumping machinery of the waterworks supplying the town to have to lift it twenty feet (which is a low average of existing works), in order to obtain the requisite fall, so as to reach the second floor of dwellings, the adoption of waterclosets would cause an additional expenditure of lifting 8,680 pounds twenty feet high per minute, which of course forms no small item in expenditure.

But this is not the only expense incurred. Waterclosets, or some arrangement with valves and cocks to let on the water when required, must be provided; contrivances not only costly in purchase, but also expensive to keep in repair; so much so that, in many towns, only ten per cent. of the houses are supplied with them.

There are few things more disgusting or more detrimental to the healthiness of a dwelling than a watercloset out of order, or without a stream of water sufficiently strong: it soon becomes a nuisance beyond endurance, amounting almost to a prohibition of this contrivance at railway stations, and other public places, where no proper care is taken, or a promiscuous crowd has access to them.

Another drawback upon the general introduction of waterclosets is the fact, that the water is generally supplied by private companies, who of course withhold it at once whenever a rate due is not forthcoming, which is a grievous burden to many a destitute family, earning often barely enough to purchase food, and who are thus compelled to pay either heavy charges for water, or endure the horrible nuisance of accumulated excrements; a dilemma, one horn of which is just as bad as the other for the poorer classes, who largely preponderate in all cities, and are thus practically excluded from a most important sewerage arrangement, which by right should be enjoyed by all.

London, with her area of 125 square miles, offers an interesting instance of the great stress a city may be put to by the enormous waste of water occasioned by the watercloset system. The daily average of five to six cubic feet per head having proved hardly sufficient, all sorts of most costly schemes are broached to supply the deficiency: one plan contemplating to bring water from the Welsh hills by an aqueduct 183 miles in length, at a cost of some 8,600,000*l.*; another, to tap some streams and lakes between Westmoreland and Cumberland, 240 miles away, at an expense of only 11,200,000*l.*! Now it is clear that, if a sewerage scheme were provided, sparing the immense quantity of water hitherto required for waterclosets and house-drainage pipes, probably some rainfall basin much nearer London could be found, capable of supplying all the domestic wants of the inhabitants, whereby of course millions would be saved.

Another great technical difficulty is the unchangeability of the principles, according to which all works must be constructed, whereby fluids are to be kept in motion by gravitation. Thus, to admit of the regular flow of a given stream, a conduit must be of a certain fixed size, and have a certain fall, both of which cannot at all be varied to suit other circumstances. If conduits are once constructed to carry off a certain quantity of liquid, and this given volume is afterwards increased or even doubled, as is now proposed in London by the additional waterworks in contemplation, it is very evident that the existing sewers at once prove insufficient, and must either be considerably altered or rejected altogether.

In large towns the main sewers receive, almost every few feet, additional volumes of fluids from numerous tributaries right and left, demanding of course a constant increase of capacity. In really well-constructed drainage works, every sewer, whether main or branch, should always discharge into a larger one; a consideration of the highest importance, when it is remembered that few cities enjoy such peculiar topographical sites, that all water would drain from the centre to the edge all around. In by far the most cases the drainage runs from one end of a town to the other, often diagonally, in a most tortuous line. In theory, when any matter is to be moved, the shortest haul is of course always preferred; sewerage by water-carriage, on the contrary, generally compels the longest average haul that can possibly be found.

The fall or gradient of sewers, as stated before, admits also of no change or variation, except in some cases where an inverted syphon can be used for short lengths; but even then, when the dip is at all great, or the gradients leading to and from it steep, some means must be provided to remove the deposits collecting at the bottom; and this is either very costly, or totally impossible. Sewers of unequal size should never be level at their inverts; for this causes the sewage of the larger one to dam back in that of the smaller tributary. To avoid stoppages, both sewers must be level at their crowns, and the tributary have a fall at its junction with the main; this necessity of course increasing the depth of the main-sewer, and consequently the difficulty and cost of its construction.

Now, few towns have the surface of their site parallel with the plane of gradients, but undulate often considerably. In constructing subterranean drainage-works, the depth of cuttings then increases with the height of the hills or surface waves; and no matter how excessive the expense, it must be submitted to. There are cases on record where the compulsory depth of sewers actually reached sixty-eight feet! Cutting then is almost out of the question, and tunnelling with all its attendant inconveniences must be resorted to.

But even if no such great depths are required, the average is seldom much less than some fifteen feet, just about the level at which constant interference occurs with the foundations or stability of buildings, necessitating all sorts of shoring, underpinning, and other costly arrangements, or even the demolition of whole structures and their rebuilding afterwards, owing to the water which issues from subterranean arteries carrying the soil away from under the foundations, and other similar causes.

Aboveground there is another difficulty in the rooting up of the streets to the great depth so often required, the consequent obstruction of crowded thoroughfares, and long interruption of public traffic, with all its attendant annoyance and loss to the inhabitants, along the whole route where such sewerage works are in progress.

And, finally, the cost of sewers at great depth is further fearfully increased by the proportional greater height of the man-holes and ventilating shafts, and of the street-gully branches. Just imagine a long line of sewers at an average depth of say twenty feet, having at every interval of 100 feet a costly chimney of a corresponding height.

A last most onerous requirement is the necessity of straight lines, or large radii where curves are inevitable. A sewer, with frequent changes of alignement and gradient, requires in proportion more shafts or chimneys for inspection and removal of stoppages. This is so important a consideration, that many engineers justly prefer to remove intervening obstacles, such as houses or cellars, no matter at what cost, rather than allow them to interrupt the even current of streams in their conduits; and but few towns have streets straight and wide enough to give ample elbow-room for all these exigencies.

One of the main arguments in favour of subterranean sewerage is the statement, that when, in accordance with the rules of the Board of Health, pipe or pottery-ware drains are used, the cost is not near so much; and it is often asserted that many towns have been drained in this manner, which would have been unable or unwilling to expend the larger sum required for a system of brick-sewers. A dispassionate examination of these claims, and the facts which actual experience has brought to light, and which are acknowledged by both parties, will soon show us how far this view may be admitted as correct.

When the volume of fluid which is to be carried off in a given time, and with a given gradient is known, the sectional area of the conduit can be easily calculated by the formulas of Poncelet, Eytelwein, Prony, Du Buat, and others, which are established by carefully conducted experiments, and have been repeatedly verified by actual practice. It makes, of course, no difference in the calculation, of what material the conduit is made, whether of iron, lead, brick, or pottery-ware, the only point coming into consideration being the comparative smoothness of the interior surface.

But a great deal depends upon the form or shape of the sectional area; and no doubt that is the best which, at the height of ordinary flow, that is to say, when the sewer is about half full, gives the least lateral friction, and the greatest hydraulic depth. It needs no argument to prove that these requisites are better complied with by the oval section than with any other; above all, when the invert has the same small radius, which is justly claimed as an advantage in the tubular drains. Thus, a twelve-inch circular sewer, when half full, would nearly equal an oval sewer with an invert of six-inch radius; but when the volume of sewage to be carried off increases, the advantage is clearly on the side of the latter.

The statement advanced by some, that circular drains give a proportionally greater velocity with each additional volume of fluid, is evidently only partially true, as the speed of the current does not increase in the same ratio, else there would be no limit to the quantity of sewage carried off by a given conduit; the smallest sewers would be as good or better than the largest, and on that principle the Board of Health might as well have drained towns by means of mere pipe-stems or quills. The only thing that can be said in favour of small drains is that, in case of a stoppage by accumulation of deposits, the back fluid forms a hydrostatic head, which increases in height proportionally to the length of time such sediment bars the way, until finally the weight of the column overcomes and removes it. It may happen however, when the fall is not great, that sediments accumulate over a great length of drain, gradually contracting its area over that distance, and the head not being high enough, the whole eventually chokes up and becomes an indescribable nuisance.

The question of dimensions and sections being thus far settled, there remain yet those of comparative strength, durability, and cost to be looked at. In regard to strength it must at once be acknowledged, that in all subterranean structures, where no repairs can be made except after excavations of great depth, compelling obstruction of thoroughfares and interruption of street traffic, no material whatever should be used the solidity of which is in the least doubtful.

Experience has shown this to be the case with pottery-pipes, which have repeatedly been found crushed or split over their entire length, or otherwise fractured. This can of course be prevented, in some measure, by making the ring thick enough; as has been done, for instance, with some of the Manchester tubes, which have a thickness of one-eighth of their diameter, or three inches for a two-feet pipe. But then the difficulty of manufacture increases the cost so much, that brick sewers of equal dimensions are actually cheaper. Thus experience shows that a brick sewer of thirty inches costs about one-third less per yard than a pipe of twenty inches, under which circumstances no engineer will hesitate which kind to adopt.

There is also a great difficulty encountered in the joints of pipe sewers, as the socket-joints break the tubes by the least unequal subsidence; and butt-joints, which are free of this fault, constantly leak. Besides, the ring is not thick enough to stand long the abrading action of silt and street grit, much less the wearing effect of scraping tools, which in some towns it has been found necessary to use regularly for removing such deposits as somehow or other would not yield even to the strongest flushing.

This latter point also shows the incapacity of pipe sewers to meet another requirement of subterranean structures, namely, internal inspection, it being utterly impracticable to make them large enough to allow the entrance of a workman; and yet this is the only effective means for localising stoppages, removing them, and effecting repairs generally, without constantly rooting up the streets for that purpose. This necessity fixes at once the size of at least all main sewers at a minimum height of three feet six inches. The branch conduits may be brick sewers of twelve inches, and within the walls of the houses perpendicular pipe drains may be used, where they are useful and economical if made strong

enough. For the various reasons above stated, pipe drains should be rigidly excluded from any part of the arterial drainage.

2. FINANCIAL DISADVANTAGES.—The claim so often advanced, that works for sewerage by water-carriage according to the new system can be executed cheaply, is, as we have just seen, utterly delusive; for when the requirements of sewerage are to be fulfilled at all, the cost is from the very first bound to be a certain fixed sum, which afterwards generally proves out of all proportion to the results accomplished.

Not that we mean to say that any sum would be too large to secure the objects in view, viz. perfect public health and the lowest minimum of mortality; and that, if the water-carriage system was absolutely the only practicable one, all monetary considerations should not vanish. But to gain a clear idea of the case before us, two questions naturally arise.

1st, What is really the work to be done? and, 2nd, What is the price paid for it?

We answer the first question thus: simply to remove out of cities human excrements, amounting annually to some ten cubic feet per head, before they have time to saturate the soil and poison the water, and to prevent the escape of noxious gases during the process of removal. We shall presently consider whether or no the system alluded to fulfils these requirements; but supposing, for a moment, this to be the case, the price paid is certainly the highest that can possibly be imagined, because the enormous technical difficulties just explained cannot be overcome in the construction of such sewage works, without fearfully swelling the ultimate bill of cost. This is amply proved by the almost fabulous sums spent on drainage in certain towns, where the works have been executed in good faith, and not bungled by small pipes and other botching contrivances.

But the actual cost of such works, whatever it may be, is after all not the principal price exacted by the famous water sewerage system; it is rather a mere drop in a sea of lavish expenditure! The reckless and utterly foolish waste of millions upon millions, by continually throwing into rivers and harbours a material absolutely indispensable to agriculture, must also be taken into consideration. But too zealously has the maxim—remove the dirt, *coûte qui coûte*—been followed out.

We have already mentioned (see page 33) that, according to the best authorities, the annual excrements of an average individual contain some 11 lbs. of ammonia, worth about 7½ shillings; adding to this 2½ shillings for other useful elements contained therein, we have for a town of 100,000 inhabitants the handsome yearly sum of 50,000*l*., which, in nineteen cases out of twenty, is remorselessly thrown away, or at the best worked up in some poor chemical messes, which either farmers refuse to buy at all, or which do more harm than good to the lands they are applied to.

But even this enormous annual loss, amounting for a country like the United Kingdom, with some 20 millions of town population, to no less than 10,000,000*l*. a year, does not yet represent the ultimate cost of sewerage by water-carriage. The real final [illegible] the bill is yet to come. It may be many years hence; [illegible] most pernicious system be continued, come some time [illegible] it surely will.

We allude to the *exhaustion of the English soil*, which until now has been retarded by large importations of guano and other fertilisers; but this foreign source of supply is well known not to be unlimited; and when these foreign fertilisers are no longer to be found,—What then?

Then, when threatening famine, caused by exhausted fields, compels constant importation of food from abroad, and thus by the high price of bread so raises the cost of labour that England can no longer successfully compete with foreign countries in furnishing staple products or manufactured commodities—when the busy hum of thousands of workshops is silenced, and trade and commerce become stagnant—and when the poisonous exhalations arising from polluted harbours and numberless inlets and estuaries breed pestilence and death, thus to fill the cup of misery to the brim,—then, we say, will appear the enormous price which has been paid for this delusive and disastrous, silly and sinful sewerage by water-carriage.

3. SANITARY DISADVANTAGES.—After having added up the cost of sewerage by water-carriage, let us see whether the work expected of it is at least properly done, or whether the fearful price paid is altogether thrown away; that is to say, let us ascertain, whether the human fæcal matters, which, as before stated, are almost exclusively the elements imparting offensiveness to sewage liquid, are really removed without polluting air, soil, and wells, while in transit through these costly subterranean drains, wherein they are carried away by immense volumes of not less expensive water, with an annual loss of some ten shillings per head of population in waste of manure, besides interest on the enormous capital locked up in the works, and at the certain risk of causing famine and pestilence in the future.

It is well known that fresh or river water, holding excremental matters in suspense, goes through a process of fermentation, whereby very offensive gases are thrown off with comparative great rapidity. Thus, for instance, ship-captains, during the worst periods of the pollution of the Thames, continued to take below bridge that same filthy river water on board for their outward-bound voyages, experience having taught them that though the water putrefied in the casks, in course of time all gases would be thrown off, leaving a black changeless sediment at the bottom; and that thus, in the course of a few weeks, the original Thames water would become as pure as if it had been drawn from the sweetest spring.

This is a sort of natural filtration, which becomes rapid in proportion to the heat of the atmosphere. But the gases evolved during this process are deleterious in the highest degree, and become the more dangerous when they are confined in sewers, for the double reason, that there they are kept at the temperature of putrid fermentation; and that, instead of being gradually dissipated in the air, as is the case with the ship-water casks just alluded to, the gases are discharged at the outlets of the conduits in a most concentrated form. This fact explains also the seemingly singular phenomenon that, at the outbreak of cholera, the dwellings in the higher parts of towns having waterclosets discharging into sewers, suffered much more than houses situated below, and having still the old-fashioned cesspools and 'middens' outside. Mr. G. A. Rowell, of Oxford, satisfactorily proves this in regard to his city, in a paper, 'On the Ventilation of Sewers,' read before the Ashmolean Society, November 28th, 1864, pointing out at the same time, that the epidemic at Washington in 1857 was directly traced to the escape of gases from street sewers recently trapped.

The specific gravity of sewage gases being lighter than that of the atmosphere, it stands to reason that the former must tend upwards, and that the speed of their ascent corresponds to the steepness of the sewer-gradient; so that the quicker the sewage liquid flows off, the quicker the gases evolved rise up. Is it not strange that this simple natural law should have been so much overlooked; and, stranger still, that engineers should be found placing their opinion on record, that no ventilation was needed in sewers at all, as did Mr. Fulton in his account of the 'Sewerage of Dundee,' read before the Institute of Civil Engineers?

In all sewerage-works constructed by engineers of eminence, no cost has been spared in providing arrangements for allowing a regular escape of gases, with an admission of fresh air; but, somehow or other, it appears that all contrivances to that effect failed to fulfil their purpose. Thus, for instance, the charcoal filters placed in the shafts do not pass the gases if the material is closely packed; and, if it is not, the gases escape without being purified by that material. It is also difficult to construct street-gullies for readily passing rainfall, collecting street-grit, and at the same time preventing the escape of gases; while the former slip in, the latter is apt to slip out. Mr. William Menzies says, that if any engineer would set himself the task of devising the best means of discharging, in the midst of the population, all the stench from sewage drains, it would be difficult for him to plan a more complete method than street gratings afford.

A further proof of the total insufficiency of all these contrivances lies in the fact, that workmen entering sewers invariably experience a current of air running up the house-drains like so many chimneys.

Many engineers have placed their hopes upon the speed of the sewage current not allowing sufficient time for the generation of any great volume of gases; but this is another fallacy, proved to be such by sad experience wherever the theory has been reduced to practice. It might already have been found out by the opening of a bottle of soda-water, which shows more bubbles rising the more the bottle is shaken and the liquid agitated. The fact of the matter is, there are few things more '*irrepressible*' than these same sewer gases; and our readers will no doubt acknowledge with us, that this particular plan of getting rid of them is the worst of all, being *up-hill work* in the fullest sense of the word; for, notwithstanding all artificial inducements offered to the contrary, sewer gases will follow their own nature, and, like Alpine goats, always prefer the highest places.

The whole case then stands thus: the foul sewage-liquid runs down hill to a most reckless waste of manure, and the foul sewage gases rise upwards, constantly reminding the bystanders that they are 'not caught yet.' A well-sewered town may be described as being supplied with a system of subterranean retorts, so arranged that the fluids passing through give off the largest possible volumes of gases, which are carefully collected; and then, by means of chimney-pipes (for house-drains serve admirably that purpose), conducted into the very heart of the dwellings.

The pressure of these gases, increasing with the height of their column, is sufficient to force them through any small creek, crevice, or accidental leak, that may anywhere be found, and '*hinc illæ lacrymæ*:' hence that faint, sickening, poisonous odour which seems almost omnipresent, blackening paint and table-silver, and proclaiming, by all sorts of signs, the terrible fact, that truly '*death is in the air*.' This volcano of fever-damp, more pestilent than the fire-damp of a coal mine, is that which makes Liverpool, Newcastle, Dundee, and innumerable other cities so very unhealthy; which, in the case of London, makes the elevated districts, such as Highgate, Hampstead, Upper Clapton, &c., but too often mere abodes of infection, where the powerful essences of filth continually generated from Barking Creek upwards are daily and hourly consumed, thus causing putrid and enteric fevers to be almost endemic in those districts. It was this destructive gas which created the Windsor epidemic that caused the death of H. R. H. Prince Albert, and even drove the court out of Buckingham Palace. 'Go where you will,' says the editor of 'Engineering,' in his impression of Jan. 12, 1866, 'it is met with, filling the carriages passing by, lying in wait to receive us in offices, parlours, private boudoirs; being stored up in every burrow of the earth, in every hollow of the walls and ceilings, ready to issue forth at any moment, to make us sicken and shudder.'

But it is not only the editor of this, the ablest and best conducted engineering periodical, who thus expresses himself. Mr. Bazalgette, chief engineer to the Metropolitan Board of Works, who is no doubt the most practical sewerage engineer of the country, frankly confesses, in his report of 1865-66 to the Board, the almost impossibility of arresting these gases, or keeping them from doing harm. Thus he states, in Appendix C:—'It is necessary that all sewers should have free ventilation into the open air, or the gases generated in them escape through the untrapped house-drains into the houses, where they become dangerous* and offensive. Moreover, without such ventilation it would not be possible for men to enter the sewers to cleanse and repair them. . . . This question has for the last twenty years engaged the attention of most persons interesting themselves in drainage and sanitary reform. It has formed the subject of special inquiry by parliamentary committees and various experiments. . . . Up to 1850

* How dangerous an accumulation of such gases may sometimes become is shown by an accident which occurred on February 8, 1867, at the corner of Third and Noble Street, Philadelphia, U. S. The sewer exploded, lifting up pavement and earth, discharging a great quantity of filth and mud in the streets, and covering the passengers and surrounding houses with the most offensive dirt. Luckily no one was hurt. Frank Leslie's illustrated newspaper, of February 16, has a graphic picture of the accident.

the sewers were mainly ventilated through the street gullies situated near the foot-pavements, and were most offensive to the passengers and the adjacent houses. . . . This led to the trapping of these gullies, and constructing ventilating shafts in the middle of the streets. . . . In 1849 Mr. Henry Austin, the consulting engineer of the Sewer Commissioners, presented an elaborate report, concluding as follows:—

'"That the system of ventilating sewers by means of shafts and grates was objectionable, and should be discontinued.

'"That ventilation by means of furnaces and chimneys at great distances would be attended with great difficulties, labour, and cost, without promise of satisfactory results.

'"That the experience obtained as to the draught of air through tubes carried to the tops of the houses . . . warranted the recommendation of more extensive trials in that direction."

'. . . In 1853 I made a report upon certain experiments made on the south side of the river, by forming connections between the sewers and the chimneys of factories, and upon ventilating sewers by means of the rain-water pipes from the houses.* The former plan was tried in three cases. In two it was beneficial, but in the third . . . a jet of fire burst from the connecting-pipe, and caused an explosion. . . . The agency of rain-water pipes has been tried in various places, . . . but the principal objection is the risk of creating a greater nuisance by the removal of the lesser; and it was shown that the public would not voluntarily sanction this mode. . . . . The destruction of foul air by the agency of fire has been frequently suggested. In March, 1848, Captain Shrapnel proposed the erection of lofty cast-iron cylinders over the sewers, with furnaces therein, feeding exclusively upon the sewer gases; the flame of which he asserted would, at the top of the pillars, be as brilliant as that of gas.' Mr. Bazalgette then describes a number of other plans, and makes suggestions, all more or less costly, complicated, and for various reasons objectionable; and thus continues:—

'In 1858 a committee of the House of Commons was appointed, to inquire into the state of the river Thames in the vicinity of the Houses of Parliament. In that committee Lord Palmerston, Lord John Russell, Lord John Manners, Sir Benjamin Hall, Mr. Robert Stephenson, and Mr. Tite took active parts, collected evidence, and reported upon the subject of the ventilation of the metropolitan sewers by means of furnaces. . . . The following evidence was given before that committee:—

'Mr. William Haywood, engineer to the City Commissioners of Sewers, stated as follows:—

'"2,576. Have you made any experiments yourself upon the burning of gases and the ventilation of sewers?—No, I have not; but I have examined into all the experiments which have been instituted both in this country and in France. . . .

'"2,577. What is the result of your experience?—My impression is that there will be exceeding difficulty in doing it at all; and if done, only at an enormous annual expense. The difficulties to be overcome are gigantic, and there are no data of sufficient value whereon to make more than an approximate estimate of what the cost will be. . . .

'"2,578. What would cause this great expense?—The great expense would be the traction of air from the sewers, . . . having perhaps in the metropolis over 1,000,000 inlets. . . .

'"2,581. Then it comes to this, that it would be impossible to carry out the 'trapping' to the necessary extent; and, if it could be carried out, the expense would be so great as not to make it worth while to resort to it?—That is my conclusion.

'"2,666. How do you propose to ventilate the sewers?—*I am utterly at a loss to suggest any better means than are used at present. I have examined the question with the greatest care; and although I am compelled to state that the present system is very far from perfect, yet every proposition for improving the ventilation is met with hosts of difficulties, which really look insignificant until you investigate them, when they become so formidable that you may call them invincible. I am afraid that we must let out the stink in the middle of the streets.* . . . . .*

'"2,667. I thought that you spoke of a lofty chimney and a ventilating shaft for the sewers?—As an experiment, I carried up a few rain-water pipes as ventilators, which answered the purpose to this extent, that, instead of having the stink in the streets, it was brought close to the sleeping apartments of the houses, which I do not think will improve the health of the inhabitants."' . . . .

In the examination of Mr. Bazalgette by the committee, he gave evidence regarding the ventilating of sewers by means of furnaces and chimneys, to the effect that, for that purpose, 230 such furnaces would be required for the 1,500 miles of sewers in the metropolis, the cost of each of which would be about 2,000*l.*, making a total outlay of 460,000*l.*, or half a million of money, while the coke or fuel required would cost annually at least 201,480*l.*, exclusive of labour and incidental expenses.

Mr. Haywood and Mr. Hawkesley confirmed these views, and the committee thereupon reported the scheme of burning the sewer gases impracticable.

Mr. Bazalgette then advocates, as the only plan of abating the nuisance, to flush the sewers with such copious supplies of water, that the matter should be more fully diluted, the sides of sewers washed clean, and the speed of the current become so swift as to prevent, as far as possible, the formation of the gases. But in regard to carrying this plan into execution, he says, 'It is difficult to determine what minimum quantity of water will sufficiently dilute sewage to prevent the escape of the noxious gases therefrom, inasmuch as the products of the gases vary considerably, and the varied conditions of the atmosphere, the rapidity of the currents, and other circumstances, more or less affect the process of decomposition and the gravity of the gases; but taking the sewage of the north side of the river at 62½ millions of gallons per diem, and assuming this to be diluted with an equal volume of water for twelve hours per diem, for six months in the year, the necessary addition to the present water supply would be about 42 millions of gallons daily.'

From inquiries made at the various waterworks, it appears that they would charge at the rate of 6*d.* per 1,000 gallons, amounting to 1,050*l.* daily, or the enormous sum of 383,250*l.*

* The italics are our own.

annually. It appears, however, that the existing waterworks can furnish only about 5 million gallons additional for this purpose per day; and the scheme, such as it is, becomes, therefore, impracticable.

According to this, the official report of the ablest drainage engineers in the country, who certainly have more experience in this matter than any other, and who may be considered the leaders of the sewer-system school, it is evident that there is really no way of avoiding the formation, or the escape, of these pestiferous gases, which bring death and dismay wherever they come; and that cities whose misfortune it has been to become provided with this mode of removing their sewage, must, according to the conclusion of these engineers, 'let it stink on,' and abide the consequences.

Further evidence on the subject we find in a valuable publication on the sewerage of Berlin,* by Dr. Fr. J. Behrend, who quotes a letter he received from Dr. Sillman, formerly a member of the Metropolitan Board of Works, containing a passage to the following effect: London sewers having become a most terrible plague to the inhabitants, various remedial means were resorted to, such as new sewers, reconstruction of existing ones, different connections and outlets, improved flushing and cleaning, ventilation, &c., none of which, Dr. Sillman thinks, will ever effect the purposes sought, as certain characteristics of the old sewers must always reappear in the new ones.

Dr. Behrend, in his official report to the Berlin Board of Health, quotes also the following extract from the 'London Medical Times' (March 23, 1861, p. 306): 'Now the first advice we give is, not to take any house close to the line of a large sewer, unless the number of favourable circumstances are such as completely to outbalance this disadvantage; and disadvantage we hold it to be, because we believe, as an empirical fact, that *more deaths and illness occur along the line of the great sewers than elsewhere*,' &c.

Now let us see whether sewers are an improvement as regards the poisoning of the soil and wells; another important point in the bill of indictment, which finally led to the condemnation of cesspools.

It is very well known, that whenever the salts and acids contained in human excrements come in contact with lime, mortar, or stone, their combination with oxygen results in the formation of nitrous acid, which, as a white efflorescence, covers the walls, and is commonly known as saltpetre. This substance acts most injuriously upon the strength of masonry, causing it to lose gradually its density, and making it porous to such a degree, that finally it crumbles to pieces.

This was the process which caused the sewage liquids of cesspools so soon to find their way through the walls, no matter how well constructed they originally were; which evil, it was supposed, could be remedied by abolishing these pits altogether, and discharging the sewage into sewers; but it was entirely overlooked that the latter were constructed of masonry just as well, and were, in fact, nothing else but a new kind of cesspools of very great

* Die Kanalisirung der Stadt Berlin. 1866.

length, always half full, and subject also to the most destructive agency of ammonia. Thus it came to pass, that these very costly structures, the new subterranean drains, soon caused the liquid sewage-poison (which, under the old cesspool system, affected the soil only in isolated spots) to be diffused through the entire length and breadth of the site upon which a city stands, their wide distributing arteries leaving no place untouched, and thus saturating the whole area with infectious fluid.

That, under such circumstances, the water supplying the wells of a city becomes charged with poisonous sewage ingredients and gases, must of course be patent to all; and the more so, when it is considered that the strata from which wells draw their supply, generally lie considerably deeper than the bottom of cesspools and sewers. In all soils there is a neutral plane of more or less height, according to the density or porosity of the ground; above this plane, water tends upwards through evaporation on the surface; below, it sinks downward by mere gravitation for feeding the thousands and thousands of minute and tortuous arteries, which, like so many branches of rivers, constantly supply the larger water veins. These veins again communicate with numerous, often very large, burrows or clefts, forming, of course, so many reservoirs filled with water, not seldom under very considerable pressure.

A well, striking any of these veins or reservoirs, is constantly supplied with water, and when much worked by pumping, the stream becoming more rapid, takes along with it great quantities of the lighter particles of the soil, thus gradually enlarging these natural subterranean conduits.

The sewage gases contained in the water cannot be evolved, as there is no outlet for them. Therefore, whatever water is supplied to wells through a stratum lying below the neutral plane, and which is polluted by saturation, will, instead of being purified by filtration, as is often supposed, absolutely become infected and tainted by direct percolation with noxious sewage ingredients, nearly in the same form as they found their way through the masonry of cesspools or sewers.

This infection or poisoning of well water is sometimes perceptible by taste or smell, but as often not, or in so slight a degree that, first tolerated, it soon becomes pleasant, or even indispensable, by custom. There are actually cases on record, in times of cholera, of people insisting upon drinking from certain wells, often far distant from their dwellings, on account of the peculiar sweet taste and sparkling nature of a particular water. This sparkling and sweetness was afterwards discovered, by scientific analysis, to be due to nothing else but to the bubbles of most deadly sewage gases; and the sequel showed that those who had partaken of this water, were the only victims of the pestilence in the locality where they lived.

Having seen what sewage liquid accomplishes in its passage through subterranean conduits, let us now glance at the sanitary disadvantages it entails on the community when debouching from them.

We know already that, thus far, it has only been found practicable either to pour sewage over lands, or to throw it into rivers or harbours, so as to find its way eventually to the ocean. Though the former mode of disposing of a so-called nuisance has as yet been applied in comparatively but a very few instances, still so much noise has been made by its advocates praising its perfect nature, both in a sanitary and agricultural point of view, extolling it, in fact, as the final solution of the great sewage problem, that it will not be found quite uninteresting to examine the evidences upon which the irrigation enthusiasts raise all their shouts of triumph. We cannot do better than bring forward their own statements in support of their favourite theory, just as we meet them in their own speeches and text-books, having no doubt but that an unbiassed reader will with us deem these evidences ludicrous enough.

So we find Sir Morton Peto, in a debate upon the liquid sewage question before a meeting of the Institute of Civil Engineers,* stating that 'he is well acquainted with the meadows near Mansfield and Edinburgh; and he must say that, however great the agricultural advantages of the system may be, they would be dearly purchased if the region near any town were infected like the two places mentioned; . . . . that, if the air in the vicinity of all large towns were to be rendered like that of these cities, the direst consequences might be anticipated.'

Mr. Chadwick, the great advocate of mixing water with sewage to any extent, meets Sir Morton Peto's statement by saying that the foul stench of the Edinburgh meadows does not at all proceed from them, but from the ditches distributing the manure.†

And yet it is only about 1,000 out of the 13,000 houses of Edinburgh, which furnish the pestilential liquid so ably apologised for by Mr. Chadwick, the remaining 12,000 houses still allowing their excrements to fester in old-fashioned cesspools. After this it is not very difficult to imagine the state of affairs, if the entire sewage of Edinburgh were applied to those famous meadows!

Regarding the meadows of Mansfield, Mr. Chadwick denied Sir Morton Peto's charge altogether, asserting that there the sewage fluid was in fact so weak and diluted, that it could not emit stench at all. This may be true enough, as the Duke of Portland has spent enormous sums of money on those very same meadows, without ever getting anything like a corresponding return. But what is the use of quoting such a dismal fact as an argument for the agricultural value of Mr. Chadwick's favourite theory?

Nor will it do, at this time of day, to adduce the fields near Croydon as an illustration of the salubrity, or at least harmlessness, of the sewage-irrigation process; for it must be remembered, that there the sewage is first made to precipitate its solids, and is deodorised afterwards by carbolic acid, so that very little noxious matter is brought on the lands at all to evaporate, provided only much acid is used, which, however, fills the air with a most disagreeable tar scent, and besides kills the fish in the river; when little acid only is applied, the sewage liquid stills throws off a considerable stench.

* Account of Drainage and Sewerage of Bristol, by James Green, M. Inst. C. E.

† An excuse reminding us of the sailor's defence when accused of having got drunk on grog: 'It was not that,' said he, 'but the sperrits that 's in it.'

Latterly the use of carbolic acid has been abandoned at Croydon, and the settling tanks in consequence emit a most overpowering effluvium. Much has been said by the advocates of sewage irrigation that, since this change, the water, after passing over the meadows, is so purified as to be quite fit for drinking; in fact, visitors are often induced by the managers to partake of that beverage, as a sort of practical clincher to their arguments!

How great the illusion, however, in this particular, is proved by Professor Voelcker, consulting chemist to the Royal Agricultural Society, who, according to the 'Economist' of February 23rd, 1867, states that he 'has repeatedly analysed the clarified water of sewage after it has undergone the *purifying* influence of irrigation, and, in the majority of instances, has found such purified water, though clear and free from smell, almost as unfit for drinking, cooking, and washing purposes, as it was in its original filthy condition.' He further says:—'The clearest, most inodorous, and even *agreeably tasting* purified sewage, unless diluted with purer water to a considerable extent, would be unfit, not only for drinking, but also for cooking, washing, and general domestic purposes.'

Again, we find in the 'Preliminary Report of the Commission appointed to inquire into the Sewage of Towns Question (1858)' on page 28, an Article 5 saying, 'that this method of sewage application, conducted with moderate care, is not productive of nuisance or injury to health.' This view is confirmed by two subsequent reports, but afterwards singularly refuted in the very same volume (pp. 50, 51) by the testimony of the physician Dr. Antonio Capelli, of Milan, a town again and again triumphantly quoted as a striking example of the virtues of the sewage-irrigation system. This most important testimony of a gentleman, who certainly ought to know all about it, reads as follows:—

TESTIMONY OF DR. CAPELLI OF MILAN.—'Then the only difference between the water used in irrigation within the walls of the Lazaretto and that used in irrigation generally is, that in the former case the washing refuse is mixed with the irrigating water?—That is the only difference.

'So that the ground within the Lazaretto, as now treated, is in point of fact a winter meadow (marcita)?—Just so.

'Have you observed any influence on the health of the inhabitants from this use of the ground?—A most decided one.

'In what respect has it acted injuriously on the health?—First, in producing every kind of ague; secondly, in producing the other forms of disease due to marsh miasma, such as neuralgia, rheumatism, chest inflammations (pleuritis, &c.); thirdly, in sometimes producing pernicious remittent fever, which often kills in a few days.

'Are such diseases frequent among these people?—Very frequent indeed.

'Is the health of infants and children more especially affected?—Yes, most especially, as is shown in the unusual prevalence among them of scrofula and rachitis.

'When epidemic diseases prevail in Milan, such as typhus, scarlet fever, measles, miliary fever, small-pox, &c., are the inhabitants of the Lazaretto more subject to these diseases than others of their class?—I have not observed much difference, but the inhabitants of this place form a very inconsiderable portion of the population. The injury to the health in their case has reference to endemic, rather than to epidemic, disease.

'That is, to those forms of disease which are recognised as the products of marsh miasma?—Just so.

'Have you observed whether the ordinary organic diseases produced by marsh miasma, such as enlargement and hardening of the liver, enlargement of the spleen, and dropsy, are common diseases among the residents in this place?—Certainly they are; it must inevitably be so.

'Then it is the result of your observation and experience that the diseases you have named are produced generally, wherever irrigation is carried on close to human habitations?—Everywhere; it is so inevitably.'

To reach the climax, a foot-note in this report says:—'Dr. Capelli regards the cesspool as a safer receptacle for cesspool matter than the open ground.' What must an impartial reader now think of any attempts to prove the harmlessness of the sewage-irrigation system?

Now it must be known, that at Milan most of the solid excrements are collected in well-constructed water-tight cesspools, which are emptied twice a year by market gardeners buying the matter up, and paying for it in proportion to its solidity. There are but few waterclosets in that city, because the farmers refuse to buy excrements diluted by water, insisting rather on payment for removing such comparatively worthless sewage. Now as most householders, out of motives of thrift, allow as little fluid as possible to get into their cesspools, urine is the principal fertilising ingredient contained in the river Vettabia, which conveys the refuse water from the city to the lands. A thinner dilution of sewage is hardly to be found, and still we have the testimony of Dr. Capelli of the poisonous exhalations arising from the lands irrigated with it.

Another rather curious defence of the sewage-irrigation plan we find in Professor Thudichum's paper, 'Ueber die Grundlagen der öffentlichen Gesundheitspflege in Städten,' read before the Agricultural Society of Frankfort-on-the-Maine. The learned professor, one of the most zealous champions of this system, gets quite into a passion with the late Mr. W. Thorwirth, engineer, of Berlin, who justly condemns it, and devotes many pages to prove the salubrity and harmlessness of lands irrigated with sewage; at last, however, pulling up short in a foot-note with this most sensible advice, 'always to locate such fields a mile or so away from any human habitation, not by any means on account of any unpleasant smell arising from them, *but only because they are not healthy!* *

But we have said enough to show that, even on the testimony of its most zealous supporters, the healthiness of the irrigation system has always some hitch invalidating the whole of it. To quote all that the opponents have to say would fill volumes, and would be quite superfluous here, as every observing mind readily acknow-

* We have every respect for the professor's real learning and ability, and, indeed, consider this very remark as an instance of it. But the oddity of that good honest advice strikes us rather forcibly, after reading all that has gone before, and brings to mind the celebrated verdict of: '*Not guilty, my lord, provided the prisoner be ordered to leave the country immediately!*'

ledges the fact, that the vapours thrown off by large tracts of land covered with inundated vegetation, are exceedingly unhealthy, even if the water be comparatively pure; and that the case is of course much worse, if the inundating liquid be charged with masses of organic substances in every stage of putrefaction.

Besides, it surely is evident, that whether or no the health of a town or village suffers from sewage-fields in the neighbourhood, does not depend on the distance they are respectively located from each other, but on the winds or air currents which carry the poisonous exhalations to them for consumption by the inhabitants. A town situated in the course of a prevailing wind which passes over both field and town, and is thus regularly supplied with the gases arising from the former, or which, perhaps, has swept over remote harbours or swamps, will be sickly, as a rule, all the year round, and cause the town to suffer in consequence, though its own immediate vicinity may have all the qualifications which should ensure general health.

The sense of smell, so often relied upon in testing the purity of air, is just as far from being a safe guide as that with regard to water. For, even as the microscope has detected myriads of animalculæ in a drop of water, which to the eye appears perfectly clear, so chemical analysis has discovered, by instruments arranged for that purpose, poisonous gases in air that seemed peculiarly balmy and pleasant to inhale.

We now proceed to review the sanitary disadvantages resulting from the far more generally adopted mode of disposing of sewage, namely, by discharging it into rivers or harbours; and in this connection the following questions at once present themselves to our mind.

What makes the sea-coast towns and cities, crowded around harbours, so very unhealthy? Why is it that, when cholera appears, these suffer so pre-eminently, nay often almost exclusively?* Certainly the fresh sea breezes cannot be the cause, nor the country in the rear, which often remains quite unaffected by the epidemic. It is obvious that the origin of the evil must be confined to the shore line and harbours themselves.

Now, it is well known that, in all harbours and coast towns, almost without exception, excremental matters are regularly discharged into the sea, together with the sewage of scores or hundreds of ships lying in port. We have already explained how these substances, having less specific gravity than sea water, rise to the surface, and, though discharged at great depth, or carried on the bosom of rivers a long distance out, are continually brought back by every returning tide to the beach, and along the shore line of harbours, estuaries, and every indentation of the coast. But we have not yet called attention to another peculiar effect sea water has upon these organic matters; an effect which cannot be more accurately described than as a process of 'pickling,' which prolongs the period of fermentation or oxygenation to an indefinite extent.

When river water holds in suspense effete organic substances of the animal or vegetable kingdom, a process of combustion rapidly

* The registrar-general has repeatedly made statements to this effect in his official reports.

goes on by the oxygen contained in the water itself; and when all the oxygen which for that purpose can be spared* is consumed, the remaining organic ingredients pass into a state of putrefaction. It is just this absence of a proper amount of oxygen in polluted water which kills fish, literally by suffocation, as they need that gas for respiration; and which is also the reason why sewage water is such an admirable preserver of timber, destroying even the *teredo navalis*, or sea-worm, when striking the woodwork of harbour piers. It explains also why water taken out of polluted streams and purified on board of ships, is consumed in such large quantities by sailors, the paucity of oxygen preventing the slaking of thirst.

In sea water, on the contrary, the salt delays combustion, as it does always; hence organic matters which, in sweet water, would pass off into the air in the shape of gases in the course of a few weeks, are preserved in salt-water harbours and estuaries to an interminable period. The constant addition of 'unburnt' organic substances carried down by the rivers, naturally converts these points on the coast into perpetual manufactories of the most deadly gases, charging the atmosphere about them like an enormous gun-powder magazine, ready for instant explosion on contact with the smallest spark.

That fatal contagious spark is generally lighted in climates where the accumulation of malaria is promoted by a sultry temperature. Thus, epidemic diseases, like the cholera, usually originate along the shores of the Mediterranean, that immense inland sea, around which history tells us numerous nations have existed and decayed in endless succession during thousands of years, and which has thus received the fæcal matters of countless millions, all of whom allowed them to collect and fester in harbours and estuaries and along the whole coast, just as is done elsewhere even in our so-called civilised times. And thus some of the most beautiful spots in those regions, some of them the classic cradles of ancient powerful races, have become quite desolate and uninhabitable, either by the exhaustion of soil in the interior, or by the deadly pollution of the coast.

There are few of the Mediterranean harbours which are not more or less marred in this respect. So, for instance, the Bay of Naples, so justly celebrated for all that is lovely and picturesque in natural scenery. But behind the road from Chiaja towards the Grotto of Cicero, a spot which otherwise might be emphatically called an earthly Paradise, lies in the direction of Posilipo a veritable infernal pit, the outlet of the cloaca of Naples into the sea. The effluvium arising from it, horrible beyond description, brings sure death to all within its vicinity; in consequence of which many noble castles and villas scattered along the coast have long since been abandoned; amongst others, the beautiful but gloomy palace of Queen Giovanna I., which, once the favourite abode of wealth and luxury, now lies in utter desolation, mouldering in ruins and dust.

Who does not know the almost deathlike fatality hanging over the port of Marseilles? Founded some 400 years B.C., it was

* Water can hold two and a-half times its bulk of oxygen.

already, in the times of Cæsar, celebrated for its trade and shipping. The harbour is quite a marvel of nature and art, but at the same time wofully notorious for its immense accumulation of filth, which is still daily increased by the recently constructed sewage works.*

A most striking example of the baneful effect of discharging excrements into the sea we encounter also in the sanitary condition of the Bay of Cadiz, another ancient shipping port, renowned in the days of the greatness of Carthage. This harbour, one of the most sickly ones known, has also been a receptacle of fæcal matters during a long succession of generations, and the gigantic swell of the broad Atlantic has failed to wash away the pollution.

To prove that, when assisted by a hot climate, the most salubrious situations may, in a comparatively short time, become most unhealthy, we have but to point to Rio de Janeiro, which, some fifty or sixty years ago, was yet used by many physicians of the United States as a sanitary station for patients to be sent to, like Madeira in the present day. But, unfortunately, it was until very recently the universal custom there to pour, night after night, excremental matters from the quay into the harbour, until the yellow fever became such a terrific scourge that the port was very reluctantly visited by merchants and mariners, notwithstanding its excellent central position for the commerce of Europe and Africa to America, Asia, and Australia. It is only since the Rio City Improvement Company † have carried out their scheme of deodorising the houses that sanitary affairs have assumed a more cheerful aspect; but it will be next to impossible to deodorise also the harbour itself, and make it again what it used to be in former times.

A similar sad experience has been made at Havana, where, in spite of a constant purifying sea-breeze, yellow fever also reigns supreme almost all the year round, principally owing to the incessant pollution of the magnificent harbour by the sewage of the city.

Still another instance, of quite a recent date, we find in the well-authenticated fact that, during the prevalence of cholera at Brest, especially in its extensive prisons, the pestilence exclusively visited those wards which were supplied with waterclosets in communication with the polluted harbour, the deadly gases of which, together with the sewer-exhalations, were blown directly into these wards.

Is it not strange indeed that, with such examples before us, which might be multiplied to any extent by history and scientific investigation, and which are fully confirmed by our own daily experience, and proved by many able works, placed within the

* This latter circumstance is, no doubt, that which makes the French sailors sing, with reference to Marseilles :—

> '*Et l'on dirait que l'on y respire*
> L'AIR *de toutes les nations !*'

There is a story current among mariners, that the Marseilles pilots bring, unerringly, ships into port by soundings, even in the thickest of fogs and darkest of nights. When the leadsman sings out 'Merde,' the pilot cries out 'Let go the anchor,' well-knowing he is all right. Are there no other harbours in which pilots might follow this method with advantage and certainty? And is it then to be wondered at that Marseilles is so often visited by severe ravages of cholera? In fact, it scarcely ever escapes when an epidemic breaks out.

† We see, from a recent report, that this company deodorises already some 11,000 houses at an annual charge of 6*l.* 5*s.* each, amounting to nearly 70,000*l.* a year.

reach not only of professional men, but of every one who cares to read and think—is it not passing strange, we ask, that the fatal, ruinous, and deadly error of pouring excremental matters into rivers and harbours should still find zealous advocates amongst men occupying high positions in social life, in the learned professions, or even in the council-halls of municipal and national legislatures—men to whom their fellow-citizens naturally look up for all measures concerning their interest and welfare? *

Look for instance at Hamburgh, the greatest commercial emporium of Germany, where the eminent engineering talent of Mr. Lindley, assisted by most foggy municipal wisdom, has succeeded in poisoning the Elbe just the same as London has poisoned the Thames, a feat perpetrated even in the face of a most spirited opposition, carried on for a long time by the hydraulic engineer, Mr. Hübbe and other professional men, who did their utmost to avert the calamity. Dublin too is, at the present moment (April, 1867), in the most imminent danger of being persuaded into the foolish outlay of some 400,000*l.*, which some 'water-carriage zealot' proposes to devote to works by which the entire city sewage will be discharged into the sea, and thus entail a loss of 125,000*l.* worth of manure annually, the city having a population of fully 250,000. Let us hope that the corporation will be kept from this crime against public health and the best interests of the town, as well as against agriculture and national economy generally.

Munich, that city of architectural beauty and museums of arts and sciences, affords another warning example, being rendered a most unhealthy abode by many waterclosets discharging into the recently built sewers, although in violation of the local police regulations and the intention of the engineer, Mr. Zenetti, whereby the river Isar is rendered a fearfully prolific source of typhus and other endemic diseases. Vienna is in a similar predicament, by the pollution of the Danube with sewage to an alarming extent. To describe all this in detail would be superfluous, as it would only be a repetition of what has been said of other places. Berlin has thus far escaped the infliction of the water-carriage system mainly through the ability and activity of Messrs. Salviati, Röder, Eichhorn, and Thorwirth, though many efforts have been made (and are still being pressed) by Mr. Wiebe and others to carry out that most pernicious scheme.

At the city of Frankfort-on-the-Maine, which was sadly in need of an efficient drainage system, the authorities consulted long and anxiously as to what plan to adopt. Finally, the investigations, and indirectly also the decision, was left to the Board of Works (Bau-Amt), which is composed of but three members. To obtain correct information, the authorities of Hamburgh were applied to, and the question being directed to a personage who had been

* As a recent most remarkable instance, we may state that, at a public discussion on the sewage question, held at Frankfort-on-the-Maine, March 28th, 1867, *Dr. G. Varrentrapp*, medical referee to the local board of works, and a most zealous advocate of sewerage by water-carriage, waterclosets, irrigation with sewage liquid, withal—emphatically declared that all that had been said against this sewerage system *was nothing but a downright lie*, this being evidently his only means of defence! *Sapienti sat!*

mainly instrumental in carrying sewerage by water-carriage through that city, of course the answer was moulded by his desire to uphold the system for which he was responsible. This statement was supported by Dr. G. Varrentrapp, medical referee to the Board of Works of Frankfort, who seemed not to know that water is no disinfectant, and totally ignored the existence of sewer gases; and thus it came to pass that this Board of Works determined to carry out the same system as adopted at Hamburgh, and was not even satisfied until it obtained for that purpose the same engineer, Mr. William Lindley, mentioned before. The plan included the compulsory introduction of waterclosets in all dwellings deemed necessary for the efficiency of the 'system;' the sewers were, besides fæcal matters, to carry off rainfall and household fluids; and this mixed and most offensive and worthless mass was to be discharged into the small river Maine, just below the town.

This extraordinary proposal, which, it was estimated, would cost some undefined sum, of from 4 to 10 millions of florins, excited, naturally enough, a general and deep murmur of indignation, both by the more intelligent citizens and by the poorer classes in particular, who objected to the expensive nuisance of waterclosets; while all, with one voice, expressed their resolution to keep the Maine undefiled. There being no River Pollution Act in existence, this insane scheme would perhaps have been carried out, notwithstanding the general public disgust, if the late Nassau government had not most energetically protested against the impending horrible pollution of a river within their jurisdiction. This seems to have awakened the ill-advised Frankfort Board of Works, and caused new consultations, which resulted in a decision, supported by the engineer himself, *not* to introduce waterclosets, a decision strange enough surely, after these had been made the conditions, *sine quâ non*, for rendering the water-carriage system at all practicable. The plan was then so far modified, that large open basins were proposed to hold the sewage during freshets, which basins were to stand in connection with some meadow irrigation scheme or other. That this silly arrangement has been unmercifully ridiculed, both by the public press and various lampoons, is natural enough. It seems, however, that thus far no definite resolution has been come to, as to what is to be done with the sewage, or how to collect it; but the good sense of the Board of Works, and the really painstaking intentions of the senate to do what is best for the city, will no doubt eventually result in the construction of mere drains for house and rain water only, leaving the sewage to be dealt with by some superior method; nor would they have ever erred in this manner, but for the extraordinary pressure of bad advice, and the self-seeking zeal of certain unscrupulous cliques.

To what extent such unlawful pressure may go in cases like this, is shown in the official report of Dr. Frederick J. Behrend, of the local Medical Board of Berlin,* who openly states that the chief burgomaster Seydel, actuated by an inexplicable bias for sewerage by water-carriage, as proposed by the engineer Wiebe, actually was guilty of taking advantage of the absence of various

* Published by Julius Springer, Berlin, 1866. See the preface.

opposing members, and of the medical referee appointed to report on the subject, and that thus the scheme was adopted by a small majority. It availed him nothing, however, for the angry protest by all right-minded professional men, the public press, and the citizens of Berlin generally, caused a re-examination, and finally, it seems, the utter condemnation of Mr. Wiebe's project. A similar instance is stated in the official report of Dr. Sieber, chief sanitary officer of Berlin,* concerning the flagrant conduct of the municipal authorities of Munich, who utterly denied to the agricultural commission of Berlin the notoriously evil effects of the sewers they had recently built. When accused of this baseness, they excused themselves by saying that it was not patriotic to expose the faults of their city. The truth is, they were ashamed of the result of their own foolish contrivances.

