Papers Presented

at

Second Ontario

INDUSTRIAL

WASTE

Conference

JUNE 19th, 20th, 21st, 22nd
1 9 5 5

SPONSORED BY

THE POLLUTION CONTROL BOARD

OF ONTARIO

AT THE

Ontario Agriculture College
Guelph, Ontario

Papers Presented

at

Second Ontario

I N D U S T R I A L

W A S T E

CONFERENCE

June 19th, 20th, 21st, 22nd

1 9 5 5

Prepared for distribution by

THE ONTARIO WATER RESOURCES COMMISSION

Parliament Buildings, Toronto.

SECOND

ONTARIO INDUSTRIAL WASTE CONFERENCE

This pamphlet contains copies of the papers presented at the Second Ontario Industrial Waste Conference held at the Ontario Agricultural College, Guelph, Ont., on June 19th, 20th, 21st, 22nd, 1955.

The conference was sponsored by the Pollution Control Board of Ontario, the purpose of which was to review methods for the treatment of industrial wastes and to focus attention on measures required for protection of stream sanitation.

The Industrial Waste Conferences are designed to deal with one aspect of pollution, namely that originating from industrial activity. In many places it is necessary that these wastes be treated by industry rather than discharged into public sewers. In other places the responsibility for treatment is placed upon the municipalities. In either case it is essential that there be full information available on how these wastes can be dealt with most effectively. Industrialization in Ontario has been proceeding at a rapid rate and as a result of this the situation in respect to the disposal of the wastes from these industries becomes more complex.

The Pollution Control Board recognizes industrial wastes as one aspect of the pollution control problem. The fact that attention is focused primarily on these industrial wastes at this conference does not mean that domestic sewage is less significant in the overall problem. There is, however, a greater variety of methods needed than in that for municipal sewage.

The Pollution Control Board is grateful to all who have contributed papers to this Industrial Waste Conference as well as to others who have assisted in any way in making the conference possible.

For further information write to The Water and Pollution Advisory Committee of the Ontario Water Resources Commission, Parliament Buildings, Toronto, the new name for the Pollution Control Board.

D.S. Caverly,
Secretary.

Dr. A.E. Berry,
Chairman.

TABLE OF CONTENTS

WASTE DISPOSAL AT SUN OIL COMPANY, LTD. SARNIA, ONTARIO, REFINERY

by

Gordon R. Henderson, Manager

The protection of the purity of the international boundary waters between Canada and the United States has stimulated considerable public interest, while governmental authorities and industries have initiated extensive efforts to maintain this water quality. The objectives for boundary water control of the International Joint Commission, stated in their report of 1951, have been adopted by Provincial pollution control groups in Canada and have been used as a criteria by industries in planning and installing pollution abatement facilities.

When Sun Oil Company, Ltd., began preliminary design in 1952 for a refinery on the St. Clair River below Sarnia, the need for providing adequate pollution abatement facilities to preserve receiving stream quality was recognized. The Sarnia Refinery, placed in operation in November, 1953, to process 15,000 bls. per day of crude oil, contains completely integrated facilities for control and treatment of plant waste waters.

Included in the original installation was a completely segregated sewer and separator system designed in accordance with the latest American Petroleum Institute recommended standards. Independent drainage systems were installed for the process waste waters, contaminated storm drainage, cooling water, uncontaminated storm drainage and sanitary sewage. The process wastes, contaminated storm waters and spent cooling waters are each provided with individual oil-water separators of the latest A.P.I. design for removal of oil and settleable solids before discharge to the effluent sewer. The total flow of the combined waters in the final effluent sewer averages 14 million gallons per day.

Of particular interest from a water pollution standpoint is the process sewer system. Although the process waste flow averages only 250 GPM, or 350,000 gallons per day, it carries over 90% of the phenols, sulfides, mercaptans, emulsified oils, and other water-soluble contaminents. These wastes come from contact with oil in the plant including process condensate drains from vessels and towers, pump gland leakage and desalting water. It was anticipated that these process waters would require secondary treatment to reduce their oxygen-consuming properties before discharge, and their segregation was considered a practical initial step.