In expressing ourselves thus strongly condemnatory of the exertions made to execute, in large and populous towns, works which have proved by dearly-bought experience to be not only a failure in every respect, but which are now known to have been, and are yet, the cause of incalculable mischief, we do not wish in the slightest manner to reflect upon the able and distinguished engineers who advocated them at an earlier period, and are now still engaged in carrying out the main and other drainage works of the metropolis. We are well aware that the sewer system there was begun when the special science of sewerage was still in its infancy, and that, as stated before, it is rather one of development than of design, each successive wrong move necessitating another one, until it finally became the gigantic failure it is. We know that since these works were entrusted to them, they have constantly availed themselves of all the improvements which time has developed. How fully alive they are to the faults and insurmountable difficulties inherent in the water-carriage system can be seen in their report, quoted in extenso, pages 52 to 55; where it is honestly confessed that the purpose for which such works are designed (viz. to remove the offensive parts of fæcal matter from among human habitations) has proved by this system to be unattainable, and that it therefore is worthless, so far as sanitary requirements are concerned. We doubt not if these engineers had to prepare a new plan, they would, instead of precipitating the night-soil in the rainfall and house-water conduits, endeavour to carry it off by some such means as will be described in the latter part of this volume.†

If cities on inland streams are affected by their pollution, as above described, it may be easily imagined how much more those towns located on tidal rivers suffer, where, as explained before, all the sewage received from the upper lands, together with that

* See Dr. Behrend's report, p. 56.

† That this will be eventually the manner in which the metropolis and other similarly drained cities will be freed of the sewage nuisance, there can be hardly any doubt, for the simple reason that there is no other way to do it. And this will happen whenever the municipal authorities have become aware of the fact (which is now ascertained), that by simply *not* diluting the sewage, it can easily and without offence be removed, and at the same time become a source of revenue to the city instead of an expense. To bring this about, it is to be hoped that all engineers will be as candid as Mr. Bazalgette and his associates, instead of (out of false pride or old prejudices) rejecting all improvements suggested by others, and thus preventing municipal authorities from adopting them.

furnished by the city itself, is held in suspense by the play of the tides swaying to and fro for weeks in succession, as for instance in the case of London, where the sewage matter takes sometimes as long as fifty days to float from the city to the sea, a distance of some forty-six miles.

Many advocates of the sewage system by water-carriage rely upon what they consider a dissipation of noxious ingredients and elements over such a large space, that they can no longer do any harm. We, on the other hand, maintain that, instead of an effectual dissipation, nothing is obtained but a distribution or diffusion, which, in the long run, must have similar results, though in a less degree, as concentration on a single spot, the only difference being that, in the one case, the measure of evil is filled gradually grain by grain, whilst, in the other, handfuls are thrown in. Just as water continually evaporates, so the atmosphere absorbs all noxious gases evolved by sewage matter along its whole course in rivers until it stops at the sea coast; and as the saturation of the air by evaporated water infallibly produces rain, so must an accumulation of poisonous gases, however gradual, ultimately result in pestilence.

Now it appears there are two modes by which a polluted atmosphere affects animal life, viz. by direct respiration entering the lungs and the blood; and, secondly, by imparting germs of microscopic fungi and infusoria, which are invariably developed by putrefaction of organic matter.

To understand the first mode of infection, we must remember that all organic poisons are composed of the very same elements constituting the air we breathe, and the food we eat, only in different combinations. The elements are, as is well known, oxygen, hydrogen, nitrogen, and carbon; and the following table shows how one set of combinations serves to sustain our life, whilst the other destroys it in the shape of the most virulent poisons:—

	Oxygen.	Hydrogen.	Nitrogen.	Carbon.
	Atoms	Atoms	Atoms	Atoms
Combinations sustaining life:—				
Pure atmosphere . . .	1	—	4	$\frac{1}{8000}$
Pure water	1	1	—	—
Gum, starch, sugar . . .	5	5	—	6
Casein, gluten, albumen . .	5	5	certain proportions of nitrogen, with sulphur and phosphorus	6
Combinations destroying life:—				
Oxalic acid*	3	—	—	2
Hydrocyanic or prussic acid .	—	1	1	2
Cyanic acid	1	—	1	2
Strychnine	4	24	1	44
Belladonna	6	23	1	34
Hemlock	—	17	1	17
Carbonic acid gas . . .	2	—	—	1
Ammonia	—	3	1	—
Proportional atomic weights .	8	1	14·20	6·12

Although of these dangerous combinations only ammonia is

* One of the most virulent poisons existing; two or three drachms produce a speedy death.

present or developed in human excrements, these contain always some sulphuric (SO^3) and phosphoric (PO^6) acids, both of which are not less poisonous. Anyhow it is evident that nothing but a different combination is required to make the very same elements sustaining life absolutely deadly; and if in a polluted atmosphere we inhale one or more of them in undue quantities, we may just as well hold a loaded pistol to our head and play with the trigger. Another means of infection by the effluvia arising from human fæces lies, no doubt, in certain microscopic fungi and infusoria, which are developed wherever decomposition of organic substances is effected by air, heat, and moisture.

The fungi, commonly called mould, are nothing but exceedingly minute plants, growing up with great rapidity wherever humidity combines with filth of any kind, and have even been found on the skin of unclean people, causing horrible cutaneous eruptions. The infusoria are atomic animalculæ, abounding, like the fungi, wherever putrefaction goes on. They are generally invisible to the naked eye, except the larger kind, called 'vibrio tremulans,' which may sometimes be seen frisking about in myriads, when a solitary sun-ray penetrates into some dark, moist place: they are then usually mistaken for dust.

These animal and vegetable atoms, which only recently have become known to the scientific world, are most dangerous parasites, the eggs or germs floating about in the atmosphere until they adhere to some moist place, where they develop themselves and multiply with astonishing rapidity. They have frequently been found on the slimy tongues of sick people, and between neglected teeth. That they are also inhaled in millions upon millions by almost every breath we take, can hardly be doubted.

Now, carefully-made experiments have satisfactorily shown that, when some species of infusoria and fungi have entered into the human body, they immediately begin to diffuse themselves amongst all the softer parts; and it is presumed that, by their penetrating the stomach and intestines, that irritation is caused which, after incessant violent evacuation, speedily produces death.

It is a point much disputed amongst the learned, whether cholera and yellow fever generate these pernicious germs in the body of the patients; or whether, on the contrary, they are the primary cause of these diseases: a problem similar to that of the ancient Greek philosophers, whether, in the beginning of things, a hen produced an egg, or an egg a hen. But, on one point, nearly all agree, viz. that the epidemics named and microscopic fungi and infusoria are always found in company.

Another point generally agreed upon is, that these infectious microscopic germs of fungi and infusoria are never met with in a dry, healthy atmosphere in its normal condition, but only appear when the air becomes polluted by the gases evolved from organic substances passing into a state of putrefaction.

There appear to exist two distinct kinds of microscopic germs, wherever fæcal matters are exposed to the putrefying action of a high temperature: the one kind, when this process takes place in combination with decomposing animal substances; the other, when these additional matters belong to the vegetable kingdom.

The first kind of epidemic germs makes usually its appearance when, in times of war, near a camp infected by fæcal deposits, corpses are imperfectly buried, or when, in crowded military hospitals, ghastly wounds throw off infecting effluvia: the fatal result is usually cholera. The second kind of infectious germs is usually met with in hot climates, near swamps, when, after freshets, fæcal matters are mixed with putrid vegetable substances: the awful result in this case is yellow fever or black vomit. The most eminent physicians of the southern parts of the United States now acknowledge that yellow fever is much promoted, if not actually generated, by the decomposition of large masses of human fæces left exposed to the open air, though they very much disagree respecting the manner in which this terrible distemper is propagated. According to Captain Liernur, who was for a number of years a resident in the Southern States, and from whose notes, as stated in the preface, we are working,—according to his decided opinion, the infection by yellow fever is simply caused by the germs of infusoria or fungi, developed by a combination of fæcal matters with vegetable substances, putrefying together under the influence of a torrid clime.

The effluvia of decaying vegetation in the endless American swamps and marshes, without the admixture of fæcal gases, produce only various fevers and the so-called 'chills,' which, however, are not contagious. The season when such occur is always that when the fungi bloom and shed their seed, which are then taken up in the atmosphere like the pollen of flowers, and enter our lungs by respiration. This has been verified by recent experiments, and may be witnessed, by anyone caring to run the risk, in the following manner: Place in a closed room a bowl of sweetened water and leave it undisturbed. After a few days mould or fungous plants will grow upon the surface, and in the course of time, as the liquid thickens, become very luxuriant. This microscopic forest will remain harmless until a certain season of the year, when the plants shed their seed; but whoever during that time remains long or often in the room, will become subject to chills and ague, very difficult to cure, as many experimentalists have found to their cost. Whenever animal substances putrefy in the sultry atmosphere of a southern clime, in addition to this growth of fungi, the infectious germ is at once developed, and yellow fever becomes inevitable.

Captain Liernur's opinion on the origin of yellow fever receives much countenance from the fact, that this fearful disease breaks out only in cities, or such other localities of tropical climes, where masses of human excrements are accumulated. The captain furnishes us with the following revolting description of privy accommodations in many parts of the Southern United States, details which we would hardly venture to put into print, if we did not believe that the best means of putting down such disgusting arrangements was just to hold them up to public scorn.

Just imagine an open box sunk into the ground, with a small shanty or shed built over it, containing three or four seats in a line for simultaneous use, without any lids to the openings, so as to allow an uninterrupted escape of the deadly gases continually evolved by the filthy mass beneath, festering under an almost tropical sun, the box being never emptied until it overflows. So exceedingly nauseating are these places, that most men prefer to walk out of the town to obey the call of nature in the open fields! This foul practice being almost universally followed, and repeated day after day, week after week, month after month, added to the volumes of poisonous gases incessantly thrown off by the fermenting privy pits with which the towns are studded, it is clear that the air is in a constant state of pollution, and forms, during the dry and hot summer season, a most prolific breeding element for the germs of yellow fever.

A similar phenomenon is noticed with regard to cholera, which also does not appear to be contagious, unless the atmosphere is largely impregnated with fæcal gases, in which alone the cholera germs seem to generate and propagate. The latter have been known to exist even in a Russian winter, whilst yellow fever germs, on the contrary, are invariably killed by the first frost.

Both yellow fever and cholera germs, whether of the vegetable or animal, fungus or infusoria class, abound of course in the evacuations of the stomach and bowels of the patients, a single drop of which, however diluted, contains millions of these poisonous atoms, which are ever taken up into the air by the evaporation of the infectious fluid, and afterwards return in the rain.*

The scientific investigations of the celebrated *Professor Pettenkofer*, of Munich, have thrown additional light upon this subject, and disclosed important facts, which may be summed up as follows:—

1. Cholera is neither altogether a contagion, nor entirely a miasma, but a most dangerous bastard, combining all the virulence of both.

2. The origin of cholera lies in a specific ferment or germ, contained in the excrements of cholera-stricken persons, or even of otherwise healthy people, coming from an infected locality.

3. Cholera, if once introduced in the shape of this germ, develops itself into an epidemic only in such localities where the water, circulating in a loose porous soil, is impregnated with fæcal matter, through percolation out of cesspools, sewers, and gutters.

4. Such polluted subsoil-water becomes the more dangerous, when, by atmospheric influence, it alternately rises and falls, leaving, in the latter case, the upper strata impregnated with putrid organic matter, to dry up, and thereby exhale volumes of most poisonous gases, which enter the human system through our lungs.

5. Cholera is, therefore, propagated not only by the atmosphere, when charged with fæcal gases, but also by wells, when contaminated by excremental percolation, the latter being by far the more dangerous mode, as the cholera ferment or poison is much more concentrated and powerful in the water we drink than in the air we inhale.

6. Excrements, even of cholera-stricken persons, never spread their infectious ferment whilst they are fresh, but only after the second day, when alkaline fermentation sets in, which therefore must be prevented by admixture of proper disinfectants in sufficient quantity.

These views of Professor Pettenkofer exactly correspond with what we have said in other parts of our treatise, with this difference, that, instead of disinfecting excrements, we propose to remove them altogether out of harm's way, day by day, as they are produced, before fermentation can develop the fatal germ they may contain, and this can only be accomplished by the pneumatic method afterwards explained.

Professor Pettenkofer's theory has been much contested, on the ground that, in January, 1854, cholera broke out at Moscow with the thermometer at 10° Fahrenheit,* when, of course, there could be no exhalation of noxious vapours from the soil. Other instances of cholera outbreaks in Russia, with 15° to 35° below zero, are mentioned by Griesinger in his 'Infections-Krankheiten.† These facts, however, may be explained as follows:—In Russia, not only the rooms, but the entire houses are artificially heated during winter, which of course keeps the soil underneath the dwelling in a gentle but permanent stew, highly favourable to the generation of most deadly gases out of the fæcal matters with which the ground is saturated, owing to the very primitive state of privy accommodation in Russian houses of the lower class. Consequently, whilst the soil in the open air is deeply frozen, the fatal evaporation goes on, only so much more effectually, in the very heart of the dwellings, with the usual result of disease and death. Besides, there is the poisoning of the wells near the houses, by percolation of fæcal liquids, which likewise goes on uninterruptedly underneath the frozen surface of the ground. We, therefore, cannot see any cause for changing our decided opinion, that one of the principal causes of cholera outbreaks lies in the pollution of the soil with fæcal substances.

Dr. Klob, of Vienna, has recently, by means of a microscope of 800 to 1,000 power, discovered in the evacuations of cholera patients millions and millions of microscopic fungi very similar in form to common mushrooms. That these fungi form the basis and medium of propagation of that terrible disease, there can hardly be any more doubt, as all kinds of fungi most rapidly propagate under favourable circumstances.

Dr. William Hamm, in his highly interesting paper on 'Die Desinfection der Städte,'‡ says: 'Professors Pettenkofer, Buhl, and Ranke have succeeded in proving the connection between the appearance of cholera and the miasma produced by an accumulation of putrid organic matter. The native country of this terrible epidemic, which since 1830 has repeatedly visited and decimated Europe, was hitherto reputed to be the East Indies, where numerous marshy tracts no doubt favour the generation of many a malignant disease. Public opinion, however, has lately changed in this respect. Last year (1865) the cholera undoubtedly broke out first in Arabia, amongst the Mecca pilgrims, who introduced it into Egypt, where it caused incredible devastation. Thence the awful epidemic spread to Europe, being much promoted by very hot dry weather, without rain or wind, which dried up wells and rivers, and thus filled the atmosphere with immense volumes of most noxious putrid gases. Now, most careful investigations have proved that, in this instance, cholera spontaneously broke out in Mecca, in the midst of hundreds of thousands of Mahomme-

* St. Petersburger Medicinische Zeitschrift, volume xi. 1866.
† Virchow's Handbuch der Pathologie und Therapie.
‡ Unsere Zeit, Brockhaus. Leipsic. January, 1866.

dan pilgrims huddled together in incredible filth and misery, every one of whom, besides, is bound by his creed to sacrifice a sheep, the carcass of which must putrefy uncovered near the Holy Mountain. This, of course, causes such a pollution of the atmosphere, that the generation of epidemics, pestilence, and cholera, is not only probable, but plainly obvious. At least, such is the view now taken by the civilised world, and the great European Powers have accordingly appointed conferences at Constantinople to deliberate upon the means of preventing in future such a poisoning of nations. The same causes produce the same effects. The noxious gases arising at Mecca from the decomposition of organic bodies, are generated wherever this process takes place, and everywhere exercise the same pernicious influence on healthy living organisms. There can, therefore, not be the slightest doubt but that cesspools, receiving the fæcal matters of populous cities, and allowing them to pass into a state of fermentation, if they do not actually originate, at least propagate epidemic diseases; above all, cholera and typhus.'

These views are fully borne out by a highly interesting table we find in Dr. John Macpherson's valuable work, 'Cholera in its Home' (London, John Churchill & Sons, 1866). This table we here reproduce as follows:—

DEATHS BY CHOLERA AT CALCUTTA DURING TWENTY-SIX YEARS.

	Number of Deaths.	Rainfall. Eng. Inches.	Medium Temperature.	Variation of Temperature.
			Reaumur.	Reaumur.
January	7,150	0·21	13·9	8·0
February	9,346	0·42	18·7	7·7
March	14,710	1·13	22·5	7·1
April	19,382	2·40	24·5	6·5
May	13,335	4·29	25·3	5·9
June	6,325	10·10	24·1	4·0
July	3,979	13·90	23·1	2·8
August	3,440	14·40	22·3	2·3
September	3,935	10·40	22·9	2·9
October	6,211	4·72	21·7	3·8
November	8,323	0·90	19·4	6·4
December	8,159	0·13	15·5	7·2

This table, representing as it does careful observations during a period of twenty-six years, places a most important fact beyond all dispute, namely, *abundance of rain checks the propagation of cholera, whilst scarcity of rain greatly promotes it.* The reason of this is obvious. A copious rainfall causes the subsoil water to rise towards the surface, and fill up the pores of the earth, thereby preventing the atmosphere from penetrating those very pores, and a consequent contagious evaporation of the putrid organic substances arises, especially fæcal matters, which unfortunately pollute more or less the soil of every city. Scarcity of rain has, of course, just the contrary effect, by causing the subsoil water to sink deeper and deeper into the ground, thus exposing the upper strata to the pernicious exhalation just alluded to.

A high temperature naturally promotes this contagious exhalation of the soil, whilst a low temperature rather impedes it. The most dangerous period for the propagation of cholera is, therefore, when a high temperature coincides with a scarcity of rain, as in Calcutta, from March to May.

Another important fact entering into our consideration is the geological formation of the soil, which, according to its nature, either impedes or promotes the absorption, accumulation, and subsequent contagious exhalation of fæcal matters, and other decomposing organic substances. To the latter class belong all loose, porous soils, such as sand, loam, &c., whilst, on the other hand, a solid, rocky ground is the best safeguard against the propagation of cholera and other epidemic diseases.

The last root of the evil is, therefore, neither the alternate rise and fall of the subsoil water, nor the influence of a high temperature, nor even the geological formation of a city-soil, but the *saturation of the latter with fæcal matters, and other putrid organic substances*, which alone can cause exhalations capable of developing germs of contagious diseases.

Now it is just their invisibility, omnipresence, and altogether irrepressible nature which renders these infectious germs of parasitical infusoria and fungi so highly dangerous in a polluted atmosphere, when a few sultry days may cause the outbreak of a most virulent epidemic. But though in our favoured climate we are only at intervals suffering the extreme penalty of our sanitary follies, especially as regards sewerage by water-carriage, the intervening periods are far from being without their misery. Impure air and tainted water* must always entail all kinds of diseases, and tend to increase the average mortality of a city, which may be said to live in an unremitting rain of sickliness, interrupted now and then by a violent epidemical thunder-shower.

It would be needless to expatiate any longer upon the awful consequences of distributing both the aërial and liquid poisons of fæcal matters all over a country by means of a most pernicious sewerage system; but let the mourning of mothers bewailing the loss of babes who have hardly seen the light of life; let the deep and silent grief of fathers lamenting hopeful sons and daughters, who are either slowly consumed by endemic fevers or ruthlessly torn away by the rapid workings of typhus and cholera; let the pallid cheeks of invalids painfully struggling to prolong a doomed existence,—let all these sad evidences of suffering humanity loudly proclaim the terrific fact to all dwellers in badly sewered cities, that death is constantly hovering in the air they breathe, lurking in the water they drink, and compassing them about in every variety of form!

In concluding this part of our treatise, we cannot do better than refer to an excellent leader of the 'Daily News,' on the progress of cholera in London in 1866, in which we find the following judicious remarks:—

'What we have said is quite enough to indicate the unabated activity of the zymotic poison, and it would therefore be better to

* In the year 1849, nearly all the water used in London for drinking and culinary purposes was notoriously contaminated by cesspools and water-closets, in many instances even by direct percolation of the evacuations of cholera patients. Fortunately, the quality of London water has since improved. Hence the mortality by cholera in the years 1849, 1864, and 1866, has decreased as follows: 62 – 43 – 18 of every 1,000 inhabitants.

exaggerate the danger than to indulge in a sense of security which may be illusory. Perhaps we are only experiencing a foretaste of a much greater outbreak next year. There are not wanting signs that this is probable, and no relaxation of precautionary and curative measures ought to be tolerated among us, as long as the danger impends. It has been said that the laws of zymotics are now understood, and no doubt we do know with some certainty, that cholera is propagated most readily through one agency. That agency—the water supply of the metropolis—will hardly be changed for the better next year, or, we fear, for a much longer period; and herein, as we conceive, lies the chief source of danger in connection with the germs of cholera poison now so widely scattered.'

Depend upon it, all use of disinfectants however abundant, all house to house visitations, and inspection of privies and water-closets by sanitary committees and local authorities, will only prove poor palliatives, as long as the axe is not laid to the root of the evil, by the introduction of a sewerage system in strict conformity with the laws of nature and the teachings of modern science.

As regards contagion from abroad, we surely cannot draw a sanitary cordon round the country, because the incubation time of cholera being some ten days, a trip from Paris to London would thereby be prolonged to eleven days, which is quite out of the question with our present international intercourse; but we can and must destroy the hotbeds of pestilence at home in the way so clearly pointed out by reason and experience, and until we fairly make up our minds to do that, the death-roll from cholera alone will still more than exceed that from all other causes!

4. AGRICULTURAL DISADVANTAGES.—Even as every steam-engineer well knows that the black smoke emitted from the chimney of ill-constructed boiler-furnaces, while being a positive nuisance, represents so much fuel not utilised through imperfect combustion, so every agricultural chemist is aware, that any gases evolved from excrements, when dissipated in the atmosphere, are just so many fertilising elements wasted through incorrect collection or manipulation.

We have fully and clearly seen how highly detrimental to public health any escape of fæcal gases must always prove; we have further noticed how sewage liquid, except under a certain combination of local circumstances but rarely met with, is not capable of imparting vigour and fertility to the soil, denuded as that liquid is of a great part of its strength through the evaporation of its gases; and, finally, it has been conclusively shown, how futile any attempts have hitherto proved, and will always prove, to extract from sewage liquid any manuring ingredients worth having, by means of chemical precipitation or mechanical straining.

It now behoves us to point out more in detail the very serious consequences entailed on agriculture in general by the carrying out of that most pernicious theory, that water is the best and cheapest carrier of city sewage; a fallacy which, after all, lies at the bottom of most sewerage schemes.

As the sewage liquid actually utilised bears such a very small proportion to the gross amount of excrements annually produced by the population of a whole city or country, we may as well take it for granted that, in many cases, the entire enormous quantity is practically thrown into the sea, or left to evaporate into the atmosphere. Now, to gain anything like a correct idea of the immense annual loss thereby inflicted upon the agricultural interest, we have first to ascertain, as near as possible, the quantity of fertilising ingredients thus wasted, and their approximative market value in pounds, shillings, and pence.

We find a remarkable divergence in the estimates made thereof by some of our most eminent scientific men; which, however, is easily accounted for by the variety of circumstances influencing the quantity and intrinsic value of fæcal matters produced in a given locality. Both appear to depend not only upon the degree of dilution by water, but also upon the general habits of a people, their social position and national customs; nay, even upon their religious creed, in so far as frequent fasting, or a preponderance of vegetable over animal diet, of course considerably affects the quantity and quality of the fæces produced.

For instance, Dr. Schultz-Schultzenstein, in his valuable work on 'Pflanzenernährung,' &c., states that in Nice and Genoa the farmers contract with Protestant householders for the fæces collected in their cesspools at the annual rate of five francs per head, whilst to Catholics they pay only four: the excrements produced in the Minority monasteries, on account of the inferior kind of food there consumed, farmers refuse to buy at all, not considering them even worth the trouble of removal.

The following table shows the average quantity of fæces produced according to various estimates:—

AVERAGE QUANTITY OF FÆCES PRODUCED BY AN AVERAGE INDIVIDUAL, OF ALL AGES AND BOTH

	Per Day.		Per Annum.	
		Pounds.	Pounds.	Cubic Feet.
I. *Average of the Estimates*, of Baron Liebig, Mr. Lawes, Professors Hofmann, Witt, Way, Thudichum, Boussingault, Stöckhardt, Saussure, Macaire, and others	Solids, about 1-tenth	0·24	87·60	1·39
	Fluids, 9-tenths	1·95	711·75	11·29
		2·19	799·35	12·68
II. *Average of Adults*, as per Report of 1857, on 'Engrais des Villes,' presented to the Chamber of Representatives of Belgium	Solids	0·332	121·18	1·92
	Fluids	2·536	935·64	14·85
		2·868	1056·82	16·77
III. *Average of all Ages*, being a reduction of 30 per cent. on the preceding quantities of adults, nearly corresponding with Estimate I.	Solids	0·232	84·83	1·34
	Fluids	1·775	654·95	10·39
		2·007	739·78	11·73
IV. *General Average*, by Capt. Liernur, of excrements actually collected, allowing for waste by evacuations out of doors, &c.	Solids	0·24	87·60	1·40
	Fluids	1·51	542·40	8·60
		1·75	630·00	10·00

Taking again an average of the analyses of various authorities, we find that the solid and fluid excrements of an average individual of all nations, sexes, and ages, contain the following percentage of ingredients:—

ANALYSIS OF EXCREMENTS.

Ingredients.	Fæces.	Urine.
Water	75·00	93·99
Organic Substances	12·20	4·15
Nitrogen*	1·40	1·42
Phosphoric acid†	1·06	0·24
Potash	0·29	0·20
Insoluble silica	1·48	—
Oxide of iron	0·54	—
Lime	1.72	—
Magnesia	1·55	—
Sulphuric Acid	4·27	—
Soda	0·31	—
Chloride of sodium	0·18	—
Total	100·	100·

* Nitrogen equal to ammonia, fæces 1·70; urine 1·73.
† Phosphoric acid equal to phosphate of lime, fæces 2·30; urine 0·52.

The annual produce of an average individual of the four principally useful ones of the above ingredients is as follows:—

	Fæces.	Urine.	Total.	Value.	
	Pounds.	Pounds.	Pounds.	s.	d.
Ammonia‡ (nitrogen)	1·49	9·38	10·87	7	3
Phosphate of lime (phosphoric acid)	2·00	2·80	4·80	1	7
Potash	0·25	1·08	1·33	0	7
Organic substances, &c.	10·51	22·49	33·00	0	7
	14·25	35·75	50·00	10	0

‡ The above estimate refers to the excrements actually collected, allowing for waste.

It will be seen from this table that, if human excreta, including urine, were reduced by evaporation to the dry condition of guano, it would contain by weight fully 20 per cent. of ammonia, in which respect it compares very favourably indeed with the latter kind of manure, the best specimens of which contain only 8½ per cent.

According to these estimates, the annual value of human excrements, both solids and fluids, would in round figures sum up as follows:—

	Value.	London.	United Kingdom.
	1,000,000 Population.	Some 3,000,000 Population.	Some 30,000,000 Population.
	About.	About.	About.
Ammonia	£380,000	£1,140,000	£11,400,000
Phosphate of lime	70,000	210,000	2,100,000
Potash	20,000	60,000	600,000
Organic substances, &c.	30,000	90,000	900,000
	£500,000	£1,500,000§	£15,000,000

§ Professor Hofmann's estimate is 1,400,000*l.*

These calculations show the value of the excrements of an average individual, some 10 cubic feet containing about 50lbs. of fertilising ingredients per annum, to be about 10*s.* sterling.* For London, with its 3,000,000 inhabitants, the annual value is 1,500,000*l.*, hitherto utterly thrown away by the sewers into the Thames. Of the United Kingdom, assuming one-third of the population to save their excrements, and apply them to agricultural purposes in one shape or another, the other two-thirds lost through 'sewerage by water carriage' would still amount to 500,000 tons of fertilisers, or thereabouts, worth the enormous sum of some 10,000,000*l.* per annum. But this sum, large as it is, does not by any means represent the real extent of the loss sustained. To estimate that we must, of course, also bear in mind, that England imports both foreign fertilisers (guano, bones, &c.), and foreign food (corn, beef, butter, cheese, &c.), involving, year after year, a very considerable drain of capital out of the country, for which no adequate returns are obtained.

To gain some approximative idea of this enormous annual drain of capital to foreign parts, let us first ascertain the real intrinsic value of the fertilisers thrown away by our present mode of sewerage by water-carriage, by taking also into account what quantities of food these very same fertilisers might have produced, if applied to agriculture in the way so clearly pointed out by nature and reason.

The fertilising ingredients contained in the annual fæcal matter of an average head of population are capable of raising as much grain as 75 lbs. of Peruvian guano; and the application of $2\frac{1}{2}$ cwt. = 280 lbs. guano per acre gives, according to Prof. Voelcker, an increase of 12 bushels of corn. The manure of one individual would thus yield an increase of $3\frac{21}{100}$ bushels, worth at 50*s.* per quartern, say 1*l.* To cast away the 10,000,000*l.* worth of manure due to two-thirds of the population of Great Britain, is thus equal to a waste of 20,000,000*l.* worth of food!

Now let us see what is done to repair the fearful loss inflicted upon the country by throwing its sewage away: the only means applied are importation of foreign fertilisers and importation of foreign food.

The fertilisers imported consist chiefly of bones and guano. For the first-named article large depôts have been established all over the Continent of Europe, to receive whatever scavengers and bone-pickers † can possibly collect in streets, courts, butchers' stalls, &c.; and shiploads of bones are thus annually sent to England, amounting, from Bavaria alone, to some 6,000 tons. Besides this, nearly all old public cemeteries have been ransacked, amongst others the catacombs of Sicily, which are now completely exhausted.

* Baron Liebig estimates 16 francs, or 12*s.* 9*d.* per head per annum, for ammonia and phosphates alone, omitting the other ingredients which are included in our estimate of 10*s.* Good scientific authorities, however, consider the baron's valuation by far too high.

To give a good comparative idea of the value of human excrements as manure, we may state that, according to Macaire and Marcet, 1 lb. of this substance is equal to 13 lbs. of horse-dung; or 6 lbs. of cow-dung, in fertilising qualities. Dr. Voelcker says that horse-dung contains but a mere trace of free ammonia at any time; when perfectly fresh it is scarcely measurable, there being only 3 parts in 100,000 parts of dung; 40 tons of dung yield only 49 lbs. of ammonia.

† These receive about 1*s.* 8*d.* per 100 lbs.

Nay, even the solemn repose of the warriors fallen on the glorious fields of Leipsic, Waterloo, the Crimea, and elsewhere, has been repeatedly disturbed, thus compelling them twice to serve the requirements of humanity, first by their stout hearts and strong hands in bloody warfare, and afterwards by their dry bones, ground up into fertilisers to replace those insanely thrown away.

In fact Britannia may be said to feed like a huge vulture on the carcasses of all Europe, nay of nearly the whole world, consuming their very marrow and substance, without, however, gaining any permanent relief for herself. 'It is impossible,' says Liebig, 'that such a sinful violation of the divine laws of nature should for ever remain unpunished; and the time will probably come for England, sooner than for other countries, when with all her wealth in gold, iron, and coal, she will be unable to buy one thousandth part of the food which she has, during hundreds of years, thrown so recklessly away!'

The imports of guano began in 1841. This substance, known in Peru as 'pichin huano,' bird manure, consists of the excrements of sea birds, principally the 'Sula variegata.' It is composed, like those of snakes, of mixed fæces and urine, containing large proportions of ammonia and phosphates, and is chiefly obtained from the Chincha Islands, off the Peruvian coast. Already, in 1832, attempts had been made to introduce this fertiliser into Europe; but the scheme then failed, as it was deemed preposterous to go all the way to the Pacific Ocean for mere birds' dung.

From 1841 to 1860, the average annual export of guano from Peru amounted to about 20,000 tons; in 1861 it rose to 348,500 tons, the transport of which cost about 1,000,000*l*. The export from Peru of guano in 1862 was as follows:—

	Tons
Great Britain*	121,709
British Colonies	1,630
Belgium	50,237
France	44,300
French Colonies	4,730
Germany	27,644
Spain	20,771
Mauritius	13,590
United States	12,470
Italy	4,655
Holland	2,466
China	460
Total	304,662

Which, at the price of 8*l*., or 40$ per ton, yielded Peru an income of 12,186,480$, being more than the total of all her other exports.

In the same year (1862) the Peruvian Government ordered a survey to be made of the guano beds on the Chincha Islands, when the supply yet on hand was reported to be 9,548,735 tons, which, with an annual consumption of some 400,000 tons, would last only about *twenty-four years* to come. Alarmed at seeing their principal mine of wealth so nearly exhausted, the government ordered a second survey to be made, which, however, reported still more

* During the nine months ending September 30, 1865, the importation of guano in Great Britain was 170,945 tons against 82,683 tons in 1864, and 170,382 tons in 1863. The value during the first eight months of 1865 was 1,685,803*l*., the average price about 12*l*. per ton.

unfavourably, namely, that the whole supply would not last longer than *twenty years*, an estimate found still too high by practical men well acquainted with the subject, who fully believe that the Peruvian guano beds will be *exhausted in about ten years*.*

In the meantime the most strenuous efforts were made to find out new sources of supply of this, under existing circumstances, quite indispensable fertiliser, leading to the following discoveries:—

	Tons.
Lobos Islands, estimated to yield some	4,000,000
Macoli group " "	1,500,000
Guanape group " "	2,500,000
New Guano beds, total, some	8,000,000

This fresh supply, however, is only of an inferior quality compared to the Peruvian article, which owes its superiority to the circumstance that, as it never rains on the Chincha Islands, the fertilising ingredients of the manure are not washed out.

The enormous annual loss inflicted upon England by sewerage through water-carriage may now be summed up as follows:—

The fæcal matter of 20,000,000 of people now utterly thrown away, if applied to agriculture in the way pointed out by the laws of nature,

Would produce an increase of crops at the rate of 1*l.* per head (see page 76)		£20,000,000
They would further save the annual importation of guano, say	£1,500,000	
Bones, &c.	500,000	
		2,000,000
Total per annum		£22,000,000

now needlessly drained out of England by importation of foreign fertilisers and foreign food.

According to Kolb's 'Vergleichende Statistik,' the public funds applied to the relief of the poor in 1863 amounted to:—

England	£9,325,071
Scotland	736,028
Ireland	701,031
Total	£10,762,130

The budget of 1864-5 contains:—

Income tax	8,600,000
Stamps	9,320,000
Total	£28,700,000

* So Admiral Moresby reported in 1861 to the British Government, that the guano beds then known would be exhausted in from eight to nine years. Notwithstanding this, we find the Royal Prussian engineer, Mr. Veit Meyer, in a paper on the 'Utilisation of Sewage,' read before the Polytechnic Society of Berlin, condemns the Parisian plan of poudrette manufacture, and advises to conduct the whole sewage into the Seine, as is done in England, 'it being better,' he says, 'to purchase annually that quantity of manure in the shape of guano!' The opinion of this gentleman was taken as that of an expert by the Frankfort authorities, in their discussions about the drainage of that town. No wonder that their lengthy deliberations led to such curious conclusions, as stated on pages 63 and 64.

A late Peruvian paper states that continually an average of nine ships are loading guano at the Chincha Islands, and that this material is so rapidly decreasing, that all the beds are likely to be exhausted in about two-and-a-half to three years at the latest!

which, in future, might to a great extent be defrayed out of the proceeds of a rational utilisation of sewage all over the country.

The only attempt that seems to be made to save some of the London sewage is the gigantic plan of Messrs. Napier and Hope, to use it for fertilising the *Maplin Beach Sands*, or flats, at the mouth of the Thames, to effect which an immense new culvert, or sewer, is required, some forty-five miles long, estimated to cost with

embankments and all contingencies, about .	£2,028,000
Together with pumping engines . . .	72,000
Total	£2,100,000

Baron Liebig, in a letter to Lord Robert Montague, president of the Sewage Committee, condemns this project altogether and emphatically predicts its utter failure; because all the sewage in the world is not capable of converting barren sand into fertile soil, unless the sand be first largely mixed with clay, lime, magnesia, and similar ingredients, capable of solving and absorbing the fructifying elements contained in the manure.

According to this letter, written in July, 1865, the baron says, '*All the sewage matter of the whole earth will not be able to convert the Maplin Sands and Dingie Flats into good meadows, or arable land*, such barren sandy soil merely absorbing, but never *assimilating*, sewage salts, various other ingredients being also imperatively required to effect the change contemplated. Baron Liebig satisfactorily proves that, if such an experiment has partially succeeded with the Edinburgh Meadows, so often quoted, it is only because the loam and clay carried down by the sewage liquid from the heights above impart fertility to the sands below. Baron Liebig's natural deduction is, that '*the Maplin Sands and Dingie Flats must first be treated with loam, clay, lime, and magnesia in enormous quantities, before irrigation with London sewage liquid could produce any vegetable life; a process of course quite out of the question with such extensive tracts.*' Messrs. Napier and Hope's grand scheme must therefore, according to Liebig, prove an inevitable abortion, entailing heavy pecuniary losses on all those who are foolish enough to invest their capital in it. Let us hope that, at the eleventh hour, the voice of true science and common sense may yet be heard, and that millions of pounds, shillings, and pence may be saved to better purposes.

This and various other reasons, fully explained in our remarks on the utilisation of sewage, loudly proclaim against a new and costly experiment in a wrong direction, which could only result in the loss of the sewage together with the 2,100,000*l.* to be expended on the works, and would besides render the whole neighbourhood uninhabitable by spreading deadly exhalations for miles and miles around.

5. NATIONAL ECONOMY.—Sound national economy, as understood and promulgated by many eminent public men and distinguished authors of the present day, teaches us, amongst other highly important truths,

1st, Whatever can be advantageously produced in a country, should never be imported from another; and,

2nd, All capital, finding healthy employment at home, should never go abroad.

It is seen, at the very first glance, that both these fundamental principles are constantly and openly violated by the present system of city-sewerage by water-carriage.

The immense quantities of manure daily produced in our populous cities, a first-rate article, at least fully equivalent to guano and bones if only the water be kept out, is remorselessly thrown away into rivers and the sea, whereby the farmer finds himself compelled to import guano from Peru, and rake up for bones old battlefields all over the world. These fertilisers, imported from abroad at great cost, being far from sufficient, agriculture languishes; millions of acres of excellent arable land, remain untilled; and the famishing cities, in retribution for their sinful waste of manure, are under the necessity of constantly importing enormous quantities of breadstuffs, cattle, butter, and many other articles of food, nearly all of which might just as well be produced at home.

Thus a constant and most serious drain of capital remitted to foreign countries is kept up, which might far more advantageously be employed at home, if only the divine laws of Nature and the teachings of true national economy were more generally understood and obeyed; an anomaly which must strike anyone who bestows the least consideration on the subject.

It would certainly be a noble task for the Press to enlighten the public, and cause it fully to recognise the astounding facts which we have endeavoured to point out with regard to city sewerage by water carriage, as many abler writers have done before. In the meantime, the multifarious disadvantages, technical, financial, sanitary, and agricultural, explained in the preceding pages, may serve as a kind of indictment carefully drawn up under the guidance of stern modern science, daily experience, and common sense; and the ultimate verdict be left to the judgment of an enlightened public.

VI. CONTINENTAL SEWERAGE SYSTEMS.*

We now proceed to describe very briefly the various systems in use on the Continent for removing excrements from towns by transport, or what in German is called *Städte-Reinigung* (city-cleaning), and in French, *Travaux de Vidange*, or *Travaux d'Assainissement* (works for emptying, or making healthy). As in English we find no words exactly corresponding with these terms, we have adopted the above title, although no 'sewers' form part of the methods we have to treat of.

Generally speaking, the Continental sewerage systems may be divided into two distinct classes, viz. :—

1. Cesspools;
2. Movable receptacles (*fosses mobiles*);

both serving to collect fæcal matters only, excluding other refuse substances, such as household waste water, kitchen-stuff, &c. This exclusion is rendered imperative by the fact that otherwise the mass would soon become too bulky for removal by transport; and, besides this, farmers would refuse to buy it for manure—objections which of course absolutely forbid the use of any waterclosets, which would increase the annual produce of 10 cubic feet fæcal matter to some 600 or 700 cubic feet per head.

1. Cesspools.—The general construction of cesspools on the Continent is mostly left to the private judgment of the householder or builder; but, in some cities, very strict police regulations exist, with regard to their form, dimensions, and other details.

For instance: in Ostend, cesspools must have at least a capacity of 4 cubic mètres (148 cubic feet), and an arch of 18 centimètres (8 inches) thickness; wall and bottom to be 33 centimètres (13½ inches) thick, and the manhole 20 inches in diameter. In Metz, the cesspools are compelled to be made of water-tight brickwork, 2 mètres high, and covered with an arch. In Strasburg cesspools may be round, elliptic, or square; but, in the latter case, the corners must be rounded off with circles of 9½ inches radius. In Lyons, they are made of all sizes, some actually of 30 cubic mètres, or 1,110 cubic feet. In Munich, cesspools are compelled to be outside of the house walls, and 4 × 4 feet section, and 7 feet high. In some towns the law prescribes a ventilating flue running up from the pit to the house-roof, or into the chimney, and various other regulations, to suit local circumstances.

These cesspools are periodically emptied in three different manners:—

* We have included the *Eureka process*, *Moule's Earth-closet*, *Professor* [illegible] *invention*, &c., amongst the Continental 'systems,' because they are so closely related to them.

1. By hand, shovel, and bucket;
2. By suction pumps;
3. By pneumatic pressure.

The first mode luckily requires no description, as its details are too revolting for print. This offensive practice, notwithstanding the intense suffering it entails whenever it occurs, not only on the inmates of a house, but on a whole neighbourhood, is still regularly practised and officially sanctioned in many Continental towns which occupy a high rank in the scale of civilisation and social refinement.

The mode of emptying cesspools by suction pumps, which is far more preferable, is accomplished by various contrivances. First we have Mr. Mestdagh's 'Pompe à soufflet,' patented in Belgium, where it has been introduced in various towns. This pump may be described as follows: Two large bellows, having their nozzles turned towards each other, communicate through their valve-openings with a roomy pipe, to which a 3-inch suction pipe is attached; a lever, pivoted in the middle like that of a fire-engine, operates upon the bellows in such a manner that when one is raised the other is depressed; which alternate motion first sucks the fæcal matter, and then forces it into the ascending 3-inch pipe. This pump, costing about 20*l.*, is placed upon a little waggon, carrying also the hose and other fixtures. An iron receiving cylinder, 6½ feet long and 3 feet in diameter, lies upon a separate carriage, and generally remains in the street whilst the pump is placed as near the cesspool as practicable. A 3-inch hose laid through the house, court, or garden, establishes the communication between the pump and the receiving cylinder.

Another pumping arrangement is the so-called 'New York Pump,' manufactured by Mr. Schiettinger of Mühlhausen. It resembles somewhat an ordinary horizontal high-pressure steam-engine, with this difference, of course, that the motive power is derived from two cranks on the driving axle worked by labourers, whilst the cylinder is filled with and emptied of sewage matter through the reciprocating motion of the piston. The pump is of double action, and has a regular D slide-valve worked by a segmental cam, instead of the ordinary four-flap valves; a heavy balance-wheel regulates the motion. This pump seems to be easier worked than the bellows class, and gives more satisfaction. It is in use in Munich, Zürich, Basle, Lyons, and many other towns.

To obviate the offensive effluvia arising from the cylinder while it is gradually filling, the latter is now in many towns furnished with a sort of chimney, in which about midway a little charcoal fire lies glimmering; the air displaced by the sewage matter running into the cylinder must pass through this fire and is thereby purified.

A still better arrangement for emptying cesspools is the more modern one, by pneumatic pressure, by which the pumping waggon is dispensed with, and only the receiving cylinder used. When about to be employed, this cylinder is filled from a small stationary boiler with steam of about 1¼ atmosphere pressure, which drives all the air contained in it through a chimney containing a charcoal fire to make it inoffensive. When the cylinder is filled with steam, the valve is closed, the connecting pipe detached, and the waggon drives to its destination. During the transit the steam condenses, leaving a perfect vacuum above a little water collecting in the bottom. To empty a cesspool it is then only necessary to fasten one end of a hose to a coupling socket on the cylinder, and lower the other end into the pool. The moment the valve in the socket is opened, the air forces the sewage matter into the cylinder, until the gases collecting in the upper part balance the pressure of the atmosphere. The resistance of these gases prevents the filling of the cylinder to more than about three-quarters of its capacity, the suction being very powerful in the start, but gradually slackening off, until brought to a dead stop by the above cause.

Another mode of making a vacuum in the waggon cylinder is used in Turin by filling it with wator, and allowing this to discharge into a vertical pipe of 36 ft. in height, with a short bend below like a barometer. The cylinder will of course entirely empty itself both of air and water, when the valve is closed and the waggon is ready for use. This method requires not only abundance of water brought to that height, but also a clear fall of 36 ft. for the free discharge of it.

In Milan, where these local advantages cannot be had, the following strange arrangements are applied to obtain what is called by the high-sounding name of 'hydro-pneumatic force.' A sort of box-reservoir, containing 20 cubic mètres of water, stands with its bottom 2½ mètres above the ground. Under it, sunk half in the earth, lies an iron cylinder of $1\frac{4}{10}$ mètre diameter, and of 16 cubic mètres capacity. A pipe conducts water from the reservoir into the cylinder and fills it. A pump, worked by a yoke of oxen, pumps the water out of this cylinder again, after every other opening has been shut; the result is a vacuum in the cylinder below. The pneumatic waggon cylinder is now backed up to the reservoir, and also filled with water, which, by means of a connecting pipe, is then emptied into the evacuated cylinder below, leaving of course a vacuum behind in the waggon cylinder. As the latter contains only 2 cubic mètres, eight such cylinders can be simultaneously evacuated by connecting them with the apparatus. Of this roundabout way of establishing a vacuum the good people of Milan seem to be very proud, never taking into account the amount of force needlessly spent by constantly moving about such great masses of water. The same result could of course be obtained much cheaper by applying a steam airpump direct to the waggon cylinder to be evacuated.

In Turin, where it appears all sorts of sewerage schemes have been tried, it was also proposed by Mr. Chapusot to connect all cesspools by means of subterranean pipes with a central depôt, which, when evacuated of air, would enable the emptying process to go on without even the knowledge of the inhabitants. This would, of course, have been a great point gained, as few domestic occurrences are of a more revolting nature than the emptying of cesspools. But as Mr. Chapusot did not strike at the root of the evil, namely, by removing these disgusting pits, his scheme, being also otherwise too complicated, fell to the ground.

The principal objection to all these various systems is, of course, that cesspools form an integral part of them. We have already sufficiently pointed out that these pits are an intolerable public nuisance, for the following reasons:—

a. The walls, however well cemented, always allow more or less filtration of the noxious matters contained in cesspools, a danger incurred already by the slightest crack or fissure resulting from a subsidence of the ground, which filtration or percolation saturates the soil and poisons the wells, to the serious injury of the public health.

b. The sewage matter being retained in cesspools for months and even years,* it soon passes into a state of fermentation and putrefaction, evolving continually large volumes of most noxious gases, whether there be a ventilation chimney or not, thereby polluting the surrounding atmosphere.

c. This fermentation and putrefaction most seriously diminishes the agricultural value of the fæcal matters, rendering them almost worthless for fertilising purposes, if the retention in cesspools is of long duration.

d. The emptying process must always be accompanied by more or less of noisome effluvia, even when deodorisers are used, and with a disagreeable bustle, drawing the attention of the inmates to a business which, on refined people with sensitive nerves, must always have a most nauseating effect, even when the operation goes on at night, the entrance of working men into dwellings with their tools and fixtures causing only much greater disturbance and annoyance.

These and many other well-known and universally acknowledged objections led, in many places, to the adoption of other systems, which we shall now have briefly to consider.

2. FOSSES MOBILES.—The 'fosses mobiles' of the French, or 'Abfuhrtonnen' of the Germans, consist of wooden or metal vessels or barrels, which are placed directly under the outlet of privy pipes in the basement of buildings, and when filled are either emptied into a waggon waiting in the street, or taken away altogether and replaced by empty vessels. The use of waterclosets is in this case, of course, also out of the question.

An example of the simplest and oldest-fashioned arrangement of this kind can be seen in Groningen in the Netherlands. There, simple open buckets, 18 inches in diameter and 18 inches in depth, are placed immediately under the openings of the privy seats. When filled, which occurs once or twice a week, according to the numbers of a household, they are emptied into vehicles, which, at the expense of the town, perambulate the streets in the morning. These vehicles are of two kinds, namely, four-wheeled waggons for the fluids, and two-wheeled carts for the removal of the solid excrements. The buckets are emptied into these vehicles quite openly in the street, causing, of course, a stench and offensiveness more easily to be imagined than described. Groningen, with some 37,000 inhabitants, employs for this purpose 22 waggons

* There are many instances on record of cesspools being emptied but once in a century, for instance, in the old-fashioned town of Lüneburg, Hanover.

and 8 carts with 30 horses, transporting the fæcal matters to an enclosure outside the town, where they are discharged and mixed with the town ashes and street scrapings. The compost thus formed is, every two or three months, sold by auction to farmers, coming often from 20 to 50 miles distance to obtain it, principally for growing rye, barley, and oil with it. Groningen has had recently to pay very dearly for her utter disregard of sanitary laws by a severe visitation of cholera, which carried off some 2,500 victims in a comparatively short time. The immediate neighbourhood of the municipal compost manufactory, of course, suffered the most.

Amongst many other towns where this bucket-system is in practice, Leipsic deserves to be mentioned as a favourable exception. This town, with a population of some 80,000, possesses a well-constructed system of sewers, intended, however, to carry off only the rainfall and domestic waste water, all excremental matter being excluded by law, and the use of waterclosets being also prohibited. The removal of fæces and urine is leased to a contractor, who empties the cesspits by means of pneumatic waggons with cylindrical receivers of 62 cubic feet capacity. The price of removal is 2*s.* per waggon load.

But a good number of houses have adopted the 'fosses mobiles,' large strong buckets capable of being hermetically closed when taken away. The householders must pay 3*d.* per bucket for removal, and furnish the vessel itself at a cost of 7½ thalers (£1 2*s.*), and about 5*s.* annually for repairs. The Leipsic contractor discharges the excrements into open pits, and treats them with sulphuric acid, allowing the fluids to run off from the precipitate obtained. The latter, when sufficiently dried, is cut up with spades, taken out, still further dried, ground to fine powder by means of heavy stones, put into sacks and readily sold at 1½ thaler (3*s.* 8*d.*) per 100 lbs. The fluids, which largely preponderate, bring only 6*d.* per waggon load of about 50 cubic ft.

3. Utilisation of Excrements.—The fæcal matters taken out of cesspools and movable receptacles are utilised in various ways, with more or less success, according to the simplicity of the manipulation and the comparative freshness of the material, which, as stated before, continually decreases in agricultural value the longer it is retained in fermentation. These various processes may be classified as follows:—

a. Evaporation by the atmosphere.
b. Evaporation by artificial heat.
c. Mechanical and chemical filtration,
d. Admixture of solid deodorisers.

We shall now have a few words to say about each one of these systems.

4. **Evaporation by the Atmosphere, combined with clearance of watery parts through rest.**

As this scheme is most completely carried out at Paris, a short description of the sewerage works there may be found not quite uninteresting.

The city of Paris is drained by a system of sewers built upon a scale which throws the London intercepting culverts, and even the famous Roman Cloaca Maxima, completely into the shade. The Parisian sewers, principally executed under Napoleon I., partake more of the character of tunnels, many of them being 18 ft. wide and 18 feet high. It is asserted, with how much truth we cannot say, that these enormous dimensions were given, not so much for the sake of drainage as for opening a subterranean military communication to facilitate strategic movements in cases of revolutionary outbreaks.

No solid excrements are allowed to be thrown into these sewers, which, however, carry off all other sewage matters, including the proceeds of all public pissoirs and the rainfall. In the middle of the sewers there are open gutters, the large ones some 11½ feet wide and 4½ feet deep, with a banquette on each side, furnished with a railway track.

As these sewers have but little fall, and are not supplied with any water for flushing, the stoppages by sediment and street refuse are of course frequent enough. To remove these, dams or weirs fitting in the gutter are employed, which are fastened to the railway cars running on the banquettes. These weirs are looped with washholes, through which the water, backed up behind, spouts with considerable force, thereby scouring away the sediment, while by the same force the weirs slowly move forward. What stoppages cannot be thus removed are taken out with spades, thrown on the banquettes, and carried off by the railway-cars.

The solid excrements are collected partly in masonry cesspools, partly in movable vessels of all kinds. Concerning the first, many police regulations have been enacted, of which those of 1819 are very important. It is thereby required that cesspools must at least be 6 ft. 7 in. high; that they be constructed of granite and hydraulic cement, and provided with an effluvium escape 8 inches square, connected with a flue leading up to the roof of the house. In December, 1850, it was further enacted, that no cesspool shall be emptied without previous disinfection; that the cesspools must be provided with a perforated wall, called 'separateur,' for allowing the watery parts of the excrements to run off into a lower compartment, and thence into the sewers; that the division holding the solids must have an 'indicateur,' showing always how full it is; that the disinfection must take place the night before the emptying process; and, finally, that it is not allowed to postpone this operation until the cesspool is quite filled, but that sufficient room must be left for a proper disinfection.

The novelty here introduced, the 'separateur,' like its imitation in the movable receptacles, the strainer or 'diviseur,' of which we shall speak afterwards, was applied to prevent as much as possible the fermentation which always ensues, whenever solid excrements remain mixed with urine. The consequence of this police regulation was, that all the urine of entire Paris flowed directly into the Seine, resulting soon in such an intolerable nuisance, that in 1855 the municipal authorities, upon the special request of the prefect of the Seine, suspended this part of the law again until further notice.

The withdrawal of all the watery parts by this straining process has also another great inconvenience, namely, the solid excrements obtain such a consistency that removal by pumping or suction becomes impossible; so that the primitive use of shovel and spade must be resorted to. And what kind of work is that! Notwithstanding a constant shower of disinfecting fluid, saturating even the labourers' clothes, the process is disgusting beyond all description, the more so as a great many cesspools in Paris and France generally are built in or under the cellars of the houses.

The poor labourers employed in this fearful business are subject to two terrible diseases, both due to the deadly effluvium of fæces, and known by the names of '*La Mitte*' and '*Le Plomb*,' the first being caused by ammonia gas, the second by sulphureted hydrogen, nitrogen, and hydro-sulphureted ammonia.

'*La Mitte*' consists of most painful distempers of the nose and eyes, and is also called 'Ophthalmie des Vidangeurs.' The 'conjunctiva' swells and every ray of light striking the eye gives a most excruciating pain (*photophobie*). Sometimes the patient recovers in two or three days; but very often the poor man becomes blind, or loses at least one eye.

'*Le Plomb*,' on the other hand, is a sort of suffocation. In a light degree it causes a feeling of faintness, general debility, shortness of breath, and delirium. When, however, the air in a cesspool is heavily charged with sulphureted hydrogen or hydro-sulphureted ammonia, then the wretched labourer falls to the ground as if struck by lightning, and expires at once, after uttering a painful cry of suffocation. To utter this peculiar cry is called by the vidangeurs '*chanter le plomb*.' If speedily brought to the open air, the patient may revive; but he is still liable to repeated attacks of the same painful complaint.

The plain truth is, this occupation of cleaning cesspools is so extremely loathsome and revolting, that only the most degraded and needy men can be brought to earn their livelihood by it. Surely a beneficent Creator never intended that human beings should be put to such vile uses, at the imminent risk of losing their eyesight, nay, even their life; a state of things which should no longer be tolerated in this the nineteenth century; and the less so, as modern science teaches us how to reach the end required, without resorting to such revolting processes.

It was this and many other manifest disadvantages, combined with the fact that many houses had no cesspools at all, or had chambers without access to one, which led to the introduction of the 'fosses mobiles' at Paris. These movable receptacles are generally made of sheet-iron galvanised with tin, about 20 in. high and 10 in. in diameter. To prevent fermentation by mixing fæces with urine, a perforated partition reaches from the top to the bottom, dividing the utensil into two unequal parts, proportioned as one to nine. The larger division receives the mixed excrements, and allows the watery part to filter through into the smaller compartment, from which it escapes to the sewers, the whole bucket being filled in about twenty-two days.

There is still another neater barrel in use, called 'tinette,' consisting of two concentric tin cylinders, the inner one perforated over its entire surface, for allowing the watery parts of the excrements to filter through into the outer one.

As it was soon found out that the holes of these divisions, when small, easily became choked, and, when large, allowed much of the solid excrements to pass through, another apparatus came upon the stage, called the 'Capillary System' of Belicard and Chenaux. This is a simple wooden barrel, in the middle of which the solids fall, the fluids being supposed to drizzle by capillary attraction down the sides of the pipe into a second barrel. It is evident that, in case of a violent or quick discharge, the urine will not always follow the sides of the pipe, but enter the wrong barrel in spite of Messrs. Belicard and Chenaux, thus upsetting the whole ingenious 'system.'

We see thus that, in all the various arrangements Paris can boast of for sewerage purposes, both cesspools and 'fosses mobiles,' the watery parts of the excrements are by some 'artful dodge' or other to be kept separate from the solids, the former eventually to find their way into the Seine, the latter to be retained in bulk 'for higher purposes.'

The removal of the solid excrements is generally in the hands of but one contractor, bound by the authorities to a certain tariff in his dealings with the citizens. To empty a cesspool a charge of about 8 francs per cubic mètre is allowed, and from 2 to 4½ francs for each 'fosse mobile' or 'diviseur,' these prices varying not according to the size of the vessel but to the length of haul. When an inhabitant desires a movable apparatus, the contractor charges 35 francs for the first arrangement, with 20 francs annual rent, including repairs and deodorising.

The fæcal matters thus collected are carried by the contractor in all sorts of waggons and carts, some 400 in number, to 'La Vilette,' the so-called 'depottoire,' or emptying station, of Paris. A canal runs from thence to Bondy, where the celebrated 'Poudrette Factory' flourishes.

The 'fosses mobiles,' 'tinettes,' and all similar fixtures are, upon their arrival at La Vilette, at once put on board of barges for conveyance to Bondy. The pneumatic and common barrel waggons, on the contrary, are emptied in a building close by La Vilette, upon the floor of a sort of gallery, of which there are nine, from whence the sewage runs down through sink-holes into large sewers, provided again with partitions, so arranged that the fæcal matter has to run a long time before reaching the further end, and leaves behind the heavier particles, such as street grit, sand, &c. The other softer parts finally arrive in a well-pit, from which a steam pump forces them through a cast-iron pipe to Bondy, about 1½ mile further on. The Vilette buildings are well provided with gas, water, and ventilation.

At Bondy, the sewage is converted into manure, the so-called poudrette, into sal-ammoniac, and other chemical products, the first being the chief article manufactured.

For poudrette there are eight large open basins excavated in the ground, which are in succession filled from the iron pipe above alluded to, all the solid matter being gradually precipitated by slow movement from one department into another, whilst the watery elements evaporate. When one of the basins has a precipitate of about three feet it is isolated, and another one begun: it takes, however, not less than five to six years before a precipitate reaches that height.

When, by evaporation, this precipitate has become so dry that it can be cut with spades, it is taken out in blocks, spread out, and afterwards stacked up to dry further. When the blocks are finally about 'all right,' and begin to heat, which they do very soon, they are reduced to powder and then put up for sale.

The watery parts, however, separating themselves in the basins and pipes, cannot all be got rid of by evaporation, but accumulate in great quantities. They are also put up for sale, but only partly disposed of on the line of the canal, where barges can be used, as otherwise the transport is too difficult and expensive. *The balance of the fluids is pumped back again to the Seine by means of a six horsepower steam engine!*

The account-books show that, in 1859, there were transported to La Vilette:—

115,111 cylinder waggons of about 2 cub. mètres each,
242,178 barrels and latrines,
240,925 tinettes and diviseurs,

having a total contents of 278,155 cub. mètres.

Out of this raw material was manufactured, but not all sold:—

21,463 cub. mètres poudrette,
4,936 „ „ fluid manure,
13,070 lbs. sulphate of ammonia,
784 „ ammoniacal liquids.

And the prices realised were as follows:—

Poudrette, 47frs. 50c. } per cubic mètre.
Fluid manure, 1fr. } per cubic mètre.
Sulphate of ammonia, 45frs. . per 100 kilos.

The buildings and arrangements, including the steam-engine, at Vilette, were erected and are maintained at the expense of the city of Paris, the contractor paying:—

For the sewage, 1fr. } per cubic mètre.
For the liquids, 1fr. 25c. } per cubic mètre.

Considering that he receives 8frs. per cubic mètre for removing the sewage out of cesspools, and that he is spared the expense of Vilette, and even the cost of pumping the matter 1½ mile to Bondy, it may well be said that he is doing no bad business, as far as his own pecuniary interest is concerned. But the case is totally different with regard to the city of Paris, as is shown by the following statement:—

		Francs
In 1858 the city of Paris received from the sewage contractor .		545,000
Defraying, on the other hand, the following expenses:—		
Interest on capital invested in buildings, &c., at	Francs	
Vilette and Bondy	50,000	
Maintenance of works	100,000	
Pumping to Bondy	35,000	
Labour, &c.	33,000	218,000
Leaving a nominal surplus of		Frs. 327,020

We call this surplus only nominal, because the account in reality stands thus:—

	Francs
Removal of excrements paid by the inhabitants, 433,628 cubic mètres at 8 francs	3,469,024
Above expense borne by the city	218,000
	3,687,024
Receipts from the contractor	545,000
21,463 cubic mètres poudrette cost thus	Frs. 3,142,024

to the citizens and city combined, being about 146frs. per cubic mètre of a stuff selling only at 47frs. 50c.

And when to this sum is further added the enormous capital expended on the sewers carrying off the urine, &c., the cost and maintenance of pneumatic and barrel waggons, carts, tinettes, diviseurs, &c., the wages of labourers, feed of horses, and all other expenses, it will easily be understood that Paris has about as costly a system of removing excrements as could possibly be imagined.

In fact, the total annual expenditure runs up to about 9,000,000frs. or nearly 5*l.* per house! And, in addition to this enormous charge, the inhabitants are constantly annoyed by 'vidangeurs' entering their houses to disinfect or remove, both operations of the most disgusting kind; for, even by the first-named process, if it is to be effective at all, the great quantity of disinfecting fluid required throws off a very offensive effluvium, the more so as the police allow the same to run off through the open street gutters into the next sewer.

We must further add the great loss inflicted upon agriculture by allowing 90 *per cent. of the most valuable fertilising* ingredients to evaporate into the air, for the sake of producing a miserable 'poudrette,' containing only a *poor remnant of* 10 *per cent.* of the original manuring elements; and by throwing away all the urine, which alone would yield a princely income, if saved for agricultural purposes, but now only serves to pollute the Seine and contaminate the atmosphere, to the serious injury of public health.

Considering all this, an intelligent reader will surely agree with us, that it is high time another and better sewerage system were adopted in a metropolis which claims to be the first in the world in arts, sciences, and refinement.

5. EVAPORATION BY ARTIFICIAL HEAT.—This method, called by the modest name of the 'Eureka process,' is or was in operation at Manchester and Hyde, and effects by artificial heat what the Parisian plan does by the natural action of the atmosphere. If the latter system has proved a dead loss in a financial point of view, what chance of a profitable investment can there be, when the same ends are aimed at by the far more costly means of artificial heat?

There is one point, however, in favour of the 'Eureka process,' namely, that the urine is not entirely wasted as in the Parisian poudrette manufactory. The excrements are collected, mixed as produced, and then so strongly deodorised, that is to say, the soluble gases are so absolutely fixed, that they do not escape even in the great heat to which they are subjected for the evaporation of the water.

The apparatus by which this is effected is very well arranged in point of economy of fuel, but fails to dry the matter entirely. To accomplish this it is mixed with substances having themselves a little value as fertilisers, such as ashes used in Hyde, or coal and bone dust employed in Manchester. When such is done, the blocks are broken, reduced to powder, and packed in sacks, in which form the manure is transportable and not offensive. It sells for about 6*s*. per 100 lbs.

To show what expense is incurred in obtaining this weight of manure powder, we submit the following estimate. From our tables on page 75, it appears that the daily excrements produced by an average individual consist of:—

	Lbs.
Solids	0·24
Fluids	1·51
	$1\frac{75}{100}$

containing the following ingredients:—

	Solids Pounds	Fluids Pounds	Total Pounds
Water	0·180	1·419	1·599
Organic substances . . .	0·029	0·064	0·093
Nitrogen	0·003	0·022	0·025
Phosphoric acid	0·002	0·005	0·007
Minerals	0·026	—	0·026
Total	0·240	1·510	1·750

that is to say, of the $1\frac{75}{100}$ lb. daily excrements of an average individual, $1\frac{60}{100}$ lb. are water, and only the remaining $\frac{15}{100}$ lb. useful solid ingredients.

To obtain 100 lbs. solid dry substances, we should thus require the excrements of 666⅔ individuals, producing at the same time 1,066 lbs. water. As it is, however, not possible to evaporate all this, we may safely assume that, to obtain 100 lbs. concentrated manure, we need 1,000 lbs. excrements, of which 900 lbs. water must be evaporated, as follows:—

80 lbs. of solid useful ingredients
20 „ water retained
900 „ „ evaporated

1,000 lbs. of excrements.

The expense incurred may be estimated as follows:—

	s.	*d.*
Disinfecting fluid	1	8
Collection and transport of 1,000 lbs. of excrements at 6*d*. per 100 lbs.	5	0
Of stone coal	2	3
Labour, attendance, &c.	1	1
Total expense	10	0

for evaporating 1,000 lbs. excrements into 100 lbs. concentrated manure, which, as stated before, does not sell for more than 6*s*., leaving a clear loss of 40 per cent., without counting the interest on the capital invested in costly machines, &c.

This surely does not at all look like a profitable business.

The real fertilising value, however, of an average individual's excrements, as we have seen on p. 75, is some 10s. annually, giving

	£	s.	d.
for the 666⅔ individuals above alluded to . .	£333	6	8
The Eureka process would yield in 365 days at 6s.	109	10	0
Clear loss some 67 per cent., or . .	£223	16	8

This highly unfavourable result is partly due to the deodorisers used, causing the most valuable fertilising elements to become insoluble, and partly to the fact that the manufacturers generally add some earthy substances to promote drying, which, having in themselves no material value, of course lessen the quality of the whole.*

6. Mechanical and Chemical Filtration.—In treating of the sewerage works of Paris, we have already described the 'Système diviseur,' which is a general name for all kinds of receptacles so constructed as to separate the watery parts from the solids, at the time the excrements are produced.

In most cases the means employed are nothing but a sort of coarse strainer, made of a perforated sheet of tinned iron or zinc; and the filtration thereby effected is, of course, of the rudest mechanical kind, resulting in a loss of at least 85 per cent. of the fertilising ingredients flowing off with the liquid into the street gutters or sewers.

A great improvement upon these clumsy contrivances is the arrangement introduced by 'Compagnie Foncière Lucien Henri Blanchard & Cie.,' consisting of a barrel with a double bottom, the upper one of which is perforated and covered with a cloth of horsehair, 1 centimètre thick, with a layer of sulphate of magnesia (Epsom salts) spread over it, and over this another layer of some substance saturated with phosphoric acid.

The barrel so prepared is placed under the privy pipe, and both fæces and urine fall into it, the first being of course retained, whilst the latter flows off through the strainer, which is here said to work at once both mechanically and chemically, in such a manner, that all the fertilising ingredients are absorbed, and the watery parts flowing off are not only made inodorous, but also so purified, that they do not afterwards become putrid. Finally, it is stated that the solids themselves are deodorised. When the barrel is full, the contents are removed, and manufactured into a highly concentrated manure.

This arrangement has been introduced into the colonie of Mettray and in Toulouse, and is stated *by the inventor* to have given every satisfaction. It appears, however, that the high price of phosphoric acid, &c., prevents this manufacture of manure being a profitable one, as may be seen by the following estimate:—

To prepare 100 lbs. of solid manure, containing, however, some 20 per cent. of water, the inventor considers necessary—

300 lbs. of mixed excrements
11 „ phosphoric acid
5¼ „ sulphate of magnesia.

* Messrs. Lawes and Gilbert state, in their treatise on the 'Composition and Value of Sewage,' that an analysis of the 'Eureka' manure, made in 1863 at Rothamsted, St. Albans, proved it to contain but 1 to 2 per cent. of ammonia, so that it could not be useful unless applied in quantities of many tons to the acre

Involving the following expenditure :—

	s.	d.
Filtering substance, maintenance of barrel, &c., for 300 lbs. at 9*d.* per 100 lbs.	2	3
Labour and contingencies	1	7
Phosphoric acid, 11 lbs. at 4*d.*	3	8
Sulphate of magnesia, 5½ lbs. at 1*d.*	0	6
Total	8	0

The 100 lbs. of manure obtained are said to contain :—

	Lbs.	Value	s.	d.
Water	20			
Nitrogen	5	at 10*d.*	4	2
Phosphoric acid	10	„ 4*d.*	3	4
Organic substances	45	„ ⅛*d.*	0	5⅝
Minerals	20	„ ⅛*d.*	0	2⅜
	100		8	2

The manure, if sold at its estimated value, would thus yield a profit of but 2*d.* per 100 lbs., provided the raw material were brought free of all cost to the manufacturer's door; but if he has to pay for collecting the excrements, it requires no further proof that his balance will appear on the wrong side of the ledger.

Besides, without wishing to detract from the merit of this invention, we doubt whether the deodorisation of the solids, working from below upwards, and that of the fluids escaping towards the sewers, be really so perfect as is claimed, judging by the results of experiments made in deodorising sewage liquids with the same or similar chemicals. Finally, the arrangement is as little free as any other movable apparatus of the great nuisance caused by the periodical visits of labouring men upon a nauseating business.

The method introduced by Professor A. Müller, of Stockholm, and Dr. Schur, of Stettin, called the 'Müller-Schur System,' belongs also to the mechanical-chemical filtration class. To prevent fermentation, the solids are separated by a strainer from the fluids, and at every discharge are covered with mixed lime and charcoal powder—the one acting as a dryer, the other as a disinfectant; so that the mass can afterwards be reduced to a comparatively inoffensive powder. The valuable fluids, however, are completely lost, and the manure obtained is worth not more than 1*s.* 3*d.* per 100 lbs. This system, like the others, has also the great fault of incurring the double expense of transport—first in bringing lime and coal to a house, and then carrying them away again with the excrements, besides requiring periodically the undesirable visitation of labouring men.

7. DEODORISING FÆCAL FLUIDS.—By this class of sewerage systems the fluids are retained and allowed to be absorbed by earthy matters. The simplest mode of doing this is that practised in Manchester, where, as stated before, excrements and household ashes (nearly exclusively of stone coal) are collected in the same receptacle, the best and most complete arrangement of which depends, of course, entirely upon the comparative wealth of the owner.

Considering that these ashes must be removed from the dwellings anyhow, this method is the best in point of economy, as no additional transport of deodorisers is required. But a moment's reflection will show that the process is of little practical value, owing to the varying proportions of ingredients among the different classes of society. Amongst the poor, ashes are not always so plentiful; hence the absorption of the liquids is incomplete, and the privies soon become offensive; whilst in more wealthy houses the privy contents are almost exclusively a heap of ashes of but little agricultural use. Nor is it at all a tidy or clean arrangement, as a great deal of the urine is purposely wasted, and the ashes do not prevent the escape of a large portion of ammonia in drying, unless repeatedly drenched with sulphuric acid. Experience has shown that the manure thus produced does not at all repay the cost of a distant transport.

Another variation of this plan is the preparation of the so-called 'noir animalisé,' which is nothing else than excrements mixed with pulverised and properly prepared vegetable matter containing a great deal of carbon, such as turf, peat, &c. It is not necessary to explain this process at large, as it is obviously the same as the one mentioned before, with this drawback, that it costs still more in preparation; besides, the disinfection being only partial, large quantities of the most valuable fertilisers are wasted by evaporation.

A more simple and practical arrangement for isolated dwellings is Mr. Moule's Chair, or Earth-closet, as supplied by the Moule Earth-closet Company. This is a well-made closet in the shape of a sick-chair, fit to be placed in any room or corridor. The seat is perforated, and has a good stout bucket placed under it. The back of the chair is hollow, and filled with perfectly dried and finely pulverised earth: a valve is so connected with the seat, that when, after usage, the individual rises, a quantity of earth is discharged.

The capacity of loose dry earth to absorb and deodorise fæcal matters is well known, there being perhaps no better solvent to take up the ammonia and other gases evolved, and to unite in one highly fertilising compost what before were two or three most offensive and useless substances.

The objection, however, to the general introduction of this arrangement is obvious enough. To absorb and deodorise excrements, both fluids and solids, at least 3½ times their volume of earth is required. Thus a transport takes place towards a house of 3½ volumes of earth, and from it of 4½ volumes including the excrements, equal to an average of 4 volumes each way.

The annual produce of an average individual being 10 cubic feet of excrements, a city of 100,000 inhabitants furnishes 1,000,000 cubic feet of fæcal matters, which this method would increase to 4,000,000 cubic feet including the earth, to be transported twice, first into the city and then out again into the country.

As all this transport must of course be effected by waggons, it is evident that the cost and trouble of the same would fully swallow up the proceeds of the manure obtained, just as is the case with the other systems already mentioned. Besides this, there is the nuisance of a great number of waggons continually obstructing the streets, first by bringing 3,500,000 cubic feet of earth into the town, and then by taking 4,500,000 cubic feet of compost out again into the country, which circumstance alone would forbid the introduction of this most cumbrous method.

A rather interesting exposition of this mode of dealing with sewage was made by Dr. Hawksley of London, in a paper read by him at the Sewage Conference held at Leamington, October 25, 1866. The paper was entitled, 'The Power for Good or Evil of Refuse Organic Matter,' and was full of information and many just observations on the value of human excreta, and the power of earth to deodorise them. To reduce this sound theory to practice, however, Dr. Hawksley advises the adoption of the Moule system for the city of London in the following manner, which we copy from the 'Birmingham Daily Post' of October 26, 1866.

He proposes to divide the metropolis into 500 sections. 'In each section will be a number of men with horses and carts, and pails, who will call at the houses every morning, between the hours of six and nine A.M., for the removal of the soil to a general dépôt, where kilns will be erected for drying it, and sending it away for agricultural purposes. He estimates that this will yield a very large annual revenue to the city, and the system can be carried out without any offensive smells arising from the removal of the soil. The following are the figures by which Dr. Hawksley arrives at his conclusions: Population, 3,000,000; number of habitations, 500,000; number of earth-closets required by the new system, supposed to average two to each habitation, 1,000,000; dividing the town into 500 sections, having in each a number of closets equal to 2,000; each section with 10 carts, 20 horses, and 20 men; every two men, cart, and pair of horses, are charged with the care and management of earth-closets, numbering 200; the work to be done between six and nine A.M.; each cart at leaving its station will convey a weight equal to 2 tons 1 cwt.; consisting of 200 pails, 9 cwt., and 3,600 lbs. of earth. On returning to the station the additional weight will be 16 cwt. and 102 lbs. The value of the product he estimated to be as follows: For each individual, 14*s.* per annum, at the lowest estimate—total sum, 2,100,000*l.*; or 15*s.* 3*d.*, at the highest estimate, which would yield 2,287,500*l.* per annum. Expenses of collection and management, for each sub-section having the charge of 200 earth-closets; labour of two men for three hours per diem, 3*s.*; cart and horses, ditto, 4*s.* 6*d.*; quota of rent of sheds, 6*s.*; total, 8*s.*; annual expenses of the 500 sections, 623,250*l.*; and balance of profit on the lowest estimate, 1,476,750*l.* Supposing that 7*s.* a-head was given to each person in every habitation for this refuse material, the amount would be 1,050,000*l.*: leaving a balance to pay for pails and management equal to 426,750*l.* After referring to the various arguments which had been advanced for and against the system of utilising sewage, the lecturer concluded by stating that the following were the propositions he had arrived at, after considering carefully the whole question: 1st. That the refuse organic matter cast free in human communities, is of an immense amount; that it is of great value if well applied, but that it is a source of great, varied, and increasing evils to the public health if ill applied, as well as a great drain on the resources of the wealth and food of the people. 2nd. That the present mode of dealing with the refuse organic matter fails to utilise it; but, on the other hand, so mixes it up with the first essentials of life and health—viz. the air we breathe and the water we drink—as to lower the standard of vitality, to produce much general disease, and to convey epidemic poisons in the most fatal and wide-spread manner. 3rd. That the mode referred to (that is, the existing sewerage system) is an error from beginning to end, and is incapable of any satisfactory improvement. 4th. That the employment of earth for absorbing, deodorising, and utilising the material in question, applied on the principle of detail, affords a complete, practicable, and highly profitable method of accomplishing all the objects of the sewage system.'

Though there is no doubt of the truth of the concluding remarks in the above quotation from Dr. Hawksley's paper, it requires but little shrewdness to see how utterly erroneous his estimate is, for bringing daily into town, according to his own data, 18,000,000 lbs. of earth for the closets, and removing daily 23,250,000 lbs. of compost manure back again to the country stations for drying and manufacturing it into powder. The entire conveyance would then amount to 41,250,000 lbs. of matter per diem over an average distance of say 6 miles; not counting the carriage of the earth from the surrounding country to the stations. To give an idea of the quantity of earth required, it is sufficient to state that, supposing it could conveniently be collected from one farm, the top soil of a field of about 14 acres area would be needed per diem to a depth of 4 inches, making a total daily excavation of about 8,350 cubic yards.

Taking Dr. Hawksley's estimate of the stock and plant required (which is, however, scant enough) to set the scheme in operation, the following outlay of capital would be required:—

	£
5,000 carts with harness and fixtures complete, at 20*l.* each	100,000
10,000 horses at 40*l.* each	400,000
1,000,000 earth-closets at 2*l.* each*	2,000,000
2,000,000 pails at 2*s.* each	200,000
500 stations, containing each stable room for 20 horses, furnace fixtures for kiln drying the earth and the manure; room for manufacturing the latter into powder, and storage room for 1,000 pails, at say 5,000*l.*, including cost of grounds	2,500,000
1 central dépôt, with offices for general management, contingencies, &c.	10,000
Total capital required	£5,210,000

An estimate of annual maintenance and expenses stands as follows:—

	£
a.—Interest on capital of 5,210,000*l.*, at 5 per cent.	260,500
b.—Renewal fund of stock, supposing the carts, horses, and pails to wear out and require re-purchase once in 10 years = 1-10th of 700,000*l.*	70,000
c.—Horse-feed, shoeing, and farriery for 10,000 horses, at 50*l.* per annum each	500,000
Carried forward	£830,500

* This price is taken from the company's prospectus.

Brought forward		£830,500
d.—Labour of kiln-drying 8,000 cubic yards of earth, and 10,787 cubic yards of manure, making a total mass to manipulate of 18,787 cubic yards of matter per day, including discharging pails and carts, turning the mass over, working it, reloading, cost of fuel, and all expenses connected therewith, at 2*s.* per cubic yard		685,725
e.—Labour of 10,000 men driving carts, &c., 2*s.* each per day,* = 1,000*l.* per diem for all		365,000
f.—One general manager .	1,500	
Two assistant managers	1,500	
One treasurer . .	1,000	56,000
Ten clerks at 200*l.* .	2,000	
500 station managers at 100*l.*	50,000	
Taxes, insurance, light, and all sorts of contingencies . .		62,775
Total annual expenditure . . .		£2,000,000
Supposing, now, that the earth always can be obtained gratis, that the farmers are willing to haul the earth from their farms to the stations, and the compost back again, and are willing to pay at the rate of 10*s.*† per annum per head of population for a manure which holds four parts valueless matter against one part fertiliser, then the proceeds of the sale of the Metropolitan Sewage would amount, for 3,000,000 inhabitants, to		1,500,000
Showing a clear annual loss of . .		£ 500,000

This gives rather a different result from the sanguine calculation of Dr. Hawksley, which promises to yield to each citizen 7*s.* for his excreta, and to leave besides a handsome annual reserve of £426,750 for pails and management. In addition to the yearly cost of half a million sterling incurred for the trouble and labour of conveying the top-soil of a 14-acre farm daily into town for the citizens to manure it, and carrying it away again, there is another objectionable feature, which itself is enough to condemn the scheme, namely, the great nuisance of that number of carts in the already over-crowded streets and thoroughfares, stopping before the houses in daytime for the revolting exchange of pails, and blocking the road up at the same time.‡

In connection with Mr. Moule's chamber contrivance we may briefly mention another one, 'Mehlhose's Air-closet,' consisting of a commode or settee somewhat like that of Mr. Moule, but in which the solids and fluids are separated by a strainer; the former part is then strewed with a disinfecting powder by the mechanical action of the seat, while the urine is allowed to run off into the nearest drain or house-pipe; or, in the absence of such, into a collecting basin, which is emptied by hand, while the gases evolved are conducted by another pipe into the chimney, or direct to the roof of the house.

The principal objections to this contrivance, which is in every way inferior to Moule's Earth-closet, are, the utter waste of urine, a most valuable fertiliser, the continual expense of disinfecting powder, and the fact that such a chair cannot be moved, being fixed to a wall by two zinc pipes, one carrying off the urine, the

* These extraordinarily low wages are taken from Dr. Hawksley's estimate.

† Instead of Dr. Hawksley's price of 14*s.* per head, we have preferred the value established by the most eminent agricultural chemists of the day (see p. 75).

‡ The editor of 'Engineering,' in a leading article of the impression of April 5th, 1867, upon the subject of Menzies' system of drainage, makes the following remark about Moule's scheme:—'As to the earth-closet system, the report of the Berkhampsted Committee may be taken as the requiem of that preposterous project, its alleged success being both equivocal and partial, and its admitted inconveniences very great.'

other allowing the gases to escape through the chimney or roof of the house.

8. SYSTÈME MOSSELMAN.—This process having acquired a certain reputation, especially in France and Belgium, we shall have to describe it a little more in detail. It converts excrements into substances called by the mysterious names of 'chaux animalisée,' (organic lime) and 'chaux supersaturée d'urine' (lime supersaturated with urine), and is undertaken by 'La Compagnie Chaufournière de l'Ouest,' of Paris, and 'La Compagnie de la Vieille Montagne,' of Belgium, both under the supervision of Professor Mosselman, acting under the title, 'Administrateur des Crédits Agricoles.' Let not these sonorous appellations impress us to such an extent as to prevent a critical examination of this process, which operates also under the all-claiming motto, 'Salubrité et Agriculture.' It employs 'fosses mobiles du système diviseur,' consisting of four zinc barrels with iron fastenings, each 40 centimètres in diameter, and 70 centimètres in height, one placed above the three others. This top barrel receiving the excrements as they fall from the privy or house-pipe, has a perforated zinc partition for separating or draining off the watery part into the three remaining barrels, standing so low that their tops are on a level with the bottom of the 'diviseur,' or upper barrel. The lower or urine barrels are filled with pulverised quicklime, that is, burnt unslacked lime, which absorbs the fluids as they enter, and gradually converts the whole mass into hydrate of lime.

Lime is an oxide of calcium, to slacken which requires one atom of lime (28) to one atom of water (9), making 37 for the atomic weight of dry hydrate of lime. Thus to 28 lbs. of quicklime but 9 lbs. of water are required to produce 37 lbs. of slacked lime. More moisture would not be absorbed, or at least not retained, but would pass off by evaporation, whilst less moisture would leave some of the quicklime unslacked, that is, unutilised.

When enough urine has passed into the three lower barrels, which can only be determined by frequent inspection (*how pleasant!*), all the four barrels are removed and emptied. Some of the hydrate is mixed with an equal quantity by weight of the solid fæces collected by the 'diviseur,' and this forms then the wonderful 'chaux animalisée.' The remaining hydrate is likewise mixed with an equal quantity by weight of pure urine, which combination is the no less celebrated 'chaux supersaturée d'urine.'

From these data it is easy to calculate what quantity of limestone is required for this process. On page 74 we have seen the daily excrements of an average individual to consist of—

0·24	lb. f	
1·51	„	urine
1·75	„	mixed excrements.

Giving for 1,000 persons—

240	lbs.	fæces
1,510	„	urine
1,750	„	mixed excrements.

we

require an equal weight of hydrate compound, as before stated, of 9 parts of urine and 28 parts of lime, so that

	58 lbs.		urine
	182	,,	lime
	240	,,	hydrate
together with	240	,,	fæces
form	480	,,	chaux animalisée.

Now, deducting from the original		1,510	lbs. urine
the quantity here absorbed		58	,,
we have still left		1,452	,,
from which we further deduct, for hydrate . . .		284	,,
a balance of urine of		1,168	,,
To this we add:—urine, 9 parts	284 lbs.		
lime, 28 ,, ...	884 ,,		
forming hydrate of		1,168	,,
and chaux supersaturée . . .		2,336	,,

The original	1,750 lbs.	daily excrements of 1000 persons,
mixed with	1,066 ,,	lime as above,
yield thus	2,816 ,,	manure

Namely:—	480 lbs.	chaux animalisée, containing	182 lbs.	lime
		,,	884	,,
	2,816 ,,	manure containing	1,066	,,

showing a daily consumption of $1\frac{066}{1000}$ lb. lime per average individual.*

A city like Paris, with some 1,700,000 inhabitants, would therefore require, in 365 days, not less than 660,000,000 lbs. or 330,000 tons of lime, a quantity so enormous that, in point of costliness of transport, the Mosselman system seems to be nearly as bad as sewerage by water-carriage, or Moule's earth-closet scheme.

Suppose, for a moment, this ill-favoured method were universally adopted in a country, what limestone quarries could possibly satisfy the fabulous demand arising, in addition to what is always needed for building purposes? Besides, many cities being a long, often a thousand miles, distance from such quarries, what a fearful cost would be incurred for transporting such enormous quantities of lime towards a town, and then, with the additional bulk of excrements, back again to such lands as might perhaps need, or could possibly use, this particular kind of manure! We here pause for an answer, but doubt whether we shall ever get it from the promoters of this abortive scheme, which somehow or other seems to have acquired a much higher reputation than it really deserves.

We need but remind the reader that many soils are already in a great measure made up of limestone drift, and therefore cannot bear a further addition of this mineral without detriment to their productiveness, the most fertile lands containing but four to five per cent.

The action of lime upon excrements is well known. It readily

* The above theoretical estimate does not allow for loss of lime during the transport; if this be taken into account, the amount of lime annually required by the Mosselman system may be estimated at 3 cubic feet, weighing about 400 lbs., per head of population,—really an enormous quantity for large cities!

unites with the carbonic and phosphoric acids contained therein, forming insoluble compounds with them, whilst at the same time it allows ammonia readily to escape into the air. Now, we ask, what crops could possibly be benefited by a manure which overdoses the soil with one mineral (lime), locks up the most important ones (as, for instance, in phosphoric acid for cereals) in such a manner that the roots cannot absorb it, whilst another main fertiliser (ammonia) is rendered so volatile that even the barrel in which it is evolved can hardly prevent its escape?

Here we have, then, an invention to which some twenty medals in gold, silver, and bronze have been awarded in France, Belgium, and England; and for what? For manufacturing, at a frightful expense, and in a manner most troublesome to the inhabitants, a sort of 'stinking mortar,' which in seven cases out of eight cannot be made at all for want of lime quarries within practicable reach; which, when made, costs more than the real value of the fertiliser obtained; and which, when put on lands, in ninety-nine cases out of a hundred is apt to do more harm than good. *O sancta simplicitas!*

It appears to us that we cannot do better than quote here the criticism of Professor Thudichum on the Mosselman system, as found in his paper, 'Ueber die Grundlagen der öffentlichen Gesundheitspflege in Städten,' read before the Agricultural Society of Frankfort-on-the-Maine, June 8, 1865 This learned gentleman, a most skilful analyst, who has devoted much attention to the sewage question, and is therefore an undoubted authority upon the point in view, gives vent to his feelings in the following fashion:—

'Seeing that the Mosselman system has also here (at Frankfort) found several believers, I cannot refrain from saying a few words concerning it; otherwise I would not waste a breath upon a process which is as disgusting as absurd, and as expensive as fruitless. . . . . In the basement of buildings vessels are placed, made of zinc, a metal sooner than any other attacked by the acids and alkali contained in the urine. The excrements are received in one vessel and the liquids drained off into the other, standing lower and filled with quicklime. In these latter vessels the mystery goes on, which, in Mr. Mosselman's imagination, converts the mixture into "chaux supersaturée d'urine." What really occurs is this: the water and phosphoric acid are absorbed by the lime and made insoluble, while the "harnstoff" (urea), an ingredient most valuable because it forms carbonate of ammonia, remains soluble and free, and is sure to escape as soon as exposed to the atmosphere. It is for this reason that the vessels employed in this process constantly exhale not only ammonia but all sorts of other disagreeable smells; and when the lime is saturated with urine, the fertilising ingredients of the latter are diluted by the former and have become volatile. . . . The gentlemen managers of the "Limeburning Company of the West" have found a way to dispose of their stock in trade; but as the citizens pay for it in the first place, and also for transport to and fro, why not let them rather pay for the whole establishment?'

Professor Thudichum here gives an estimate of the enormous amount of lime required, corresponding with our own, after which he continues as follows:—

'How many railroad officials and freight cars, how many horses and waggons would be required to keep this system going? . . . . Surely I do not think that anybody but one who has his money invested in a limekiln will ever become an advocate of the Système Mosselman.'

This is what Professor Thudichum says, and we fully believe he is right.

9. PROFESSOR THUDICHUM'S 'SYSTEM.'—While having Professor Thudichum's paper in hand, it will not be amiss to mention a sewerage system of his own invention, as there described. In doing so we meet, however, with this difficulty, that we cannot by any possibility make out, considering the strange whimsicality of the plan proposed, whether the learned Professor is really in earnest or not. The satirical tone of his remarks upon Professor Mosselman's system and other subjects, however, leads us strongly to suspect that he is only gravely joking in proposing the following curious arrangement :—

According to his idea, the watercloset-basin is to be divided in such a manner that, on usage, the solids are dropped into one compartment and the fluids into the other, the first to find their way with the water used into the street sewers, whilst the urine is to be conducted by a separate pipe into a conduit built for this special purpose inside the street sewer; a sort of a 'wheel within a wheel.' The reason for this novel separation, it seems, is, that the solids containing but 15 per cent. and the urine 85 per cent. of fertilising ingredients, they are not fit to flow off in each other's company.

At the mouth of the sewer the thus isolated solids are again to be collected in large open basins by means of strainers, whilst the urine is drawn into barrels and sold as manure. We are left completely in the dark why the 15 per cent. valuable fertilisers contained in the solids should be allowed to run to waste and pollute rivers, and what is to be done with the residuum of filth remaining in the basins, unabsorbed by the irrigation scheme proposed at the same time.

But it is evident that from the very first start an exceedingly nice adjustment of position is required by the individual using this 'system,' as by the least carelessness in this respect the solids become lodged in the wrong compartment, choke the urine pipe, and thereby upset the whole scientific arrangement! We repeat, the professor cannot have been in earnest in placing his fellow-creatures in so responsible a position, but was merely making a little fun of the city of Frankfort, which at the time of his lecture was ventilating the insane project of polluting the river Maine by its entire sewage.*

10. SAXON GUANO AND BLOOD POUDRETTE.—Another attempt to utilise excrements undiluted by water has been made in the neighbourhood of Dresden, under the auspices of the chemist Dr. Mendroth, who invented and patented a certain article called 'Saxon Guano,' produced in the following manner :—

* We have been much amused to learn that the professor has patented this arrangement. Perhaps to keep up the joke.

The city rubbish, street-dirt, bones, &c., on the one hand, and the urine collected separately on the other, were submitted to a dry distillation, through which light gas and ammonia were generated. The residue of the first-named substances was coal, and of the second, concentrated urine called 'urat.' The coal was pulverised and served to dry the solid excrements, fixing or binding at the same time the gases contained therein, and forming 'cloaka-powder,' which, when mixed with the 'urat' and sulphate of ammonia, composed the so-called 'Saxon guano.'

But, though a good fertiliser was made, the expenses proved greater than the value of the article produced, and the enterprise totally failed, like all the others we have already described. The buildings and fixtures were then leased to another contractor for about 60*l.* per annum, and the charge of emptying gratis the shareholders' cesspools, all other citizens paying 2*d.* per cubic foot for this service. The excrements collected are now partially drained of their liquids, and spread out in open yards to dry by exposure to the air and sun, to assist which, and to prevent somewhat the escape of gases, the mass is occasionally treated with a little quick-lime and sulphuric acid. When dry, blood from slaughtering-houses is mixed with it; it is then dried once more, pulverised, and sold at the railway station under the denomination 'Blood-Poudrette,' for about 3*s.* 6*d.* per 100 lbs. without the bag. Analysis has shown this manure to be composed as follows:—

Nitrogen, per cent.	3·55
Organic substances	46·30
Phosphate of lime	14·16
Potash and soda	5·42
Silica, &c.	30·57
	100·00

The liquids are collected in large tanks, then partly sold as manure for 1*s.* 3*d.* per cubic foot, or mixed with street scrapings and then disposed of as compost for 1*s.* 2*d.* per cubic foot.

Here again the expenses of manufacture are much too high, and this enterprise would also utterly fail, were it not for the charges for removing excrements, which for a family of ten persons amount to 16*s.* 8*d.* per annum.

11. EICHHORN, RÖDER, AND THORWIRTH'S SYSTEM.—There is one more system of removing excrements by transport which deserves our attention. It is that of Dr. Eichhorn, professor of Agricultural Chemistry at the Royal Institute of Berlin, and of Mr. O. Röder, royal inspector of Hydraulic Works of Prussia. These two most talented gentlemen, with Mr. C. von Salviati, royal councillor and general secretary of the College of National Economy of Prussia—formed a commission of three, charged by Mr. von Selchow, Prussian minister of Agriculture, with making an inquiry concerning 'the best mode of removal and utilisation of sewage.' The result of their joint labours has been published at Berlin in 1865, under the title 'Die Abfuhr und Verwerthung der Dungstoffe.'

The system proposed by these gentlemen is practically the same as that advocated by the late Mr. William Thorwirth, civil engineer of Berlin, who also published a treatise on the subject, containing much very interesting information, but principally devoted to an utter condemnation of the nefarious sewerage system by water-carriage.

The gentlemen named recommended the use of plain, strong, wooden barrels, so arranged that they can be fastened air-tight to a privy pipe. The excrements are discharged into them, mixed as produced, until the barrels are full, when, by a simple contrivance, they are closed and transported by railroad or otherwise, direct to the farmers, who return them empty, asking for more. These barrels are really inoffensive, and may be conveyed, like any other merchandise, provided they are kept out of a hot sunshine; otherwise they are apt to leak, or even burst, by the action of the gases evolved.

In this simple system much good common practical sense is manifested, these gentlemen knowing what they were about, and having evidently, like us, come to the conclusion, that the straightest way is the best, and that all chemical doctoring, scientific handling and fussing about such a peculiar article as human excrements, only increases the expense, while it diminishes its intrinsic value, nothing being so advantageous as to convey it in the shortest and quickest way to the place where it belongs, and where it is so much needed, namely to the farmer's domain. But this system also, undoubtedly the best of all hitherto proposed, has three grave faults, which really make it almost worthless, and must for ever remain a hindrance to its general adoption.

First.—It is next to impossible to ascertain when the barrels are filled, unless by actual inspection, which must be, of course, a great nuisance. When the barrels are not full, and the householder is told to go on 'filling,' the chances are that it may be overdone, and a large quantity may remain in the pipe above the valve, when such a barrel is unscrewed for removal; which is also a nuisance, and no small one indeed. When, on the other hand, a barrel is not quite full, there is room for air to enter and promote fermentation, thereby increasing the danger of leakage, or even explosion. Besides, there is the dead weight to be carried of a barrel only partially filled.

Second.—Like all other 'Tonnen' or 'Fosses mobiles' systems, this one has also the great and insurmountable objection, that, by their very occupation, a repulsive set of operatives must frequently enter dwellings, to 'inspect,' remove, and replace barrels, the very idea of which creates nausea in sensitive natures. If the unpleasant business is done by day, a number of waggons required for the purpose continually interrupt and obstruct the other traffic in the streets and thoroughfares. If done at night, the bustle and annoyance of men entering a private dwelling draws only so much more the attention of the inmates to a 'great nuisance,' and more or less disturbs their repose. If the receptacles are made very large, fermentation ensues through long standing; if small, frequent inspection and removal are unavoidable.

Third.—This system provides no other plan of utilising excrements than the very old-fashioned one of spreading them over the surface of the land! Now, treating barrels of fermenting matter in this manner is literally 'casting to the winds' the most valuable gases they contain, which will escape the very moment a barrel is opened. This explains the almost overpowering stench infecting, in a very short time, a whole neighbourhood, wherever excrements, confined in a state of fermentation, are suddenly exposed to the air. Sulphureted hydrogen, always evolved in great volumes by putrefaction, and readily known by its peculiar fœtid smell of rotten eggs, is unhealthy in the highest degree, causing invariably much nausea, vomiting, and latent fevers.

It is idle to maintain that this last evil can be remedied by forming compost manure heaps upon the open field.

As long as excrements have not yet passed into fermentation, a little earth will suffice to disinfect them, especially when it is fine and dry. Thus, with Moule's chair, 3½ volumes of earth are found to effect the purpose, absorbing both the liquids and the gases evolved by the solids. But such a small quantity of earth, or any other disinfectant, is quite inadequate, when fermentation has once set in and rendered the gases volatile, as is proved by the constant smoking and horrid smell of compost heaps.

To prevent this noisome escape of gases, at least some 20 to 25 volumes of earth would be required, depending upon the nature and dryness of the soil. The expense of carrying to and fro such large quantities of earth would again exceed the value of the manure produced, and furnish the same poor financial result as all the other attempts to make compost messes.

Nor is anything gained in a sanitary point of view by allowing fæcal gases to escape in the open country instead of in towns, in the hope that such dissipation would render them harmless. When the atmosphere becomes charged with these noxious gases, it depends entirely upon the wind in which direction the diseases they entail are to be spread; and as from any given farm, almost at every point of the compass, a town is located, it is absolutely certain that the fatal result will be felt somewhere. As an instance we may quote the well-ascertained fact, that places on the coast of England are often visited by the marsh-fevers endemic in Holland, whenever the wind from that quarter has prevailed for a certain length of time.

Besides, it must be remembered that ammonia, sulphuret of hydrogen, and similar gases are readily absorbed by water, and consequently taken up by the moisture of the atmosphere, only to come down again with the rain, which, when evaporating from the surface of the streets, brings the aforesaid gases almost immediately under the noses of the townspeople, to be inhaled by them.

It thus appears that even this plan, as we have said, by far the best of all hitherto attempted, totally fails to accomplish the main object of rendering human excrements useful instead of detrimental.

12. **SEWERAGE IN HOLLAND.**—We must not conclude this part of our treatise without saying a few words about the sewerage arrangements of Holland. To understand these well it is necessary to bear in mind the peculiar situation of the towns in that country, which in many places is so low, that there is no natural drainage at all, the rain invariably inundating it, unless steadily removed by mills or pumping engines.

Besides, as we have already mentioned, mediæval architecture was almost exclusively governed by principles of warfare and religion, utterly regardless of sanitary considerations. Thus nearly every town in Holland was originally laid out only with a view to successful defence—a precaution but too necessary in a country which, by the unsurpassed fertility of her soil, and the industry and commercial enterprise of her citizens, soon became so wealthy that all surrounding potentates constantly watched her with greedy eyes, repeatedly trying to subjugate her, under pretext of religious conversion or political necessity.

This permanent state of defence against foreign aggression required, on the part of the Dutch people, not only unceasing watchfulness, but also various measures calculated to insure their safety and independence, even against overwhelming numbers.

For this purpose the towns were mostly laid out in concentric circles of broad ditches or canals; often, as for instance in Amsterdam, barely a hundred yards distant from each other. The bridges uniting the annular slips of lands were so constructed as to interrupt communication at a moment's notice; the houses built on these slips being set back some thirty to forty feet, so that most streets have a broad canal on one side.

That these canals, under existing circumstances, naturally became the receptacles of all kinds of refuse, is easily understood. The vertical privy pipes all discharge into sewers running from the houses into these canals in front of them, with their outfall about level with the water.

The sewers are, therefore, always entirely or partly filled with water, through which the excrements slowly descend into the canals, having thus converted them long since into large open sewers. The Dutch in former times knew as little as other nations, that the liquid parts of excrements are far more valuable fertilisers than the solids, but considered them as mere dirty water, which somehow or other must be got rid of, whilst the solids alone were used as manure.

But as this extremely clean people wash all and everything, so it seems they also wash their 'solids' before using them as manure; for they actually dredge them out again afterwards by means of scooping nets, and then convey them in boats to their lands.

The very little agricultural value of this stuff was never for a moment suspected to be the natural consequence of this most unnatural washing!

The stench, the nauseating stench, continually arising from these Dutch canals can hardly be imagined. As the want of natural drainage makes the change of water so very slow, that to all intents and purposes it may be considered stagnant, the oxidation or combustion of putrefying organic substances goes on quite undisturbed, so that the deadly gases evolved may be constantly seen bubbling up to the surface, especially in summer time, when a powerful sun assists the process of fermentation.

The effect of this state of affairs upon public health is of course most deplorable. Every kind of disease due to marsh miasma is endemic in Holland, such as neuralgia, rheumatism, chills, intermittent fevers, enlargement of the spleen, enlargement and hardening of the liver, dropsy, pleuritis, and all sorts of chest inflammations; and many of these distempers prove so very malignant as to kill in a short time. Besides, there are the ever-recurring visits of epidemics, such as miliary fever, scarlet fever, measles, typhus, small pox, and last, but not least, *cholera*, which, when imported from abroad by some unfortunate mariner or traveller smitten therewith, at once finds countless victims amongst the inhabitants of that country, who, by breathing an atmosphere so very congenial to that fell disease, are, day by day and year after year, preparing their whole bodies, lungs and liver, blood and fibres, like so many mines only waiting the fatal spark.

Is it surprising, then, that only a short time ago cholera again made sad havoc through the length and breadth of the Netherlands, otherwise so prosperous, robbing many a city of a tenth of its population, and bringing death and desolation to almost every household?

Not surprising at all. For the Dutch people, whose devotion to habits of scrupulous cleanliness is proverbial, who continually wash all and everything, down to their very excrements—this people omit, strange to say, to keep unpolluted that which compasses them about everywhere, the atmosphere they daily breathe, in which they move and have their being; and thus, with all their ablutions, they in the end fare not a whit better than other people wallowing in filth. Happily, there exist yet means to avoid these fearful evils, as we shall presently demonstrate. We have no doubt but that this highly intelligent people will speedily adopt the remedy alluded to, which H.R.H. Prince Henry has favoured with his approval and protection, and to which the city of the Hague is now about to give the *first* trial.

13. SEWERAGE IN BELGIUM.—Belgium having a denser population per square mile than almost any other country, and meeting on that account with so much greater difficulties in her sewerage arrangements, it may not be without interest to consider what has there been done in that respect.