Prior to the initial processing operations at the Sarnia Refinery, Sun Oil developed plans for a biological oxidation unit for reduction of phenolic compounds in the refinery waste waters. Helpful information was made available by the Dow Chemical Company and Imperial Oil Company, Ltd., who had plant and pilot-scale experience with this type of treatment. Construction of the bio-oxidation unit was expedited by use of the above-mentioned process sewer and separator system in which the phenolic wastes had already been segregated and by utilizing other existing equipment and lines already in place. After removal of floating oil in the process separator, the 250 GPM flow is transferred by a self-priming centrifugal pump rated at 500 GPM and 35 psig. to an earth-wall oxidation basin, with top dimensions 90' long, 65' wide and 10' deep. The bottom half of the side-walls of the aeration basin are surfaced with a 2" layer of cement grout to minimize erosion. The fresh feed water and recycle enter the bottom of the basin through a nest of 40 mixing eductors. A rotary blower, rated at 500 c.f.m. at 7 psig., supplies air to the eductors to supply oxygen and provide intimate mixing. The overflow from the aeration basin flows through a peripheral slit-pipe flume to a large concrete A.P.I. gravity separator originally designed for oil removal service. This separator is equipped with continuous flight scrappers and serves as a secondary settling tank for bacterial sludge. A positive displacement sludge pump, rated at 125 GPM at 43 psig., returns the settled bacterial floc to the oxidation basin and the treated water flows from the secondary separator to the St. Clair River. Piping has been provided to recirculate all or a portion of the oxidation basin effluent during periods of low volume feed and when the refinery is shut down.

These modified activated sludge facilities were placed in operation at the middle of November, 1953, in time to treat the first waste waters from the refinery. Two tank truck loads of bacterial sludge from the Dow Chemical Company waste treatment plant at Midland, Michigan, were obtained for initial seeding. Bacterial oxidation of phenol began within the first few hours.

Experience through the first year of operation indicates an initial phenol content in the process waste feed of 150 pounds per day. Numerous refinery start-up, mechanical difficulties and variations in feed water quality have interfered with continuous efficient performance of the bio-oxidation unit, although good removal of phenol and sulfide has been effected when operation conditions are normal and feed water characteristics are satisfactory. Recent high alkalinity and sulfide concentrations in the process waste water has interfered with satisfactory operation. Efficient operating conditions include a bacterial sludge volume index of 4-6%, a temperature range of 70°-85°F., and a pH range of 6.5-8.0. Experience indicates that the process will operate with a temperature as low as 60°F. Dissolved and emulsified oil concentrations as high as 150 to 200 ppm, phenol concentrations up to 200 ppm and sulfide concentrations as high as 50 ppm have had no pronounced harmful effect on biological activity, although higher values can seriously injure the bacterial sludge. In the case of all these factors, it is important to avoid sudden or shock loadings whenever possible. It has been observed that organisms can remain inactive for several days under adverse conditions, and then regain their former activity with the return of normal temperature and food supply. Each jet aerator or eductor in the Oxidation Basin supplies 50 lbs. of oxygen or a total of 2,000 lbs. of oxygen per day from the air into the waste water to oxidize the 150 lbs. of phenol, considerably in excess of the theoretical required amount. The aeration tank loading is equivalent to 5 lbs. of phenol per 1,000 cubic feet of tank volume, and the applied air rate is equivalent to 0.1 cubic feet per minute per square foot of aeration surface. Total power requirements amount to approximately 60 HP.

Among the difficulties encountered in operation, low temperature below the 55°F. minimum, high alkalinity and sulfides in excess of 75 ppm have been the most troublesome. Steam, when available from the refinery, is introduced through 1" steel pipe coils with submerged exhausts into the Oxidation Basin. A direct-contact 2,500,000 BTU/hr. water heater has been installed above the surface of the basin as an auxiliary source of heat. A flue gas stripping tower, 5'-6" dia. by 30', is currently being installed to remove sulfides and lower hydroxide alkalinity prior to the treatment in the Bio-Oxidation Basin. The stripping tower will utilize up to 150,000 SCFH flue gas from the regenerator of the Catalytic Cracking Unit in the refinery to lower alkalinity and sulfides to a safe level. It is anticipated the stripper will be operating by this summer.

High oil content in the feed water, although apparently not toxic to the organisms, is absorbed on the biological floc and floats the latter to the surface of the basin, thereby removing organisms from the process. It is believed that some oil is partially oxidized. Change in feed water characteristics, including variations in pH and type and concentration of phenolic content, interferes with acclimatization of the bacteria to the waste water. The secondary settling tank was originally designed as an oil-water separator and is over-sized and not of conventional design for biological sludge recovery. Mechanical difficulties with the pumps and the usual start-up problems associated with a new refinery presented difficult operating conditions. There have been periods, for example, when the refinery units were not operating, and there was no continuous flow of waste process water. During such periods, it has been necessary to recirculate water in the biological treatment unit, and chemical-grade phenol was used to continue the food supply.

Additional experience, continuous normal operation of the refinery, and current installation of the flue gas sulfide stripper column will permit more effective operation of the treatment facilities. Eventually, additional equipment will be installed to maintain continuity of operation. Much has been learned in the initial operation of these facilities, and it is contemplated that further experience will permit additional improvement of effluent quality.

THE MATHEMATICS OF THE BIOLOGICAL OXIDATION OF INDUSTRIAL WASTES

By

W. WESLEY ECKENFELDER, Jr.

Asst. Prof. of Civil Engineering

Manhattan College, N.Y., N.Y.

Biological oxidation finds application for the economic disposal of organic wastes. The two basic processes employed are the fluid bed (Activated sludge process), where microbial sludge is continuously mixed with the organic waste, aerated in intimate contact for a predetermined period and then separated by sedimentation or flotation,and the fixed bed (trickling filters), in which organic matter is continuously passed over microbial growth on a rock or similar surface. Process variation of the above systems include modified-aeration, step-aeration and contact stabilization in the fluid bed system and high and low rate filters in the fixed bed system. Among some of the wastes which have been successfully treated in the aforementioned processes are cannery (1) (2) (3) (4) (5), pharmaceutical (6) (7), dairy (8) (9) (10) (11), chemical (12) (13), refinery (14) (15) and pulp and paper (16) (17).

The microbial sludge or biological floc employed in these processes is a miscellaneous collection of microorganisms such as bacterial, yeasts, molds, protozoa, rotifers, worms and insect larvae in a gelatinous mass. Algae will also be present in those areas exposed to sunlight. The bacterial growths consist of a partially water soluble polysaccharide slime layer of low structual strength, a cell wall, a lipo-protein cytoplasmic membrane, and cytoplasm as shown on Fig. 1. These componants play various roles in the BOD removal and bacterial growth cycles (18) (19).

Kinetic Theory of BOD Removal

In the biological oxidation process organic matter is removed from solution by reaction with enzymes associated with biologically active slimes and sludges. The rate removal is probably dependent on diffusion of essential foods into the cell. A portion of the organic matter removed is synthesized to new microbial cells. The remainder is oxidized to provide energy to sustain life and to permit synthesis. These reactions follow basic chemical and biochemical laws:

COMPONENTS OF MICROBIAL CELL
(After Knaysi)