Antwerp, with some 117,000 inhabitants, still contents itself with good old-fashioned cesspools, with Mestdagh's pumping process for removal, the whole business being under the control of the municipal authorities, who manage to draw an annual revenue of some 4,000*l.*, by selling the city manure to neighbouring farmers.

Liège, with a population of 100,000, rejoices in a mixed sewer and ash-box system, having formerly had many canals which received all the excrements from the houses near them, quite on the Dutch plan just described. In the last few years, however, these canals have been arched over to gain room for streets, and have thus been converted into regular sewers, which, conducting the noxious gases evolved directly into the dwellings through the house-drain pipes, soon became an intolerable nuisance. A plan has been proposed to lead river water through these sewers for flushing them; but the example of many cities in England and elsewhere sufficiently shows that no cure of the evil can be effected thereby. Other houses in Liège, not in communication with the sewers, empty their excrements in boxes, receiving also the ashes, &c., somewhat on the Manchester plan, and selling the compost as manure; a most untidy, disagreeable arrangement, loudly calling for improvement.

Ostend, Ghent, Louvain, Mons, and other towns have various removal systems, subject to excellent police regulations, but all based on the faulty cesspool and pumping principles, and therefore subject to the many grave objections elsewhere pointed out.

Brussels is about to undergo extensive changes in her drainage system. This beautiful city, the population of which will in a short time number half a million, is piled up on the two slopes of a deep valley, between which the little river Senne has its natural bed. This stream divides the city in its course from the south-west towards the north into about equal halves, and, receiving nearly its entire excremental matter, resembles a huge open sewer. The habitual scarcity of river water causes the only liquid which fills the channel to be that proceeding from waterclosets, with which nearly all the houses are provided, the town having ample waterworks. The stream has thus become the source of all sorts of malaria. At the same time, the numerous manufactories along its banks, after sudden thaws, continuous rains and storms, prevent the accumulated waters flowing off, so causing dangerous inundations. These two bad features are the cause of the centre portion of the town being inhabited by those of the labouring classes only, whose scanty means compel them to seek cheapness instead of health.

To improve this state of affairs, the corporation has decided upon large works, which will include the preservation of the river from the danger of inundation, the purification of the part which passes through Brussels, and at the same time the sanitary improvement and embellishment of the heart of the Belgian capital, bringing air and light into unhealthy streets and dwellings. For the latter purpose the river is to be straitened and arched over, and a broad boulevard constructed over its entire length. Lateral main drains are to be constructed, to intercept the contents of the city sewers, and these will discharge into large reservoirs outside the town, for deodorising and collecting the manure. The inferior houses each side the future boulevard are to be pulled down, new ones of a superior character built, and also a market-place, a monumental fountain, and a large edifice erected, which will be at once a hall of exchange and a museum for artistic exhibitions. The estimated cost of these works is twenty-six millions of francs, of which the city contributes sixteen millions, the province of Brabant three millions, and the general government seven millions. The king laid the first stone, May 6, 1867.

The works are being carried out by the Belgian Public Works Company (Limited), to which the municipal council has granted the concession, including the right to the town sewage for a period of sixty-six years.

The project is a magnificent one, and will, no doubt, greatly enrich the company, with the valuable frontages for traffic, business, and residential purposes, acquired on the boulevard, in addition to a free grant (fee simple) of all town and suburban land obtained by diverted streets, open public places, and closed river courses.

But it is also evident that Brussels, with an outlay of 640,000*l.*, and a yearly loss of 200,000*l.* worth of manure (supposing the city to hold 400,000 inhabitants), obtains only a few public buildings and the use of some new wide streets, while 'the stink' (we use the expression of the chief sewer engineers of London, as see page 54) will issue forth from the new main drain, which is to be built parallel to the Senne, with the same certainty and regularity as it formerly did from the river, and as it now does in every town which has been unfortunate enough to be persuaded into constructing such works. And this 'stink' will, in its now more concentrated form, make the beautiful new palaces more uninhabitable than the former lowly dwellings, keeping the centre of the Belgian capital just as much a hotbed of typhus, cholera, and all sorts of diseases as it ever was before. Nor will it be pleasant afterwards to reflect that the general government and the province have contributed additionally 400,000*l.* to make this change, which, in comparison with the former condition of affairs, may be called a distinction without a difference.

14. General Summary.—Any one of our readers who has at all taken the trouble to follow our examination of the various systems hitherto in use for removing and utilising human excrements (and we believe we have described them all), and who with an unbiassed mind has weighed the facts and arguments adduced in proof both of their merits and demerits, will surely long before this have arrived, like ourselves, at the conclusion that not one of these systems really answers the purpose in view, or even comes up to that degree of comfort and decency which may well be expected from the great advances made in our days in all branches of science, art, and industry.

Baron Liebig very justly considers the consumption of soap by various nations a good standard of their comparative civilisation; in our opinion, their manners and customs with regard to excremental matters offer just as correct a gauge. Savages deposit their fæces anywhere, like brutes; semi-cultivated people use some rude contrivance or other, partially sheltering from observation; whilst the so-called civilised nations prefer closets and other arrangements for privacy, more or less perfect according to their comparative wealth and sensitiveness.

In fact, just as public morality forbids all indecent exposure, so true refinement is incompatible with the presence of any kind of filth, but more especially of that which is most revolting to our senses of sight and smell. We are not alluding here to the secluded wealthy few, but to the general mass of the people, forming from 70 to 90 per cent. of the population of most countries.

When city sewage is removed by water-carriage through subterranean drains, we have seen that the noxious gases evolved by fermentation rise up the inclined planes of these conduits, invariably escaping through even the smallest fissure they can find. We have further seen, that such gases as are still held in solution find their way surely enough through the best and heaviest masonry of cesspools and sewers, gradually infecting the soil and poisoning all neighbouring wells, plainly proving that such arrangements offer no bar whatever to their fatal exit. We have conclusively shown, that the only thing effected by water-carriage is to remove the sewage from the privacy of a closet into the streets and rivers, where deadly exhalations continually force upon us its most disgusting presence.

A similar result we have noticed with moveable receptacles of all kinds and descriptions, some being so very imperfect as to offend even the dullest sense of smell by their direct exhalations, whilst all of them affect our sight and hearing, whenever the too frequent process of inspecting, emptying, or removing goes on, be it by day or by night.

As regards utilisation of sewage, we have found the case to stand even worse.* We have seen that the water-carriage system produces such an enormous volume of sewage, that it can neither be stored nor transported, but must in most cases be lifted up by costly machinery, if it is to be applied to lands at all. We have seen that when, in exceptional instances, the mere force of gravitation would move the sewage, soils can seldom be found adapted to such peculiar treatment, and that, even under the most favourable circumstances, no cereals or garden vegetables are produced, except rice in hot climates; that most lands need rather drainage than irrigation to prevent their breadstuff crops running to straw; that the only crop sewage liquid will raise, under a very rare combination of local advantages, is a sort of rank grass, which, though grown in great quantity, is of inferior quality, not producing good rich milk, butter, cheese, or meat; that even this meagre chance of utilisation is by no means to be tolerated within the neighbourhood of human habitations, unless first treated with large quantities of carbolic acid, owing to the deadly exhalations of all water charged with putrefying organic substances, especially when spread over a large surface of land with little depth, causing the evaporation to be only the more rapid; that, even when such irrigated tracts are far removed from towns, the atmosphere will continually take up the noxious vapours and gases, carrying them by every gust of wind to some inhabited spot, to become there as dangerous to human health as on the spot where first evolved; that, in fact, no surface application of sewage liquids should be tolerated on any part of this terrestrial globe.

We have further seen, that all mechanical and chemical contrivances to extract fertilising ingredients from sewage liquids have utterly failed, because the residuum did not retain any of the valuable elements running to waste with the fluid; or, if some were saved, that they were bound up in such an insoluble form as to be totally inaccessible for the tender rootlets of the plants.

It has also appeared that all movable receptacles, or transport systems, have likewise failed to reduce excrements to an inoffensive, and at the same time profitable, manure; that all chemical mixtures with other substances have only increased the bulk and diminished the agricultural value, or at least involved so great an expenditure, that the proceeds of the fertilisers manufactured did not cover the cost; that if excrements are retained even only a few days, fer-

* Professor C. A. Cameron states, in his work on the 'Chemical Composition and Fertilising Value of the Sewage of Dublin,' that Mr. Miller, on his grass farm at Craigentinny, which now consists of nearly 250 acres reclaimed from the sea, actually uses the sewage from a district of Edinburgh inhabited by 80,000 souls. The rent of these meadows yields but 22*l.* per acre, whilst the total annual value of the manure at 10*s.* per head is 40,000*l.*! The fertiliser used is, therefore, worth 160*l.* per acre, or nearly 8 times more than the yield by rent!

mentation ensues, rendering the gases so extremely volatile that they invariably escape at the slightest exposure to the air. We have seen that this escape of gases through fermentation is the true cause of the great difference between the theoretical value and practical value of human excreta as produced, and the market price paid for the effete cesspool matter. All this appeared as so many potent reasons why all cesspools, all barrels, boxes, and other fixtures retaining excrements for any length of time, are utterly to be rejected, not only from a sanitary but also from an agricultural point of view.

We have also found that the utter failure of all attempts hitherto made at utilisation of sewage has almost resulted in a disbelief that such a thing is at all practicable; that, in consequence of this, nearly all excrements produced are thrown into rivers, harbours, and the sea, or otherwise wasted, the very few cities utilising their sewage in some shape or other forming as yet only a very small minority.

On the other hand, it has appeared that human excrements have a very high value indeed, containing as they do the very minerals indispensable to the production of new crops serving for our food, containing besides also certain organic nitrogenous substances, greatly assisting in the formation of the nutritive elements of breadstuffs and other vegetables, and evolving certain fertilising gases, which will largely increase the harvest, if only made to penetrate the soil instead of polluting the atmosphere.

We have seen that the best authorities on agricultural chemistry value fæcal matters at 10*s.* at least as the annual product of an average individual, giving an increased yield of crops worth 1,000,000*l.* for every million inhabitants; a national wealth, which as yet, in most countries, is nearly all wasted or utterly lost.

We have found that, to make good this enormous loss, guano, bones, and other fertilisers are imported, and all sorts of temporary make-shifts employed, involving a continual, serious drain of capital out of a country, and thereby considerably diminishing its national wealth. We have besides noticed, that the guano beds of Peru are nearly exhausted, and have asked ourselves, What is to become of agriculture when this foreign supply of manure is finally cut off?

Again, we have noticed that, in spite of all the capital continually wasted on these poor palliatives, the soil almost everywhere diminishes in fertility, a given number of acres yielding no longer the same produce they did in former times; that this astounding fact is especially striking in the United States of America, a country acting, with regard to her agricultural interests, somewhat like a fast young heir, squandering in a very short time resources intended and sufficient to last him for his whole life.

We have seen how bountiful the reward, if we obey the divine Laws of Nature, by applying to agriculture the most valuable mineral and organic substances daily ejected from our bodies, and how severe the punishment if we neglect to do so, and allow fæcal gases, fluids and solids to pollute our atmosphere, infect our soil, and poison our wells.

We have also traced the connection between these poisonous exhalations and endemic and epidemic diseases of every kind. If the theories thereby propounded should not quite agree with the abstract notions of many a learned doctor deeply versed in medical lore,* who assigns all sorts of mysterious causes for the origin of the distempers alluded to, seating them so deeply that neither his medicine nor our understanding can reach them; why, we have only to say that we prefer our actual observation and the dictates of plain common sense, which have invariably shown a polluted atmosphere and tainted water to be everywhere the sure forerunners of sickness and death; whilst our simple faith teaches us, that a beneficent Creator never intended pure air and undefiled water to injure our health. The laws of nature, which are His laws, are also in this connection so plainly written on every leaf of a tree, on every atom that exists, that they might well be read and understood by all; but if, instead thereof, we prefer to rely upon human wisdom, we are sure to be utterly confounded.

* For instance, Dr. G. Varrentrapp, medical referee to the Board of Works of Frankfort-on-the-Maine! It is really melancholy to think that a gentleman of such undoubted learning and ability (see page 63, footnote, and page 64) should have devoted so much of his time and energy to the nefarious purpose of advocating sewerage by water-carriage, waterclosets, irrigation with pestilential sewage liquid, and all, at that beautiful city, just at the very nick of time when the foremost engineering, sanitary, and agricultural authorities, both of Great Britain and the Continent, have so justly stigmatised all this as the *great fallacy of the age!* Let us hope that the more enlightened portion of the Frankfort citizens will *use all and every legal means within their reach to stop even at the eleventh hour an undertaking* which, begun against their better conviction, and in spite of frequent vehement protests, is sure to entail bitter disappointment, public shame, and heavy pecuniary sacrifices upon all concerned, especially after the mournful examples of London, Hamburgh, Munich, and many other cities, have but too conclusively shown how the case really stands!—'*Errare humanum est! Cujusvis hominis est errare: nullius, nisi insipientis, in errore perseverare.*' CICERO, PHILIPPICA XII. 2.

VII. CAPTAIN LIERNUR'S PNEUMATIC SEWERAGE SYSTEM.

The various important facts stated in our preceding chapters, the considerations bearing upon city-sewerage in general, and the great interests therein involved, carefully collated by Captain Liernur in the course of his professional and scientific investigations, led him to certain conclusions, resulting in an altogether new system for removing and utilising human excrements, which we shall now proceed to submit to the public.

As we have been hitherto engaged in demolishing all English water-carriage sewers, French 'fosses mobiles,' and German 'abfuhrtonnen,' it will now be our more pleasing task to build up again, by pointing out a way to conform with the wise ancient Hebrew sanitary law: '*to cover with earth that which cometh from us*;' with this great improvement, that, instead of compelling each citizen* '*to go forth abroad without the camp*,' the new system, by applying the glorious inventions of Otto van Guericke and James Watt, the air-pump and steam-engine, enables all good people to stay comfortably at home; and instead of requiring them '*to dig a hole in the ground with a paddle on their weapon*,' a novel plough apparatus is employed, which for simplicity and efficiency is truly without a parallel.

1. Leading Principles.—The captain, considering the failures of all preceding attempts at solving the great sewerage question, at once determined upon certain leading features, imperatively demanded by civilised, social, and refined habits on the one side, and by the immense agricultural, sanitary, and economical interests on the other; and these we shall now have first to point out:

a. Householders and citizens must not on any account be disturbed by sewerage operations; therefore no dwellings are to be entered for that purpose, either by day or by night.

b. For most important sanitary reasons all existing cesspools should be suppressed, and the construction of new ones be strictly forbidden by law.

c. All fæcal matters must be daily removed, so that no fermentation can take place.

d. No gases whatever must escape during the removal of excrements, in order to avoid all pollution of the atmosphere.

e. No washing or 'flushing' by water must be required, so that the sewerage arrangement answers also in towns without so-called water-works, and that privies may not become offensive when the water is cut off.

f. The privy-basin must have no valve or contrivance liable to become deranged, and so give offence.

g. No substance of any kind, whether water, earth, lime, ashes, &c., must be used to dilute or change fæcal matters, as this seriously diminishes or even destroys their agricultural value.

h. Excrements must be so arranged for transport that they can, like any other commodity, be sent any distance to lands requiring fertilisers, without emitting the least effluvium.

i. When applied to arable soil, no gases whatever must escape, as this will not only cause a loss of most valuable fertilising elements, but also convert the atmosphere into a medium for diffusing cholera and other diseases.

k. When applied to meadows, fæcal matters must not be spread on the surface, as this will likewise pollute the atmosphere, and cause, besides, cattle-diseases.

l. Whether applied to arable land or meadows, fæcal matters must never come into direct contact with the roots of plants, as experience has shown this to be hurtful.

m. The whole sewerage system must be so cheap as not to saddle the poor with heavy rates, or burden municipal bodies with unmanageable debts, or cause the cost of collecting excrements to equal or exceed their agricultural value.

The reader will perhaps think that this is rather a formidable array of requirements, and begin to question whether it is really possible to contrive any plan that will fulfil them all. This conclusion might be justifiable, as hitherto really no such method has been discovered, notwithstanding all the talent and genius devoted to the subject.

But is not this the history of nearly all inventions? Are not all first attempts generally most complicated and cumbersome, until repeated improvements finally effect the purpose in so simple a manner, that every one wonders why he did not think of it before; whilst those who never gave their minds to the subject, insist that they could just as well have made the invention themselves? In fact, it is only the old story of the famous egg of Columbus over again.

To afford the reader a clear view of the way in which Captain Liernur carries out his great plan, we must first describe in a general way his mode of removing fæcal matters out of houses and towns.

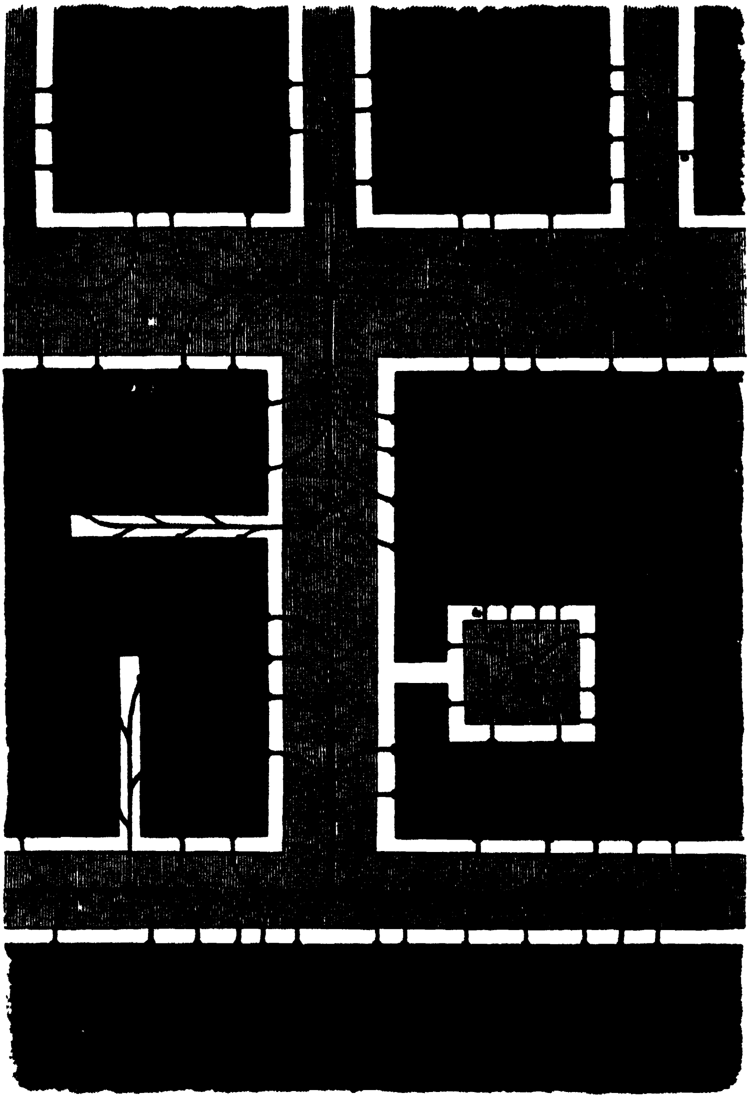
2. GENERAL DESCRIPTION.—The engraving on next page shows Captain Liernur's arrangement, as applied to any part of a city or town.

Small iron reservoirs are placed under the pavement of all principal street-crossings, each reservoir being connected by means of small iron pipes with the privies of the houses next to it, in such a manner that no offensive gases can escape; in other words, from every single privy a continuous air-tight passage leads into the next subterranean street reservoir, without the intervention of any cesspool.*

The pipes are provided, each one, with a valve, to be worked

* Country-seats and other detached buildings, which cannot be connected with such a group of houses having one common reservoir, are provided each one with an iron reservoir of its own, of a capacity calculated for one to three months, or any other convenient period. Such a house-reservoir is hermetically closed by a valve, opened only once a day by means of a lever fixed somewhere in the basement of the building. When full, this reservoir is emptied by pneumatic pressure, as elsewhere described.

from the sidewalks of the street, so that the communication between each privy and a street reservoir can be established or cut off at will. These valves remain always hermetically closed, except during a short moment, when the privy contents are to be discharged into the street reservoir connected with it, which occurs during the night, in the following manner:—



Part of a Town showing Reservoirs and Pipes.

A locomobile steam-engine working an air-pump is driven near the small subterranean street reservoir, to exhaust the air out of it, and out of the entire system of main and branch pipes up to the hermetically-closed house-valves, which are then, one after the other, opened and shut again, thus discharging the privy contents, including all gases, into the street reservoir.

If the vacuum made in the reservoir and pipe system is complete, or nearly so, the mechanical force of the atmospheric column rushing in the moment a house-valve is opened, equals that of some thirty hurricanes. In order to maintain this vacuum, while a number of privy pipes are discharged one after the other, the air-pump standing near the reservoir is kept continually in motion, creating a constant draft, which causes all discharges to fly just into the reservoir, and nowhere else, like so many shots from air-guns.

The urine exceeding the solid fæces about eight or nine times in volume, affords sufficient moisture not only to prevent the excrements from drying or caking, but also to keep the whole mass in so fluid a state that removal is easy, unfailing, and complete, especially under the above-mentioned powerful blast operating upon it. All the privies and their pipes will thus be every day thoroughly cleaned of solids, fluids, and gases, and be filled with fresh air instead.

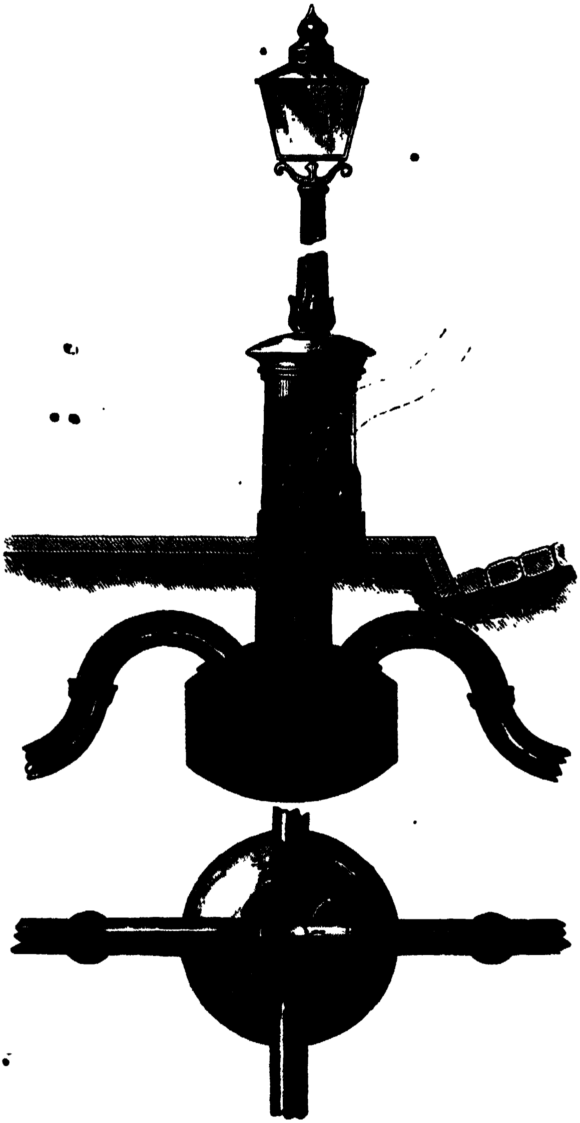
After all the house-valves have thus been successively opened and shut, an operation which practice has shown can hardly be done quick enough, the small reservoir itself is emptied by pneumatic pressure into a hermetically closed waggon-reservoir, attached as a sort of tender to the air-pump carriage. This done, the connecting hoses, by which the movable apparatus communicates with the stationary one under the pavement, are uncoupled, and the locomobile with its tender proceeds to the next reservoir, and then to another and another, until the tender is filled.

As the particular street reservoir where this will occur can by practice be pretty accurately known beforehand, arrangements are made that, when arriving there, the locomobile meets an empty tender drawn by two horses, which changes place with the full one, thus allowing the sewerage operation to go on without interruption, the filled tenders being always drawn away by the horses to a temporary depôt, where they are decanted by direct hydraulic pressure into air- and water-tight barrels, which are then at once sent like any other goods, by rail or steamboat, to the lands requiring the excellent fertiliser thus collected.

We shall now describe more in detail the various parts constituting what in future will be called the 'Pneumatic Sewerage System.'

3. STREET RESERVOIRS.—These reservoirs are constructed of boiler plates, strong enough to resist atmospheric pressure when evacuated. Their size is a matter of detailed calculation, depending upon the number of individuals whose daily excrements are to be discharged into them. Now, as we have seen that an average individual of any population produces not more than 1¾ lb., or $\frac{1}{36}$ cubic foot per day (see page 74), it follows that thirty-six average individuals will produce only one cubic foot of excrements per day. A reservoir of twenty cubic feet capacity will, therefore, suffice for about 700 persons, and its dimensions would be three feet in diameter in the middle, and a total depth of three and a half feet. These reservoirs, however, are made of various sizes, to suit all local requirements. In the spherical reservoir top there are openings for the connection of the main-sewage pipes. Besides,

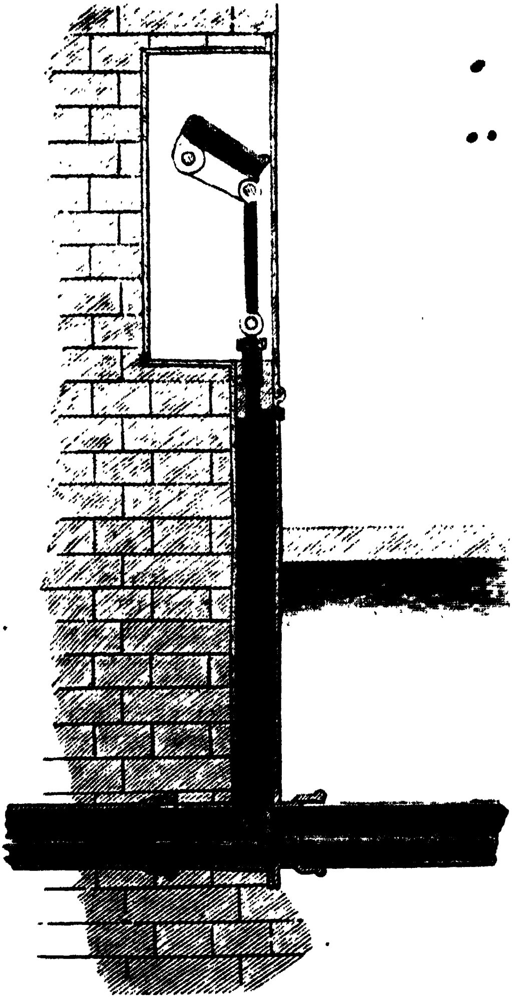
there are two vertical pipes—the smaller one, the air-pipe, of three inches in diameter, pierces only the reservoir top, and serves for exhausting the air. It has an arrangement at the upper end for coupling a hose to it, by means of a clasp, which is fastened by a single movement of a small handle. The larger vertical pipe, with



Plan and Section of Street Reservoir.

a 6-inch bore, is the dung-pipe, and reaching nearly to the bottom of the reservoir, serves for transferring its contents into the waggon-reservoir or tender. It is similarly fastened to a coupling hose by means of a clasp and a handle. Both pipes stand close together, and are prolonged up into the pedestal of a gas lamp-post, standing on a convenient spot in the street. A little door in the pedestal gives access to both pipes, for the purpose of fastening coupling hoses, &c. The gas lamps are provided with a bright stained glass, and numbered, so that the sewerage labourers may so much more easily find them during the night.

Public urinals are to be erected at far more frequent intervals than now existing, draining of course into the nearest street reservoir, and not, as hitherto, into the sewers. The little expense thereby incurred is amply repaid by the valuable fertiliser saved. Proper and convenient places, with female attendance, are also to be provided for the better half of humanity; because there is no earthly reason why this most important sanitary reform should be any longer delayed, after railway companies have set such a good example all over the civilised world, especially in large cities, with long distances; much intense individual suffering and actual sickness will thereby often be prevented.



Section of House Valve (see next page).

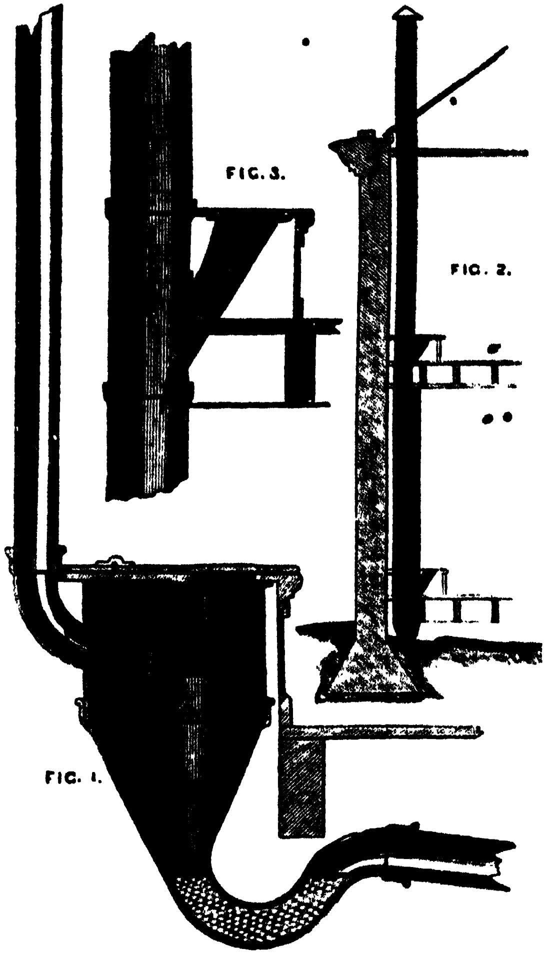
4. HOUSE VALVES.—The valves (see cut, page 117) closing hermetically every single privy-pipe in front of the house, are case-hardened, with the lower part sharpened to a chisel edge, so that, in case any substances, such as rags, old shoes, &c., should find their way into a privy, and by accident get across the valve-seat, they are cut asunder by the downward movement of the valve, and no stoppage can occur. The valve-seat is smoothly planed, so as to make a perfectly air-tight joint. The valve is worked from the street by a labourer applying an iron bar to the socket of a short lever, the lower end of which is coupled with a connecting-rod to the valve-rod. By turning the lever about a quarter of a circle, the valve is lifted up and opened, and shut again by immediately reversing the motion. To prevent a valve being left partially open by a careless operator, the lever fixtures are placed in a little recess in the house front or garden-door-pillar, the iron lid of which recess shuts only when the valve is completely closed and 'all right;' when not, this lid does not shut, thereby calling the man's attention to his own negligence. These valves are of easy access in case of repairs. Similar valves are placed in the main pipes, at certain distances from each other, their rods reaching up into iron boxes closed by lids on a level with the pavement. These valves are kept open, except in case of leakage, when they are consecutively closed, in order to localise any defect in a short time.

5. PRIVY ARRANGEMENTS. — There are two classes of privy arrangements, both exceedingly simple and effective. The first, shown in figure 1, is in case the accommodation exists only on the lower floor, and there is no other privy above it leading into the same pipe. The second class, shown in figures 2 and 3, is used when there are several closets placed on different floors above each other.* We will describe the latter, as this will enable the reader to understand readily both arrangements.

A vertical pipe of brown stone or pottery-ware runs from the basement to the top of the house, for the privy funnels of the different floors to discharge in. These funnels are made of white stone ware, smoothly glazed inside, and have a peculiar shape, depicted by figure 3. The rear part of this funnel recedes, instead of having the dish-form of ordinary watercloset basins, which is invariably struck and soiled by fæces discharged at about a right angle, requiring a great deal of water to clean it again. By the form shown in our plate, on the contrary, the excrements, entering more or less in a slanting direction, fall upon the front surface, which is steeply inclined in the same direction, whilst the rear part of the funnel remains altogether untouched. Whatever stain is left in front is immediately washed away by the urinal discharge. Any one of our readers may satisfy himself of the perfection of this simple arrangement, by noticing that in a smooth watercloset basin no matter is ever found adhering to the front part; this is partly due to its being continually washed clean by the urine, and partly to the acute angle under which the excrements strike this front.

* Those people preferring the straighter funnel shown in fig. 1, regardless of a little extra expense, may be accommodated by a separate vertical pipe for each floor, these pipes of course converging below in one common bend.

The short funnel terminates in a sort of downward drooping lip, tapering off to a rounded point, which conducts the excrements towards the middle of the vertical pipe, so that in dropping off that lip they descend through the space alone, without ever touching the sides of the pipe, which, consequently, are kept absolutely clean. To make quite sure of this, the vertical tube is



of Privy Funnels, etc.

fourteen to sixteen inches wide, depending upon the number of privies entering into it. For purposes of ventilation this pipe is prolonged to the roof of the house like a chimney, and covered with a wind-cap turning upon a pivot, so that, with all breezes, an uninterrupted exit of gases can take place. Below, where the excrements accumulate, the vertical pipe is made of cast-iron, and narrowed down to a diameter of about five inches, curving towards the house-valve, first downward and then upward, so as to form a sort of hydraulic trap. This bent cast-iron portion of the tube is of easy access in the basement or cellar of the house, and may be removed in case large, unyielding objects, such as broomhandles, pieces of wood, &c., should happen to be thrown into the privy by careless servants or children.

The excrements, solids and fluids, are all, without any impediment, collected in this bend, thus offering only a surface of some five inches diameter to the air for evolving gases. Experience has shown that fermentation evolving sulphureted hydrogen and ammoniacal gases sets in only some three or four days after excrements are produced, and that the gases thrown off in the interim are mere watery vapours tainted with only a trace of ammonia;* therefore but very little offensive effluvium will arise from the contracted surface of the said hydraulic trap, which is besides entirely cleaned out every twenty-four hours. To prevent, however, even the smallest volume of fæcal gases from entering the houses, the privy funnels are furnished on the seat with a lid, turning on a strong continuous brass hinge, and provided on the inside with a good india-rubber ring, one inch wide, and projecting about one-eighth of an inch. This india-rubber ring serves the double purpose of giving a really air-tight closure, and of preventing the noise the lid would otherwise make in falling. It is evident, when such a lid is opened for usage a current of air must at once set in downwards through the funnel, and then upwards through the vertical pipe to the roof, creating a draught just like a chimney, for the simple reason that the pipe being closed below, no air can rush in from that quarter. It is therefore impossible that any offensive gas should escape through the funnel, as that would create a partial vacuum in the lower part of the pipe. The only chance for a momentary suspension or weakening of this air-current would be the simultaneous opening of privy lids on two different floors, which of course will not occur very often. The funnels are manufactured with drooping lips of different lengths, those on the upper floors projecting the farthest, so that excrements falling from a higher funnel cannot strike the lip of a lower one. The drawing is too small to show this clearly, but it is easily understood, the main point being to prevent any fæcal matters adhering to the interior of the vertical pipe.

As we have already had occasion to mention, in case of there being only a first-floor closet, the simple basin used is shown in figure 1, which is placed so as to allow the excreta to drop at once vertically through, without touching either it or the vertical pipe anywhere; of course the soiling of any part is then utterly out of the question. By these means a good substantial closet is provided, in which nothing whatever can get out of order, as there are no valves, nor traps, nor machinery of any kind. When the lid is opened, nothing is seen but a short, clean, white funnel, with a dark outlet below, emitting no effluvia whatever, and never offending our eyesight in the manner so often presented by ordinary watercloset basins, quite choked with a disgusting mass of excrements and soiled paper, whenever the fixture is deranged, or when there is a short supply of water, or when some careless individual has forgotten to work the handle. Both fæces and urine falling free from a comparatively great height into the hydraulic trap below, they are by their own gravity pounded together into

* This slight exhalation even ceases, when the matter becomes cold.

one homogeneous mass, to which the paper used gives a sort of consistency and tenacity, greatly facilitating the daily cleaning process, by offering a sufficient resistance to the column of air rushing in through the ventilator on the roof, the very moment a house valve is opened in the manner before described.

As we said before, this atmospheric pressure, equalling a force of some 200 lbs. in a 5-inch pipe, will suddenly, like a hurricane, sweep away even the last vestige of matter collected in the hydraulic trap, thus leaving the whole privy pipe entirely cleaned out. So powerful is the force operating, as experience has shown, that not only all solids, fluids, and gases, together with the troublesome flies infesting all privies—above all in hot countries—are completely swallowed down, but that old shoes, rags, and even small brickbats are likewise hurled into the street-reservoir as if by magic. To give the reader a just conception of the force employed, we must remind him that a hurricane or tornado, which tears trees out of the ground by the roots and flings them along, which unroofs buildings, knocks down chimneys and drives their bricks along like hail, has a measured pressure of 50 lbs. per square foot only. The power applied by the pneumatic system being about 10 lbs. per square inch, or say 1,500 lbs. per square foot, is thus equal to a combination or concentration of some thirty tornadoes: when such a force is suddenly exerted to move a plastic mass exceeding but seldom one foot cubic, no wonder that it disappears so quickly!

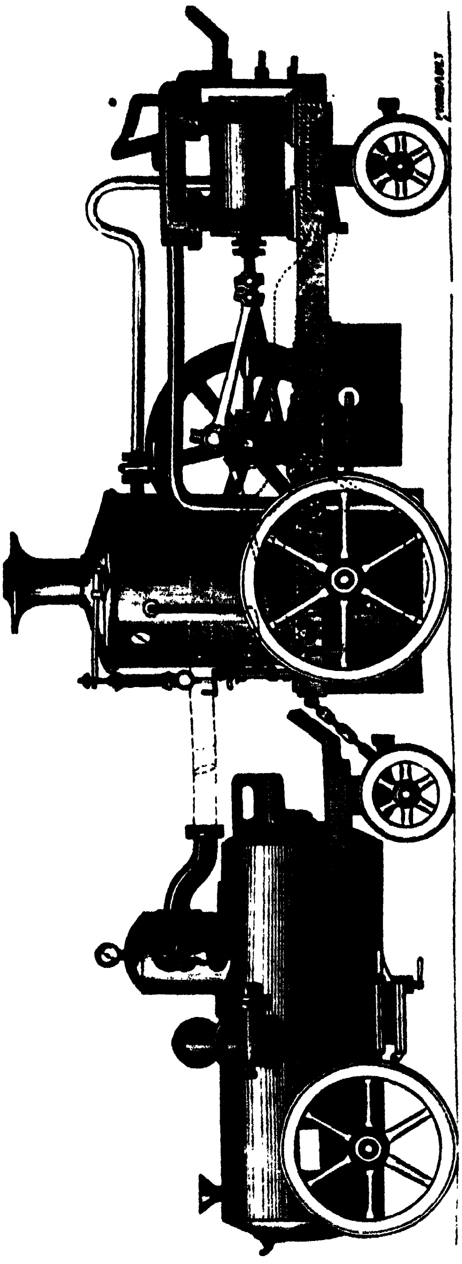
6. STREET-MAINS AND BRANCH PIPES.—These pipes are all only five inches diameter in the clear, and laid down just like common gas pipes, requiring no foundations whatever, and following all the undulations of the ground. There is no necessity for making the main pipes larger than the branches, because there is never any accumulation of matter within, but each little volume of privy contents possesses a clear track and undisputed right of way from the house-valve to the next street reservoir, where it is bound to. Cast-iron is the material of these street pipes, cast as thin as practicable; even the thinnest (as they are only five inches diameter) being capable of resisting atmospheric pressure. The reader need not be told that, with so dense a material as cast-iron, percolation or filtration of noxious fluids or gases is impossible, whereby all danger of poisoning the soil and wells is entirely obviated. In regard to wear and tear we have only to say, that cast-iron in sewers is known to engineers to have lasted more than sixty years, without even street or road grit having had any perceptible abrading effect upon it. Now as no street grit ever enters these pipes, we may safely assume that they will last still longer.

There is also never any occasion for inserting scraping tools, which might injure the metal. With regard to rust or oxidation, it has been found that the fatty elements contained in fæces form an excellent preservative to the inside of the pipes, whilst the outside is fully protected by various cheap chemical preparations. To prevent all danger of leakage through flaws in the casting, which in gas and water pipes often gives so much trouble, Captain Liernur has invented a simple method of testing his cast-iron [illegible] merits a description. Each piece of pipe is laid in a trough filled with water, after both ends are hermetically closed with india-rubber cushions, by means of two light rods and a simple lever contrivance, which presses and holds them tight. One of these cushions communicates through a flexible hose with a small steam engine driving an air-force-pump. The latter, with a few strokes, trebles the density of the air within the submerged pipe; and, if there is the slightest flaw in the iron, bubbles rising to the surface of the water will infallibly show it. From twelve to fifteen pipes may thus be thoroughly tested within an hour's time, before putting them into the ground.

The joints are of the socket style, and made air-tight by a ring of iron cement and clay. The branch pipes enter the main pipes at an angle of about thirty degrees, with a curve of two feet radius, to facilitate the current of the fæcal matter towards the street reservoir. The main pipe is, wherever practicable, given a gentle inclination downwards until near the reservoir, which it enters by a sudden upward bend, thus forming another sort of hydraulic trap which collects all fæcal matters in one compact mass, and forces it without any scattering into the reservoir. Sometimes there are opportunities to simplify the system by applying only one valve to a main pipe, or even the reservoir itself, instead of a separate valve to each branch pipe; for instance, in garrison barracks, schools, colleges, asylums, prisons, in fact all large buildings having a number of privies systematically distributed and regularly filled. This simplification, however, is only practicable under such favourable circumstances; else there is danger of having only the pipes containing the least matter cleaned, and the others left undone.

7. Pneumatic Locomobile and Tender.—The engine and tender of the model shown next page, are manufactured by *Messrs. de Bruyn-Kops and Backer*, engineers and machinists, at *Breda*, North Brabant, Netherlands. The engine-carriage stands upon four wheels, two large ones supporting the boiler and principal weight of the apparatus, whilst two small front wheels serve more for steerage. The boiler is upright with vertical flues, so arranged as to afford the greatest possible heating surface.

The steam cylinder and air-pump are horizontal, and bolted side by side securely on to the carriage frame. The steam piston operates upon an intermediate transverse-lying shaft, which, with a second crank and a return connecting rod, works the air-pump piston. The shaft has on one end a fly-wheel, to promote regularity of motion, and on the other end a small toothed wheel which, when in gear, works by means of an endless chain upon a similarly toothed rim, fastened against one of the wheels of the carriage, and thus propels it. When the engine is at work pumping out a street reservoir, this propelling gear is of course unshipped. The air-pump has sixteen inches stroke and sixteen and a half inches diameter, giving a capacity of two cubic feet; and as the engine is worked at 100 revolutions per minute, the pump will of course develop 400 cubic feet per minute. The steam cylinder has seven inches diameter and sixteen inches stroke, with a cut-off at half stroke, and the engine has twenty-two and a half horsepower. All parts which can be made of steel and hollow, are so constructed, in order to combine the greatest strength with the extremest lightness. The carriage frame is hollow, and the exhausted steam circulates through it, before entering the chimney, so as to deaden the noise of the blast, while the exhausted air is passed under the fire-grate, in order to purify it by burning.



In another pattern of a vacuum engine, invented by Captain Liernur, the air is not exhausted by the action of a pump, but by that of *two retorts*, out of which the air is driven by steam, the latter being immediately afterwards condensed by injecting water. Each retort or condenser has three feet diameter and four feet height, holding thus 28 cubic feet. Being exhausted ten times per minute, both retorts develop a volume of 560 cubic feet per minute.

The little mingled air and steam driven out of the retorts is led through an upright 6-inch pipe, in which also a fine spray of water is injected for condensing the steam, and leaving the air alone to escape under the fire-grate, there to be purified by burning. A small donkey-engine works the condensor-valves, the injection-pump, and the boiler's feed-pump, and besides, when shipped in proper gear, propels the whole apparatus.

Both kinds of engines are drawn by a single horse, the greatest part of the motive power being supplied by the engine. Part horse, part steam-propelling arrangement is used, because experience in such matters has taught that passing horses do not shy as long as they see one of their own kind in front of an engine. In thus giving these animals an impression that 'all is right,' accidents are prevented, and the objections removed which some municipal authorities have raised against the use of locomobiles in public streets. Besides a horse saves a complicated steering gear for turning street corners. The boiler of the model shown in our cut is fed by a Giffard injector from a tank holding but five cubic feet, in the middle of the carriage. Either engine, as described, together with three tenders, is sufficient for every 10,000 inhabitants, being capable of removing one day's supply of excrements within seven or eight working hours during the night.

8. PNEUMATIC TENDER.—This tender stands also upon four wheels, the two rear, very large ones, supporting three-quarters of the weight of the manure cylinder, the small front wheels bearing the other fourth, and serving mainly for steerage. The tender has no carriage frame, the cylinder itself serving as such. There is on each side a 6-inch suction pipe, either of which can with a flexible hose be connected with the vertical dung-pipe in the lamp-post pedestal before alluded to, a valve establishing or breaking off the connection at will. On the top of the cylinder stands a dome with two 3-inch pipes attached to it, provided with well-closing valves. One of these is, by means of a flexible hose, to be connected with the small air-pipe in the said lamp-post pedestal, the other by a similar hose with the suction pipe of the air-pump on the locomobile, after the tender has been coupled to it. This coupling is done in the following manner: the tender coming up empty with two horses, is placed alongside of the locomobile; horses and centrepole are taken off, the latter by simply lifting the draw-bolt. By partly turning the tender's front wheels, it is easily slewed round, so as to stand right behind the locomobile; after which a short coupling bar is fitted with one end in the centrepole-slot of the tender, and with the other hooked to the engine. The tender cylinder is 3 feet 7 inches diameter, and 10 feet length, therefore 10 square feet section, and 100 cubic feet capacity. Of these, only 90 cubic feet are used for storage of sewage, the remaining 10 feet being partitioned off as a water-tank for the engine. These 10 cubic feet or 75 gallons of water are brought along by the tender driving up empty, and after coupling gradually discharged by a small hose into the engine's tank. The tender, on its way to the engine, carries also two square baskets of stout wicker-work, filled with mixed coal and gas coke, so that the engine is constantly kept supplied both with water and fuel, by the tenders passing to and fro. The fuel baskets are merely hung up on hooks behind to the tender, so that they can be easily taken off, and placed handily alongside the furnace.

9. OPERATION OF ENGINE AND TENDER.—This is as follows: the propelling gear of the engine is unshipped, and the air-pump set to exhaust the air both out of the tender cylinder and out of the subterranean reservoir and pipe-system, connected therewith by means of the hoses and pipes described. The air-pump has a

capacity of two cubic feet, and runs at the rate of 100 double strokes per minute, developing therefore, in one minute, a capacity or volume of 400 cubic feet. Now, supposing the subterranean main and branch pipes to develop a total of 8,000 linear feet, which is about the average, giving a

Capacity of, say	1,090	cubic	feet.
To which add for reservoir	20	"	"
And for tender cylinder	90	"	"
Which total of	1,200	"	"

three minutes pumping would reduce to an internal pressure of 7½ lbs. per square inch, and three minutes more to 3¾ lbs., thus leaving a working atmospheric pressure of 11¼ lbs., or, allowing some loss by leakage, of say 10 lbs. on the square inch for emptying the sewage pipes, which experience has shown to be more than sufficient.

As soon as the vacuum gauge on the tender indicates that pressure, labourers proceed to open the house-valves one after the other, the air-pump of course continuing to work, so as to maintain the vacuum. To promote rapidity of action, two men are employed turning alternate valves, one walking while the other stops, thus continually passing each other, the engineer remaining all the while by his engine. When all house-valves have thus been opened and immediately shut again, the engineer disconnects the air-pipe, and turns the dung-pipe-valve, thus transferring, in a few moments, the contents of the street reservoir into his tender cylinder. He then disconnects the hose of the dung-pipe, and drives both engine and tender coupled up as they are, to the next street reservoir, one labourer leading the horse, whilst the other stays for a moment to close the door in the lamp-post pedestal just done with. As the air-pump throws the foul gases exhausted from the reservoir and tender cylinder directly under the grate of the furnace, they are consumed; and as also the smoke of the engine, and even the blast is stifled, the whole performance is so inoffensive to smell and hearing, that not the least annoyance is given to even casual passers-by. One engine, with three men, can in eight hours night work empty with ease say fifteen reservoirs, each connected with an average of sixty houses, removing thus the excrements of some 10,000 persons more or less as stated before. Each engine requires three tenders, one coupled to it, the second on the road coming or going, and the third discharging at the decanting station, which we shall now describe.

10. DECANTING STATIONS.—The tenders, when full, are driven by two horses, as mentioned before, to decanting stations, located in suitable parts of the suburbs or environs of the city. Whenever practicable, they are placed in the immediate vicinity of a railway station, steamboat landing, or canal; if not, it will in most cases be good policy to build a little side track to such means of transport. The decanting buildings are roomy, well ventilated, and arranged for stabling the horses, storing their feed, sheltering engines and tenders, storing fuel, with a workshop for repairs. There is besides a tank and pump for supplying the tenders with water for the engines. The principal feature of these buildings,

however, is the arrangement from which they obtain their name, viz. an apparatus for decanting the excrements out of the tender cylinders into barrels, which is always done immediately upon arrival.

The tender is driven on a platform inside the building, below which is a pit in which the decanting process goes on. The discharge valve is fitted to a decanting measure, holding exactly five cubic feet. This measure is simply a cylinder of boiler plate, fixed in a little frame inside the pit, and having a pipe below, which can be fitted to the bunghole of any barrel. The measure has two valves, one above allowing it to be filled, the other below for emptying; its use is to fill the barrels, without danger of spilling any of the matter.

11. Manure Barrels.—These barrels, 28 inches in exterior diameter, 32 inches in length, and 5 cubic feet in capacity, are made of stout oak staves, and strongly hooped with iron, so as to stand considerable internal pressure and even rough handling, like beer barrels; the wood being previously saturated with a preserving mixture, so as to close the pores more effectually and prevent rotting. Experience has shown that such barrels, filled with excrements, can be forwarded like any other commodity without the least smell. The tenders, when filled, holding just 90 cubic feet, 18 barrels are required to empty one of them.

The bunghole of the barrel is strengthened by a cast-iron ring, firmly inserted and fastened into the wood, and closed with an iron cap, which is screwed into the ring when the barrel is filled. This cap has in the middle a hole, ¼ inch in diameter, with a little conical plug fitted in, held by a spring inside, and so arranged that, when the internal pressure exceeds 2 lbs. per square inch, this plug lifts up a little and allows the gas to escape, which might otherwise burst the barrel or cause at least a leakage. Of course the barrels are always laid bunghole up. This arrangement is adopted in case of unexpected delay occurring in forwarding the barrels to their destination, which is not likely to happen often, if the whole of this system be properly followed out.

12. Transport of Manure Barrels.—It has been seen that, by the preceding arrangements, all fæcal matters produced in an entire city are not only collected, but also barrelled up ready for transport, only some twenty-six hours after the first, and two hours after the last has been discharged, giving an average time of fourteen hours after the moment of production. The plan being never to allow fermentation to set in, of course no time whatever is to be lost in forwarding the barrels to their proper destination, where, we now all know, they can do no harm but only good.

For this purpose the system requires the city or company undertaking the sewerage works to own or control one or more tracts of land, capable of absorbing all the manure not called for by farmers or others. If the latter need any city manure, they must send in their orders to the nearest decanting station, so that the very first produce may be forwarded to them, they paying the established price and freight charges, and returning the barrels when emptied.

The land to be used by the sewerage works must be large enough to receive all manure not otherwise disposed of, and should be lying contiguous to some railroad, canal, or navigable river, to facilitate and cheapen the daily transport of barrels, which should arrive there, if possible, while the contents are still quite fresh.

13. UTILISATION OF HUMAN MANURE.—The lands required by the 'Pneumatic Sewerage Works' may be laid out according to the system followed by irrigation companies, viz. in various lots or tracts, of which some parts alternately receive their manure, whilst on others crops are growing. At any rate this is in accordance with the plan advised by many eminent agriculturists, for the purpose of providing on the farm a constant place of deposit of manure for complete and immediate utilisation on the spot; that is, in the land itself, and without first forming compost heaps, or bare-fallowing any part of the grounds. In other words, the advocates of this method maintain, that by rotation of crops, it can be managed that always some field is open or in season for receiving manure, while the others bear growing plants, so that during the year each acre receives its proper amount of fertilisers, and yields a corresponding harvest.

Many farmers, however, stoutly deny the practicability of this, arguing, that even if one field could always be had for manuring, the time which must be allowed to elapse between this operation and planting the seed would in many cases be too short for properly developing the manure into plant-food, which, unless thoroughly effected, would cause the plants, instead of being benefited, to be rather injured, through the peculiar nature of the material used. This objection would hold good if the ordinary mode were followed of mixing the manure with the top soil, say within two or three inches of the surface, into which the seed shortly afterwards is deposited.

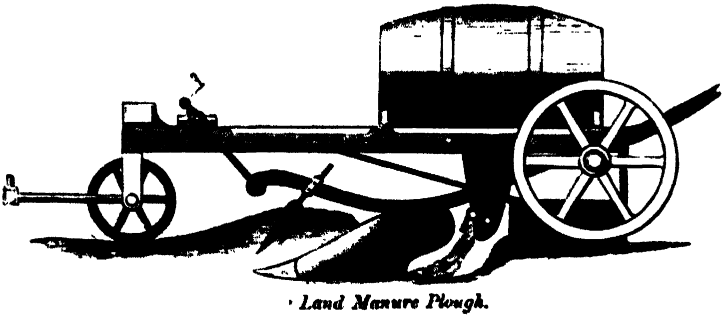
Such is not the case, however, when the apparatus is used for putting the manure in the ground which will be described presently. But as, notwithstanding the assertion of the rotation crop advocates, it surely may occur through unfavourable weather shortening the spring, or other circumstances, that all the land is simultaneously occupied by planted seed or growing crops, leaving no field open for deposition and utilisation of sewage, Captain Liernur prefers a method of his own, which effectually overcomes all difficulties.

It is as follows: all the arable land is laid out in alternate beds of plants and fallow strips, the former being about sixty inches, and the latter forty inches wide and occupying thus an area of one-third of the whole field, leaving but two-thirds for the growth of plants. The planting beds are, as usual, sown in drilled rows, from eight to twelve inches apart, as the nature of the plant and soil may demand, thus leaving room for 'inter-tillage,' while the fallow strips are used for depositing manure, which, by means of the manure plough, now can be done during the entire season, even while the plants are growing or ripening. The following season, the position of the beds and strips is reversed or exchanged, so that the plants will grow on soil manured the season previously, while the soil which yielded harvest before, gets fertilised anew in its turn.

It is evident that in this manner manure can be utilised on a given farm the whole year round, which in dealing with sewage is absolutely necessary, as its supply is without intermission;* and it will be shown, in the following pages, that by this method, called by the inventor 'fallow-strip-manuring,' a larger crop may be expected from a given field, than by sowing broad cast, or in drill-rows over the whole area.

But in either case the application of the human fertiliser is not effected as hitherto by merely spreading it over the surface of the land, thereby infecting the atmosphere for miles around,* and weakening the manure besides by allowing the most valuable elements to evaporate; on the contrary, the new method puts it immediately under ground, where it should be, and this is done in the following simple and efficient manner:—

14. TILLAGE LAND MANURE PLOUGH.—We may here observe, that the ploughs known in agriculture can be divided generally into three classes, viz 1st. The *common plough*, which partly breaks up and turns over the surface soil by cutting a slice of earth in a slanting direction from one side of the furrow, and putting it on the other; 2nd. The *subsoil plough*, which merely loosens and breaks up the earth below the surface, so as to admit air, to let surplus moisture through, and to let the roots of plants penetrate it; and, 3rd, the *trench plough*, which turns the earth of the furrow over in such manner that the surface soil is buried, and the lower soil thrown up to the surface. It is this class of ploughshare that is preferred for the operations here described; but even the common plough of any shape the land may need, or the farmers fancy, will answer the purpose in certain cases, as hereafter will be shown. Over any plough a light carriage frame is placed, and so fastened to it that both move together. The carriage frame stands on three wheels, the front one turning on a pivot.



Land Manure Plough.

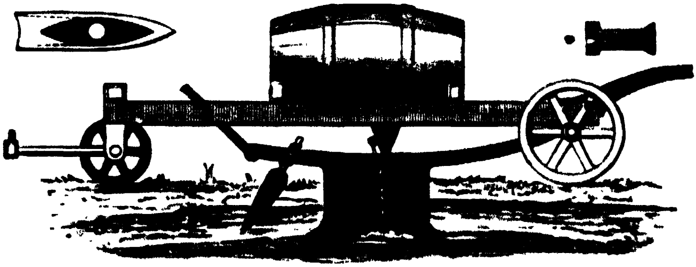
One of the manure-barrels, as soon as practicable after its arrival from the decanting station, is laid over the plough and carriage frame, with the bunghole up. The iron cap is then

* Any surplus of manure which, perhaps, cannot be disposed of even by this method, is at once ploughed into some barren tract or other, acquired for the purpose of being gradually converted into arable land; so there is at all seasons a chance of applying the sewage matter somewhere.

removed, and by means of a stout leather breeching and two broad straps, a short pipe is fastened to the bunghole, after which the barrel is turned round, as shown in the drawing, so that the pipe comes immediately behind the ploughshare, and discharges the barrel-contents directly into the furrow made. Placed behind are two little shovels or scrapers, levelling again the ridges of the cast-up earth, and thus closing the furrow immediately with loose soil. The pipe has a small valve to regulate or stop the discharge.

To enable the operator to deposit the manure at various depths, the ploughshare is held by a screw-rod, so that, by turning a handle, it can be elevated or depressed. This contrivance enables also the combined apparatus to be driven over common roads, for which purpose the ploughshare is entirely raised.

15. MEADOW MANURER.—The above arrangement is intended for arable lands of all descriptions: for meadows, on the other hand, the variation explained by the accompanying engraving is required.



Manurer, with Sections of Manuring Tool.

The barrel is fixed in the same manner as before, and placed upon a similar carriage-frame; but, instead of a ploughshare, a simple tool is used for injecting the manure underneath the sods, without injuring the roots.

This tool is a sort of double-edged vertical knife, fifteen inches broad, and three inches thick in the middle, and makes with a sharp front knife a running incision into the sods. Below, it has a broad hollow foot, sharpened in front and on the edges, with a sort of swell or increase of thickness in the middle, which gently lifts up the sods a little behind the incision made.

This manure-drill has in the middle of its stem a vertical hole, two inches in diameter, running through its entire length. The upper part of this hole is widened out funnel-shape, to receive the manure liquid issuing from the barrel tube. The lower part is also widened out, and gradually merges into the hollow foot.

In case of great toughness of sods or thin roots, to prevent their being displaced or torn, an ingenious arrangement is provided, not shown in the drawing to avoid indistinctness by complication. It consists in a sharp blade in front of the main tool, moving vertically up and down about three inches, its lower end passing through the broad foot, and the upper one hanging on a 1½ inch crank of a small axle, which receives its rotary motion by means of an endless chain from one of the rear-wheel-hubs, in proportion of about two to one.

Now it is evident that, when this manure-drill is set in motion, the liquid dung will run out of the barrel through its hollow stem into the cavity made underneath the sods by the hollow foot; after its passage, the sods will immediately close again, through their gravity and elasticity, just like two lips parted for a moment.

This immediate closing of sods effects two important purposes. Firstly, it flattens the little rivulet of dung into a thin layer, thereby distributing it over a larger surface; and, secondly, it effectually prevents the contamination of the atmosphere by fæcal gases. The main point, however, in view by this arrangement, is to give cattle food uncontaminated by putrid organic animal matter, of which more hereafter.

The manure-drill is fastened to the carriage frame with a screw rod like that described before, for raising and lowering to suit circumstances. The incisions in the sods are made as close together as the nature of the meadow may require; they may also be run in two directions, one at right angles with the other.

There is no practical difficulty whatever in the application of human manure to arable lands and meadows in the manner just described. The dung itself being composed, as we have explained in page 74, of some 8 or 9 parts of urine and only one part of solid excrements, has by pneumatic pumping and repeated forcible churning, which even reduces the paper to a soft pulp, received such a homogeneous liquid character, that it will issue from the barrel over the plough as a very thin slush, without any lumps to mar an even exit through the pipe or the hole of the manure-drill. But should there be even now and then something or other to interrupt the passage, both barrel, pipe, and knife-hole are easily approached and cleared out.

For the rest, the whole apparatus is as easily driven and managed as a common plough, as the weight of the barrel presses not on the ploughshare but on the carriage frame provided for it, the only requirement being an extra horse or ox to pull the additional weight of the barrel. In gardens, or other small tracts of land where no plough can be used, the following simple method of manuring may be applied:—A handy tin pot or pail with a well-closing lid, is filled out of a manure barrel, and then emptied through the spout into the ground, the liquid being covered with earth immediately afterwards. This spout, shaped like a broad duck's beak, is provided with a screw for regulating the thickness of the manure stream, according to circumstances, and closing the passage hermetically when not in actual use, so as to prevent all unnecessary effluvia out of the pail. In this manner even the smallest garden may be made to share in the benefits of this universal fertiliser, and great quantities of fæcal matter will thus in detail be safely lodged underground, which otherwise would perhaps lie festering on the surface.

16. **Winter Storage of Manure.**—There is, however, one difficulty in the way of constantly carrying out this plan of putting excrements into the ground immediately after produce, and storing them there, and nowhere else, for the future use of agriculture. It is when frost has so hardened the ground that the ploughshare cannot break it, or when the fields are so deeply covered with snow that to attempt the process would involve an expenditure of force

and money not justified by the circumstances. Of course, the case is not any worse than that of the irrigation system, which, experience has shown, is often brought to a dead-lock in the winter time; but that does not help the matter.

Some mode of storage must therefore be provided to keep human manure, over such periods, both from freezing and fermenting. For that purpose winter sheds are built, being simple light covered structures, in the immediate vicinity of decanting stations or other convenient locations. During frost the filled manure barrels are stored there, and kept at an equal temperature of about freezing point, by occasionally slightly heating the building or allowing cold currents of air to enter, so that the fæcal matters can neither freeze nor pass into fermentation through heat.

Of course some care is hereby required; but it may always be easily ascertained whether the manure barrels are too hot or too cold, by simply unscrewing a few of the iron bung-caps. If the material begins in any way to throw off gases, the temperature of the building must be reduced by letting in a cold draught; on the other hand, it must of course be gently raised, if ice is found in a bunghole.

That this plan, if the frost long continues, will involve a considerable outlay in barrels, especially for large cities, is of course disagreeable, but altogether unavoidable; because, whatever the frost, excrements are daily produced and must be stored somewhere, and any other plan would not be less expensive or troublesome. These winter sheds have at any rate the merit that they preserve human manure unspoiled for immediate application the moment the frost disappears; with this further advantage, that part of the barrels at least can be disposed of to large estates, keeping steam-ploughs capable of breaking up even frozen ground. In many cases, it will be actually cheaper to keep a steam-plough for disposing of the sewage at once, than provide a number of barrels for storing it during frost or deep snow.

17. RECENT PATENT SEWERAGE SCHEMES.—Our account of sewerage schemes would not be complete if we omitted to describe some projects which, under the title of improvements, have been in the last few years proposed and patented in this country; but, before doing so, we may as well state that the process of removing fæcal matter by atmospheric pressure, through either surface or subterranean pipes, which, in some recent patents, is claimed as an original invention, is not by any means a novelty.

Plans to that effect have been repeatedly proposed by various eminent engineers; and many foreign standard engineering works, treating of city drainage, make mention thereof. Most eminent among them are those of the French engineer Latour, and also those of Mr. Chapusot, who worked out such a plan for the city of Turin some twenty years ago, as stated already in page 83. All these schemes, however, are hampered with awkward and impracticable details, which forbid their execution. Moreover, in most large continental towns, the pneumatic process can be daily seen in full operation for the removal of cesspool matter. In some places even the cesspools are built immediately under the privies, and provided with a permanent iron pipe, which comes out into the street. At certain stated periods a pneumatic waggon, carrying a simple iron cylinder, in which a vacuum has been created by condensed steam, is attached to it by a coupling hose. Here is practically the whole permanent pneumatic drainage system on a small scale, and for that reason all patent rights, the claims of which go no further than the removal of fæcal matter by these means, are null and void.

We have already plainly shown, that Captain Liernur's system is quite another affair. He not only removes the matter, makes it portable, and gives it a practicable shape for agriculture, but shows also the way how to extract by its means the largest crops from the soil. His own language is: 'My method deals with fæcal matter from the moment it is produced until the moment it is put under the ground, for stimulating useful vegetable life; and all means I thereto employ are but parts of one single comprehensive design.' In fact, his system is nothing but a combination of acknowledged practical measures; but this combination, with all its ingenious details, is new, and his claim as its inventor indisputable.

Nearly all *useful* inventions consist of similar combinations, all their various component parts being well-tried contrivances, the effect and operation of which is known, and therefore there is no chance left for failure by an impracticability of details. And it is generally in this particular that so many schemes (often patented at great expense) are weak; above all, when they claim the application of some well-known natural agent (as, for instance, pneumatic force) to some particular purpose, but fail to point out the exact manner how, and the precise modes by which, the thing is to be accomplished. As the physical law upon which the alleged improvement is based cannot in that case be exclusively claimed, because it is the common property of all, and the mechanical means are not specified, the invention is, of course, worthless, because there is nothing invented, and the problem is still left for solution by others; while the patent claim amounts to nothing.

In the following descriptions of patent sewerage schemes, we have considerably condensed their respective specifications, stating only the leading features, and accompanied them, *pour encourager les autres*, with a few words indicating their true bearing and value.

June 22, 1860, *Mr. Walter Macfarlane*, engineer, of *Glasgow*, obtained a patent for certain iron dry-excrement-closet-basins, they being oblong troughs with sloping bottoms, and a pipe at one end coming out in the street. The dustman is expected, ever and anon, to open this pipe and fetch the matter away, and if it does not readily flow downwards by the inclined bottom and pipe, he is required to use a little rake and scratch it out. The invention has the merit of keeping the manure intact for agriculture; but as to its domestic value, we do not think any body would like to have such a trap in his house or neighbourhood, or wish to be that dustman.

October 11, 1860, *Mr. J. W. Rogers*, civil engineer, of *Rogerstown*, obtained a patent for a pneumatic scheme, consisting of iron pipes laid within the sewers. The said pipes have branches connecting them with the waterclosets, and, at certain distances, are also connected with reservoirs placed under the pavement of the streets. Within the reservoirs are fitted filtering beds of peat-charcoal, through which the water of the sewage is to pass upwards, leaving the solid matter below, when a vacuum is made in the upper end of it. After having thus imparted its fertilising properties to the charcoal, the liquid is allowed to run off in the sewers, while the solid matter collected below is brought up by means of buckets, or an Archimedean screw. The main pipes within the sewer have lock-valves at certain distances, so as to divide them into compartments, and thus to make a vacuum in any particular portion when stoppages occur. The patent has no drawing or description explaining the arrangements of these reservoirs, with their filtering beds; nor does it show how the discharge of the fluids into the sewers is going to happen; and there is also nothing to point out how the solid matter is going to come out with an Archimedean screw. The buckets we all understand, but think the police would object. The general suggestion, however, of collecting fæcal matter, and depriving it of the surplus fluids obtained in the water-closets, is good, and the invention would perhaps be a first-rate one, if the inventor had only shown us how it is to be done. As it is, the inquirer is left to his own devices, and Mr. Rogers can have no claim on contrivances which outsiders are expected to invent for him. As to employing a vacuum chamber and pipes, for the purpose of moving the fæcal matter, that is not patentable, for reasons before stated.

April 9, 1861, *Mr. Francis Taylor*, of *Romsey*, obtained a patent for the most wonderful mode of dealing with sewage perhaps ever imagined. Under the privy floor a turn-table of ten feet diameter, moving upon a central pivot, is placed in such a manner that the fæces can drop on its outer part. Each time the closet door opens the table turns a couple of inches round, so that every new deposit may alight on some fresh place. The urine being considered worthless, is allowed to run off somehow; but the solids are expected to dry and cake in the circular ridge, which they, in process of time, form, and to become like guano, having, as the inventor asserts, retained all their fertilising properties through not being decomposed! To promote drying, artificial heat from an adjacent furnace is to be used. (Would not a small steam-engine, with a hot-air fanblower, be preferable?) The paper is to be carefully picked out, washed, and scalded, and made up again into new paper, for writing down similar inventions. It would be interesting to know how much Mr. Taylor charges for the use of his patent.

February 18, 1862, *Mr. M. A. F. Mennons*, of *Paris*, obtained a patent for a barrel into which the fæcal matter is to drop direct. It is fitted internally with a triple metallic perforated tube, for the waste water, and around this is placed a filtering, decomposing, and absorbent mass, composed as follows:—1st layer: equal parts crushed peat and calcined clay; 2nd layer: equal parts sulphate of zinc and sulphate of magnesia; 3rd layer: like the first, with addition of sulphate of lime; 4th layer: like the first; 5th layer: like the third; 6th layer: like the first; 7th layer: peat, calcined clay, and carbonate of lime; 8th layer: peat and sulphuric acid.

In fact, in that barrel is to be put a whole apothecary's shop. The inventor, however, leaves thoughtfully everyone the liberty to arrange the medicaments to suit himself, which is fortunate, as then perhaps many can dispense with the whole affair altogether, and thus escape patent fees.

September 22, 1864, *Messrs. T. and T. F. Walker*, engineers, of *Birmingham*, obtained a patent for certain tanks, to be placed at the outfall of sewers, in order to let the solid matter therein settle by natural subsidence, leaving the liquid to flow off for irrigation purposes. The tanks are really very ingeniously arranged; but, in common with all structures of this kind, incur the risk of being indicted for a nuisance wherever they are built, on account of the overpoweringly offensive effluvia they throw off. Besides, the whole sewerage system for which they are designed is, as we have said elsewhere, objectionable on all accounts.

November 10, 1864, *Mr. J. A. Manning*, of the Inner Temple, *London*, obtained a patent for collecting the sewage in watertight cesspools, in which is put a layer of dry seaweed and sulphuric acid. The fæcal matter thereby deodorised is to be removed by a pneumatic waggon to a factory, having a tank large enough to hold the town sewage of an average night. Thence it flows to large iron evaporating pans, which are heated by furnaces. The pans are covered air-tight, and have agitators worked in them, to stir the matter up and promote drying. Pipes lead the heated vapours thus generated to a large reservoir, somewhat like the hydraulic main of gasworks. From these they are passed (it is not half done yet) by means of a fan-blower, worked by a steam-engine, to a condenser, in which water is spouting up like fountains of spray. This water is expected to absorb these vapours or gases, and then run off to a hole in the ground somewhere, thus to be got rid of. (A critic at our elbow suggests, that the sewage liquids might as well have been run off into that hole in the first instance, without all this trouble; but perhaps he does not understand.) The thickened mass remaining in the evaporating pans is tapped off to heated floors of large rooms, for further drying, and the gases arising therefrom are treated and condensed in a similar set of receivers and utensils as described above, but made not quite so large. The matter finally, after all these adventures, having become perfectly dry, is now smashed to powder by disintegrating machines, and sold, as the inventor hopes, for manure. Who will be the first to try this?

April 12, 1866, *Mr. J. P. W. Schmick*, civil engineer, of *Frankfort-on-the-Maine*, Germany, registered as his invention an arrangement, somewhat like that of Captain Liernur, with the exception that the town is to be divided into large districts, each one of which is to have a reservoir of suitable size, into which the main sewage pipes empty themselves, and wherein a vacuum is maintained by an underground hydraulic pressure engine. The sewage thus withdrawn from the waterclosets is to be discharged and collected into large tanks for eventual agricultural use—in what manner, however, is not stated. This complicated and still incomplete invention is not patentable, for reasons already stated; and, besides, Captain Liernur placed, some three months previously, on record at the Frankfort Board of Works a description of his system, with a request for its examination, and urging its adoption.

It is evident that all the above inventions comply only partially with the requirements of the question, because they omit to provide means of disposing, let alone of utilising, the material after having collected it. Thus, one patents the combination of a dustman and a little rake, and having put it in operation, abandons that official to his fate; another contrives to collect the matter into a subterranean chamber, and then leaves us to get it out into the street by means of buckets, or some sort of a screw; a third lets the urine run off 'somewhere,' collects the solids on a round table, and lets them dry in a circle, but gives us only specific instructions what to do with the paper; a fourth puts the excreta into a large barrel, half filled with chemical compounds, but omits to say what to do with the horrid mess, and there seems to be no way to get it out of the barrel except by smashing the whole concern with an axe; a fifth carefully stews and cooks the matter, lets the water which has absorbed all valuable ingredients, run off 'anywhere,' and then hopes to sell the residue for guano; while a sixth collects, by means of a complicated apparatus, the sewage into large subterranean tanks, in the hopes that somebody will find a way to do something with it afterwards. In fact, all contrive to remove the offensive matter from the original place of deposit to another, where it is a greater nuisance to the inhabitants than before.

18. MENZIES' SEWERAGE SYSTEM.—One more system deserves mention, though it is opposed to the principles of the first drainage engineers of the country. It is that of Mr. Menzies, who has not so much invented as adopted it, and identified himself with it to such an extent that it bears his name. He is opposed, as well he may be, to discharging fæcal matter into sewers, preferring to keep these for what they were originally intended, namely, for rainfall and household fluids. For the sewage proper he lays down a separate set of pipe drains, in which the waterclosets discharge. The pipes are so small that their normal condition is to be entirely full, and that there is never room left for any gases to collect. In case of stoppages, the matter backs up, until a hydrostatic head is formed, which sweeps them away; and this force also removes any additional quantities requiring to be discharged, by the increased speed of the current thereby generated.

In this arrangement the evils of sewers acting as conduits for fæcal matter are, perhaps, somewhat mitigated. There certainly is but little chance for gases to collect, and, if formed, they are compelled to move downwards with the whole mass, by which means all danger of their upward escape in houses and streets is prevented. The manure becomes also less diluted, and more fit for general agricultural use; but by no means enough to bear transport, or to be used on arable land; for the least amount an ordinary watercloset uses, per head of population, still dilutes it with fully 100 volumes of water. The chief objection is, however, the great fall which pipes conveying this more thickened mass must have, and the consequent great gradual depth of their location, unless constant pumping up to a new gradient is resorted to. Both these methods are expensive, and still a considerably steep gradient is the only means for preventing or removing stoppages; for the danger is, not that a lodgment is made by the sticky sediment on one spot, but along a more or less greater length, which will result in the gradual choking of the pipe over that entire distance, and which will cause a stoppage requiring more force and friction than the backed-up mass of sewage can give.

The editor of 'Engineering,' in his impression of April 5, 1867, alluding to this difficulty, says: 'If the hydrostatic head were on any occasion found to be not quite sufficient to procure the requisite rapidity of flow, there would be nothing simpler than to aid it to any required extent, by producing a vacuum more or less perfect at the place of debouchement.' We quite agree with this suggestion, for that virtually amounts to using Captain Liernur's pneumatic system; only we should say that, as steam power is to be used anyhow to keep the mass moving, or to collect it in tanks, surely the deep location and 'gravitation gradients' have become unnecessary, and might be dispensed with; and also that the masses of water used in the waterclosets to wash the matter down be also either entirely left out or considerably reduced; in other words, that the new pneumatic system be adopted in its entirety, and thus a valuable fertiliser be saved, instead of the half-way arrangements of Mr. Menzies, the partial benefits of which are more than counterbalanced by the great additional expense of constructing a second gravitation and water-carriage sewerage system, at equal depths with the other, and labouring under the same financial and technical difficulties.

VIII. ADVANTAGES OF PNEUMATIC SEWERAGE.

COMPARED with sewerage by water-carriage and with all the various transport systems hitherto in use, Captain Liernur's pneumatic method of removing fæcal matters, and his subsoil application of the same, offer many remarkable advantages, which we shall now shortly point out.

A.—TECHNICAL ADVANTAGES.

1. NO WATERWORKS REQUIRED.—The pneumatic pressure being more than sufficient to remove all fæcal matters, together with any foreign substances occasionally thrown into privies, there is no daily waste of water, as with the watercloset arrangement. Consequently, many a town will find the water at hand quite enough for drinking, cooking, washing, and all other purposes, and thus be saved the necessity of providing waterworks; or, if any should be required, they may be executed on a much smaller scale; and, in cases of superfluity of water, it may more advantageously be used to provide public baths for the poor, irrigate the streets, &c.*

The 'Economist' of February 23, 1867, furnishes the following interesting particulars of

NEW SCHEMES FOR LONDON WATER-SUPPLY.

Promoters	Sources of the Water	Daily Supply	Length of Conduits	Estimate of Cost
		Millions of Gallons	Miles	£
Mr. Bateman .	Sources of the Severn, North Wales . .	130	183	8,600,000
Messrs. Hemans & Hassard	Lakes of Westmoreland and Cumberland . .	150	260	11,200,000
Mr. Fulton . .	Sources of the Wye, Mid-Wales	130	180	6,877,000
Mr. Bailey Denton	Higher sources of the Thames . . .	80	—	4,500,000‡

By way of comparison lengths of other aqueducts are given, viz. ancient Rome, *Anio Novus*, 59 miles, New York, 40 miles, Rio de Janeiro, 3 miles. At Vienna, a few years ago, a proposal was made to obtain a water supply from the foot of the Sömmering pass by a conduit 40 to 50 miles long, and estimated to cost some 1,600,000*l.*

'The mere thought of such stupendous works,' says the above paper, 'is enough to make us doubt the possibility of their execution.' And yet surely something or other must be done, as

* Mr. Lawes, one of the Royal Commission of Inquiry, &c., in the Journal of the Royal Agricultural Society, vol. xxiv. pt. 1, speaks of the desirability of diminishing, wherever possible, the amount of water used for sewerage purposes; and Mr. Menzies, in his work just published, recommends the adoption of a special plan of drainage by water, for the reason that it is more economical of that element. We have stated in page 135 what this plan is.

† And 60 millions of gallons daily to other towns on the way.

‡ Exclusive of the delivery of the water at high level.

Her Majesty's speech, on opening Parliament, contains the following important passage:—

'Estimating as of the highest importance an adequate supply of pure and wholesome water, I have directed the issue of a commission to inquire into the best means of permanently securing such a supply for the metropolis, and for the principal towns in densely-populated districts of the kingdom.'

The present moment would, therefore, seem most auspicious for the metropolis to take the question into serious consideration, whether the enormous waste of water caused by the existing sewerage system is to be kept up in future or not. A plain answer to this plain question may save millions of good English money!

2. URINE CLEANS THE PIPES, and is the only fluid required for that purpose, being constantly supplied free of expense, never freezing in winter, nor getting scarce in summer—difficulties which often enough seriously interfere with the watercloset arrangement, as almost every householder knows, by sad experience of pipes bursting through frost, or getting choked through failure of water during a dry season.

3. REDUCED BULK OF MATERIAL.—The main-pipes being made of the same size as the branch or house-pipes, the quantity of material is considerably reduced. The sewerage by water system, on the contrary, strictly requires for each additional branch sewer a corresponding increase of the main conduits.

4. SAVING IN FOUNDATIONS.—The pneumatic pipes being so very light, in ordinary ground no foundations at all are required, and in shifting soil a light concrete bed at the most will suffice. Brick sewers, on the other hand, demand in any case the utmost solidity and stability of foundation, to prevent cracking of masonry; hence most careful examinations by boring, &c., must be made to find out the right strata for such foundations, all of which expensive work is avoided in the other case.

5. NO CRACKING OF PIPES occurs in the case of subsidence of soil, a danger to which tubular pottery drains and heavy brick sewers are constantly exposed.

6. NO VENTILATION SHAFTS NOR MANHOLES are required in the pneumatic system, because ventilation is most efficiently effected by the daily pneumatic process, and no inspection of internal parts is ever necessary, for the simple reason that there is actually nothing to inspect.

7. PNEUMATIC PRESSURE WORKING IN ALL DIRECTIONS, no other care need be taken in laying the pipes, than that a sewage column never rises above fifteen or sixteen feet, or half what the atmospheric column would hold in equilibrium. Even this would happen only in extreme cases, as in most towns an undulating surface can be so divided that all reservoirs are located at the foot of grades.

8. NO COSTLY GRADIENTS are therefore required, the pipes following invariably the natural undulations of the ground, very unlike water-carriage sewers, where gravitation is the motive power. The pneumatic pipes are laid just like common gas pipes, as they do not much more than skim the ground, the greatest possible advantage being taken of even a partial decline of plane.

9. AN EASY ALIGNMENT is thus gained for pneumatic pipes, compared to other sewerage conduits, which require an unbroken equal current to prevent sediment, and can afford any variation from a straight line only by means of a circle of large radius.

10. NO DEEP EXCAVATIONS are needed for pneumatic sewerage works, nor any tunnelling or interference with foundations of buildings or cellars, all of which renders the construction of gravitation sewers often so very difficult and expensive.*

11. THE UPROOTING OF PAVEMENT required for the shallow and narrow cutting sufficient for pneumatic pipes is insignificant indeed compared with that occasioned by gravitation sewer works, an immense advantage to the public traffic in crowded streets and thoroughfares.

12. GREAT DISPATCH OF EXECUTION is secured by the preceding advantages for sewerage works according to the pneumatic system, which should certainly be a great inducement to towns suffering under the evil effects of imperfect drainage.

13. GRADUAL INTRODUCTION of the pneumatic system may be effected by dividing a town into independent sections, beginning with that part most anxious for the improvement, and gradually extending it from one section to another, as local circumstances may suggest. The case is quite different with sewerage works for water-carriage, which of course can only be undertaken after one single comprehensive scheme, to which everything else must yield.

14. GREAT SIMPLIFICATION OF DRAINAGE may be obtained, when all fæcal matters and the water hitherto used in waterclosets no longer enter the sewers, which thus have to carry off only the household waste water. Sewers then may, of course, be made much smaller and cheaper, and their contents discharged into rivers

* Illustrative of the dangers incurred thereby is an accident given by the 'Evening Standard,' of May 8, 1867, as follows:—

'An accident occurred this afternoon at the sewerage works being carried on in Southampton Row, Holborn (formerly King Street), which very fortunately was unattended by loss of life, or even bodily injury, to the many hundreds engaged on the works. It would appear that the engineers of the sewerage and gas works have always experienced great difficulties in carrying out their plans when this street was included in them, in consequence of the immense number of vaults of an ancient date which had been built from the different private houses on both sides of the street, and which nearly met in the centre. So *great*, indeed, was the difficulty of carrying on the necessary works in consequence of these obstructions, that considerable expense was incurred in order to avoid that which has now taken place. Whilst the men were away from that portion of the sewerage works, some of the before-mentioned vaults gave way, which carried with them the shoring supports of the sewerage works, and caused a falling in of from 1,000 to 1,200 tons of earth and stones.'

without danger to public health, passing at the most through basins to drop sediments.

According to Captain Liernur's plan such house-water sewers should be laid, following principally the natural lines of drainage, such as the topography of the town site directs. Simple pottery-ware tubular drains may, in most cases, be advantageously used, placed in the ground no deeper than necessary to protect them against frost, so that they are in no danger of being cracked by the weight of the soil. Where the little house-drains enter the street sewers, a sediment-cesstrap should be placed to collect all matters which might cause stoppages. By placing a 12-inch pipe-chimney just over this sediment-cesstrap, an easy access is secured, and any obstructions may be removed by means of a short scooping tool. A stout cover closes this chimney, and is only taken up to remove sediments. About every 100 yards a 4-inch pipe should be connected with the sewers and run up to the roof of the nearest and highest house, away from bed-chambers; this arrangement giving ventilation amply sufficient for the very few gases evolved. The house-pipes, before entering the sewer, should have two or three dips or inverted syphons acting as hydraulic traps. The rainfall might be conducted entirely away by properly graded side gutters, using the rain thereby as a powerful agent for cleaning the surface of the street.

By way of illustration, Captain Liernur states in his notes that he has even sometimes regraded several streets, giving the side gutters such an inclination that the rainfall would speedily flow away without inundating any lower places. This natural expedient is certainly preferable to undermining streets with large sewers, which are always very costly and difficult of access; and the experiment alluded to gave entire satisfaction.[c] At frequent intervals in the gutters, little sink-traps of brickwork are placed, about one foot square and two feet deep, covered with iron grates, with bars laid transversely to the gutter line, for catching all drift carried by the rain-current. When the streets are steep, such grates are placed at proportionally shorter intervals, and the bars of the grates are made to project considerably upwards, which arrangement breaks the current and collects all the filth. Streets so drained keep themselves constantly clean, the rain acting as an excellent scavenger, especially if, as should be done in every well-regulated city and town, street-sweeping machines are used for the regular daily removal of all dust, horse-dung, and other street-dirt, so that no slush can arise on a sudden rain setting in. These street-sweeping machines are now constructed to such perfection and efficiency, that they are well calculated to supplant the old-fashioned hand-brooms still so much in use.

This simple arrangement is surely an improvement upon the rather foolish plan of collecting street grit and dirt into sewers thirty to fifty feet deep, and then bringing it up, with the greatest difficulty, to the surface again, by means of scraping, cutting, and hoisting up through most expensive manhole-shafts, and finally to remove it with waggons as the only means left to get rid of it. As waggons are needed anyhow to remove ashes and other household rubbish, they may just as well be so organised and managed as to clean out the gutter traps at the same time, thus taking the refuse matter out of a depth of only two feet, instead of fifty feet, as with the other arrangements.

15. DURABILITY OF MATERIAL is another great advantage of the pneumatic system, as we have stated more fully already, at page 121, the iron of the pipes and reservoirs being fully protected in the inside by the fatty substances of the excrements, and on the outside by a strong coat of lacquer or similar substance.

16. FACILITY OF REPAIRS is likewise fully secured, the subterranean parts of the apparatus lying so near to the surface of the ground, that if any stoppage should occur, it can easily be detected and amended, without interrupting the street traffic. As the whole machinery, however, is exceedingly simple, repairs will be but very rarely needed.

17. SAVING OF LABOUR AND TIME, to a considerable extent, is obtained, compared with any French 'fosses mobiles,' or German 'abfuhrtonnen' system, which all require two or three labourers, who ring a bell, wait for admittance, and then, if not sent back to call again at a more convenient time, finally enter, unfasten, inspect, refasten, hoist and drag a heavy barrel over narrow staircases and passages, often with considerable noise and profane language, all inside a private dwelling, and often in the night; after which they create a similar disturbance in the street, by placing the barrel on a waggon—the whole annoying operation often consuming at least half-an-hour for a single house. By the pneumatic system, on the contrary, two men during the night move quietly about a street, turning a number of house-valves, whilst an engineer is tending his apparatus, which works with a stifled blast, and emits neither smoke nor sparks; these three men emptying and thoroughly cleaning the privies of some sixty to one hundred houses, all in the course of half-an-hour or so, without the inhabitants even becoming aware of the operation.

18. NO ENTERING OF PRIVATE DWELLINGS is therefore required, either by day or by night; certainly a great point gained for the refined and sensitive, as thereby a most necessary but always disagreeable business is nightly done, without the inmates of a house ever having their attention called to it.

19. A DAILY REMOVAL OF FÆCAL MATTER is thus rendered practicable, which, for efficiency and regularity, is not equalled by any other plan. It is true that sewerage by water-carriage also effects a constant removal of fæcal matters, but only at a fearful cost to health and to the agricultural interest, as is, we think, sufficiently explained in other parts of our treatise.

20. THE DWELLINGS OF THE POOR are easily dealt with, by their sharing in the benefits of a daily inoffensive removal of fæcal matters, no expensive waterclosets nor high water-rates being required for the purpose, and no unclean habits being ever able to disturb the pneumatic process, after the privies of their dwell-

ings are once properly constructed and duly connected with the subterranean pipe and reservoir system.

21. SMALLEST BULK FOR TRANSPORT.—All other systems, with the exception of that of Messrs. Eichhorn, Röder, and Thorwirth (see page 103), mix water or some deodoriser or other with the excrements, increasing of course considerably their bulk, and consequently the trouble and expense of removal; requiring besides, in many cases, the transport of the deodorisers themselves to a house, and also of the 'fosses mobiles' and 'tonnen,' going continually forwards and backwards. Now all this is different with the pneumatic method, which collects and removes the excrements only, and nothing else, reducing the transport, therefore, to the utmost possible minimum.

22. THE SHORTEST HAUL IN TRANSPORT is secured by the pneumatic engine and tender taking, of course, the nearest way to and from a given reservoir; whilst the water-carriage system, on the contrary, is generally compelled to choose the longest haul from one extremity of a town to the other, as the gradients of sewers and other reasons may dictate.

23. THE SHORTEST LIFT is also obtained of always collecting excrements as near as possible to the surface of the ground, instead of first throwing them into deep sewers, and then often lifting them up again, together with an enormous mass of rainfall and other water, by means of most expensive pumping-stations required by new gradients.

B. FINANCIAL ADVANTAGES.

That the pneumatic system, owing to its great simplicity and strict obedience to the laws of nature, is immensely cheaper than any other hitherto tried, will be manifest to all unbiassed minds; we may therefore limit ourselves to calling attention only to the following main features:—

1. SAVING IN CONSTRUCTION to an enormous extent is effected by dispensing with special water-works, deep excavations, consequent interference with foundations of existing buildings, tunnels, manholes, ventilating shafts, pumping stations, difficult and costly gradients and radii, uprooting of large surfaces of pavement, consequent long disturbance of public traffic in streets and thoroughfares, and many other difficulties, altogether unavoidable in the construction of sewerage works for water-carriage.

2. SAVING IN MATERIAL AND MACHINERY.—The pneumatic sewerage-pipes and reservoirs being all made of iron and of small size, their cost is very cheap indeed compared with the immense outlay of capital called for by heavy brick sewers, or tubular pottery drains, this difference of course increasing with the size of a town; especially when it is considered that the whole expensive machinery of waterclosets, 'fosses mobiles,' 'tonnen,' and other complicated contrivances, is also entirely done away with.

3. SAVING IN REPAIRS.—The material used by the pneumatic system being of an almost indestructible character, protected as it is inside by the fatty substances of the excrements themselves, and outside by lacquer or other chemical preparations, combined with the exceedingly simple construction of all parts, will make repairs of but rare occurrence, or, if necessary, of easy, rapid, and cheap execution.

4. SAVING IN DRAINAGE.—By keeping fæcal matters entirely out of sewers, draining off the rainfall over the surface of streets, and providing simple pottery tubes for household waste water only, and nothing else, an immense sum of public money may be saved, hitherto often quite needlessly spent in old-fashioned cumbrous drainage works. In towns where sewers already exist, they are of course used for carrying off the rainfall and household waters, thus saving the expense of laying new pottery-tubes.

5. SAVING OF LABOUR AND TIME.—When, according to the pneumatic plan, a single engineer, with his engine and tender, and only two assistants, is able to carry into effect the thorough daily sewerage of a group of some sixty to a hundred houses, and all in the course of half-an-hour or so, whilst common transport systems require labourers to enter periodically every single house for cleaning cesspools, or inspecting, removing, and replacing 'fosses mobiles,' or barrels, it must strike everybody that an enormous amount of labour, wages, and time, which is also money, is saved by the new method.

6. SAVING OF BULK, HAUL, AND LIFT.—If not only all water, but also all deodorisers and chemical messes are kept out of privies, the removal of their contents is necessarily immensely cheapened by reducing them to the smallest possible bulk, which besides is taken away by the very shortest haul and the smallest possible lift, and not in some expensive round-about way, or out of great depths, as with the other systems.

7. SAVING IN MANUFACTURING MANURE.—The new system unceremoniously using living human bodies as chemical retorts for manufacturing constantly an unadulterated, universal fertiliser, of course all the vast expenditure is saved, hitherto so foolishly lavished on poudrette and other artificial manure factories, inundation works, and other impotent attempts to evade the laws of nature, and extract sunbeams from a cucumber; all of which attempts, by the stern logic of facts, must invariably show a balance on the wrong side of the ledger.

8. SAVING OF NATIONAL WEALTH.—The chief point, however, gained by the pneumatic system, is the saving to agriculture of the enormous amount of manure which has hitherto been thrown into rivers and the sea—some 500,000*l.* a year for every million of persons, or 1,500,000*l.* for a city like London, or 10,000,000*l.* a year for all the towns of the United Kingdom; to which must yet be added the millions upon millions needlessly drained out of the

land, by importing guano, bones, and other fertilisers, together with immense quantities of breadstuffs and other articles of food from abroad.

C. SANITARY ADVANTAGES.

Those who with an impartial mind have examined the various sewerage and utilisation schemes described in our preceding pages, and compared them with the pneumatic system of rendering human excrements useful instead of detrimental, will readily agree with us that also, in a sanitary point of view, the new method carries off the palm. It may, however, not be amiss to point out, in a few words, what sanitary advantages really are gained by this improvement.

1. NO CONTAMINATION OF THE ATMOSPHERE.—Tracing the process from the very moment excrements are produced to the time they are applied to agriculture, we shall see that not the slightest chance is given for noxious gases to escape. Fæcal matter discharged into the privy-funnel drops at once down to the bend of the perpendicular pipe (see page 119), without being able to soil its sides, on account of the projecting lip, or the form of the basin. Within this bend, a surface of five inches diameter only is exposed to evaporation during an average of not more than twelve hours, in which short time, instead of fermentation setting in, a mere watery vapour arises, which, confined by an air-tight privy-lid, is carried off through the ventilator over the roof. It is during this time, when the matter is yet comparatively inoffensive, that it is allowed undisturbedly to collect. But when enough has accumulated to make its presence disagreeable and dangerous, and to call for active measures, it is most vigorously dealt with. And this occurs at night. After being artfully huddled in a small compass, it is upon a given signal swept, even to the last morsel of it, with the speed of lightning and the concentrated force of thirty tornadoes, through subterranean passages to the air-tight street-reservoir, the house-valve shutting behind it. Without loss of time it is then forced with the same headlong speed and irresistible power into a hermetically closed tender, which when filled is without delay carried off to the decanting stations, where the matter is immediately transferred to air-tight barrels. These are then hurried by railway or steamboat to the country, where ploughs are already prepared to plough it into the earth, or put it under the sod barely twenty-four hours after its collection.

2. NO POISONING OF WELLS.—Both subterranean pipes and reservoirs being made of good iron, no percolation or filtration whatever can take place, such as must invariably occur with cesspools and sewers, even of the most solid masonry, which, as has been explained before, always succumb to the destructive chemical agency of certain ingredients contained in fæcal matter; allowing thereby the most noxious liquids and deadly gases to penetrate the soil and gradually to poison all surrounding wells, cisterns, and other subterranean water-receptacles, to the most serious injury of public health.

3. NO POLLUTION OF RIVERS, HARBOURS, AND THE SEA.—The pneumatic system entirely doing away with the practice of throwing sewage into rivers, harbours, and the sea, the terrible consequences of this folly, which we have described at length in another part of our treatise, are of course also avoided.

4. PREVENTION OF ENDEMICS AND EPIDEMICS.—It is evident enough that by keeping not only the atmosphere, but also all water in wells, rivers, and harbours undefiled by fæcal elements, a great point will be gained by gradually eradicating the very germs of many endemic agues, fevers, and other diseases, and preventing, at the same time, the hitherto but too frequent recurrence of dreadful epidemics, such as typhus, cholera, &c.

5. NO PROPAGATION OF TAPE OR ENTRAIL WORMS, ETC.—Professor Carl Vogt of Geneva significantly ascribes the frequency of the tapeworm in Switzerland to the disgusting practice, almost universally followed in that country, of manuring fields, meadows, and gardens, by simply spreading human excrements over the surface, without even using any disinfectants! Lettuce and other vegetables are thereby of course polluted, the microscopic eggs of the tapeworm, &c., adhering to the leaves, and thus entering the intestines of the unsuspecting consumers of such food. Dr. Volger, in his work 'Die Erde,' vol. ii. p. 303, states also that in some parts of Switzerland a certain species of tapeworm is met with, peculiar only to the Sclavonic race, and thinks it most likely that it was transplanted by Polish refugees, who from the time of Kosciusko have ever found a home in the Alps. It is obvious enough that such a pernicious propagation of tapeworms, &c., cannot take place, if human manure, instead of being applied to the surface, is properly ploughed into the ground.

6. PROLONGATION OF AVERAGE DURATION OF LIFE will be the natural consequence in certain cities, and even countries, hitherto suffering by endemic and epidemic diseases to such a degree, that the annual number of births was often nearly equalled by that of deaths.

7. CLEANLINESS OF THE DWELLINGS OF THE POOR.—It is well known that waterclosets are too costly for the poorer classes, on account of their more or less complicated valve gear, which by the careless handling of the ignorant, the awkward, and children, easily gets broken. Besides, being wholly ineffective without water, they become, among those who cannot afford a liberal supply of this luxury, but too soon a complete nuisance. With the pneumatic system, on the contrary, the removal of the fæcal matter, and the consequent cleansing of the privy pipe, is as regularly attended to in the dwellings of the poor as in those of the rich, it occurring nightly without their let or hindrance. It is actually the interest of the sewerage works to connect them with the system, on account of the valuable manure thereby additionally gained; and thus a practice of cleanliness will be enforced and kept up in just those parts of a town which generally prove the hotbeds of cholera and all other epidemical diseases.

8. NO SUFFOCATING OR BLINDING OF SEWERAGE LABOURERS.—Let our readers turn again to the scene we have described on page 125, of a 'pneumatic' engineer, tending his engine in the open air, and two assistants moving along the streets to turn a number of house valves for seweraging some sixty or a hundred houses at a time; and then glance at the terrible fate of a poor French 'Vidangeur,' who, on entering a pestilential cesspool or sewer, is sometimes blinded by 'la Mitte,' or struck down dead by 'le Plomb' (see page 87). Let our readers look at that picture and at the one presented by the pneumatic system, and then frankly say which they consider most in accordance with the spirit of an enlightened age.*

9. PRESERVATION OF FISH IN RIVERS.—The pneumatic sewerage system not only tends to protect and prolong human life, but its blessings are also shared by the animal creation. Thus, for instance, fishes are preserved in rivers, as the oxygen in the water, so indispensable for their respiration, is no longer absorbed by the decomposition of organic matter.

10. PREVENTION OF CATTLE DISEASES.—Captain Liernur's new manuring system enables a 'progressive' farmer to send his cattle in future to graze on meadows not polluted with putrefying fæcal matter, so that they need no longer 'turn up their noses,' or 'get off their feed.' That by such improved diet many a cattle disease will be prevented, certainly no intelligent man will deny.

* DEATH FROM NOXIOUS GASES.—Mr. C. Jewison, jun., deputy coroner, held an inquest on Saturday, at the Ivy Hotel, Barkerend Road, on the body of Abraham Maxfield, aged twenty-four, who died on Friday evening, in a tank on the premises of Messrs. J. & W. Garnett, worsted spinners. James Maxfield, his son Abraham Maxfield, and Wm. and John Anderson, were on Friday evening engaged in emptying a tank of night soil, received from eight privies connected with a shed on the premises of Messrs. Garnett. The tank is beneath the ground, was seven feet deep, and reached through a man-hole. They had been engaged for some time in lading the night soil out of the tank with ladles which had long handles, and when the night soil had been reduced to about two feet in depth, Abraham Maxfield entered the tank in order to expedite the process by filling a bucket, for his associates to pull up through the man-hole by means of a rope. He made the proposition, in the execution of which his companions seemed not to suspect any involved danger. He went and changed his clothes, and then, returning, descended through the manhole into the vault beneath. He had not been there more than two minutes before he was heard to stumble. William Anderson, then in apprehension, immediately threw his coat off, and entered the tank in order to rescue Abraham Maxfield, but, although both were heard apparently on their feet, they soon fell in the tank. James Maxfield then put a rope down into the tank and Wm. Anderson seized it, and he was dragged through the manhole to the surface. This process was effected with difficulty, for it was thought that Abraham Maxfield had laid hold of his legs. Abraham Maxfield could not be recovered, and he fell down dead in the night-soil. The body of Maxfield was recovered by Joseph Midgley in about half an hour by means of a coal-rake. His death had been caused by the sulphuretted hydrogen gas at the bottom of the tank. William Anderson, who was fortunately rescued by a great effort, had a narrow escape from the same cause. James Maxfield also attempted to enter the tank in order to make an effort to recover his son, but was fortunately prevented by John Anderson. The witnesses said that no one had ever entered the tank for the same purpose, that they had no authority to do so, and that the deceased entered of his own accord. The jury returned a verdict of 'Accidental death.' The deceased leaves a widow and two children.—Bradford Observer, 21st March 1867.——That sewers are no better than cesspools, with respect to the danger incurred by those whom dire want compels to labour in them, is proved by the death of four men in the newly-built Fleet sewer, London, on the 8th of February, 1861. Three of these unfortunates were suffocated outright, whilst the fourth was drowned.—London Medical Times, February, 1861, page 176.

The outbreak of rinderpest especially, that dreadful scourge so often rapidly diminishing national wealth by ruining farmers, will no doubt be at least partially prevented. There are various abstruse speculations and far-fetched theories on the origin of this strange distemper, which, on the whole, must yet be considered an open question in science. The fountain-head of cattle plague has, by some writers, been traced to the steppes of Russia, near the banks of the Wolga, Don, Dniestr, and Dniepr. The first historical records of it date from the great migration of nations after the fall of the Roman empire, and from the times of Charlemagne, whose warlike expeditions were instrumental in propagating it to various parts of Europe.

The old-fashioned practice of manuring meadows on the surface with human and animal excrements, no doubt tends much to spread rinderpest when once brought into a country, because, when fæcal matters are thus exposed to sun and air, as stated elsewhere, immense volumes of microscopic infusoria and fungi are developed, the germs of which are copiously inhaled by the unfortunate cattle grazing on such polluted grounds, and thus both their blood and lungs are poisoned.

The 'Times' of October 27, 1866, says:—'The cattle plague is all but "stamped out." There have been more than a quarter of a million attacks; more than 200,000 poor animals have died, or have been killed, and only about 33,000 are known to have recovered. The total loss to the country must be nearer four millions than three, and Cheshire alone must have suffered to nearly the amount of a million. . . . . In the middle of last century a very similar plague hung about the island for twelve or fourteen years, indeed for half the reign of George II., and there is no reason to flatter ourselves that we are now better prepared against an annual return of the plague than we were in those days.' In the Netherlands, the cattle plague of 1865 is estimated to have caused a similar loss of some 2,000,000*l.*

D. AGRICULTURAL ADVANTAGES.

1. UNDILUTED SEWAGE.—Professor Way, one of the most prominent and active members of the Royal Commission of Inquiry, speaking of the best mode of utilising sewage, says:—'There is no doubt that, if you could obtain the urine and the fæces together by any possibility without the water (used by water-carriage sewerage), you would have a most valuable manure.'*

Mr. Lawes, a member of the same commission, and under whose management the extensive irrigation experiment at Rugby was chiefly made, very justly observes:—'No one doubts if the sanitary requirements of the nation could be obtained by any system which would preserve the excrements of the population free from admixture with water, and present them for use at once, undiminished in value by decomposition, and in a portable and innocuous condition, the land of the country devoted to the growth of human food might be greatly increased in its productiveness.