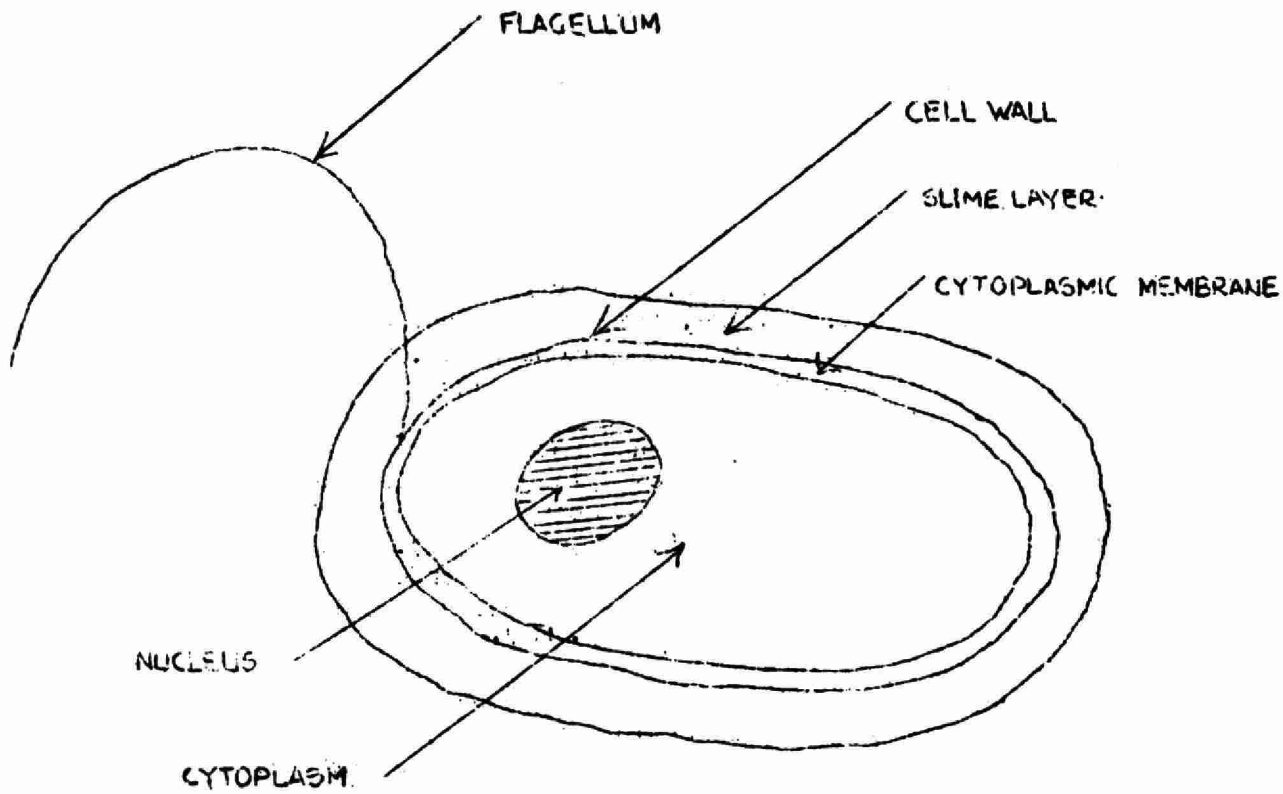


FIGURE I

organic waste (BOD) + O_2 + NH_3 = sludge + CO_2 + H_2O (1)

The sludge produced by equation (1) undergoes continuous auto-oxidation (endogenous respiration).

Sludge + O_2 = CO_2 + H_2O + NH_3 (2)

This process is graphically illustrated on Fig. 2.

The above equations, (1) and (2), indicate that a definite ratio should exist between the quantity of BOD removed, the portion oxidized and the portion synthesized. This ratio has been evaluated for several organic wastes (20), (21), (22).

In the presence of oxidizable organic matter microbial cultures (sludge) will undergo several growth stages the principal of which are a lag phase, a log growth phase, a decreasing log growth phase and a death phase (endogenous respiration) as shown on Fig. 3. During the growth cycles, many microorganisms are capable of removing organic matter at a greater rate than the oxidation and assimilation process (storage). This organic matter is stored in the cell as complex carbohydrates for future oxidation and synthesis (23).

For convenience in process design only four growth phases need be considered, namely, storage, the log growth phase, the decreasing log growth phase and the endogenous phase. The lag phase is largely eliminated in activated sludge and trickling filters due to the large innocculum employed. Lag phases may be induced, however, if the sludge is not acclimated to the particular waste being treated. An example of this is the innoculation of an industrial waste with activated sludge from a domestic sewage oxidation (24) (25) (26) (27) (28). Process lags will also result when sludge in the advanced endogenous phase is recycled for treatment. This effect has been interpretated in terms of sludge age (defined on p. 13).

Storage may be defined as BOD which is removed from solution by sludges, but which is not immediately metabolized. The concept advanced by Porges, et al, shows storage principally as glycogen in the bacterial cell (23). To illustrate, let us consider the bacterial cell in the endogenous phase to have the general composition $C_5H_7NO_2$ Immediately after aeration contact with organic waste the sludge enters the active respiration-storage phase and its general composition can be defined chemically as $C_5H_7NO_2$ $C_xH_yO_z$. As aeration continues and the soluble BOD in the waste is removed, by the sludge mass, the microorganisms consume the stored material for metabolism and growth. After sufficient aeration for complete oxidation and synthesis of the BOD removed from the waste, the sludge is reduced to the endogenous form $C_5H_7NO_2$ This is schematically illustrated on Fig. 4. Using previously derived equations for oxidation and synthesis, Porges, et al, computed the bacterial storage in milk waste oxidation to be 625 ppm of COD for 1000 ppm of sludge solids. The storage may be graphically derived from batch waste treatment data employing a form of plot as shown on Fig. 5