* Committee Report of 1862, page 45, answer 928.

The question of the sanitary arrangements of our houses was taken up by our engineers before agricultural chemistry was much studied . . . .; but it must be admitted, that no feasible scheme has yet been proposed by which this could be accomplished without the use of water. Such is certainly a great desideratum, *but perhaps a consummation more to be wished for than expected.*'*

Neither of these undoubted authorities upon the subject before us seems to have dreamed that what their profound knowledge told them was the real thing wanted, and what they considered so great a desideratum, should after all be within easy reach. Captain Liernur's Pneumatic Sewerage System actually provides for agriculture what these learned gentlemen so emphatically call for, namely:—

1st. Urine and fæces united.
2nd. Without admixture of water.
3rd. Undiminished in value by decomposition.
4th. In a portable and innocuous condition.

The air and water-tight manure barrels elsewhere described containing the real, undiluted, unspoiled article, fluids and solids together, are delivered to the farmer in a portable and perfectly inoffensive condition, ready for immediate application to his fields, only some twenty-four or thirty hours after the matter has been produced; that is, long before fermentation or decomposition can set in.

2. MANURE, MOIST BUT UNLEACHED.—All intelligent farmers and well-informed agriculturists, unless infatuated with the pet project of swamping lands with volumes of dirty water, know the maxim, that manure should always be moist, but never leached. Now this moisture, so indispensable to the roots of the plants, nature has provided in just the right proportion in human excrements, in the shape of urine and other watery parts, constituting fully 90 per cent. of the whole fæcal mass. These liquids hold in solution the fertilising ingredients in just that exact state of fluidity which is necessary for their absorption by the tender rootlets of plants, when the manure is placed in the soil.

3. FERTILISING GASES.—Soils, as we all know, consist of organic and inorganic parts; when heated to redness, the first burn away, whilst the other remain. The organic parts are animal and vegetable matter in process of decay, but not yet wholly decomposed, and consist always of what chemists express by CHON, namely, carbon, hydrogen, oxygen, and nitrogen.

In a poor, worn-out soil very little of these gases is present, which yet are indispensable for the increase or multiplication of seed, constituting, in fact, the nutritive elements of our harvests. It is true that the principal volume of these elements plants absorb out of the atmosphere by means of the leaves; but a certain quantity is also required in the soil, to mix with other ingredients. In a new and rich soil, there is a larger amount of these fertilis-

* Agricultural Journal, vol. xxiv. part 1.

ing gases, often some 10 per cent., and sometimes even as much as 20 per cent. So much, however, is not necessary, many productive, so-called light or open soils possessing only 3 per cent. Less, however, will not do, as crops, to flourish well, must not be compelled to obtain all their nourishing elements out of the atmosphere only.

4. STORING MANURE IN THE SOIL.—Organic matters in soils pass through successive changes before being entirely decomposed into their original elements, or merged into new combinations necessary for the growth of the plants. Hence time is required for this chemical action to take place, and this is the reason why direct application of manure to the roots is hurtful to vegetable life. To be really useful, manure must be stored in the ground some time before it is actually wanted, which is also beautifully and completely effected in the agricultural system here described, as we shall presently demonstrate.

During the process of organic decay, oxygen is taken in and an acid formed, which, by the addition of more oxygen, changes again into other acids, called organic acids, of which agricultural chemists distinguish no less than five, viz. *humic*, *ulmic*, *geic*, *crenic*, and *apocrenic acids*. Part of the inorganic or mineral ingredients of the soil is also taken up by the plants, forming their stems, fibres, and husks, and furnishing building material for the vesicles, which contain the nutritive elements of the fruit or seed. Without these minerals, no plant can possibly grow or yield a crop.

5. ANALYSIS OF SOILS.—To show the proportion of the various ingredients of soils, we present below an analysis, as given by Professor Johnston :—

INGREDIENTS OF SOILS	Fertile without Manure	Fertile with Manure	Barren
Organic matter	9·70	6·00	4·00
Silica (in the sand and clay)	64·80	83·30	77·80
Alumina (in the clay)	5·70	5·10	9·10
Lime	5·90	1·80	0·40
Magnesia	0·86	0·80	0·10
Oxide of iron	6·10	3·00	8·10
Oxide of manganese	0·10	0·30	0·05
Potash	0·20	trace	trace
Soda } chiefly as common salt	0·40	"	"
Chlorine } chiefly as common salt	0·20	"	"
Sulphuric acid	0·20	0·08	"
Phosphoric acid	0·45	0·18	"
Carbonic acid { combined with the lime and magnesia }	4·00	0·45	"
Loss	1·40	−1·01	0·45
	100	100	100

This table shows, at a glance, what peculiar minerals are wanted to convert a barren soil into a fertile one. To show the great importance of these minerals, we give below also Professor Johnston's analyses of the ashes of various crops :—

INGREDIENTS	Wheat	Oats	Barley	Rye	Indian Corn	Beans	Turnip bulb	Potato tuber
Potash and soda . .	31	26	32	33	32½	45	51⅓	63
Lime	3	6	2½	5	1½	8⅔	11¼	2
Magnesia	12	10	8½	10½	16	6⅓	3	5
Oxide of iron . . .	1	½	½	1½	¼	⅓	½	½
Phosphoric acid . . .	46	44	26	48½	45	33	11¼	18
Sulphuric acid . . .		10½	2½	1	3	4½	15	4
Chlorine	6	¼	5	?	¼	1¼	5½	6
Silica	1	2¾	23	½	1½	¾	2	1½
	100	100	100	100	100	100	100	100

With reference to these two tables, Mr. Nash, in his 'Progressive Farmer' (New York, 1856), makes the following remarks:—

'From an inspection of these analyses, it is reasonable to infer that the first soil would produce any of these crops without manure; that the second would produce good crops, if manured with something containing potash, soda, and chlorine; and that the third would be likely to require more manure than the crop would be worth, and might therefore be abandoned as hopeless. The first contains all the ingredients contained in the ash of plants; it contains plenty of organic matter; and it contains no one of the mineral substances, as oxide of iron or common salt, in such quantities as would be likely to prove hurtful. The second has also a large supply of organic matter; and it has all the mineral substances required for any crop, except potash, soda, and chlorine. This also is free from any hurtful excess of one or two ingredients. The amount of oxide of iron in it is more favourable even than in the first soil. When we look at the third, we find it not only destitute of those ingredients which are the most expensive to furnish, but abounding in oxides of iron to an injurious extent. The owner of three such soils as the foregoing, could he be informed how they are constituted, would naturally cultivate crops of the most valuable kind on the first, as wheat, corn, clover. With regard to the second, he would look into the analyses of crops, and select for it those which contain least of those mineral matters in which the soil is deficient.' We shall presently see, how far the human fertiliser may go towards supplying soils with the mineral ingredients they may happen to be in want of.

6. EQUAL DISTRIBUTION OF MANURE.—To bring, however, the organic and inorganic matters, supplied by the manure, into the proper combinations and forms required by the structure of plants, so as to enable their roots to absorb by election that which they most need according to their peculiar organisation, there is, as stated before, time wanted, not only for that purpose, but also for the equal distribution of those ingredients, so as to impregnate and fertilise the entire soil. This is absolutely necessary for cereal plants, which, growing always in loose soils, obtain stability against winds only by the equal extension of their roots in all directions. Now a soil, fertile only in sporadic spots, could nourish only the roots extending in one direction, causing the slender haums to break down in the other by any sudden gust of wind.

This question of time is one of a series of most beautiful arrangements in the providence of Nature, in so far as it prevents the sudden exhaustion of soils, fertilising agents being always carefully stored up and distributed for the proper time and opportunity, literally to *re*store the elements diminishing in the soil.

7. EARTH THE BEST DEODORISER. — Earth has a remarkable power to deodorise and decompose organic matter: a power, as Professor Way says, which nothing else possesses. This explains the utter failure of all attempts to deodorise excrements by water or chemical mixtures: experiments simply against the law of Nature and those ordainments upon which our health, nay, our very life, depends. Dr. Gilbert Child, in his valuable paper 'On the present State of the Town Sewage Question,' very justly remarks:—'Water is no disinfectant, chemically speaking; and, in our ordinary system of sinks and waterclosets, it is the mechanical power of water only of which we avail ourselves. The difference between the capacity of soil and water to deodorise may be thus illustrated:—If we take a given quantity of refuse animal matter, say two ounces weight, divide it into two equal portions, and putting each in a separate vessel, throw upon one a gallon of water, and upon the other put a pint and a half of loam, or other soil, in a moderately fine state of division, we shall find that in a few days' time the whole quantity of the first has become infected and putrid, while the latter may be handled even without disgust.'

This power to deodorise and absorb solutions containing acids and minerals, the soil has to such an extent as to extract these ingredients also from water if it be only strained through it. Potash, silicic acid, ammonia, phosphoric, carbonic, and sulphuric acids, all most important elements for the culture of plants, are then retained, whilst the water which held them in solution runs off in an almost clear condition. But when water so charged with fertilising solutions flows over the surface of sandy soils already saturated with moisture, these deodorising and absorbing properties of the earth are of course to a great extent neutralised by the very presence of the water itself filling every pore of it, and thereby keeping out those ingredients, which hence float off again, or are absorbed only in a very slight degree.

It would of course be a different thing, if the fertilising liquid could be made to strain through such a saturated light soil, as for instance that in a flower-pot, where the holes below allow the superfluous moisture to run off. To imitate this would, however, require the expensive operation of subsoil drainage.

8. MANURE ABSORBENTS.—But mere sand has no power of retaining fertilising matter. For that purpose carbon and clay are wanted, which may be called manure absorbents and retainers, acting, as it were, as the bankers of the valuable material entrusted to their care, until vegetable life draws upon them. Unless these elements are present in sufficient quantity, no animal manure, even when applied in enormous quantities, can make a soil fit for the growth of plants. The only herbage that can at all

stand such conditions in a slight degree, is rye-grass* (*Lolium perenne*), which, when sown on a naked sandy soil continuously irrigated with diluted sewage, will faintly come up, because its roots and stems have the faculty of drawing their sustenance directly from the liquid. If the grass is then ploughed in the ground, again sown and irrigated, and these operations repeated several times, a sort of mucky humus may at last be formed, which with continuous irrigation may give crops of grass and hay every two years out of three. But the yield can never be commensurate with the value of the manure wasted on it, for the reason that clay, the principal absorbent and assimilator, is wanting, and hence the scheme of Messrs. Napier and Hope, for the reclamation of the Maplin flats, can never be a profitable investment.

Seeing then that soils absolutely refuse to absorb and retain water beyond a certain extent; that there is room necessary between the constituent particles of the earth to hold fertilising gases and salts; and that human excrements have just that exact proportion of moisture required to retain them or hold them in solution for the tender roots of plants, we may well be assured that what Messrs. Way and Lawes have pronounced to be absolutely necessary, can only be effected by applying fæcal matters to the land just in that state in which they are produced in the human body; and of all methods hitherto tried, the new system is the only one enabling us to do so in an efficient, and at the same time in an inoffensive manner. We are further supported in this assertion by Baron Liebig, who in his 'Chemical Letters,' chap. xxxviii., clearly proves that water is by no means the only channel by which plants may be nourished.

9. HUMAN EXCREMENTS THE BEST MANURE.—As we have seen, the tendril roots of plants possess the power to select their food in such combinations of constituent atoms as are best adapted to their special organisations. On page 66 it has been shown that, by adding just a few atoms more of one element or subtracting a few of another, a wholesome substance may at once be changed into a virulent poison. Water, being itself composed of but two elements, if present to excess, may convert useful manuring elements into substances more or less hurtful to vegetable life.

This explains sufficiently why nearly all cereals refuse to yield crops, and run to straw, when land is too wet; and why, in fact, most soils, at least in our climate, require drainage rather than irrigation. Now, by reference to page 75, we see that the ingredients distinguishing a fertile soil from a barren one are, all of them, present in human excrements, and by turning to page 150 we find these ingredients again as component parts of the principal cereals and field fruits. What kind of manure then, we ask, could we apply to our lands with better advantage than just these excrements?

The 'Moniteur' of February 5th, 1867, published a convention, concluded at Lima on December 2nd, 1866, between France and Peru, according to which the Peruvian guano is to enter free of

* The proper English name is not rye, but *ray-grass*, being a corrupted contraction of the French word *ivraie*, which means all sorts of rank herbage.

duty into all the ports of France and her colonies, at a cost of 300 francs per ton of 1000 kilogr.,* this price being liable to an increase or a decline in proportion to any change which may occur in the general market-price of guano in Europe. What an immense relief to French agriculture, then, if in future a farmer may buy at the next town an excellent human fertiliser at the rate of, say, 40 francs per ton; about *one-ninth* of the price of guano, counting the cost of transport from the seashore!

We, therefore, hope to see the empire of France, with Great Britain and the Netherlands, soon take a prominent part in a great social and agricultural reform, which cannot fail to confer the highest benefits on all mankind. Then it will no longer be true what a celebrated French author has said:—

'La statistique a calculé que la France, à elle seule, fait tous les ans, à l'Atlantique, par la bouche de ses rivières, un versement d'un demi-milliard. Notez ceci: *avec ces cinq cents millions, on payerait le quart des dépenses du budget.* L'habileté de l'homme est telle qu'il aime mieux se débarrasser de ces 500 millions dans le ruisseau. C'est la substance même du peuple qu'emportent, ici goutte à goutte, là à flots, le misérable vomissement de nos égoûts dans les fleuves, et le gigantesque ramassement de nos fleuves dans l'Océan. Chaque hoquet de nos cloaques nous coûte 1000 francs. À cela, deux résultats: *la terre appauvrie et l'eau empestée; la faim sortant des sillons et la maladie sortant du fleuve.*'

10. HUMAN MANURE FIT FOR ALL SOILS.—If the question comes up as to what kind of soils are best adapted for the fertilisers ejected from the human body, it is evident that all lands producing human food must be so, the different classes calling merely for a proper variation of quantity, time, and mode of application. That amongst these lands meadows are included, need hardly be told, as we consume also their crops, after they have been prepared and concentrated in the shape of meat, milk, butter, and cheese, through their consumption by cattle.

This cannot at all be said of guano, which is far from being that excellent fertiliser it was formerly supposed to be, ere practical experience and the test of agricultural chemistry had reduced it to its true standard. Thus, for instance, it has been found in various colonies, that the continual use of Peruvian guano, so far from invigorating, gradually exhausts the soil on which sugar-cane is cultivated; so much so, that at last only a feeble plant is grown, subject to various kinds of distempers.

11. SUBSOIL MANURING.—Now let us see how Captain Liernur's subsoil manuring system operates both on arable land and on meadows. The ploughshare first breaks up and turns over the earth in such a manner that the soil which was below the surface, according to the depth given to the ploughshare, is brought up and laid bare to receive seed. At the same time the liquid manure is evenly discharged out of the barrel lying on the carriage frame into the furrow, which a moment after is lightly closed by the scrapers fastened to the rear part of the plough (see p. 128).

* Corresponding to about the English average price of 12*l*. per ton.

That part of the soil, which before was on the surface of the ground and holds a great deal of oxygen, is now turned below to absorb gradually all the fertilising ingredients of the liquid human manure injected into the furrow, in compensation for those it was deprived of by the last crop. Beneath the soil, the most important chemical process of decomposition and assimilation goes on entirely undisturbed, ample time being afforded for a thorough absorption and equal distribution, without the slightest escape of fertilising gases to taint the atmosphere. Now, when in the following season the plough turns up the soil again, it is already found so thoroughly manured that the seed can only be quickened, but not injured by it, whilst, *if required*, at the same time new fertilisers are injected underneath, to act in the same manner upon the following crop, and so on in endless rotation.

It is easily understood that by this system an intelligent farmer is enabled to graduate the amount and power of manure with the utmost accuracy to the peculiar nature of the particular crops he wants to raise, by simply lowering or raising his ploughshare, running the rivulets of manure more or less apart, planting seed between the rills made, and in various other ways easily suggesting themselves to a practical agriculturist. Now, when we bear in mind that this system not only secures to the soil every particle of fertiliser contained in the manure, but at the same time entirely prevents both the contamination of the atmosphere and the infection of water, we ask our readers, was there ever a contrivance which in so simple and natural a manner accomplishes so many important objects?

12. MANURING OF MEADOWS.—When we turn to the meadow manurer (see page 129), we find it just as complete in its appointments and appurtenances as the one designed for arable land. A neat incision is made, if necessary, with a particular knife, moving up and down in front, allowing a temporary passage through the sods, without tearing or otherwise injuring them.

By the same operation the manure is deposited underneath the sods at such depths as the farmer may deem best. Thus removed from direct contact with the roots of the grass, the fertiliser undergoes the chemical process above alluded to, entering into the new combinations necessary for the proper nourishment of the plant, again without the slightest escape of gases, the sods closing always immediately after the passage of the manuring tool.

Grass being in some manner a constantly growing plant, the manuring may take place at any season of the year, as long as the ground is not stiffly frozen or deeply covered with snow, and cattle can continue to graze all the while without feeding upon grass soiled with excrements, as is but too often the case with the old-fashioned plan of spreading manure over the surface of meadows. That cattle do turn up their noses at such foul treatment, all practical farmers know; but that they also get sick of it, and, if they do not actually die, at least give very poor meat, some perhaps will deny, who, wedded to old ideas and habits, do not yet see their way clear to modern improvements, especially if suggested by one who has not himself been raised on a farm. We for our part prefer to be guided rather by the instinct of animals, provided by

Nature herself as a substitute for reason, than by mere routine, and certainly stand by the plain common-sense doctrine, that what cattle refuse to eat and even to smell, cannot at all be a fit source for their food.

Another great advantage is, that by this meadow-manurer, human excreta can advantageously be applied to all kinds of grasses, whilst irrigation with sewage, as mentioned before, answers only with rye-grass, the only species which can stand repeated drenchings, or grow in water. If it is necessary to irrigate meadows in dry seasons, why, in the name of Heaven, let it be done with clean water, and then, no doubt, Heaven will bless the process!

By way of comparison of this system with the only other one in which undiluted human manure is mixed immediately with earth, namely Mr. Moule's, it is evident that the latter, besides the insurmountable difficulty of an enormous transport explained in pages 94 to 97, has the additional disadvantage of producing a compost manure which cannot at all be applied to meadows.

13. INCREASE OF TILLAGE LAND.—But the main advantage this system possesses over that of irrigating rye-grass meadows with fæcal matters in a high state of dilution, lies in the fact, that it can be applied for the purpose of fertilising tillage land; and this advantage can only be properly appreciated, when it is considered, how much more profitable such culture is than pasturage, even for dairy purposes. To make a cow give the largest quantity of milk she is capable of yielding, the food must be composed of clover-grass, turnips with their tops, and other green crops; but to obtain milk of the best quality, which is at the same time rich in butter, her food should be drier, such as oats, beans, bran, oil-cakes, and clover-hay, besides the turnips and green food. None of these crops can be raised with liquid sewage, and all require tillage land for their production. The juicy herbage known as rye-grass, grown on wet or inundated land, gives abundance of milk; but it is watery, and yields proportionally but little butter and cheese.

The advantage will be still more apparent, when it is pointed out, what is now acknowledged by the first and most experienced agriculturists,* that more stock animals, more meat, wool, and dairy produce can be raised, acre for acre, upon plough land than upon meadows, except perhaps in the case of rich natural pasturage. This latter is, however, not often met with, and, when found, cannot stand treatment with the irrigation system. Medium and light lands which, in cultivated tracts, form a very large percentage, and, in fact, constitute the majority of farm lands, yield far more of such produce and pay a higher rent, when converted partly into tillage land and partly into good pasture, than by remaining grass land entirely. The importance of this fact will be understood, when we call attention to the necessity of keeping the markets supplied with an abundance of animal food, to maintain both the mental and physical vigour of the people in our climate; above all, of that portion dwelling in cities and towns.

As an instance of the above assertion we may point to a farm of 400 acres of fair pasture land. This will yield, as is well known,

* Such as T. K. Fowler, Esq., of Aylesbury, and others.

besides the dairy produce, from 600*l.* to 800*l.* worth of meat and wool. But if one-third of the same soil is brought under the plough, and worked in a fair course of crop rotation, for the growth of green crops, &c., it will yield, besides the same amount of dairy produce, fully 1,000*l.* worth of beef, mutton, and wool, together with some 600*l.* to 800*l.* worth of corn and seeds, and a large quantity of bacon, pork, and poultry; in other words, the farm, instead of the above 600*l.* to 800*l.*, will yield some 1,600*l.* to 1,800*l.*, being 1,000*l.* to 1,200*l.* per annum more than in the other case. This increase of produce has been shown by actual practice; but we doubt not that, if the tillage land were increased to two-fifths or one-half, keeping the remaining three-fifths or one-half in pasture, a still larger yield might be had, and the advantage of such management is still more obvious on very light soils, which cannot grow good natural grasses. Allowing for the difference in labour expended, it is estimated that the medium and light lands can be made two-thirds more productive and remunerative under a good system of mixed husbandry than by pasturage only. It is thus evident that bread and meat would become more abundant and cheaper, by breaking up with the plough a large proportion of the present inferior old pastures.

14. INCREASE OF PEASANTRY.—A writer on the agriculture of Ireland estimates that the light soil, which constitutes one-half of the entire surface of the island, and two-thirds of the area under cultivation, would yield far more stock animals, meat, wool, dairy produce and grain, if farmed as above stated instead of by pure grazing. The labour required for the additional 4,000,000 acres thus given to tillage would, according to the said writer, provide work for some 600,000 men, which represent the heads of families of a population of 2,500,000. This, in point of national economy, is a matter of the highest importance. If a country is powerful in proportion as it is inhabited by a robust and vigorous peasantry, it is evident that any scheme which increases the area of pasturage, not only diminishes the produce of the soil, but also lessens the strength of a nation by mere diminution of numbers, which no doubt is another most serious objection against the irrigation scheme.

15. SUBSOIL MANURING SUPERIOR TO IRRIGATION.—We do not mean to say, what many, among others the great Liebig, have insisted upon, that the utilisation of sewage liquid, as produced by waterclosets, for growing rye-grass on sand is impossible. There is no doubt that this herbage may be thereby produced, even, perhaps, upon such barren places as the Maplin and Dingie Sands on the Essex coast, if the many conditions and requirements are properly complied with, and the matter is managed rightly. At the same time we do not accept as a guarantee even of such success the apparent satisfactory experiments recently made. These consisted in levelling a ten-acre lot of barren land, near the Great Northern London Sewer outfall at Barking Creek, and covering the ground with one foot deep of sand brought from the above-named sand-banks on the sea-shore, which was then sown with rye-grass and treated with sewage liquid. We learn, from the report to the Metropolitan Board of Works, that this test proved satisfactory, to

all appearances, in so far that a good crop of grass came up, which made good food for cattle; but much more, it seems, cannot be be said about it, for we find, among Captain Liernur's notes, a letter addressed to him by Mr. Hemans, the chief engineer of the company, to the effect that, not before summer (1867), will the works be sufficiently advanced to give particulars, or enable us to judge properly.

To our mind, however, it is not a fair test to shovel, handle, and transport a given soil on to another subsoil, for the purpose of finding what it may be capable of doing in its original place. The material must in that case have obtained different qualities by the very fact of this manipulation, and the sweet-water subsoil, as found on the bank of the Thames, is not by any means the same as the sea-drenched hard sand-bank of the coast. But however this may be, there is no doubt but that such grass can be made to grow somehow on such places, and with such kind of manuring; and there is also no doubt but that, to do so, is far better than wasting so much good fertiliser by throwing it into the Thames, as has hitherto been done.

But the question is: 1. Will it pay? that is to say, will the crops produced pay anything like a dividend on the capital of 2,100,000*l.* (see page 79) which is required to bring the Maplin Sands farm into operation? 2. Will the crops, or rather the beef, butter, and cheese produced thereon, be anything like commensurate with the value of the fertilisers expended in obtaining it, which, supposing North London to have two million inhabitants, amounts to fully one million pounds sterling per annum? 3. Could not this immense amount of fertilisers be turned to a far better account; and is it not now well known, that it is more than capable, by its application in an undiluted state to tillage land, of raising sufficient food for the two million people who produced the manure?

But, perhaps, we cannot more forcibly point out the shocking waste of manure the irrigation scheme necessitates, than by stating that the area usually allotted for utilisation in this manner is one acre for every one hundred inhabitants. Now, the utmost that an acre of rye-grass, manured with the fæcal matter of one hundred people, worth fully 50*l.* per annum, can bring, is only about 6*l.* per annum! The sewage farm of Croydon,* which again and again is pointed to as an example of the brilliant success of the irrigation process, comprises 312 acres, which receive the sewage of a population of 35,000; the whole crop raised thereon brings annually about 1,800*l.* and the manure is worth 17,500*l.*! Can any more reckless waste be imagined, considering how easy and simple it is to produce far different results? And what can be said of a system of utilisation, or of farm-management, in which the manure is worth ten times more than the crops, except that those who advocate it do not, or perhaps will not, understand the question?

16. PRINCIPLES OF THE NEW UTILISATION SYSTEM.—But let us now turn to Captain Liernur's system. As already described on page 127, he applies the manure to what he calls 'fallow intervals, which bear a proportion to the alternating planting beds of 2 to 3;

* See also pages 28 and 29.

that is to say, two-thirds of the field bear crops, while one-third lies fallow, and is manured and tilled preparatory to the next season, at which period this part changes place with the other one. This changing of places of two-thirds on one-third is effected by 'overlapping;' that is to say, the planting-beds being 60 inches wide, and the manured soil only 40 inches, the former is placed centrally over the latter, thus overlapping each side 10 inches, which, considering how thoroughly the earth is worked and saturated with manure, can be done without any loss in the growth. The planting-beds are worked by drill-sowing and cross-rotation in the most approved form.

17. ALL MODERN IMPROVEMENTS APPLICABLE.—Now here is a system which takes in all that modern agriculture has discovered to be most advantageous, and adds two important improvements. Under the former head come principally the rotation of crops and the planting in rows instead of broad-cast; while under the latter we have 'manure-ploughing' and 'fallow-strip-fertilising.' Supposing that these pages will be read by many to whom the subject we treat of is new, we will shortly explain the advantages of these improvements.

18. ORIGIN OF CROP-ROTATION.—Already more than two thousand years ago, farmers cultivated their fields by leaving them as meadows for some time, whenever they became exhausted or yielded poor crops; and thus the natural droppings of cattle grazing on them, with the addition of organic elements obtained from the air by the herbage growing there, slowly enriched the soil again, so that, after a while, it became in a measure capable of growing grain once more.

Increase of population, however, compelled in time the more continuous growth of grain crops, for which reason the fields were laid fallow only every third year, besides being strongly manured and broken up with the plough, so that air and rain water could enter and impart new vigour to the soil. To obtain the manure, however, meadows were required, at least twice as extensive as the plough land, unless cattle were fed with grain, which of course could only in exceptional cases be thought of. This mode was practised already by the Romans, who divided and worked their plough land in the following manner:—

Rotation.	First Field.	Second Field.	Third Field.
First year .	Fallow	Winter grain	Summer grain
Second year	Winter grain	Summer grain	Fallow
Third year .	Summer grain	Fallow	Winter grain

Charlemagne introduced this, the oldest system of rotation, generally in Europe. When population became still more dense, attempts were made to grow in the interim something also on the fallow field, and beans and peas, &c., were the plants first used for that purpose; requiring, however, also much manure to obtain any crop. This difficulty continued until the introduction of clover, which for 'fallow culture' proved indeed to be of inestimable value. This herbage, which through its dense growth chokes all weeds out, has also powerful roots, which open and loosen the soil, thus admitting air and rain, with broad foliage shading and keeping it moist; and as this plant itself derives most of its food from the atmosphere, it actually leaves the field more fresh and vigorous than it was before. The culture of this plant caused of course an increase of tillage and a corresponding diminution of pasture land.

19. PLANTING IN ROWS.—These peculiarities of clover also led first to the practice of planting grain in rows instead of broadcast, through the advantage which resulted from sowing it between the corn plants of the preceding year; the vigorous herbage choking out all the weeds, keeping the soil open and moist, for the grain to develop itself better, and yielding a good crop of excellent grass or hay afterwards. Many farmers tried to cultivate this plant exclusively, until experience showed it would not do to charge a field with it every third year; at least, the yield was insufficient. This led to a succession of crops, in which grain was followed by clover, legumens or roots, so that clover was only repeated every fifth or sixth year. Such a rotation turned out to be a great step forward, for the green crops which now proved a more profitable food for cattle than pasture grass, caused a further increase of tillage land, much improvement of the latter, and increased abundance of live stock and animal food. In Belgium, where cattle are mostly fed with produce from ploughed land, the great quantities of good manure thus obtained and saved, yields proportionally large crops of breadstuffs.

It will thus be seen that, by rotation of plants, crops can be had from every field without leaving them fallow any season; and that by planting in rows or with drills, inter-culture has become practicable; two improvements which largely increase the agricultural produce of the total area under cultivation.

20. EXHAUSTION OF THE SOIL PREVENTED.—But all these ingenious processes did not, and cannot, prevent the gradual exhaustion of the soil, unless manure is applied, containing a quantity of mineral elements equal to that the crops take from it, and unless also sufficient human organic matter, and principally nitrogen-holding substances, are given; for these, and especially the latter, 'drive' the plants, and make the fruit they bear manifold.

At first the only manure put on land was the solid excrements of cattle, while the urine was allowed to waste. It was, however, noticed that the roadsides receiving the droppings and leakings from the manure carts in passing by, became more fertile than the fields, which received the then so much prized solid manure, and this led to the eventual saving and usage of the liquid. Of course this occurred before chemistry was applied to agriculture, and fully established the value of these substances. The excreta of men were, however, almost completely lost, and even when here and there some market gardener used them, he had to do it secretly, or lose his customers; such was the repugnance felt against food obtained by means of these so-called impurities. The fact is, man shares with the brute the peculiarity of having a greater abhorrence for his own fæces than for those of other beings. The loss of valuable material thus incurred was tremendous, for the fæcal matter of man does not only contain the various mineral elements of the vegetables directly consumed by him, but also those which are indirectly obtained from animal food, and which are of course likewise derived from the soil. The importance, then, of giving these elements back to the earth, which is the fountain head of all our food, was in course of time duly appreciated. But the question was,—How to do it?

21. Improved Mode of Manuring.—We have already seen that every method hitherto tried was more or less a failure, and that the only mode which to a small extent effects utilisation, namely irrigation, is open to so many objections as to make it in a civilised country absolutely a nuisance not to be tolerated. At last Captain Liernur points out a way. And in accomplishing the purpose he aims at two things: 1. to do it without loss and offence; 2. to do it usefully at all seasons, because the produce of manure is also without intermission, all the year round; otherwise, the work would be but partially accomplished.

The first point is effected, *a*, by obtaining the manure pure and unadulterated, and diluted with as little water as possible, as already explained; *b*, by not allowing it to become weakened by premature fermentation, which involves always a loss of ammonia, that most valuable of all fertilisers; *c*, by mixing it at once with the soil itself, for the use of which it is designed. This is done by means of the ploughs already described, and the advantages of this method are so obvious, that it is almost superfluous to state them. The formation and protection of compost manure heaps can never be so perfect, as not to throw off a great deal of ammonia, which is not only a loss, but very offensive and unhealthy; and this is especially the case during the act of loading and unloading, carting and spreading it on the fields, for the purpose of ploughing it in afterwards. It cannot but be a saving of fertilising material and of much labour, to combine these operations in one, as here proposed.

As there are, however, a great many routine people, who never dream of doing anything unless their great grandfathers have done it before, even if it is the best thing for their interest, and as this species abounds largely among farmers, we may as well state that the best agriculturists in the world have substantially practised this mode for thousands of years. We allude to the Japanese, who, as stated already, with an area under cultivation smaller than that of Great Britain, manage to produce all the food wanted for their large population, and still have a surplus for export. They simply place their excrements, mixed and fresh as produced, in shallow trenches, which are immediately covered up again, and sow the seed or plant in the ridges between the trenches. The only difference between their system and that of Captain Liernur's is, that the Japanese employ manual labour and ill-constructed tools, while the captain uses horsepower and the best plough that can be found.

22. Professors Johnston and Voelcker's Approval.—The system is further supported by the text-books of some of the ablest and most scientific agriculturists of Great Britain, namely Professors Johnston and Voelcker, the latter being consulting chemist to

the Royal Agricultural Society. As an instance see question 289 of their 'Catechism of Agricultural Chemistry and Geology,' which reads as follows:

'*How do you best prevent loss in fertilising matter?*

'Answer. By carting the manure upon the land, and ploughing it in as soon as possible.'

Now, as in the new system it is carted and ploughed in at the same time, it is evident that this is the most saving method.

23. APPROVAL OF MR. LAWES.—Among Capt. Liernur's copious notes we also find a letter from J. B. Lawes, Esq., of Rothamsted, St. Albans, F.R.S. and F.C.S., one of the members of the 'Royal Commissioners of Inquiry into the best mode of Utilising Sewage,' addressed to him under date of November 13th, 1866, upon the subject of his system, in which the following passages occur: 'I fancy that, however rapidly you remove the excrements, there will be always a sufficient amount of old matter in the plough barrels to cause decomposition, and that your manure, before you can apply it to the soil, will be in a high state of putrefaction. In an agricultural point of view, I see no objection to this, provided the matter is placed *below* the surface of the soil. . . . .

'With regard to the application of the sewage to arable land, the first and most important element to be considered is evenness of application. (This the plough accomplishes with mechanical accuracy.) '2d, that the manure should be covered with the soil as soon as possible. Although it is better to have the manure near the surface of the soil, it is of no consequence if it be covered to the depth of five or six inches.'

These statements, made by one of the most eminent agriculturists of England, confirm completely the principles involved in the new system. There is no doubt that the old matter adhering to the interior surfaces of the barrels (and it would be too much labour to clean them) will act upon the fresh excrements somewhat like yeast upon dough, and start its fermentation. Before, however, it can make head and become dangerous, the barrels are emptied into the furrows, so that the manure has then received the property the farmer justly prizes so much. This fermentation is modified into another process on being mixed with the soil, when a sort of natural compost manure is formed on the very spot required, and the whole is gradually converted into those solutions and combinations which constitute the food of plants.

24. PUTREFACTION WITHOUT LOSS OF FERTILISER.—In Professors Johnston and Voelcker's Catechism we read, question 288: '*Is it desirable to allow dung to become quite rotten before it is put on the land?*

'Answer. By no means; for although rotten dung is more valuable, weight for weight, than fresh, it is difficult to convert the latter into rotten dung without loss.'

The objection here made has reference to the old mode of carting and afterwards ploughing it in; but rotten dung is evidently preferred, if it could be applied without sustaining loss of ammoniacal gases in the process. By the new system this can be done; and thus, even if the matter had gone entirely into a state of putrefaction, there would be no harm.

25. PRINCIPLES OF FALLOW-STRIP MANURING.—The second purpose aimed at by Captain Liernur (see page 160) is effected by his fallow-strip manuring system. He states that the considerations which led him to this method were:—

a. That crops produce more abundantly in proportion as the soil is well kept opened, loosened, and cleaned of weeds, all of which can only be accomplished by 'inter-tillage or inter-culture.'

b. That the yield is larger in proportion as the manure has had time to dissolve and incorporate itself with the soil; in other words, that a better crop can be raised on a soil manured a year previously, than if manured only a month since.

What better can, therefore, be done, than to apply a manure, which must be usefully disposed off the whole year round, to those very intervals left for tillage which of course are at all seasons open for that operation? But as room is wanted to work and manœuvre the plough, Captain Liernur divides the land into alternate strips for planting and manuring, giving the latter at once the 'elbow room' required. He then takes advantage of the second consideration mentioned above, namely, the long time required by the manure to dissolve and diffuse itself, and makes the planting bed one-third larger than the tillage or fallow beds; rightly conceiving that the apparent loss of area sustained by having one-third of the field 'fallow,' is amply compensated by the highly fertile condition of the soil, obtained through so much tillage and complete manure assimilation; a condition rich enough to allow a planting bed of sixty inches in width to be placed centrally over a soil actually worked and fertilised only forty inches wide, as is practically the effect of this system. The result will be, a much larger crop can be raised from the two-thirds area, than otherwise from the whole field.

Any one at all acquainted with the effect of thorough tillage and long-time manuring upon crops, will readily understand and know that this is fully and in all respects correct, and that the new system is based upon what nearly every farmer daily experiences. In fact there is no doubt but that the knotty sewage utilisation problem is now fairly solved in a most simple and practical manner; and if he be a most meritorious and useful man who can make '*two grains grow where one only grew before*,' and raise two pounds of meat, where one pound was formerly with difficulty procured, Captain Liernur has succeeded in bringing about an improvement, which will bestow as great and as lasting a benefit upon mankind, as any other discovery or invention made during the last and present century; and we sincerely congratulate him on the magnificent result of his labours, providing, as it does, the first necessaries of life, namely, abundance of food and public health.

26. SUCCESSFUL EXPERIMENT OF FALLOW-STRIP MANURING.—But without at all wishing to detract from the merit of Captain Liernur's invention of fallow-strip manuring, we must state that, in this respect, he has been partially forestalled by the experiments of others, the success of which, however, goes completely to establish the correctness of his theory. We allude to the fallow interval

tillage, practised by the Rev. Samuel Smith, M.A., vicar of Lois Weedon, Northamptonshire. Our attention was first called to this by a very able article in the 'London Telegraph' of February 28, 1867, and having since read up and examined carefully the subject, we find the statements made therein substantially so correct, that we cannot do better than quote them.

'The Rev. Samuel Smith,' says the editor, 'is noted in the agricultural world for having carried out, upon a portion of his glebe, a most wonderful experiment in "successive" corn-growing. The "Agricultural Gazette" pays this tribute to his memory: "Among the names of those to whom the science of agriculture has been in our own day indebted for illustration and advancement, it would be difficult to find one more deserving of note, more entitled to lasting honour and appreciation. Those only who have read his brief but most remarkable little work on 'Lois Weedon Husbandry' can form any judgment of the valuable qualities of mind and powers of close observation which he gave to the task he undertook, namely, of vindicating and practically exhibiting the truth that lay partially developed in Tull's theory of the nutrition of plants; and those only who have enjoyed the privilege and pleasure of visiting the scene of his admirably conducted and successful course of experiment can form an idea of the deeply penetrative mind and the impressive sweetness of disposition of this ripe scholar and Christian gentleman."

'Without entering into any examination of what Jethro Tull really did teach, the points wherein Mr. Smith differed from, or rather went beyond, his great instructor, may be briefly stated. At a time when tillage implements were of a rude description, and arable husbandry was almost entirely unmanurial, Tull completely established three propositions—first, that inter-culture amongst growing crops is a necessary operation in well-conducted farming; second, that adequate mechanical tillage is an economical substitute for manure; and third, that thorough tillage is also competent, with or without the aid of manure, to secure the profitable growth of any given species of cultivated plant, year after year, on the same ground. At first derided, at last universally appropriated, Tull's maxims have become the foundation of modern practice in the culture of all roots, of many green crops, and certain kinds of grain. Tull conceived that the rootlets of plants "depastured" (as he called it) upon the superficies of minute particles of earth, and that, therefore, to feed a crop with all the nourishment it needs, an abundance of this pasture must be provided by pulverisation, effected partly by mechanical tillage, partly by air and moisture introduced by this means into the soil. And farmers now are fully alive to the stimulating power of ploughing and stirring the ground between rows of plants sown in rows wide apart for this purpose.

'But the soundness of the theory is still disbelieved in, and the practice repudiated in relation to cereals—the drilling of wheat and oats and barley being adopted mainly as a facility for cleaning the crop of "annual" weeds. Tull himself had grown small but remunerative wheat crops year after year on the same land, and without manure, disproving the supposed necessity for what is called the "rotation" or alternation of different crops; and

Mr. Smith devoted his leisure to the delightful employment of testing Tull's principle to the uttermost. If that mingled mass of oxides or rusts of certain metals which we call "earth" really held an inexhaustible store of plant food within it, or had the power of acquiring this fertility in proportion to its divisional treatment by tillage, there could be no valid reason for limiting mechanical operations, as Tull did, to the few inches of ground called the "staple;" for if sufficient pabulum for a prolific wheat crop cannot be procured in this thin stratum, why not search deeper with our tools, and try if successive crops will not find pasture enough in a comminuted subsoil? Mr. Smith dug his way inductively into the exhaustless fecundity of his clay subsoil. The details of his husbandry would make too long a story for this paper; but in general his plan was this—he sowed his wheat in strips of three rows each, the rows being ten inches apart, and left between the strips bare intervals of forty inches breadth, which he followed by spade, fork, and horse-hoe. The next year's wheat strips were sown upon these intervals, and the strips of stubble dug in four fallow spaces.

'Absolutely, each crop stood upon strips of land that had been bare-fallowed throughout the previous year; but so extraordinary was the effect of digging and horse-hoeing the fallow intervals for next year in close proximity to this year's growing plants, that the area occupied by the wheat strips—that is, half the surface of the field—was found to yield in measured produce of grain fully double what the same area would yield if, after a year's bare fallow, the wheat were sown "together," or in one whole plot, without interlined strips of fallow; that is, each row gave an increase of 100 per cent. from the mere circumstance of being what a printer would call "spaced out." Mr. Smith's maximum crop gave 40 bushels per acre over the whole field; or, to state the fact in another way, half the field (in the form of 30-inch-wide strips) bore a crop of 80 bushels per acre; while the other half of the field (in 30-inch-wide tilling strips) was dead fallowed for the next year's crop. Mr. Smith, however, preferred to speak of his wheat as grown annually without intermission on the whole field.

'The average produce of the first eight years, beginning with the harvest of 1847, was fully 34 bushels per acre—the whole area within the boundaries of the field being included in the measurement; for the next four years (1855–1858) the yield averaged 38¼ bushels per acre; and in another equal period (1859-1862) the average was 33 bushels per acre. The crop of 1863 thrashed no less than 40 bushels per acre, which had been equalled before both in 1855 and 1858; and the last harvest of which any account has been published (1864) produced 32 bushels per acre, this being the eighteenth wheat crop in yearly succession. The average yield of the last ten years was 35¾ bushels per acre, which is just 1¾ bushels in advance of the average for the previous eight years. As to quality, Mr. Smith usually made the price of the best red wheat in his market; and the quality of his latter samples surpassed that of the earlier. No manure, animal, vegetable, or mineral, was ever applied to the land during all this long course of incessant corn-bearing; mechanical tillage did it all. Indeed, the length and bulk of the reedy stems and broad flags of the "straw," and the weight of the huge heavily loaded "ears," would not bear any forcing by manure; that is, heavier crops would have "gone down" flat, and failed to ripen properly.* This was the Lois Weedon experience with corn, which is thought an "exhausting" or manure-loving crop; whereas roots and green crops, which are looked upon as acquisitive or fertilising crops, would not respond to Mr. Smith's treatment unless he plentifully pampered them with manure. The effect upon the land of eighteen years' wheat-growing without manure was that a good brown heavy loam, equally good and fertile to a depth of 1½ to nearly two feet—for to this extent did the spades penetrate, accomplishing a perfect "inversion" of top and bottom "spits"—took the place of the original 5-inch staple and the 13 to 18 inches of raw clay subsoil which used to lie under it. So far from "exhaustion" coming in view, the land became not only ameliorated, but greatly enhanced in value. Mr. Smith's annual profit upon his outlay was also large; though he sold the grain at low prices, and set a moderate valuation upon his straw, which was all carried away and applied as manure to other land.

'It is remarkable that the success of the Lois Weedon wheat-growing has never thoroughly commanded the sympathy of practical men. If Mr. Smith had happened to win his great results by the use of horse-drawn instead of hand-worked implements, his practice would probably have found numbers of eager imitators. But it will be a lasting reproach to British husbandmen if they allow the whole experiment to die, merely because hands are not numerous enough, over thousands of farms, for a slavish copy of Mr. Smith's manipulation. The magic power lies in the tillage, not in the tools; and it is a poor compliment to modern agricultural art, to think that it cannot adapt the Lois Weedon system to implements worked by animal or steam power traction. In fact, the "Journal of the Royal Agricultural Society" for 1865 does contain a paper describing four years' experience of the strip-cultivation of wheat, in which the plough, subsoiler, grubber, and horse-hoe, the harrow, drill, and roller, were the implements employed. The whole process is explained, every item of outlay stated, the annual profit fully proved, and a system suggested for introducing with advantage two or more successive white-straw crops in rotation. The writer, Mr. John Algernon Clarke, concludes his essay in these words: "I know that it is difficult to move the mind of a practical man out of its habit of settling things from general considerations. I shall be told that an extension of wheat culture is not advisable, because roots, clover, and cattle crops have of late years answered better. But what can the wheat crops that don't pay possibly have to do with my wheat crops which will pay? The entire case rests upon the low cost of production by my method, in comparison with the cost of a wheat crop in ordinary farming. I raise two good wheat crops in succession for 5*l*. 10*s*. per acre each (every source of outlay included); and at the same time, and for the self-same money, I am following and cleansing the ground in readiness for roots or other

* The writer, in the latter statement, is right enough; but when the planting are *manured*, as in Captain Liernur's system, the 'rows' can be placed closer together, and thus produce even a larger crop on the ground actually planted than the 80 bushels got by Mr. Smith, without danger of blight, or of falling down, and mildew.

of the third year's crops. Can any other system show an economy of expenditure like this?"

'We believe that a few attempts at the spade culture of annual crops of wheat have been made in different parts of the kingdom, some successfully, others not. We have seen in a traveller's volume an account of a "Lois Weedon" experiment in Normandy; and in the spring of 1866 Mr. Smith received a number of earnest applications for information from persons in Canada. We may hope, therefore, that whatever of sound principle was demonstrated over and over again in his protracted and astonishing experience will not be lost to the world; that future wheat fields will bear in their beautiful triple lines the indelible mementoes of his thoughtful toil; and that thus, as well as in the fruits of a good ministry among the villagers whom he loved, his "works" will long "follow him."' *

What more need we say of the great simplicity, truth, and practicability of Capt. Liernur's new agricultural improvement? For though we do not agree with all the enthusiastic conclusions of the above writer, who seems to argue that mere tillage can prevent exhaustion, there is still no doubt of the high fertility of soil obtained by strip-interval culture. But, without manure, exhaustion must come, sooner or later, for no amount of manipulation and loosening of the earth can bring back the minerals taken from it year after year. The farmers in Holland have a maxim, which is very expressive upon this point. 'To obtain large crops,' they say, 'and to bring it about that our children and grandchildren can obtain them too, three things are wanted upon the land, namely:— 'First: *manure*—second: *manure*—third: *manure*! after which it is considered advisable to keep on *manuring*!'

27. CERTAINTY OF REVENUE.—It is evident, then, that town corporations may derive a handsome revenue by adopting the mode of utilisation here explained. It will and cannot but accrue to them in the largely increased yield of any farm leased or worked by them. And such a management is, in the commencement, the only practicable way for obtaining any profit from the manure; for many farmers will certainly not buy it, until after they have perceived its value during some ten or twelve years, in practice on the farm 'of somebody else.' Then, indeed, a ready sale will be found for it at its full value, with this advantage to the buyers, that they need not be afraid of the imposition practised by certain artificial manure manufacturers.

28. NO ADULTERATION OF MANURE.—And the risk to which farmers in that respect are exposed is greater than many will think. Thus on the Continent, for a long time, manures were sold composed of over fifty per cent. water, and the remaining half of insoluble matters, chiefly lime and sand with a trace of nitrogen! Another sort was found to be composed of—

* The importance and merit of this extract is our apolog for quoting it at such length.

Sulphuric acid	30·00
Organic substances	1·60
Oxide of iron	14·00
Lime	12·00
Soda	3·00
Sand	10·00
Water	29·00
Chlorine	0·40
	100·00

which worthless compound was readily sold to manure-needing farmers at 12*s.* per 100 lbs. before its true value was discovered.

Such impositions cannot happen with the manure brought into use by the new system, for the human body manufacturing it is under the control of mother Nature herself, who never yet was found guilty of deceit; and the giving this munificent and honest dame a chance of bringing her carefully prepared wares into the market, is another great merit which Captain Liernur's system may well boast of.

29. PREVENTION OF VEGETABLE DISEASES.—Another very important point to which we call attention, is involved in the following question. Are our farmers so very sure, that potato-rot, wheat-rust, and similar vegetable distempers, are not in a great measure due to the myriads and myriads of parasitical infusoria and fungi, immediately generated whenever fæcal matter is exposed to air, heat, and moisture, as it but too often is by being spread in the shape of manure over the surface of fields?

Even if it should upset the favourite doctrine of many a learned botanist or agriculturist, there is so much reason in this hypothesis, that we heartily subscribe to it, stating once more our implicit belief that a kind Providence never intended disease of any kind, vegetable or animal, as an ultimate aim or primary design; but that all such distempers must rather be ascribed to the violation of some law of Nature.

30. SUMMARY OF ADVANTAGES.—The agricultural advantages of the new system of sewage utilisation may be shortly stated as follows:—

a. A manure is brought into use, which can be applied to all tillage land, whether level or sloping, heavy or light; and all crops can be raised with it which yield human food.

b. The manure is transportable, and can thus be sent cheaply in any direction.

c. The mode of manuring prevents the loss of any fertilising elements, and gives no disagreeable effluvia whatever to the neighbourhood.

d. By the long period of a whole planting season being allowed for the assimilation of the manure with the soil, a far more useful effect is obtained therefrom than by the old method of carting it on the field and ploughing it in comparatively but a short time before sowing.

e. By the one-third 'fallow-interval system' for simultaneous tillage and manuring, a larger crop can be obtained from the remaining two-thirds area than could be raised from the whole field, whilst the fertility of the soil is fully maintained.

f. By depositing this species of manure below the surface of arable soil or the sods of pasture land, it will, by its rapid assimilation with the earth, not start into life or foster the growth of microscopic fungi or animalculæ, such as *cysticerci*, *teres*, *ascarides*, *tæniæ*, &c., which always occurs when such a decomposing substance is exposed to the action of the sun and air; and thus the danger of vegetable and cattle diseases resulting therefrom will be avoided.

g. This system of manuring will render very profitable the conversion of large areas of pasture into tillage land.

h. The larger growth of green crops, &c., obtainable therefrom, will yield the country a greater abundance of animal food than could be had from pasture land; and such nutritious food will much increase the physical and mental vigour of the nation.

i. The larger extent of plough land thus gained will provide labour for a far greater number of men than pasture land, and will thus support a proportionately larger number of families.

IX. APPLICATION OF CAPTAIN LIERNUR'S SYSTEM.

1. Estimate of Cost.—In order* to indicate the salient points whereon to base a calculation of cost and other incidents due to introducing the new system, we will take an illustrative town of 100,000 inhabitants, or a corresponding part of a larger city, with an average rate of density of 20,000 per square mile, and having streets intersecting each other at right angles 300 feet apart. The ground occupied would then be five square miles, or about two and a half miles diameter. Supposing that a privy closet and a branch pipe were required, at an average, for every six and a quarter inhabitants, making thus 16,000 closet fixtures with branch pipes of, say 100 feet length, then the cost of the whole pneumatic sewerage scheme may be estimated, with the average prices of iron and other material, at 350,000*l*. This sum includes twelve air-pump engines (allowing two for repairs), thirty-three pneumatic tenders (three for repairs), sixty horses, four decanting station buildings, with all fixtures complete, 10,000 barrels,* all the main and branch pipes with necessary valves, also branch pipes to public urinals, and all labour and superintendence.

2. Annual Receipts and Expenditure.—The annual gross receipts, as derived from crops raised on the sewage farm, or by direct sale of manure, for 100,000 inhabitants at 10*s*. per head, would be 50,000*l*.

During the first thirty-five years the annual expenses would be about as follows :—

Interest at 5 per cent. on a capital of £350,000 . .		£17,500	
General manager's salary	£500		
Assistant manager "	250		
Treasurer "	350		
Clerk "	200	8,400	
Four decanting-station masters . . .	600		
Twelve machinists' wages	1,500		
Sixty labourers "	5,000		
Feed, shoeing, &c. of sixty horses			
Fuel for engines		3,600	
and renewal of worn-out plant and stock		5,000	
Oil, taxes, contingencies,		2,500	
Expen			£40,000
Receipts as above			50,000
Clear annual			£10,000

3. Financial Scheme.—With these data before us, the following advantageous financial scheme might be suggested. Let the required capital of 350,000*l*. be raised by the issue of 3,500 bonds of 100*l*. each, having a coupon sheet attached for 5*l*. coupons, payable during thirty-five years. Let the surplus of

* If a town or company keeps a steam plough, for ploughing in the sewage, even during hard frost or deep snow, the number of barrels is of course considerably reduced, none being required for winter storage (see page 130).

10,000*l.* be annually devoted to paying off or buying back 100 bonds as determined by lot, but the holders who then receive their capital back to continue in possession of the coupon sheet, and draw the annual interest therewith just as before; then of course *the holders of bonds drawn the first year will receive their money back, and besides, during the course of thirty-five years, the* total sum of 175*l.*; while those whose numbers are drawn the last *year will receive the same total sum, without, however, having the use of their capital* during the interval. This liberal scheme, which any corporation could very well afford, might serve as an inducement to the thrifty citizens of the town to contribute towards a most important improvement, and turn a handsome penny by the transaction. At the end of the thirty-five years the works will become an unencumbered property of the town, yielding a revenue of 27,500*l.* per annum; this sum, being made up of the surplus and the interest of the cancelled debt, might then be devoted to embellishments or further improvements, such as paving, lighting, street-cleaning with steam-traction sweeping machines, or might serve to diminish rates and taxes.

4. Soundness of Financial Scheme.—To show how easily and with what certainty the ten shillings quoted here as the basis of a sewage revenue of a town may be obtained, we submit, by way of illustration, the following statement:—

According to Professors Johnston and Voelcker, in their 'Catechism of Agricultural Chemistry,' sixtieth edition, page 53, the increase of grain in a wheat crop obtained on one acre, by manuring it with 2½ cwt. = 280 lbs. of Peruvian guano, is 12 bushels; that is to say, with manure, 58 bushels are raised, and without manure but 46.

And according to Messrs. J. B. Lawes and J. H. Gilbert, in their treatise on the 'Composition and Value of Sewage,' (Harrison & Sons, London, 1866), page 26, the annual fæcal matter of an average individual, if properly collected, is in agricultural value equal to ⅔ cwt. = 75 lbs. of guano. Consequently, to obtain the same increased yield of 12 bushels on one acre, $\frac{280}{75} = 3\frac{3}{4}$ annual human manure will be required; or, in other words, the fæcal matter annually produced by 3¾ average individuals will have an equal effect as 280 lbs. of Peruvian guano.*

Now, the 12 bushels of grain additionally thereby raised are worth at least 50*s.* per quarter, or 8 bushels . .	£3 15*s.* 0*d.*
While the manure is worth, for 3¾ individuals, at the rate of 10*s.* per head, supposing this price to be actually paid	1 17*s.* 6*d.*
Leaving still a clear profit per acre of . .	£1 17*s.* 6*d.*

It will be seen that, in this calculation, we have supposed the farm in question to be a separate concern from the town-sewerage works; and that, after its owner had purchased from the corporation the manure, at the rate of 10*s.* per head, there would still be 1*l.* 17*s.* 6*d.* per acre, or 10*s.* per head of population, left in profits

* See also page 76.

by the sale of the grain. If, then, the corporation had the farm under their own management, it would also receive this additional sum of 10*s.* per head, half of which is sufficient to pay railway transportation a distance of 180 miles, at the rate of one penny per ton per mile, supposing the manure barrelled up to weigh 746 lbs. or ⅓ ton;* while the remaining 5*s.* will pay whatever waggon transportation may be necessary from the railway station to the farm lands. It is also evident that farmers, wishing to buy manure from the city, must live within a less distance than 180 miles, in order to profit by the purchase, as they have to pay the transportation.

In the above exposition of profits we have placed the total yield of grain at 58 bushels per manured acre; but we have seen on page 164, that the Rev. Samuel Smith succeeded, at Lois Weedon, in raising 80 bushels per acre on the area actually planted, by a process of interval-culture only, and without manure. We may thus safely take it for granted that, if he had added such a stimulus, the yield would have been increased by at least 10 bushels, making the total 90 bushels. By Captain Liernur's fallow strip manure system the total crop per acre would be (because the planting beds occupy only two-thirds of the area†) 60 bushels, worth, at 50*s.* per quarter of 8 bushels, 375 shillings, which, divided over the 3¾ individuals who furnished the manure, makes just 100*s.* or 5*l.* per head.

5. SUMMARY ESTIMATE.—The clear annual profit of well managed municipal sewerage works, after the original debt has been paid off within thirty-five years, may be summed up as follows, per head of population:—

		£	s.	d.	£	s.	d.
I.	Absolute annual market value of manure per head . . .				0	10	0
	Total annual expenditure for maintenance, working, all and everything included				0	5	0
	Clear annual profit on manure, per head of population .				0	5	0
II.	Net profit on agricultural utilisation in the immediate vicinity of the town, per head of the population	0	10	0			
	Deduct waggon transport, &c.	0	5	0			
	Clear annual agricultural profit per head of population .				0	5	0
	Total clear annual profit per head of population . . .				0	10	0
III.	If the manure has to be sent out into the country, on account of the town, an average distance of say ninety miles, deduct for railway transport at the rate of 1*d.* a ton per mile				0	2	6
	Leaving still a clear annual profit per head of population of				£0	7	6

With these plain figures before them, based as they are on the preceding minute calculations, according to the first scientific

* This estimate is liberal, for 10 cubic feet, being the volume due to one individual, at the rate of 63 lbs. per foot, make but 630 lbs., and allowing 50 lbs. for each barrel holding 5 cubic feet, the barrelled-up manure per head would weigh 730 lbs.; we have put, however, the additional 16 lbs. on, to be on the safe side of the estimate.

† The manure of 3¾ men is, in that case, evenly distributed over the remaining ⅓ acre of land, laid off in fallow strips.

authorities of the day, both in England and abroad, any corporation can easily form their own estimate, as applied to the topographical position of their town, and other local circumstances.

6. PRODUCTIVENESS OF HUMAN MANURE.—We have just shown that ten shillings' worth of undiluted, unadulterated, pure fæcal matter can grow ten times its value in human food. This entirely agrees with the statements of the most eminent agriculturists who have investigated this matter, such as Liebig, Boussingault, Saussure, Stöckhardt, Macaire, and others, all of whom have shown that the annual solid and fluid voidings of an average individual suffice for raising 800 lbs. of wheat, corn, oats, &c., and 900 lbs. of barley. Now, taking the average weight of grain to be 50 lbs. per bushel, or 400 per quarter, then the same manure (weighing 630 lbs. wet, and 50 lbs. dry, see pages 74–5) is capable of raising two quarters, making, at the above assumed market value of *50s.*, also the sum of *5l.* per head. And though, of course, only from one-fifth to one-sixth of the crop so raised is directly due to the manure, and the remaining four-fifths or five-sixths might have been raised without it, still the latter mode of culture could be carried out only for a certain limited period, when exhaustion of the soil would occur without fail. It may thus be asserted, as a most valuable fact, that 1*l.* worth of human manure is capable of producing 10*l.* worth of breadstuffs, without in the least affecting the permanent fertility of the soil.

7. THEORETICAL AND PRACTICAL VALUE OF HUMAN MANURE.—Much has been said about the great difference between theoretical and practical value of sewage, to the effect that, in actual farming, the high estimate of this class of manure is not borne out by facts or experience. So far as there is any truth in this, it is easily explained. Until now, the only application has been with effete fæcal matter, or when in a high state of dilution; the first kind having lost its strength by fermentation in cesspools and the escape of stimulating gases by evaporation, the latter by its admixture with great volumes of water. But, notwithstanding this, cesspool matter, worthless as it is, is purchased in Germany by farmers from garrisons at the rate of 2 to 2½ thalers per soldier, making the market value 6 to 7½ shillings per head, and in Alsace even 9 shillings is paid. Now, surely farmers must know better than anybody whether or not it is profitable to pay such rates.* But among those who have fairly investigated the subject, there is no question or doubt about the value of this material; for instance, Mr. J. B. Lawes writes to Captain Liernur, under date of April 10, 1867, that fæcal matter should be estimated by the market price of the constituent elements in a dry state; and this, we have already seen, amounts to 10 shillings per head of population.

* Another instance of the practical value of fæcal matter we find in the official report of the municipal authorities of Groningen, to the *Maatschappij van Nijverheid*, according to which a weekly removal of excreta, together with street-cleaning, amounts to 30,000*fl.* (2,500*l.*) per annum, whilst the sale of manure by public auction yields 50,000*fl.* (4,167*l.*), leaving thus a clear annual profit of 20,000*fl.* (1,667*l.*) in a town of 37,000 inhabitants (see also page 84). Such matter of fact statements completely refute the foolish idea of a certain agricultural chemist mentioned in page 42.

8. EXTENT OF USEFUL APPLICATION.—We have just stated that a town possessing sewerage works according to the new system, can well afford to transport the manure to farms, 180 miles distant, per railway. As transportation by water is far cheaper, of course the circle of utilisation can be proportionally much enlarged, if there is any navigable stream in the way. This is of the utmost importance, as we have seen that the manure of 3¾ individuals suffices for one acre. If we, in order to deal with round figures, assume that one acre requires the manure of 4 individuals, we find that a population of 100,000 can maintain the fertility of not less than 25,000 acres. This would satisfy the wants of a great number of farms of various dimensions, and in all directions; and the managers of lands leased by the town would then become stewards in the pay of the corporation, each receiving regularly, per train or boat, his daily quota of manure, and accounting to the sewerage works for the crops raised.

9. FACILITY OF INTRODUCTION.—It is to be hoped that town corporations will not be held back from adopting this vast scheme of utilisation, by the apparent trouble and surveillance a proper and efficient management may be thought to necessitate: for, in the first place, this is really far less than it would seem; and secondly, it can be made still more simple by adopting a system something like that which we presently will venture to submit. If, however, through fear of complication or other circumstances, corporations should decline to engage in such works, they should by all means be taken in hand by joint-stock companies, who would find concessions for long periods to be more remunerative than any other business they could possibly engage in. In that case, no premiums should be exacted for such concessions; for it is hardly just that pay should be taken for that which a corporation might refuse themselves to undertake.

10. GRADUAL INTRODUCTION.—It is evident that the gradual introduction of this system of sewage collection and utilisation would, in course of time, lead to a total revolution of the present state and condition of agriculture. We use the word 'gradual' on purpose, for the system has this most valuable feature, that it is applicable to a part only of a town, making thus the necessary changes and new arrangements less violent; for it is well known that sudden transitions in affairs or principles of management do at first often more harm than good, the salutary effects being sometimes only felt long afterwards. The revolution here alluded to, will not only considerably increase the traffic of railways and navigable waters, by the continual transportation demanded for the new branch of business here opened, but also cause the gradual extinction of the import of guano and other fertilisers. Besides, thousands of acres will be brought under superior cultivation, which now lie partially or entirely waste.

11. CENTRAL AGRICULTURAL BUREAU.—To avoid confusion, and, above all, the competition which would arise through the simultaneous search for land, by different corporations or companies, the location and adaptation of sewage farms should be entrusted

to a central directing body; which, besides this allotment, might most advantageously control and audit the accounts of all concerned.

To effect both these purposes a Central Agricultural Bureau might be instituted, having its seat in the metropolis, whose first care should be the construction of carefully drawn maps, showing all the lands, both waste and under cultivation, in Great Britain and Ireland. By means of peculiar signs or shading in the engraving, the character and nature of the soil might be indicated; while, by colouring, it might be shown, whether it is pasture or plough land, &c. *Such maps have been prepared by Professor W. C. H. Staring, author of the 'Huisboek voor den Landman,' for the kingdom of the* Netherlands, *and imparted much useful* information. Among other things, this map reveals at a glance the astonishing fact, that even in that highly-cultured country, still one-fifth of the arable land lies waste and untilled. An analytical catalogue should also be got up, showing the extent and ownership of lands, the duration and date of expiration of leases, rates of rent, average produce per acre, &c. With the information thereby furnished, and the means of transport per railway, &c., also shown on the map, it could not be difficult to arrange a proper system of allotment or selection of sewage farms, so that each town should obtain lands within the shortest possible distance; but, above all, the said bureau would serve for a proper distribution of waste lands for reclamation.

12. UNIFORM SYSTEM OF ACCOUNTS.—Another good feature would be, if an exactly uniform system of book-keeping were adopted by the various sewerage works, for the purpose of facilitating a regular monthly audit of all their accounts. As immense sums would be involved in the management of these works by the issue of bonds, by the payment of their coupons, the expenditure for construction, administration, labour, and maintenance, and by the sale of crops, it would be good policy to arrange, from the very first start, some method by which bondholders and city treasuries might be guarded against all irregularities and frauds.

13. CENTRAL AUDITORY OF ACCOUNTS.—For this purpose we may suggest a central auditory, composed of as many gentlemen well qualified for a strict examination of accounts as there are towns, or districts of towns, which have adopted the improvement. These auditors would receive their salaries through the chief of the agricultural bureau, out of a fund raised for that purpose from the various towns. The audit should be monthly, and the appointment of auditors to the various towns always be decided by ballot. This continual change of auditors would make fraud almost impossible, without occasioning any inconvenience to the central bureau, because, the books being kept on one uniform principle, each auditor would feel equally at home with every concern in any part of the country. It might also be made a rule, that every monthly auditor should revise the audit of his predecessor, so that, should an error have escaped notice, or any irregularity have been committed, it would be sure to be discovered

the following month. This rule being quite general, and its personal application subject to the chance of the ballot, it could not for a moment be considered to reflect upon the character of even the most punctilious; on the contrary, every right-minded man would cheerfully concur in a measure, the obvious and only aim of which would be the increased safety and ultimate benefit of all parties concerned. The monthly audits should be so arranged that, on being joined at the end of the year, they would dovetail into each other, and form a harmonious audit for the whole period. In regard to the books themselves, the manner of keeping them, and the items to be stated, we may refer the reader to our work on 'Statistical Book-keeping,'* in which everything relating to this matter is fully explained, and illustrated by tabular examples.

14. AGRICULTURAL STATISTICS.—Abstracts of audits, accompanied with reports concerning everything which might be of general interest regarding the sewerage works of the various towns in question, should be handed in regularly to the central bureau. The valuable facts thus collected would form the chief material for a periodical, either weekly or monthly, to be published by the chief of this whole system of administration, or under his immediate supervision. This paper, if properly conducted, would eventually be able to give complete information regarding all the agricultural resources of the country, the price of food, the value of labour, and every other question connected with the subject.

15. SAFE AND PROFITABLE INVESTMENT.—Besides the direct practical utility of the administration scheme here proposed, there is no doubt but that it would afford far greater security to the abundance of capital always seeking investment, than certain companies and stockbroking concerns, which but too often enrich a few only at the expense of the many, and by whose transactions the total wealth of the country can never be increased. Companies which are based upon unsound speculation can hardly be expected to be honestly administered. Hence we find that, in many cases, shareholders, sooner or latter, suffer by the mysterious disappearance of royal fortunes, the process being only known to those behind the scenes, whilst, in the usual investigation afterwards, it generally turns out that there is nobody at all to blame. It is far different with joint-stock enterprises for useful public purposes, the tangible benefits of which are felt by all; they are the most powerful agents to bring about improvements otherwise impossible to execute. The 'Times' of January 25, 1867, says on this subject:—'Whatever may be the feeling of stock speculators on the point, it is obviously desirable to disabuse the public of the idea generated from the rashness of a few headlong financial managers, whose heads were turned by being allowed to play with millions, that joint-stock enterprise in England is inherently unsound, and that it cannot in the future be, as it has been in the past, one of the main elements of our extraordinary prosperity.'

There is no question, then, but that the existence of a sanitary

* Krepp's Statistical Book-keeping. London, Longmans and Co. Further particulars see at the conclusion of this work.

and agricultural improvement scheme, with something like the management here suggested, would be a perfect blessing to the country; because, in the first place, its purpose would be that of securing health and abundance of food, certainly the very best and most useful enterprise that could be proposed; and, in the second place, because, by the precautionary measures alluded to, a feeling of security would be engendered between shareholders, managers, auditors, and the public generally, which could not but contribute largely to the peace and happiness of all.

16. PRACTICABILITY OF THE SCHEME.—And let not the reader stand aghast at the difficulties to be overcome in carrying out such a scheme, nor give ear to the croakings, mournful forebodings, and prophecies of failure by conceited old fogies, who always see impossibilities and impracticabilities in new contrivances. If all were left to these great stumblingblocks of progress, who consider all inventors as dangerous agitators, and disturbers of peaceful slumber, the world would still be centuries behind. Their objections to such improvements as paving roads, lighting streets, steam locomotion, post-stamps, etc., are matters of history. But the indomitable spirit of the age, created and kept alive by a few bold thinkers, has successfully brought about many an enterprise far more complicated and difficult than the scheme here presented. As a recent instance we may point to the Atlantic Telegraph, in the laying of which two unsuccessful attempts were made, involving the loss of not less than 1,350,000*l*., but which notwithstanding was finally crowned with complete success. And the same unfaltering perseverance will soon enable us to send our messages flashing round the whole globe!

Nor should we be kept back by the adverse judgments of old practitioners, who, by long routine in their own method, imagine there is no safety whatever out of their beaten track. How unreliable such opinions often are, can be seen by the statements made by Dr. D. Lardner, barely forty years ago, at the Royal Institute, and in the presence of the most eminent scientific men of the day, and members of both Houses of Parliament, when he maintained and proved, by logical deductions and algebraic formulæ, the utter impossibility of crossing the Atlantic by steam navigation. Another instance is afforded by the notorious fact, that nearly all improvements in the form and structure of ships have been regularly and persistently opposed by the most experienced sea-captains, and knowing, weather-beaten old sailors. Why, if they had had all their own way, we might perhaps still navigate in the round-breasted little tubs of centuries gone by.

Captain Liernur's system luckily embraces no new principles, or even untried mechanisms; it deals with well-known powers, such as pneumatic force and steam, in such shapes as we are accustomed to see in operation; at the same time, the new system can hardly be reduced to greater simplicity, because the main agent, atmospheric air, cannot at all be improved upon, while the treatment of the manure is of the cheapest and simplest kind, namely, that of letting well alone, and not mixing it with anything at all. There is thus a splendid field of enterprise for an intelligent and enterprising people, which, if entered upon in good faith, cannot but redound to the benefit of all, especially in a country like Great Britain, where there is no lack of clear-headed, far-sighted, energetic men of business, willing and able to take firmly hold of a good new idea, and carry it out to its logical conclusion.

And Parliament, which has already taken a step in the right direction by its Rivers' Pollution Act, will no doubt soon assist the scheme here proposed by corresponding enactments, on impartial evidence being given of the sinful waste of manure incurred by dilution of sewage with immense volumes of water, and its application to poor pasture grasses; and, sooner or later, a law will be passed, forbidding this crime against public health, agriculture, and national economy, on the ground, that thus to throw precious fertilisers away is to throw away the bread of millions!

X. MORAL, SOCIAL, AND NATIONAL PROGRESS.

1. Improvement of Public Morality.—A most important result of the sewerage system here advocated will be improved public morality, consequent upon increased cleanliness among the masses of the people. There is, perhaps, no agent more powerful to debase morals than 'familiarity with dirt.' The constant presence of filth, the difficulty of its removal, or the hopelessness of all attempts for that purpose, will give even to an individual of cleanly tastes, in a short time, dirty habits of dress and person; and the organs of sight and smell becoming blunted, a gradual descent to vulgarity of speech, low manners, indecent exposure, prostitution, and complete moral perdition is comparatively easy.

This is, above all, the case in large cities. It is not so very long ago that the public were startled by descriptions furnished by the London press, of the truly awful condition of certain tenement-houses, crowded to excess by paupers of all kinds, and so shamefully neglected by rapacious and unprincipled landlords, as far as sanitary arrangements were concerned, that the pigs of any respectable British farmer were better housed and cared for than the wretched inmates of these squalid, filthy, noisome tumble-down rookeries.

This state of affairs has been more than once graphically illustrated by 'Punch,' and was again alluded to in a poem, entitled 'The Augean Stable,'* dedicated to the Social Science Association, of which we quote the following pathetic lines:—

'The sewage that should feed the land,
Made poison for the town:
The streams, but sewers for the strand,
To drink its ordure down.
The home a den, where human souls
In beasts' lairs bestial grow:
And hand in hand, that sister band,
Vice, Drunkenness, and Woe!'

2. Dwellings of the Poor.—Now, one of the most revolting features of such tenement hovels is always the utter incapacity of privy accommodation to ensure common decency, self-respect, decorum and virtue, among the unfortunate people doomed to live and rot therein. It is, no doubt, partly this which drives these poor outcasts to the gilded gin-palaces, there to drown sorrow and despair in the cup of momentary forgetfulness, which but too soon leads to intoxication and the lowest sensuality; it is just such pestilential dens which continually send forth swarms of juvenile pickpockets, prowling prostitutes, and desperate garotters to infest our streets, and wage an incessant war upon society, bidding open

* See 'Punch,' October 13, 1866.

defiance to all laws, human and divine. What else can we expect of beings born and raised in such 'hells upon earth,' continually breathing a poisoned atmosphere, drinking, if any, only poisoned water, whilst body and soul are steeped in physical and moral corruption, dooming them from their very infancy, to disease, misery, vice, and crime?

This condition of affairs is especially aggravated, and rapidly brought to a crisis in tenements where the mistaken zeal or want of knowledge of the Board of Health has caused the compulsory introduction of waterclosets, which, by a failure of water supply, or breakage of valve-gear, soon become entirely unfit for use; and then, in a short time, create a great accumulation of filth, through the number of individuals, often in the proportion of a hundred or more to one closet, which they are meant to accommodate. Then, first, the immediate vicinity, and, finally, any place in the locality, whether yard, street, or the house itself, is used by sheer necessity as a place of deposit for fæcal matters, until at length the whole neighbourhood reeks with filth, and becomes a region of nastiness, revolting beyond description. Indeed, the old plain perforated seat, with a cavity underneath and no basin to retain any matter, is by far to be preferred, merely because it cannot get out of order. But when the cavity itself is constantly purified, both of substances and gases, by atmospheric force, as in Captain Liernur's system, so that no dirt can accumulate anywhere, and only the cleansing of the seat is left to the inmates of a house, there is no doubt but that the cause of much intense misery will be effectually removed.

3. PHILANTHROPIC ENTERPRISE.—Fortunately, much has already been effected by individual philanthropic enterprise, towards alleviating the most deplorable state of affairs described. We all remember how warm an interest the late lamented Prince Consort took in the amelioration of the dwellings of the working classes and the poor. We all know, that for years a similar philanthropic course has been followed by the Emperor Napoleon, who, in steady pursuance of his generous aim, has sent to the present great Paris Exhibition a new model, of his own conception, of an improved working-man's house, combining all that can be desired with regard to salubrity, economy, and domestic comfort, thus setting once more a glorious example of the incessant care that should be taken for the material welfare and moral elevation of the humbler classes of society.

The princely gift of that magnanimous American, George Peabody, Esq., to the metropolis, for sheltering the homeless poor, is followed up by a similar benefaction from another great philanthropist, Miss Burdett Coutts, who, it is understood, has procured an Act of Parliament for entirely clearing away one of the most densely populated and pestilential districts of the metropolis, and there building instead, at her own expense, for the use and benefit of the deserving poor, a number of cheerful, healthy, comfortable lodging-houses, surrounding an airy, handsome market-place. The Marquis of Westminster also advanced a large sum to the 'Metropolitan Association for Improving the Dwellings of the Industrial Classes,' for the purpose of erecting a large block of buildings, five stories high, in the Commercial Road and Pimlico, affording sufficient house room to 140 families.

On the other side of the Atlantic, Mr. A. T. Stewart, of New York, proposes to give a million of dollars for the erection of good tenement houses, upon condition that the city furnishes ground for the same. 'Harper's Weekly,' of October 27, 1866, says, concerning this plan:—

'We do not understand that Mr. Stewart's intention is to erect a poor house, or at least a place in which poor people are to be made paupers and treated as such, but that he designs healthful and pleasant dwellings at truly moderate but just rents. He does not offer a premium upon poverty, but he hopes to furnish pleasant, airy, and convenient lodgings at the same price which is now paid for noisomeness, filth, darkness, disease, and death. Probably he knows quite as well as the rest of us, that clean houses alone are not enough to make clean people, but he doubtless is also fully aware, that dirty and detestable houses do not make people clean. He sees also, we may infer, that a vital reform of the inhabitants of the slums must begin outwardly in their material conditions. Sunday School tracts, however excellent in themselves, are very pointless to a starving man; while the Christianity which begins by stimulating and helping those who are willing to help themselves in any way, at once proves itself to be a system of brotherly love. Good tenement houses in New York will be a model for all *other cities, while the wise generosity that builds them will inspire* similar designs everywhere.'

'*Harper's* Weekly' remarks further very justly:—

'The extortion practised upon the poor by the owners of the horrible rookeries in which the poorest people of this, or of any great city, huddle, is among the chief infamies of civilisation. If half the zeal were given to the prevention of crime that is bestowed upon its punishment, the sum of human happiness would be infinitely increased. At least half the taxes go to correct consequences which a very little foresight would have avoided.'

4. CLEANLINESS NEXT TO GODLINESS.—Now, seeing that all human experience has shown proper privy accommodation and efficient removal of sewage to lie unquestionably at the root of all sanitary improvement, and at the same time to prevent, in a great measure, moral degradation, proving thereby the truth of the scriptural admonition, that 'cleanliness is next to godliness,' it surely would be a great pity if the magnanimous efforts of these philanthropists were partially frustrated by providing their new tenements for the poorer classes with blundering fixtures of past times so detrimental in their effects, that they would undoubtedly, in course of time, convert these new comfortable homes once more into dens of pollution. And it is to be hoped that these noble minds, having given the world an example of what practical Christianity is capable of, will go one step further and contribute to prevent much disease and vice, by adopting a system which a conscientious and laborious investigation and the concurrent judgment of many eminent men have proved to be undoubtedly the best of all hitherto proposed. For the Scripture says (Matt. ix. 16, 17): '*No man putteth a piece of new cloth unto an old* [illegible] *for that which is put in to fill it up taketh from the* [illegible] *and the rent is made worse. Neither do men put new*

wine into old bottles; else the bottles break, and the wine runneth out, and the bottles perish; but they put new wine into new bottles, and both are preserved.'

5. **RECONSTRUCTION OF LONDON.**—We have in the foregoing chapter mentioned, as one of the chief merits of the pneumatic sewerage system, that it may be introduced *gradually*, and that thus the objections and troubles vanish, always accompanying complete revolutions in the arrangement and management of matters upon which all our social comfort depends. We have also seen that, through the generous initiative of philanthropists splendid opportunities thereto will be afforded as regards the dwellings of the humbler classes. We will next call attention to another most important movement, contemplated by the Marquis of Westminster, which will make such an introduction and change at once easy and practicable also for the higher ranks of society. We allude to his grand plan for reconstructing the entire south-west portion of London. To give the reader a just conception of the magnitude of this enterprise, we can do no better than quote from the 'Spectator' of December 29th, 1866, the following account of the works intended by the Grosvenor family:—

'THE RECONSTRUCTION OF LONDON.*

'The "Standard" published on Christmas Day a very remarkable paper, which probably was very little read—an account of the reconstruction of fashionable London, now in progress under the orders of the Grosvenor family. Owner of the soil from the west side of Bond Street to Sloane Square, in Chelsea—of an estate, that is, which includes all Tyburnia, all Belgravia, and all Pimlico, boasting the finest and most secure rent-roll in Europe, and possessed with the passion of business, the Marquis of Westminster is in his own district almost as powerful as M. Haussmann in the Department of the Seine. "Landlord of the House of Commons," and with whole batches of peers among his tenantry, any application of his for a private Act is sure to meet with attention, while his right of destruction as ultimate landlord is, as the leases fall in, more complete than that of the Parisian prefect. M. Haussmann could not leave great uncovered spaces in Paris, for if he did the evicted might murmur loudly, and the Emperor interfere; but the Marquis can. He could within twenty years render west London uninhabitable by a mere fiat, and it would task the whole power of Parliament to interfere with his caprice. Fortunately he is a sensible man, who loves money, and has some great ideas; and he is taking advantage of the falling-in of his leases to make south-west London a city worthy of the richest, if not the most illustrious, aristocracy in the world. If the writer in the "Standard" is not misinformed, and he must have derived some at least of his facts from the ruling architect, for he details plans as yet not commenced, the Grosvenors will, before 1880, have turned a camp of brick and stucco into a city of Portland stone. As each batch of leases falls in the houses are to come down, even Grosvenor Square being doomed, and the leaseholders either rebuild them on the plan framed by Mr. Cundy and approved by the Marquis, or the landlord does it himself. Stucco and

* Not wishing to impair this excellent article by fragmentary quotation, we reproduce it entire; the more so as the Marquis of Westminster's scheme is no doubt destined to play a most conspicuous part in the regeneration of the metropolis, especially if pneumatic sewerage should be inaugurated at the same time.

sham generally are strictly forbidden, and the plan as described seeks a kind of congruity of stateliness which, unless it is wisely restricted, may interfere a little too much with comfort. A city needs buildings other than palaces and stables. The guiding idea of that plan is to make the Grosvenor estate the residence of the rich, to cover it with houses which in any other city would be called palaces, to exclude all meannesses and uglinesses, as well as all sources of disease, and make of west London the most aristocratic city in the world. There is nothing whatever to hinder the realisation of the plan. The Marquis is as rich as a city himself, the family can afford to spend a generation or two on their great work, for under our system a Grosvenor succeeds, the list of expectant tenants is endless, and there is no possibility of resistance from without. If the poor are provided for, which will, we trust, be the case—the public have no right to complain; and if they had, the complaint must be loud indeed which would induce Parliament to interfere with a great proprietor's right to do as he will with his own. An outside observer may think that a system under which an individual can own a whole city, can order an entire aristocracy to live in the houses which seem to him best, can even compel them to spend a sum of almost national importance because he holds certain ideas of architectural propriety, is not a system calculated to endure. The privileges of property hold their ground, however, while the privileges of rank decay: the Senatorial families doubled their properties after the Senate had ceased to reign, and power like that of the Marquis of Westminster, if only wisely used, may survive our grandsons, or, for that matter, theirs.

'In this instance it is wisely used. The Marquis, strong in his wealth, his proprietary rights, and his breadth of design, will carry out in south-west London just the revolution which Parliament will one day have to carry out in the east. The more the great problem of London is considered, the more certain will it appear that, to transform the huge camp into a really great city, a place in which four millions of Englishmen can live without the mere fact of locality being a deduction from their strength, or capacities, or happiness, the Marquis of Westminster's plan is the only one worthy of very serious thought. All kinds of palliatives have been, are being, and will be tried. We shall reduce the miasma by sewers, the sulphur by smoke drainage, the filth by a tolerable supply of water, and the overcrowding by an extension of the principle of the Lodging-House Acts; but when all these things have been done, east London, from Mecklenburgh Square to Stratford, will still remain a miserable city, an encampment of brick huts, wanting in comfort, in beauty, and in the healthy vigorousness which ought, *pace* the country squires, to be the special feature of the true city life, the only life in which man can have all the advantages of association with all the benefits of individual independence. In those long lines of grey houses, too thin to keep out the cold, too huddled for ventilation, too isolated for cheapness, there is no possibility of any true or great municipal life, no trace of the scientific civilisation which might and would compensate for all deficiencies of pure air, and clear prospect, and fresh water. When we have done all that the Metropolitan Board dream of doing and all the philanthropists will attempt, the necessity of entire reconstruction, by parishes instead of streets, by blocks instead of individual houses, will still remain, and it is this necessity which the legislature will in the end have to face. There is no Marquis of Westminster east of the city, no ground landlord rich enough and wise enough to perform single-handed the function of a great municipality. It would be well for east London if there were; for the enterprise of converting a city like Shadwell into a city like Genoa, insane as it must appear to cursory observers, is nevertheless possible, would pay, and might with such a landlord ultimately be carried out. There is no one to do it, and it must be effected, if at all, by the state acting through a municipality, or a great building company, or a department of its own. Business philanthropists like Alderman Waterlow may try an experiment here and there, gifts like Mr. Peabody's may be used to create model settlements, philanthropic women like Miss Burdett Coutts—Mr. Ayrton's queen of the poor—may turn hamlets of huts into comfortable villages, but all these things are but hints of the great work to be accomplished. East London has to be carried into the air. We want streets of blocks like Alderman Waterlow's, cities of edifices like the Peabody buildings, parishes of settlements like the one Miss Burdett Coutts has finished in Bethnal Green. Ten Florences would barely house the population east of Temple Bar, and we have not a municipality, or a board, or a ground landlord, or an officer with power even to recommend and plan such a work, far less to carry it out. Suppose the city, for example, were authorised by law to do within its rigidly defined dominions what the Marquis is doing within his kingdom without any law at all—to *make* individual landlords rebuild upon a clear and magnificent plan. Or suppose a great company, helped by the state under the existing Act, authorised to *take* Shoreditch at its value, on condition of rebuilding it upon a plan authorised by the first commissioner of works after consultation with Parliament. Too expensive? The Marquis of Westminster has the reputation of being one of the keenest and hardest men of business in the kingdom, who can subscribe 10,000*l.* to a fund, but who can also resent being cheated of a halfpenny. He is not rebuilding Grosvenoria in order to impoverish his grandchildren, we rely on that. Too despotic? It is only by a despotism as strong as that which the Marquis exercises that we shall ever accomplish the end in view, an end much greater than that for which we are even now investing the Metropolitan Board of Works with all the powers they require. That board is about, we are told, to pull down the street in which we write and rebuild it, to the grave annoyance and loss of every single individual in the street, simply because it breaks what would be a handsome line of houses from the Thames side to the Strand. No prescriptive right, no lease, no damage to property is allowed to stand in the way of a picturesque improvement, and fighting the board with an "idea" in its head is as useless as fighting M. Haussmann when his masons are out of work. We do not object, we concede that "tyranny," *i. e.* the disregard of individual interests, is the condition of public improvement; but if we vest the board with such powers in the interest of architectural perfectness, why are we to refuse them in the interests of a vast population? The truth is, we treat this whole matter in a petty spirit, of which a single proprietor like the Marquis ought to make us ashamed. Suppose he owned the City Road from Paddington into Finsbury. Ten years hence north London would have a boulevard of which Paris might be proud, with handsome shops and broad pavements, and pleasant limes, a worthy nexus between the left arm of London and its heart. There is not such a site for a boulevard in Europe, and why should collective London or collective England be so much meaner in thought and design and grasp of possibilities than an individual peer? We call ourselves a practical people, yet are afraid even to think out fairly the means of making our metropolis habitable, even to dream out a thorough reform of the place in which one out of every eight Englishmen is condemned to live. An individual coolly announces that he has decided to turn the governing class out of doors in order to re-house them a little better, and everybody submits with a murmur which sounds like praise, and the great demagogue of the day grows eloquent over the wealth the plan will yield to a family treasury. And yet, when it is proposed to do precisely the same thing by almost the same means for the people, we are told that such plans are dreams, that London must remain an encampment, that for England to build a city is a suggestion either dangerous or absurd. It may be so for this generation, but the day an educated multitude becomes aware of the difference between what London is and what London might be, the suggestion will be carried out, and the objection to the hand which executes it will not be based on its want of power.'

All we have to say for the present about this grand scheme of the Marquis of Westminster is, that England may well be proud of one of her noblemen proposing to do for the sanitary and architectural regeneration of the metropolis, what the Emperor Napoleon has on such a magnificent scale effected for the capital of France.

6. London Building Companies.—That such radical changes as just described will be followed by similar ones in another direction can hardly be doubtful, for every one must admit their absolute necessity in a locality like London, where such large masses of people are accumulating in comparatively so small a compass. Thus the 'Times' says:—

'If a company were formed, sufficiently powerful to buy up large areas in the poorer districts of London, and were to erect good, lofty dwellings, they would probably find it easy to obtain a rent which would ensure them an ample profit. If, however, this be the case, capital will be sure, sooner or later, to engage in this enterprise, and it will then solve the problem in the only manner which can be permanently satisfactory. In a word, the best service which the members of this deputation * could do to the cause they have at heart would be to encourage and assist in the formation of a large company, which should demonstrate practically the remunerative character of an investment in building houses for the poor.'

This suggestion of forming a powerful company for reconstructing also the poorer districts of London, we find further advocated by the 'Spectator' as follows:—

'It is possible, by a loan from the state, most amply and fully secured, to induce builders to reconstruct very extensive tracts of London; to reconstruct, in fact, all of it by degrees, if only they can obtain the sites.'

In treating of the pecuniary result which may be expected, the 'Spectator' goes on to say:—

'In fact, the whole difference between 3½ per cent. and the net rental will be profit, no private capital being required; and the true agency for such a work would be either a co-operative association of masons, such as the one which is executing such magnificent works in Paris, or, and much better still, the Metropolitan Board of Works, which would thus obtain in the end a vast revenue independent of taxation. The state would lose nothing, any more than the Marquis of Westminster does, its loan being as well secured as any money lent on the security of landed property.'

7. Annual Revenue of Reconstructed London.—The above quotation from the 'Spectator' suggests a consideration, which at

* The deputation that waited upon Lord Derby to plead the cause of the London 'Homeless Poor.'

once points out the practicability of this scheme of reconstruction; for surely the city government should not object to embark in an enterprise so highly conducive to the public good, and which would be but a counterpart of that which a single nobleman is about to carry out by way of a safe investment of his capital. To show the absolute safety of such an enterprise, merely in a financial point of view, we may point to the revenue which, in addition to that mentioned by the 'Spectator,' would accrue to the metropolis, if at the same time the sanitary improvements involved in Captain Liernur's system were adopted. By referring to page 172, we find that, unless such eminent men of science as *Liebig, Lawes, Gilbert, Way, Hofmann, Witt, Voelcker, Thudichum, Stöckhardt, Boussingault, Saussure, Macaire, Marcet*, and others, are entirely wrong, and the practice of thousands of farmers is based on an egregious error, when they pay from 5 to 6 shillings per head even for effete cesspool matter—the full amount of 5*l.* worth of human food can be raised, by proper agricultural management, with the manure obtained per annum from an average individual; and the sale of the manure alone would yield the city, after the debt incurred for establishing the works is paid, and after all the maintenance and working expenses are deducted, a clear annual revenue of 825,000*l.* for its three million inhabitants, estimated at the rate of 27,500*l.* per 100,000 souls, as fully established by sound arithmetical demonstrations on page 170. To this handsome income must be added the profits of whatever farms the city would take under its own management, in order to utilise that part of the sewage which could not be sold to surrounding agriculturists. The fæcal matter of three million inhabitants is sufficient to maintain the fertility of not less than 750,000 acres, equal to 1,172 square miles; a tract of land contained in a circle of say 25 miles radius, a liberal allowance being made for space not accessible to cultivation.

Assuming the average distance from the city as a centre to be 15 miles, then, at the ratio mentioned on page 171, the sum of 2*s.* 6*d.* per head would fully pay for all railway and farmroad transportation of the manure, leaving, for profits on the increased crops thereby obtained, even after the first 10*s.* per head are paid into the city treasury, still 7*s.* 6*d.* per head of population, or say 1*l.* 10*s.* per acre. If then all the sewage was bought up by the surrounding agriculturists, as there is but little doubt will be the case in course of time, the handsome annual sum of 1,125,000*l.*, obtained from profits on increased crops, would accrue and be earned by them, according to the extent of ground worked by each. If not, the city would obtain its proportional share of this additional sum, like any other farmer, from the sewage utilised on grounds under its own management.*

Upon whatever plan and by whatever means, the magnificent plans alluded to for reconstructing the British metropolis on truly sanitary principles, so clearly pointed out by modern science, may be carried out, we cannot but congratulate it on the prospects for their speedy execution which the said comments of the public

* Cities having, like London, a navigable river at their command, enjoy of course an additional advantage in the cheaper transportation by water.

press shadow forth; above all, because thus, and perhaps thus only, a chance will be afforded to introduce at the same time the greatest sanitary improvement of all, involved in Captain Liernür's plan, which otherwise might be indefinitely delayed.

8. Remunerative Labour lessens Pauperism.—Another good effect of the introduction of pneumatic sewerage will be found in the many new branches of industry it will call into existence, thereby affording constant and remunerative employment to large numbers of men who now, with their families, are wholly, or in part, maintained by public or private charity, or who, if not actually starving, live upon the proceeds of vice and crime.

The chief source of labour here alluded to will of course be that required by the increased agricultural development which will surely be, so to speak, created by the reclamation of innumerable waste tracts, and the conversion of but little-work-needing pasturages into much-labour-requiring plough-lands.

This will result in gradually withdrawing from cities and towns large masses of squalid inhabitants of stunted growth, now living huddled together in foul alleys and pestilential courts, towards the open country, and in due course transform all these wretched paupers into a bold peasantry: a support to the state in times of peace and of war, instead of a heavy tax and a source of ever increasing annoyance and social danger.

Another plentiful source of labour will be found, first in the establishment of the pneumatic sewerage works themselves, including, of course, the manufacturing of all the apparatus and fixtures which will be required; and afterwards in their management and operation, which will, in a town of 100,000 inhabitants, give permanent employment, with liberal wages, to fully 100 heads of families, and thus provide bread for at least 500 persons. And this employment has the great merit of being independent of commercial stagnation and crises, of wars and political convulsions, founded as it is on the daily requirements of our common nature, and yielding, as it does, that for which there is a never-ceasing demand, namely, food. In one word, if this process of removal and utilisation were carried out in every town of the United Kingdom, pauperism, vice, and crime would surely diminish; public health and the bodily development of the population would greatly improve, whilst corporations would draw large annual revenues from what is now a source of constant vexation and onerous taxation; and, last but not least, food would become far more abundant than it can ever be under existing arrangements.

9. Abundance of Food prevents Strikes.—This increased plenty will not only be the result of heavier crops of breadstuffs, but will also consist in great quantities of healthy meat, produced by the improved mixed husbandry, which forms part of Captain Liernur's system; while neither of these products will be any longer damaged by vegetable and cattle diseases arising from surface manuring. At the same time, purified rivers will again yield immense quantities of fish, now killed or driven off by the horrible pollution of the water with fæcal elements.

The greater cheapness of provisions consequent upon this increased abundance, will not only have a corresponding influence upon the price of every commodity which adds to our comfort and enjoyment, but also upon the price of every kind of labour; and thus the principal cause will be removed which now so often induces the operatives of nearly all branches of industry to resort to strikes for higher wages, in order to support themselves and their families. And unless the fountain-head of such movements be stopped by making British soil far more productive than it is at present, these strikes will in time, by constant repetition, raise the price of all labour so high, that British manufacturers will no longer be able to compete successfully with those of other countries; then all trade will more or less become stagnant, and the best interests of the nation be most seriously affected.

10. Surplus Food for Export.—Not only will all these evils be averted, but there is little doubt that if every available acre of land were properly tilled and manured, as elsewhere described, the amount of food obtained would not only suffice for home consumption, but a surplus would be left for shipment abroad. This would raise Great Britain to the proud position of a bread-giver to other nations, instead of making her dependent upon them; and would bestow upon her the divine power of alleviating the miseries, and perhaps of often saving even the lives of millions abroad.

Who can read unmoved the harrowing accounts of the great Irish famine of 1846? A succession of bad harvests, combined with the consequences of a notorious mal-administration, at last resulted in a national crisis, the like of which the world had not seen for centuries: people starving and dying by hundreds in the ditches near the roadside and behind the hedges, while bloody riots, pillage, and murder were threatening as the culminating effect of hunger and despair. Lord John Russell demanded at that time some nine millions sterling, to bring four-and-a-half million acres of waste land under cultivation, and the general Government had to apply over ten millions to the relief of the unfortunate Island.

11. Prevention of Famine in India.—But it is not only at home that the beneficial results of a great agricultural development by a proper utilisation of sewage would prove a blessing indeed. That magnificent dependency of the British Crown, the Indian Empire, has but too often suffered the horrors of famine! Without mentioning former calamities, or even that which in 1861 devastated the North-western Provinces, we may shortly allude to the recent affliction in Bengal, by giving a few extracts of some of the leading papers. It is a melancholy fact, that the admonitions of the public press are but too often read to-day and forgotten to-morrow; if such were not the case, we might in many respects be half a century in advance! It will therefore surely not be found amiss, if we place the following comments on a little more permanent record.

The 'Times' said, some time ago:—

'In India an immense population has been suffering for nearly a year the countless horrors of famine, especially in Orissa, the populaof which depends for its food upon rice, and as the rice-crop has failed for several seasons we may assume, with too much certainty, that no part of it has escaped the visitation. Deprived of their only means of subsistence, the wretched people had nothing before them but to creep into the jungles and die. In their fear and superstition they to offer human sacrifices to the god of the earth by chopping flesh from the living body and casting it upon their fields. The protection of our Government has not availed them much more, we are sorry to say, than the practice of these revolting rites. Our correspondent informs us, that upwards of 150,000 persons are being fed by private charity, and the representatives of several religious societies and other persons seem to have been unwearying in their efforts to mitigate the general distress. But in one week 3,500 deaths are reported to have occurred in Orissa and Midnapore. In six weeks the official estimates place the deaths at 15,000, and this famine began in October (1865), and has been raging in Orissa since the beginning of April (1866). We shall never know how many lives have fallen beneath so fearful a stroke, but when we reflect that a famine in India usually rages a long time before it is brought under the attention of Europeans at all, and that it was only a few weeks ago the Government of Bengal attempted to check it, we can fill up for ourselves the outline drawn by our correspondent, of "jackals eating the corpse of one wretch while they wait for his companion who is dying," and of "living children taken from the arms of mothers two days dead."'

In another place, the 'Times' said:—

'The mortality among 13 millions in the famine of 1860-1 was half a million. . . . In 1838-9, when as little was done for relief as in 1866, the mortality in the Jumna Doab was 800,000. But the tale of victims in this Orissa visitation mounts higher than even that, as high as the greatest of all recorded famines in India, that of 1770.'

The 'Illustrated London News' of Sept. 15, 1866, said:—

'At intervals, ranging from six to ten years, an agonising wail reaches us from India, the simultaneous cry of myriads perishing of hunger. For the most part it should be listened to as Nature's stern protest against the negligence of man. Occasional droughts of long duration seem to be a feature of the meteorological system of that peninsula; where, however, the soil is well nigh as capable of irrigation as Egypt, and, under a provident administration, might produce with unfailing regularity more than sufficient for all the wants of the teeming population. Man cannot alter at his will the character of the seasons; but man can observe them, and provide against the calamitous effects which any aberration from their usual course may threaten. The people are dying off like flies. From 2,000 to 3,000 a week encounter death in its most dreadful form, absolute starvation. The road sides are strewn with their bodies. Despair reigns triumphant. The magnitude of the calamity all but paralyses exertion.'

The 'Saturday Review' said:—

'We can discover little, if any, improbability in the statement, so appalling and so impossible fully to realise, that two millions of human beings have in Orissa recently died the most cruel and lingering of deaths. It gives the lie to all the advantages, moral or material, that modern civilisation most prides itself upon, to think that a civilised government in these days should be powerless to prevent a minority of the community dying from actual want of food, while the majority is still enjoying all the luxuries of wealth. But if, in a government so situated, even want of capacity is such a blot upon civilisation, how unspeakably foul a blot upon humanity itself must be the want of will, must be the neglect of any measures by which it might have been possible to avert or mitigate the cruel disgrace.'

The 'Nottingham Journal' furnished the following report of Rev. J. Buckley, stationed at Cuttack, Orissa:—

'Orphans have been brought dying to our door; and many that we have received have been too deeply famine-stricken for nursing and medicine to restore. After a few short days death has closed the scene. Tender and delicate women, lying in our verandah, have implored rice, or money to purchase it, with cries that have pierced our hearts. Two cases of eating human flesh have been reported; in the one case it was proved that the person was insane; in the other, a child was found eating its dead father's flesh, which had been roasted, and a few days after the child died. Mothers have left their children in the maidan (dunghill) to die, or have sold them for a few pice. In one case an only son was sold for a pint of milk; the mother eagerly drank it, gave up her child, walked a few steps, and then dropped down dead. The dying and the dead have been seen lying in our streets; though this has not been so much at Cuttack as at Balasore and some other places. At Pooree it has been common for the police to find, morning after morning, in the streets and lanes, 60, 70, 80, or more corpses! In the Cuttack district 3,000 deaths from famine and pestilence were reported in one week, and it is generally believed that at Balasore and Pooree the distress has been severer.'

The 'Times' of January 9, 1867, said:—

'It is now asserted that, in spite of all our civilisation and progress, the famine of 1866 exceeds in horror and fatality any visitation formerly experienced. . . . . Even the famine of 1770 did not carry off a greater number of people than that of last year. . . . . We are assured that not less than 1,000,000 persons have perished either from actual starvation, or the immediate consequences of want: and this shocking tale becomes more fearful than ever, when it is added, that the mortality occurred not among the entire population of India, but for the most part in a particular district with a population only twice that of the county of Middlesex. . . . . In the midst of our civilisation, in the second century of our rule, after a season of unexampled prosperity, and with prospects brighter than had ever been offered before, a visitation which might have been disarmed, if not averted, by wise administration, has destroyed a million of human beings. It is a terrible story, but the best we can do is to turn it honestly to our instruction.'

The 'Times of India' said:—

'The periodical recurrence of famines in some agricultural districts of India would seem, under the present state of things, to have assumed almost the certainty of a natural law. At uncertain intervals, but under certain well-understood conditions, we may confidently expect them; and unless some grand alteration is made we shall be in the same predicament for many years to come. If famines are preventable, it is plainly our duty to address ourselves, without a moment's delay, to the task of putting a final stop to them. And that they are preventable, that they are more or less the natural consequences of our own neglect, can hardly admit of a question. In time we may so improve and change the face of the country, that plenty and prosperity will reign where death and desolation now ravage.'

It is really a strange world we are living in! Suppose for a moment, instead of a famine, a Sepoy mutiny had broken out in Orissa. Is there any one simple-minded enough to believe that the Indian Government would not have found the means to transport thither, at the shortest possible notice, enormous quantities of powder and shot, canister, bombshells, and war stores generally, quite sufficient to drown the disturbance in blood? And yet we are told by certain parties, that it was altogether impossible to forward rice and other articles of food to the afflicted districts in time to save thousands and thousands from dying in ditches and jungles for want of nourishment. Really it is a very strange world we are living in.

We cannot alter the meteorological peculiarities of the Indian peninsula; but surely we might provide against periodical droughts by an efficient system of manuring and irrigation, such as was so successfully applied in ancient Egypt and Assyria.

Occasional inundations have been another cause of Indian famine. These might also, at least to a certain extent, be guarded against by the correction of river-beds, erection of dykes, and other similar works. Finally, the means of communication and transport should be multiplied by the construction of good roads, and the extension of railways and steamboat lines, so as to enable, in case of emergency, starving districts to share in the abundance of others more fortunate.

If India were only sufficiently provided with such public works as are imperatively demanded by the physical nature of the country, and if, at the same time, the sewage of her immense population were saved for agricultural utilisation, we cannot doubt her soil would produce sufficient food to maintain her teeming millions. Suppose, for a moment, the principal cities of India, viz.—

Calcutta	with	400,000	inhabitants
Madras	"	720,000	"
Bombay	"	550,000	"
Lucknow	"	300,000	"
Patna	"	280,000	"
Hyderabad		200,000	"
Benares		180,000	"
Delhi		150,000	"
		120,000	"
Cawnpore	"	100,000	"
Total		3,000,000	population

instead of, as hitherto, polluting the air, rivers and sea with their sewage, were to apply it in future to agricultural purposes, why, they alone would furnish, at the annual rate of 10*s*. per head, some 1,500,000*l*. worth of manure, capable of producing 15,000,000*l*. worth of food.

If the principal cities of India were once to set a good example, it is but fair to suppose that the smaller towns and the open country would gradually utilise their sewage likewise, and then the annual yield of manure, capable of producing ten times its value in food, would be immeasurably increased. Then the civilised world would no more be startled with agonising tales of horror and despair, such as, for nearly a twelvemonth, have reached us from famine-stricken Bengal.

Prevention is always better than cure, and surely, in this instance, prevention is within the power of an enlightened, energetic Christian government. It is true that the principal causes of Indian famines have hitherto been long-continued droughts on the one side, and extensive inundations on the other, both combined with a great deal of administrative neglect; but there is still another great calamity to be guarded against—the exhaustion of the Indian soil, because the physiological axiom, that the ingredients the earth is deprived of by a succession of crops must be returned to it in the shape of manure, holds good for India as well as for any other country on the face of the globe.

In this respect we can only refer again and again to the excellent example afforded by Japan. If the 'benighted heathen' of Japan are able to understand and obey the sublime laws of Nature involved in the agricultural utilisation of sewage, we may fairly take it for granted that the natives of India would soon do so likewise, if their enlightened Christian rulers were only to set them an example worthy to be followed. We have repeatedly pointed out that the immutable laws of Nature are stern taskmasters indeed, admitting of no evasion or defiance, but, on the contrary, crushing us like the car of Juggernaut, if, like Hindoo fanatics, we are foolish enough to throw our bodies under the wheels.

Well are we aware, that unless the Almighty vouchsafes sunshine and rain in due succession, all our tilling and manuring the land will prove of no avail. Still we cannot but repeat our conviction, that a good government could and should do a great deal towards preventing such appalling catastrophes as the Indian famine just alluded to. By saving to agriculture the precious human fertilisers hitherto entirely thrown away, and gradually reclaiming the millions upon millions of acres still lying waste in all parts of the world, the annual produce of cereals and all other kinds of food will be so enormously increased, that if, through natural influences beyond our control, a partial failure of crops here and there should occur, the mighty resources of modern commerce, and the unprecedented rapidity of transport by steamboat and railway, will easily supply the deficiency from more prosperous quarters.

If, enlightened by the mournful experience of the past, we have at last fairly made up our minds to obey in future the wise Mosaic law of '*covering with earth that which cometh from us*,' we might perhaps go also a step further, and follow the example of Joseph in Egypt, as we find it in Genesis xli. 47–49, 53–57:—

'*And in the seven plenteous years the earth brought forth by handfuls. And he gathered up all the food of the seven years, which were in the land of Egypt, and laid up the food in the cities: the food of the field, which was round about every city, laid he up in the same. And Joseph gathered corn as the sand of the sea, very much, until he left numbering; for it was without number. And the seven years of plenteousness, that was in the land of Egypt, were ended. And the seven years of dearth began to come, according as Joseph had said: and the dearth was in all lands; but in all the land of Egypt there was bread. And when all the land of Egypt was famished, the people cried to Pharaoh for bread: and Pharaoh said unto all the Egyptians, Go unto Joseph; what he saith to you, do. And the famine was over all the face of the earth. And Joseph opened all the storehouses, and sold unto the Egyptians; and the famine waxed sore* *in the land of Egypt. And all the countries came into Egypt to Joseph for to buy corn; because that the famine was so sore in all lands.'*

As the Government of India, owing to the low state of civilisation of the native population, must naturally for many years to come bear a somewhat patriarchal character, it really might not be so much out of its way to establish *public granaries* in those parts of its immense dominions which appear to be most exposed to the chances of a famine, on the same principle upon which large arsenals and military storehouses are maintained, so as to be always prepared for the emergency of a sudden war.

12. PNEUMATIC SEWERAGE IN AUSTRALIA.—What the famous German traveller G. Forster, the friend and companion of Cook, in a prophetic spirit foretold about a century ago of New Zealand, 'the Great Britain of the South Sea,' behold, it has come to pass before the eyes of an astonished world. Forster wrote in 1769: 'For the extensive commerce uniting separate continents, no situation can be more favourable than this one, keeping the middle between Africa, India, and America. Just imagine a state in New Zealand with England's happy constitution, and she will be the Queen of the Southern World.'

Truly Australia has become the connecting link of commerce between Africa, Asia, and America, the flourishing seat of European civilisation at the antipodes, the future home of many millions. The rising colonies of New South Wales, Victoria, South Australia, Queensland, West Australia, Tasmania, and New Zealand, with their delightful climate, healthy both for man and beast, their splendid harbours, their fertile soil, bearing alike the produce of the temperate and torrid zones, together with their immense mineral wealth—all these colonies promise fair, in no distant future, to rank amongst the first commercial states of the world.

Already some of their cities, such as Sydney and Melbourne, rival in splendour and opulence with European capitals, whilst enlightened Australian legislatures, by wise enactments, such for instance as that of compulsory education, are doing all in their power to promote the progress of true civilisation. What a pity, then, if youthful, blooming Australian cities were to begrime themselves with European folly in the shape of pestiferous cesspools and sewerage by water-carriage, with their inevitable melancholy train of cholera, typhus, and exhaustion of the soil? We think it almost a moral impossibility that such should ever be the case.

Only imagine an Australian legislature enacting compulsory education, and, at the same time, wasting millions of good money on sewerage after the disgraceful European fashion, and on most extensive waterworks, merely for the purpose of polluting their rivers and harbours with a most valuable fertiliser. Only imagine an enlightened Australian legislature voting, with right royal munificence, large sums for educational purposes, and then spending, perhaps, manifold the amount in a baneful labyrinth of old-fashioned city sewers or cesspools, thereby impregnating the virgin soil with deadly filth and corruption, and gradually poisoning countless wells hitherto clear as crystal; thus promoting the healthy growth of the mind on the one side, and on the other sowing broadcast the malignant germs of diseases fatal both to the present and future generations.

Again we say, we have too much faith in the enlightenment of Australian legislatures, and in the general intelligence of the Australian public, for a moment to suppose that the terrible mistakes committed all over Europe, as regards sewerage and utilisation of sewage, should be repeated over again by our, in this respect, more fortunate brethren at the antipodes; we stoutly refuse to believe that many an 'earthly Paradise,' at least as far as nature goes, will thus wantonly be converted into a region of pestilence, such for instance as Rio de Janeiro, Marseilles, and many other cities alluded to in other parts of our treatise.

We are fully borne out in this view by a recent New Zealand paper, the 'Lyttelton Times,' of November 16, 1866, giving an account of the annual meeting of the 'Philosophical Institute of Canterbury,' president Dr. Julius Haast, M.F.D.H.,* after whom several newly-discovered rivers and mountains in New Zealand have been named. In the highly interesting address, delivered on that occasion by Mr. Dobson, provincial engineer and vice-president of the Institute, we find the following remarks under the head of 'Health of Towns.'

'From the drainage of the country we pass, by a natural transition, to that of the towns, and to those questions which may be classed under the general head of sanitary engineering. And here it must be confessed with regret, that, beyond the abolition of the cesspool nuisance, there is no progress whatever to record. Although numerous schemes of drainage have been proposed for the two principal towns, viz. Lyttelton and Christchurch, nothing has yet been done towards their realisation. This is the more to be regretted, as the Municipal Councils of both towns, having approved of the system of removing the solid sewage at short intervals by scavengers, the question is narrowed to that of the disposal of the house slops, the outfalls for which would be the sea in the one case, and the rivers Avon and Heathcote in the other.'

Thus we see that, in New Zealand, where, a few short years ago, only Maories were roaming about, a 'Philosophical Institute' is already earnestly deliberating on such questions as the health of towns, sanitary engineering, and the like, a fact highly encouraging indeed to certain European 'circumlocutionists,' who but too often take such a marvellous length of time before venturing upon the most obvious reforms.

It affords us, therefore, great pleasure here to record the fact, that preliminary steps have already been taken towards introducing Captain Liernur's system, not only into New Zealand, but also into all the other Australian colonies, a movement to which we have no doubt the Canterbury Philosophical Institute will give the same hearty support as the 'Maatchapij van Nijverheid is doing in the Netherlands.

* Master FREIEN DEUTSCHEN HOCHSTIFT, a German Academy of Arts and Sciences, at Frankfort-on-the-Maine, founded in 1859 by DR. OTTO VOLGER, and owning the ancient mansion of the GOETHE family, in which the great poet was born, and which has now become the permanent seat of that institution.

Just at the present time various towns in Australia find themselves placed in the very same predicament as the City of London, with regard to the supply of water. If such towns, as we trust they will, decide on introducing pneumatic sewerage, many costly waterworks will remain unbuilt, or at least become far less extensive, and the water supplied at a much cheaper rate, than if such towns were misled into sewerage by water-carriage. Millions and millions of pounds will thus be saved!

Another point, which will surely not fail to attract the earnest attention of Australian legislatures and enlightened municipal corporations, is the future development of agriculture by an extensive, systematic and rational utilisation of sewage. It is true that thus far agriculture has played only a secondary part in the marvellous progress of Australian prosperity; but surely all those who mean well to their country will think of the time, when some at least of the gold fields will become less productive, perhaps be entirely exhausted, such as occurred in certain districts of California, and in other parts of the world. Bohemia, for instance, was in former centuries a gold-producing country, and now no more of this precious metal is to be found there.

Besides, history teaches us, that gold alone is not sufficient to place the prosperity of a country on a secure basis for all times to come. Look at Spain, for instance. During three long centuries she had exclusive control over the splendid gold and silver mines of Mexico and Peru, which, according to Alexander von Humboldt's estimate, yielded, from 1492 to 1809, not less than 300,000,000*l*. Nevertheless, by her neglect of agriculture and general maladministration, Spain has gradually sunk into a state of fearful financial dilapidation, an ominous warning to other nations.

The produce of the Australian gold fields from 1851 to 1862 is estimated, in round figures, as follows:—

1. Victoria	£109,500,000
2. New South Wales	10,400,000
3. South Australia	200,000
4. Tasmania	10,000
Say	£120,000,000

being an annual average of 10,000,000*l*.

With the improved methods and machinery now applied for extracting gold from the rich veins of quartz found in many parts of Australia, there is no likelihood that this annual yield will soon decline; on the contrary, it may yet increase by the discovery of new diggings. Nevertheless, a time may come when certain Australian districts may have to turn their attention to another gold field, namely, that of agriculture, which, when only worked in the right manner, is indeed inexhaustible.

The Australian colonies reckon a population of 1,330,000, which by immigration and natural increase is rapidly advancing every year. Now it takes a population of 2,000,000 to furnish, at the annual rate of 10 shillings a head, 1,000,000*l*. worth of human fertiliser, capable of raising 10,000,000*l*. of agricultural produce, or just the annual average yield of all the Australian gold fields! But when the Australian population has once reached 10 millions, the annual value of this fertiliser will be 5,000,000*l*., being the raw material for 50,000,000*l*. of agricultural produce, which alone would place all the gold diggings in the shade.

13. PNEUMATIC SEWERAGE IN THE UNITED STATES.—Considering the amazing energy of the people and their habitual indifference to precedents, by which a town with all its concomitants is often built in a shorter time than it takes a European Board of Works to deliberate about a bridge, the want of which has been felt for even half a century, there is no doubt but that an immediate advantage will be taken of the sanitary and agricultural improvements involved in Captain Liernur's system. Nor is this energy merely confined to enterprises of necessity or speculation; it is as manifest in works aiming at nothing but public comfort, combined with magnificence and good taste. A remarkable instance of this may be seen in Chicago, that fair 'Queen of the West,' where the citizens did not hesitate to raise whole blocks of granite buildings bodily six feet higher, merely to give a better gradient to some streets. One great advantage the Americans possess in cities newly founded is their having a virgin soil to build upon, which can, by adopting this system in time, be wholly left unpolluted by saturation with fæcal matter from cesspools and sewerage by water-carriage.

We have also seen, on page 10, that the Americans have managed to exhaust the soil of many extensive tracts in a comparatively short time. But the rapid increase of population can, by judicious management, be made instrumental in repairing the results of that wasteful process. In 1800, the total population numbered five and a half millions; in 1825, eleven; and in 1850, twenty-three millions. This shows an increase of about 100 per cent. in 25 years; and we may thus assume that, in 1875, the number will be some forty-six, and, in 1900, ninety-two millions, or, adding increase by emigration, fully *one hundred million* souls! The immense amount of fertiliser due to the town sewage of such a large population, instead of being any longer allowed to convert the many smiling harbours and limpid streams into hotbeds of pestilence, will thus, we may rest assured, soon be used by that 'wide-awake' nation, to refertilise thousands and thousands of acres, at present barren and waste, thereby changing the desert tracts of many a fair state into rich and populous regions.

14. PNEUMATIC SEWERAGE IN THE NETHERLANDS.—We have thus far elucidated the advantages which might result from a prompt introduction of the new system. In recording the efforts hitherto made actually to secure them, it is our pleasing duty to state that, by way of setting a good example, the first move in this direction was made by H.R.H. Prince Henry of the Netherlands, who, after listening to Captain Liernur's explanations, and patiently investigating all details, at once recognised the immense benefit to be derived from this invention for his country, and, as alluded to in our preface, not only graciously promised his personal influence and support, but recommended its immediate

adoption in various towns in the Grand Duchy of Luxemburg.*

A further highly encouraging example was given when Captain Liernur laid his plans before the municipal authorities of the city of the Hague, who without any delay submitted them to the judgment of a committee for professional inquiry: the report being favourable, it was *at once resolved to make a trial* of the system at the expense of the corporation, the necessary works being already in course of preparation.

Captain Liernur also laid his plans before the section of agriculture and that of national economy of the Maatschappij van Nijverheid (Society for the Promotion of Industry in the Netherlands), at its annual session on the 11th, 12th and 13th September, 1866, Haarlem. The system having met with the approval of both these bodies, the chairman recommended all delegates to obtain drawings and descriptions of the invention, so that each might bring about, if possible, the improvements in his own town; † thus giving, by such prompt action, an example how men, having the interest of their country at heart, should proceed; and at the same time showing how unmerited is the character generally given to the Dutch, of being always behind the age.

15. Pneumatic Sewerage in Great Britain.—In the meantime it appears that in England also Captain Liernur's system has excited considerable interest, to judge, at least, by the manner in which various leading journals make mention of it; all approving both of the purpose and principle involved, and encouraging the Captain to persevere in his enterprise. We can do no better than quote a few of these comments.

'Engineering' of Nov. 2, 1866, after enumerating the leading features of the plan, says of them:—

'A critical examination will show, that they are the essentials of what all engineers who have made the sewerage of towns their study, and of what all farmers acquainted with agricultural chemistry have pronounced to be most needed. Combined they form the realisation of one single design, namely, that of rendering human excrements useful instead of dangerous.'

The editor then thoroughly condemns the sewerage by water-carriage system, and after ably summing up its highly objectionable features, both as regards removal and utilisation of sewage, gives a concise description of the pneumatic arrangement, with illustrative cuts.

The 'Engineer,' of Dec. 7, 1866, gives a similar description, with illustrations, and, commenting upon the new plan, says:—

'The arrangement possesses apparently many advantages over even

* Many towns in this really healthy and beautiful country have suffered repeatedly from cholera; above all last year, when that fell disease actually decimated several places. The cause could only be found in their ill-constructed dwellings, which, in most cases, have large cesspools *in the cellar*, emitting most offensive effluvia. To remove this evil, and to fertilise at the same time large barren tracts, is Prince Henry's chief desire.

† For further particulars see Handelingen der 89ste algemeene Vergadering van het 10de Nijverheid's Congres. Haarlem, 1866.

the London system, and disposes efficiently of several of the difficulties with which we have to contend in distributing sewage, and it is unquestionably better than the Continental system which we have described.'

The London 'Morning Post,' of December 9, 1866, in a highly instructive leading article on the subject, says:—

'Absolute failures and terrible expenses, including in some cases law costs, have convinced local authorities in various parts of the country that any attempts at deodorising and clarifying town sewage previous to its being cast into a river are delusions, so far as they are concerned, and have not lessened the nuisance to those below them. . . . . . Captain Liernur has, within the last few weeks, given partial publicity in this country to his plan for dealing with this matter. His scheme is altogether distinct from, and independent of, the water supply and of the facilities for drainage within the reach of towns. These may in every instance remain as they are at present. . . . . The plan appears to be simple as well as ingenious. If it should succeed in practice, it will be a great boon, not only to towns but also to agriculturists, by furnishing them with a valuable manure, unmixed with water and other substances, for stimulating the growth of cereal, root, and other crops. . . . . . Without pronouncing any decided opinion upon the merits or demerits of Captain Liernur's plan, we, at the same time, think that it deserves the attention of the British public. Municipal bodies not yet committed to any scheme for freeing their sewage from fæcal matters would do well to make themselves familiar with the specific objects which it proposes to accomplish.'

The 'Lancet' of March 30, 1867, says:—

'Whilst the Metropolitan Board of Works is spending its millions in carrying the diluted sewage of the metropolis either into the river, or to sandy wastes, where its very quantity renders it difficult to manage; and while, on the other hand, the Rev. Mr. Moule, aided by Dr. Hawksley, is trying to bring mother earth to the rescue of her children, our neighbours at the Hague have inaugurated an entirely different system of ridding themselves of the sewage of their city, whilst carefully utilising every particle of it in the cultivation of their fields.'

The 'Lancet' then gives a description of the new plan, and goes on to say:—

'That this amount of rich and concentrated manure would be highly prized by the agriculturist cannot be doubted; and the only weak point in the system appears to us to be that no provision is made for the water used for domestic purposes (and by the English in greater quantity than by other nations), and which would certainly find its way in great part into the drain pipes as a constituent of what is ordinarily termed "slops." . . . . We commend the very ingenious scheme of Captain Liernur to the notice of sanitarians.'

With regard to the difficulty raised by the 'Lancet,' we refer to page 140, where Captain Liernur points out a way in which rainfall and household water may be cheaply and efficiently dealt with in such towns which as yet have no drainage works at all. Where sewers exist, however, they may of course be used for rainfall and household fluids; only care should be taken to trap the kitchen drains well, so as to prevent remnants of food, &c., entering the sewers, where, by gradual decomposition, they might render the liquid putrid, and thus throw off noxious gases. But if these matters are retained, the fluid can most advantageously be discharged into rivers and watercourses.

We may here answer also another objection sometimes raised against the new system, namely, that servants would continually pour washwater and other slops into the privy, thereby increasing the bulk to be removed and spoiling the manure. On this point we can only say that, in France and Germany, a peremptory order to the servants has proved sufficient to prevent such irregularities in all well-conducted households.

The 'Sunderland Herald' of November 30, 1866, contains a very able article, treating the whole question, from which we make the following extracts:—

'Upon this question depends not only the public health, but also the abundance or scarcity of our food. . . . . A town of 100,000 inhabitants could annually obtain a sum of 50,000*l.* for its sewage (provided it is undiluted and undecomposed), either in the sale thereof, if purchasers could be found, or in increased yield of farms worked by it. . . . . The means to obtain a revenue is without doubt furnished by Captain Liernür's sewerage system. . . . . Can there be anything more silly and absurd than to throw such a valuable element in the sea as is now proposed in Dublin? Surely it is an outrage on civilisation that such a plan is seriously listened to, and it will be a cruel blow to our national economy if it is ever carried out. Imagine the capital of a country where the cry of hunger is nearly always heard, and where gaunt famine stalks through nearly every village, deliberately proposing to waste annually 120,000*l.* worth of fertiliser, enough to grow food for a quarter of a million of inhabitants!'*

The 'Birmingham Daily Post,' of March 25, 1867, contains the following:—

'Among the various applications of science to measures of practical utility, there is perhaps none which is of more importance than the proper utilisation of sewage, as it alike affects the general health of towns and agricultural interests at large. Until a few years back, only the first point was paid any attention to, and a watercloset system, combined with brick sewers, considered the best means for removing fæcal matters from towns.

'The immense volume of liquid sewage hereby produced was allowed to run to waste in the nearest stream. But it was soon surmised that the result of this would be the pollution of the rivers, and many attempts were made to extract the offensive part from the liquid again, in the hope of thus at the same time obtaining a good fertiliser from the solid parts.

'All these attempts, however, failed, for the simple reason that a

* According to the 'Birmingham Post' of May 16, 1867, *Kidderminster* is also in danger! The report of Mr. B. Latham, civil engineer, to the local sewage committee, exhibits the gross ignorance of some engineers. One advises to utilise the sewage of 20,000 inhabitants on 15 to 25 acres; while another actually proposes to precipitate and deodorise the matter after the fashion which the trials of the 'Royal Commission' have proved to be entirely futile. Mr. Latham himself recommends a plan which, after an outlay of 37,000*l.* for works, will succeed in using up the manure (worth 10,000*l.* annually) on about 250 acres! The same journal relates how the little town of *Eastbourne* has been victimised. Works, estimated at 6,000*l.*, but proving to cost 35,000*l.*, convey all the sewage into the English Channel; and when this queer piece of engineering was first put in operation, the deluded citizens had a grand holiday and much rejoicing! *O sancta simplicitas!! Risum teneatis, amici!*

large part of the manuring elements are held in solution, and being consequently afloat, escaped, leaving an offensive sediment wholly unable to repay the trouble of collecting it. Attempts were then made to utilise the sewage by its application as manure to various soils and for various plants; and, after many costly experiments, it was found that rye-grass flourished highly when irrigated therewith, but is at the same time the only plant which could stand such treatment, and that even then the meadows must be so low that the sewage can flow from the same outfall to the settling tanks by gravitation, it not having in that form value enough to repay the cost of pumping it to any elevation, or distribution by hose and jet, nor to warrant the outlay due to the costly machinery required therefor.

'This was subsequently confirmed by the Royal Commission of Inquiry appointed to examine into this matter, and since that time it has been by "routine" engineers and agriculturists (a class of people who never think of doing anything unless somebody else has done it first, and are thus a real stumblingblock to all progress), laid down as a fixed rule that there is no way whatever of utilising human fæcal matter, but by diluting it with much water, and then irrigating rye-grass with it. They accordingly preach their faith to all towns which, being "blessed" with the watercloset system, are burdened with large volumes of putrid liquid, and consequently "in a bad fix;" a conduct somewhat like advocating a 12-inch shoe as a fitting pattern for all people to wear, after having found that it makes a tolerable makeshift for two or three.'

It is not surprising to find such language in a Birmingham paper, and it has doubtless reference to the attempts which we hear are being made to introduce there also the irrigation scheme, —a most barefaced '*delusion and a snare!*' Many a clear-headed man must feel annoyed at the prospect that his town, generally so forward in all matters of progress and reform, should thus in the very silliest manner make a retrograde step. We hope Birmingham will be spared the misfortune of getting large tracts of evil-smelling meadows in its immediate neighbourhood, and at the same time lose a magnificent revenue. And this can be easily effected by all its progressive citizens energetically exposing the said mistaken measures, which otherwise, by their advocates, are apt to be promulgated until they are finally believed in and carried out, to the great detriment of public interest. Such errors have a fatal capacity of spreading and growing when they once have taken a firm foothold, not unlike a certain waterweed much found in Canadian streams, which multiplies to such an enormous extent as in time to choke a river and make it unnavigable.

The 'Birmingham Daily Post' then continues as follows:—

'But it did not escape the attention of men like Way, Voelcker, Liebig, Hofmann, Wit, and practical agriculturists like J. B. Lawes, that there is a frightful disproportion between the intrinsic manuring value of fæcal matters and the agricultural results produced by the irrigation process.

'Repeated analysis had placed the annual value of the ammonia alone at 8*s*. 3*d*. per head of the population, whilst the value of all the ingredients was rated at 10*s*. (ten shillings). It was acknowledged that all crops which yield human food can profitably be raised by this manure, because it contains the very mineral ingredients withdrawn by these crops from the soil, besides the most fertilising organic element; while it was found that by converting meadows of medium soils partly into tillage land, a yield could be produced from 150 to 200 per cent. larger than by rye-grass pasture. It was shown by men like Mr. Lawes, that human manure, in order to bring crops proportional to its fertilising qualities, must remain undiluted, unfermented, and unadulterated, and thus be given to the soil.

'This led to a close investigation of the watercloset system, which was found to be unfit for general introduction into towns, as the poorer classes, which form by far the majority of the population, are unable to pay this more or less costly arrangement, or the frequent repairs it requires, while the water needed for it imposes a burdensome tax upon them, which neither the city nor the waterworks can afford to furnish gratis, or even often furnish at all. It was also found that the highly noxious gases generated within the sewers ascend their inclined planes, and cannot be kept from re-entering the dwellings by means of closet pipes, or escape in the streets, and being thus discharged amidst the busiest hum of human life, produce the same disastrous results upon the public health as before. This is acknowledged by the first drainage engineers, as, see the Report of Mr. Bazalgette and his associates to the Metropolitan Board of Works, which states that, after a critical examination of all the schemes proposed, and many experiments, there is no way of curing the evil, and but two modes of mitigating it, namely, either building furnaces with high chimneys all over London, at a prime cost of 460,000*l*., and an annual sum of 300,000*l*. for coke and labour; or purchasing from the waterworks daily some forty-two additional million gallons of water for flushing the sewers, at a yearly cost of 385,000*l*.; as, however, the waterworks can furnish for this purpose but five millions, this plan is impracticable.

'But both plans are too costly for the uncertain, or partial, results thereby hoped to be attained. It was further found that the masonry of the sewers is as little capable of withstanding the deteriorating effects of the gases and liquid within as that of the cesspools; that it becomes porous, and allows the matter to percolate through, thus poisoning the soil and the wells located therein; that, in fact, sewers are but long cesspools, and have all their faults, but on a much larger scale.

'To sum up: the best professional intelligence and knowledge has come to the conclusion that the watercloset and sewer system is an absolute failure, both in a sanitary and agricultural point of view, and confess that there is no remedy but by the withdrawal of fæcal matter from the sewers, using the latter solely for house-water and rainfall drainage, while the former are removed by means of hermetically closed iron pipes, laid permanently under the pavement. This is called the pneumatic system, whereby the closets and pipes are nightly cleared by the force of atmospheric pressure, operating with the blast of some thirty combined hurricane winds, and removing the last morsel of excreta and their gases simultaneously. Besides thus effecting the requirement of cleanliness far more completely than waterclosets, this system has the advantage of keeping the fæcal matters "intact," undiluted, and at the same time transportable, so that they can, without great cost and trouble, be applied as a fertiliser to tillage land, and the growth of crops which are known to be much more profitable than rye-grass. The large returns thus obtained yield good interest on the outlay required for furnishing and placing in working order all the apparatus, including the necessary private closets in every dwelling in town. The poor are thus provided for as well as the rich, and a measure of cleanliness carried out among them independent of their consent and habit, which must largely improve the public health. Another great merit of this system is, that it cannot be called "an untried novelty of uncertain issue," it being a combination of well-known practical measures, but so arranged, that they mutually operate so as to produce the greatest effect.

'Thus the application of pneumatic force through flexible hoses for emptying cesspools can be seen daily in most large Continental towns, whereas most farmers know the advantage of tillage land over pasture, when the soil is light, even for dairy purposes, and of using an undiluted mixture of fæces and urine over having it flooded over with water.'

These extracts are enough. There are yet many more, proving how wide-spread the attention is which this matter has awakened; but no new facts would thereby be elicited. All these comments of the press are chiefly remarkable for their unanimous approval of the scheme, not one single objection having been raised thus far, either in a sanitary, technical, or agricultural point of view.

16. INEXHAUSTIBLE MINES OF NATIONAL WEALTH.—The reader will not, it is hoped, take it amiss if, after having indicated what Captain Liernur's system might effect, and what progress towards its introduction has been made, we with a few words point out the bright prospects its universal adoption promises. We are not going to light Aladdin's lamp, nor shall we mount Pegasus to take aërial flights; but just as in the former part of our treatise we have not depicted the Evil One any blacker than he really is, even so shall we now only deal with sober facts and dry hard figures, the correctness of which any intelligent reader may verify for himself. Will it be believed that the gold fields of Australia and California, the petroleum springs of Pennsylvania and Canada, and other similar sources of natural treasures, might all be eclipsed by the immense mines of national wealth to be opened by a proper solution of the great sewerage problem? Let us see for a moment.

Great Britain counts in round figures a population of some		30,000,000
And her colonies in Asia	183,000,000	
" " Africa	1,000,000	
" " America	4,500,000	
" " Australia	1,500,000	
		190,000,000
Total population under British dominion, some		220,000,000

Of which say one-third, or 75,000,000, may be estimated to be living in towns and cities, capable of gradually introducing a proper removal and utilisation of sewage.

These 75,000,000 of human beings produce annually, at the rate of 10*s*. per head, 37,500,000*l*. worth of manure, being just about the joint annual yield of the Australian and Californian gold mines! Our tale of wonder, however, does not stop here. Let these 37,500,000*l*. worth of human fertilisers only be properly applied to agricultural purposes, and, behold, they will produce tenfold their amount, or some 375,000,000*l*. of breadstuffs, beef, milk, butter, cheese, and all other kinds of vegetable and animal food. Such is the marvellous bounty of Nature, if we only study and obey her sublime laws.

Applied to the whole of Europe, our calculation would stand as follows:—Europe contains some 300,000,000 of people, of whom say one-third, or 100,000,000, might, in this latter half of the nineteenth century, perhaps be considered civilised enough to avail themselves, in course of time, of the immense advantages offered by modern science in the shape of pneumatic sewerage, which would yield annually some fifty millions sterling worth of human fertiliser, capable in its turn of producing some 500 millions sterling worth of animal and vegetable food. What an astounding relief to some European nations, now almost ground down to the earth by taxation for military and political purposes!

17. A bright Prospect into the Future.—Some imaginative writer might perhaps here use more eloquent language, and depict in glowing colours the glorious future yet in store for all the nations of the earth; and well might he be excused for some enthusiasm on a subject the plain honest truth of which seems stranger than fiction. No more typhus and cholera arising from pestilential sewers, polluted rivers, and poisoned wells, and ruthlessly decimating the helpless population of teeming cities. No more horrible famines strewing the plains of India with millions of corpses. No more poor wretches dying from want in filthy garrets, or in the open streets of London! Abundance of food for all who are able and willing to work for it, and a generous surplus for those who through age or infirmity cannot earn their livelihood! A good time coming for all round, and all this merely by our complying with the plain dictates of Nature and common sense in our treatment of the irrepressible Sewerage Question.

Rev. T. R. Malthus, in his once famous 'Essay on the Principles of Population,' taught, that the natural increase of population largely outstrips that of their means of subsistence, the former progressing geometrically from 20 to 20 years, as 1, 2, 4, 8, 16, whilst the latter increased only arithmetically, as 1, 2, 3, 4, 5; and that, therefore, government should limit the increase of population by forcibly reducing the number of marriages.

Had Malthus only lived to see the glorious future opened out by modern science to agriculture and national economy, gladly, we should think, would he have forsworn his mournful theory of compulsory celibacy, and fully recognised, instead, the sublime wisdom of a merciful Creator, who surely would not have commanded mankind, *Be fruitful and multiply, and replenish the earth, and subdue it*, if the earth were not capable of supporting all who are born upon it. But we must first properly '*replenish and subdue it*,' before it can bring forth sufficient nourishment for all.

As a single instance of the marvellous and inexhaustible productiveness of our terrestrial globe, we may refer to a lecture, delivered at Rio de Janeiro, by Professor Agassiz, on his return from his exploration of the Amazon. The learned professor said, the general impression in regard to the Amazon river was very erroneous, not only in regard to the climate of that region, which he had been informed was unhealthy, but also as to its fertility. He found the valley of the Amazon uncommonly fertile, and its climate very healthy. It was his opinion that it would one day become the mart of the world, supporting in comfort some twenty millions of inhabitants.

What is here said of a mere part of Brazil applies with equal force to the United States, Canada, Australia, and other thinly populated regions of the globe, where millions upon millions may yet in future find a comfortable home, with ample sustenance of life, if ever a want of elbow-room should be felt in the old world!

18. A PEACEFUL SOCIAL REVOLUTION.—We are not presumptuous enough to suppose that the measures here advocated will prove an universal panacea for all the evils flesh is heir to, but we simply ask every unbiassed mind, Is it not true that *filth and want of food* are amongst the chief causes which constantly tend to human debasement and misery, both physical and moral? If this be so—and who can doubt it?—then surely there is no task more deserving of immediate and most serious attention than that of devising means for removing these impediments to human happiness. By a judicious use of the immense resources placed at our disposal by modern science, in the shape of such acknowledged practical appliances as pneumatic force, steam-power, and agricultural chemistry, Captain Liernur has shown that this may be effected by practically transforming filth into food.

Thus a peaceful, moral, and social revolution will be effected such as the world has hardly seen before! What hitherto was only a most prolific source of constant annoyance, of disease and death, behold, it is now a most valuable specific for nourishing and stimulating vegetable growth, a fertiliser of surpassing power, giving bread to millions; a source of such boundless plenty, that, instead of the misery and strife which the 'struggle for life' always engenders, peace and good-will will more generally reign upon earth; in short, an agent of happiness and a blessing to all!

It is to be hoped, then, that all rulers of nations and enlightened statesmen, all national economists and political and social reformers, all municipal authorities,—in fact, all upon whom devolves the sublime task of governing their fellow-men, or of studying and advocating the principles according to which a sound and efficient government ought to be conducted—will not again waste years in fruitless deliberations, nor listen to promoters of obsolete projects, which sad experience and independent judgment have condemned, and which, as has been so often the case, lead, after endless bickerings, but to partial reforms; but boldly stride forward, and, following the dictates of plain common sense, use all their influence and energies to carry this great improvement into speedy execution.

19. WHERE THERE IS A WILL THERE IS A WAY.—To bring about the general introduction of this from all sides so highly recommended scheme, there is nothing needed but a firm determination to take hold of it in the spirit of the famous French maxim: *si c'est possible, c'est fait; si c'est impossible, cela se fera!* a far better rule of action in such a case than that of hesitating long, as it were, on the brink of a precipice, with the certainty of falling down at last. Perhaps some unwillingness will often be manifested to incur new expenses, after the enormous sums already sacrificed by many towns in extensive lines of sewers; but, as we have seen

in page 198, these works are not altogether thrown away, but may be made highly useful in draining streets and dwellings of rainfall and all waste water, except fæcal fluids. On the other hand, it should be remembered that, whatever the expense, the sum is not only refunded within thirty-five years, but that during that period the usual interest thereon is enjoyed, and ever afterwards a handsome revenue to a town. But even without these advantages, the outlay should form no objection, considering that by the saving of so much fertilising material, *scarcity of food and endemic and epidemic diseases* are kept at bay, enemies far more formidable than the hypothetical ones arising from political entanglements, on account of which millions on millions are constantly expended for means of attack and defence, which after all soon become useless again by new inventions. For instance, most expensive ships' armour-plates are continually found too thin, because enormous guns are invented which can easily pierce them, and when at an immense cost plates are made thick enough, the armament becomes again useless through still heavier ordnance, and so on, each improvement becoming worthless through the superiority of another. If, then, these most expensive changes are submitted to for guarding against an enemy which, perhaps, may never come, surely it would be the height of folly to grudge a far smaller expenditure for preventing the certain approach of the deadly foes alluded to, by taking proper precautionary measures whilst there is yet time.

20. Conclusion.—In concluding our treatise, which, as indicated in our preface, is the result of a conscientious investigation of all that has hitherto been done to solve the question at issue, we cannot but give a decided preference to Captain Liernur's system. We once more submit, that one of its chief recommendations consists in its not being an Utopian scheme, aiming at a perfection of arrangements impossible to attain, but that it is, on the contrary, a complete and comprehensive design, having hard dry facts for its principles, and well-known mechanical means for its practical execution.

The new system is, in fact, based upon the principles advocated in the '*Congrès général d'Hygiène*,' held at Brussels (see page 16), namely, the eternal circulation of elements through a constant series of vital duties in that sublime and beneficent order, by which the Great Architect of the universe establishes and maintains the wondrous works of His hand.

Thus the primitive elements of soil and atmosphere are converted into food, by the direct agency of vegetable life, or given a still more concentrated form in animal bodies. After consumption by us, certain ingredients are left, the only office of which is to convey the nutritive principles, and which are endowed with an active power for renewed usefulness in the same direction. As by Earth alone food is prepared, Nature points out the necessity of restoring to her these ingredients by giving them properties full of danger to us, unless this requirement be strictly complied with; allowing them, at the same time, an interval of a few days to remain innocuous, so that, with the limited means at our disposal, we may still completely execute the design.

That eminent periodical, 'Engineering,' the ablest of all professional journals, contains, May 17, 1867, in an article on the *Engineering Future*, the following beautiful thoughts:—

'To the Great Engineer, whose presence we dare not conceive, and of whose plans and tremendous agencies we know nothing, *we* are not even, as are to ourselves, those clever and enterprising little engineers the beaver, the bee, and the white ant. . . . . But of all the wonders of nature, the mystery of organic growth is greatest: the assimilation of invisible gases into the structure of plants and of animated beings. . . . . . We pretend to no powers of prediction, but we own to great faith in the future. And we look upon the engineer as a great trustee of human happiness. His works are to find employment for all, for workmen and skilled managers, for accountants and cashiers; and through these to provide new trade for merchants, new commerce for ships, new markets for every known product of the soil, of the mine, and of the sea; new engagements and commissions for men of letters and of art; and, in short, new prosperity in all the mutually reacting conditions of life. It will be the business of the engineer to double the productive power of our fields, to bring pure water to all our towns, to drain every inhabited spot, and to save all that is now wasted of sewage; and thus, by increasing the supply of food, and by improving all the material conditions of life, and thus prolonging it, to multiply the number of happy homes, the greatest object which life can present, whether to the engineer or to the statesman.'

These pertinent remarks most eloquently predict the happy results of successful sanitary and agricultural engineering, and support us in our estimate of the bright prospects portrayed in the foregoing pages, which cannot but be the legitimate consequence of Captain Liernur's system.

For we have seen that this new plan is in strict accordance with the laws of Nature: hence it is our solemn duty to comply with them, and not to mar any longer such a beautiful design by an irrational treatment of refuse organic matter.

If we do so, we may rest fully assured that a higher state of Public Health, a development of Agriculture hitherto unknown, and a permanent National Prosperity will be our ample reward.

THE END.

APPENDIX.

I. COUNTRIES, CITIES, AND TOWNS REFERRED TO.

The Figures denote the Pages of the Work.

a. England.

b. India and Australia.

c. France.

d. Germany.

II. PRINCIPAL AUTHORITIES AND OTHERS REFERRED TO.

The asterisks refer to Authors and Publications not specially quoted, but to whom we are indebted for part of our information.

d. Holland.

e. Italy.

f. United States.

g. Periodicals.

h. Foreign Papers.

III. TABULAR STATEMENTS.

IV. ILLUSTRATIONS.

aims enumerated on the title-page. It seems to be *an impossibility that any defalcations can occur where the system is tained.* Instead of being, as some think, a cumbrous and difficult machinery, *the classifications render the work so simple* that books so prepared might be kept without difficulty. It leaves *no opening for illegitimate trading*, and every honest merchant and shopkeeper will, therefore, find it to his advantage to study the subject, while *proprietors of large houses should not be without books prepared on this principle,* which "epitomises a mass of complex facts, gradually and lucidly evolves final results, and thus enables the mind to grasp with ease the whole range and drift of affairs, even of the most extensive and intricate nature." *We heartily recommend the work to the earliest consideration of all classes of the community.*'—*Liverpool Albion.*

7. 'STATISTICAL BOOK-KEEPING, by F. C. Krepp.—The *simplification and abbreviation* of the common system by double entry have long been *desiderata* in the merchant's and manufacturer's houses, and Mr. Krepp has by this publication *fully supplied the want.* It is a complete guide to the statistical system, which divests book-keeping of unessential technicalities, and has already received the approbation of first-class houses. The plan and arrangements commend themselves at once, while the *suggestions for preventing fraud are thoroughly practical, and, to our view, effective.*'—*John Bull and Britannia.*

8. 'The system is not absolutely novel as regards certain of its workings, but taken as a whole, *it is entitled to the credit of originality,* inasmuch as the statistical purpose is kept steadily in view throughout, and "returns," if the word may be used, elicited *by processes at once simple and ingenious. The book is a valuable contribution to the counting-house, and may be commended to the examination of all who are dependent upon the work and the fidelity of others.* To the shareholders in public companies we also counsel a perusal of the final chapter, in which a method of *joint auditory* is pointed out, which, it is not too much to say, *would render the perpetration of the frauds of which we have had of late but too many examples, all but impossible.*'—*Shipping and Mercantile Gazette.*

9. 'Mr. Krepp's system is *eminently practical and capable of adaptation to small as well as large concerns,* whether domestic, agricultural, manufacturing, mercantile, joint-stock, or national. *In large establishments it will save a considerable amount of time, labour, and expense.* Mr. Krepp's work appears most opportune at the present terrible crisis in the commercial world, and we cannot but think that a system of statistical book-keeping, which presents at all times a correct epitome, or "bird's-eye-view" of the actual state of affairs, must, if adopted, *prove of immense value in large commercial and banking concerns like those which have recently succumbed under the pressure of these disastrous times.* The statistical system, combined with the plan of "audit" recommended, would also *render impracticable those extensive frauds,* which, as in the case of Redpath, the Royal British Bank, and other equally notorious instances, have plunged vast numbers of individuals in the deepest distress, and swept away from the rightful owners an enormous amount of property. *A complete check upon these frauds has become a national desideratum;* and that individual will deserve well of his country who shall inaugurate a system that puts an effectual stop to them.'—*Huddersfield Chronicle.*

10. 'STATISTICAL BOOK-KEEPING.—We feel sure that *the old ledger balanced once a year is about as fit for these go-ahead days as the old stage coach for our present rate of travelling.* And we think it very possible that many traders may now be further on in their dealings than in their method of recording them. We therefore recommend Mr. Krepp's book to attention, as very likely to give useful suggestions. An astronomer who knows but half his subject will put ten times more progress into that half, than an imperfect book-keeper will do into his own system.'—*Athenæum.*

11. '*No one can doubt the importance of the object Mr. Krepp has in view in this work, and as little will any one question the appropriateness of its publication at the present juncture in our commercial history.* The subject is one to which the Author of STATISTICAL BOOK-KEEPING has devoted a very great deal of attention, and on which he appears to be fully competent to speak, and fully entitled to be heard. What more can we say by way of *urging the principals of commercial establishments to procure the work and test for themselves the practicability and value of Mr. Krepp's system?* But besides those to whom correct book-keeping is a necessity, Mr. Krepp's 'Statistical Book-keeping' appeals to those *who*

make book-keeping too much a matter of indifference. And very possibly many, by keeping really correct instead of merely approximate accounts, as we fear is too frequently the case, *would find advantages to result of which they have at present no conception. The book is one which certainly deserves the careful and attentive consideration of the commercial community.'—Blackburn Standard.*

12. '*A valuable and carefully prepared system of Statistical Book-keeping* has been placed before the mercantile community. The benefits to be derived from adopting the Statistical System cannot be better explained than by quoting from the Author's preface, in which he says, "*Statistics, judiciously applied to mercantile accounts, will be found of great assistance in keeping resources together during times of commercial depression, and weathering such storms as occasionally occur in the mercantile world,*" and that "*the system now submitted is the result of fifteen years' personal observation and practical experience in English, American, and German counting-houses.*" *Mr. Krepp's system could easily be introduced and engrafted upon others now in use. A very important feature in it is the advantage which it gives the head of a large establishment,* in being able, by a very short inspection of his ledger, to ascertain the actual condition of his affairs, without having to wait until his usual balancing and stock-taking. *The book is altogether such a one as ought to find a place in the counting-house of every large mercantile establishment;* and as the period is approaching when the great majority of such establishments balance their books and take stock, *a more favourable opportunity for introducing Mr. Krepp's admirable system could not be afforded* ; and by a careful inspection of the specimen accounts furnished in the book, *a very short time would enable the books of any establishment to be kept with a correctness hitherto only attainable by much labour and time.*' *Newcastle Journal.*

13. 'Statistical Book-keeping.—*A valuable contribution to the literature of commerce* has been made by Mr. Frederick Krepp. The work of this gentleman applies the science of statistics to book-keeping, by the establishment of a perpetual analysis, which condenses and tabularises transactions as they occur. It is not easy, of course, to give an idea of this comprehensive system, either as to its utility or simplicity, *but certain we are that neglect, as well as fraud, could be extirpated from railway accounts were this system adopted.' Railway Times.*

14. 'Statistical Book-keeping.—Under this title, Mr. F. C. Krepp has published (through Messrs. Longmans) *a very elaborate treatise, explaining a mode of simplifying and abbreviating the common system of book-keeping by double entry.* For keeping the accounts of mining and metallurgic companies, railways, and, indeed, those of public companies generally, *we believe no set of books upon the present system could give such satisfaction to either shareholders or directors* as those of Mr. Krepp, in which there is "a place for everything."'—*Mining Journal.*

15. 'This elaborate work, illustrating the theory and practice of a new system of Book-keeping, for the uses of the mercantile and commercial world, appears to have *very special recommendations in its favour.* As a work of professional utility, it cannot fail in its appeal to a class with whom the acquirements of Book-keeping are of the greatest value.'—*Weekly Dispatch.*

16. 'Statistical Book-keeping. — *The object of this work is one of unquestioned importance and utility, and its appearance at the present time is most opportune and appropriate.* Mr. Krepp has employed much labour and skill in the construction of this elaborate work. *We strongly urge the commercial public to examine the work for themselves.'—Bristol Advertiser.*

17. '*The importance of the knowledge of good book-keeping principles can scarcely be too highly estimated.* If, on taking up the work, we were disposed to regard it with surprise and some misgiving, on account of its pretensions, *we confess that an examination has satisfied us that its claims are abundantly substantiated.* The idea of the Author is, that the books of an establishment should not only be serviceable as a record of past transactions, but that they should indicate, at any time, and with the least possible trouble, *its present condition, either, as a whole, or comparatively, in its separate departments,* however complicated and extensive the business may be: *and he has produced a system which answers to this idea. As a whole the system is remarkably complete, and a decided advance upon previous publications.* The books in ordinary use are employed with slight modifications, and with the only addition of a *Monthly Balance Book*, and a *Book of Statistics. The latter*

book we regard as an important and valuable improvement, and the advantages to be derived from its use incalculable. As statistical, the system takes cognizance of more facts, and seeks to arrange, compare, and classify them more fully than the ordinary modes of book-keeping. *Its objects are accomplished on scientific principles, and this constitutes its great value.'—Bradford Observer.*

18. 'Statistical Book-keeping. — The system is concluded by "Suggestions for the *prevention of defalcations and frauds* in Banks, Railway Companies, and other concerns," which will *be read with interest and studied with advantage by all having pecuniary connection with such establishments.' Liverpool Mail.*

19. 'Statistical Book-keeping. — The *present system gives evidence of having been carefully matured, and of being sound in principle. Let it be fairly examined and tested* by professional accountants, and by the mercantile community, to whom, we repeat, it is offered at a time when, of all others, they should, and, no doubt, *will be ready to adopt any real aid in the management of their business.'—Aberdeen Journal.*

20. '*The science of Book-keeping is as yet in a very rough state. There is no science of equal importance which stands in greater need of improvements.* Mr. K.'s arrangement *enables every employer to obtain at the end of each month a clear view of the state of his affairs.* This is an advantage which the managers of large establishments, who have hitherto been in the habit of balancing their books only once a year, will be able to appreciate.'—*Newcastle Chronicle.*

21. 'Statistical Book-keeping.—*Mr. Krepp has done good service to the commercial and trading community by the publication of this elaborate and ingenious work.* It appears to *furnish very efficient checks against either accidental error or wilful malversation, and to afford very valuable facilities* for enabling a merchant, manufacturer, or shop-keeper, to "take stock" at much more frequent intervals than would now generally be considered possible. Properly carried out, it will *at the end of each month present a clear view of the condition of affairs up to that date.* We commend the work to the attention of those classes for whose benefit it is intended, merely adding that it offers a *number of shrewd suggestions for the prevention of defalcations, and frauds in banks, railway, and other companies.'—Midland Counties Herald.*

22. '*Book-keeping is a process of great importance, really simple, but much neglected and little understood.* Book-keeping is often enough made an artificial system of complicated cash entries, without reference to the essentials of the business to which it is applied. *This work is most valuable to all desirous of putting their accounts on a correct and convenient basis, because it illustrates the principles and rationale of accounts, enabling the principal to decide on the requisite system of arrangement,* instead of depending on a book-keeper. *To all, however, Mr. Krepp's work will afford valuable lessons. A very valuable part is what he calls his Book of Statistics, analysing the results of previous years' working, and bringing past experience to bear.'—Building News.*

23. 'By Mr. Krepp's system, *the actual state of a merchant's business, under every head of receipts and expenditure, assets and liabilities, and in every branch, monthly, quarterly, and annually, is brought clearly out,* and each periodical settlement or stock-taking is done without delay, as the whole system of the book-keeping is constantly culminating to its results. *There is nothing in the system which any one accustomed to book-keeping cannot understand and practise,* and the earlier books are essentially like those in ordinary use. *Many useful suggestions may be taken from it, even though the entire system be not adopted.'—Leeds Intelligencer.*

24. An eminent London Firm, to whom the work had been specially submitted before its publication, writes as follows:—'The combination which you so ably propose has not, as far as we know, been made the subject of any previous publication, and we consequently believe that *your work not only deserves attention, but that its study cannot but benefit all who are engaged in commercial or manufacturing transactions.'*

25. A leading Manchester House informs the Author, that their books are kept on a system analogous to the one he publishes, and that it gives so great satisfaction that they recommend the Statistical Method for general adoption.

26. A highly respectable Bradford Firm writes as follows:—'We have examined your work on Statistical Book-keeping, and consider it to be well worthy the attention of those to whom it is addressed. There are many suggestions in it which will be of value to the most experienced accountants.'