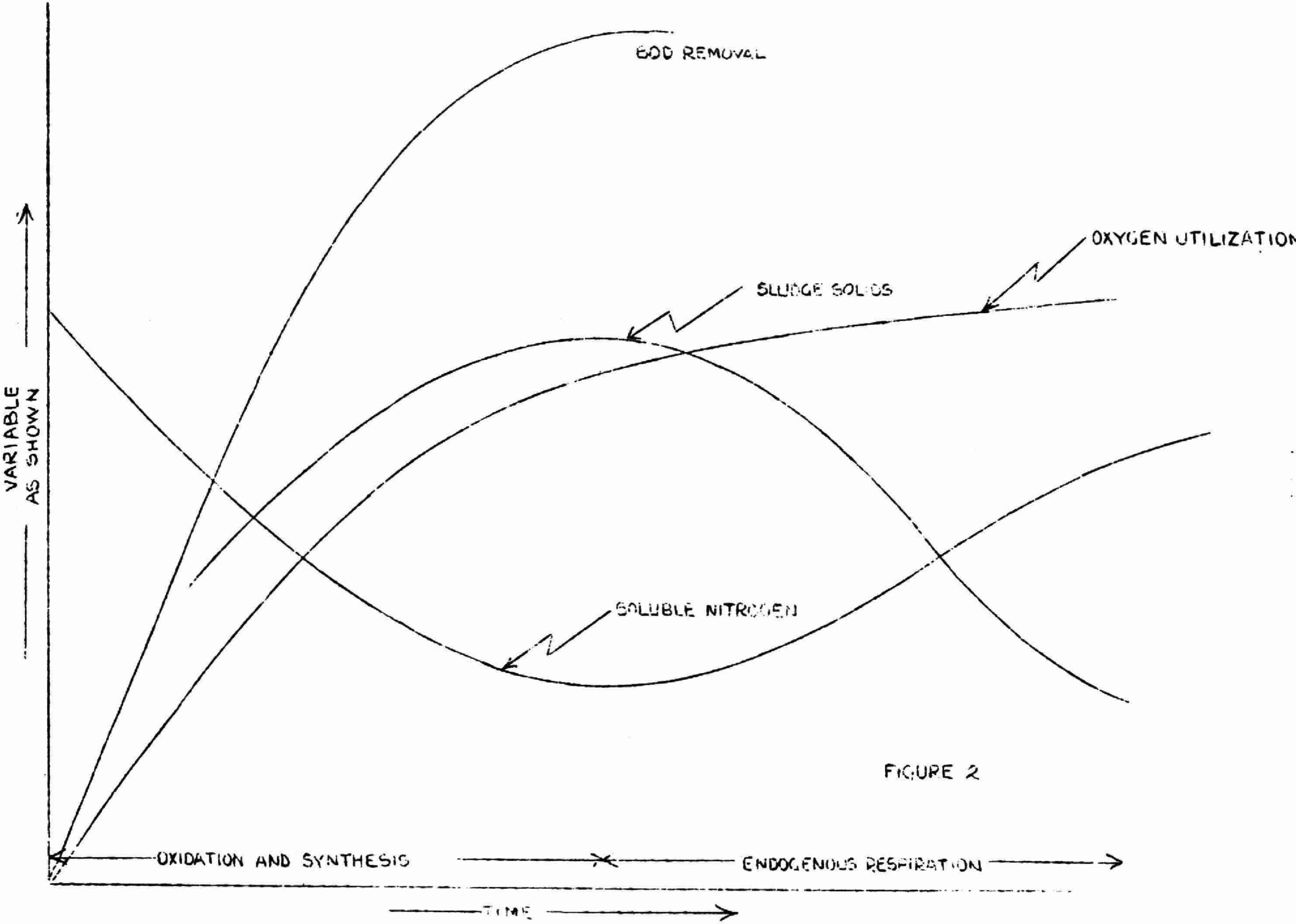

BOD REMOVAL
OXYGEN UTILIZATION
SLUDGE SOLIDS
SOLUBLE NITROGEN
VARIABLE AS SHOWN
OXIDATION AND SYNTHESIS
ENDOGENOUS RESPIRATION
TIME

FIGURE 2

GROWTH PHASES IN CULTURE

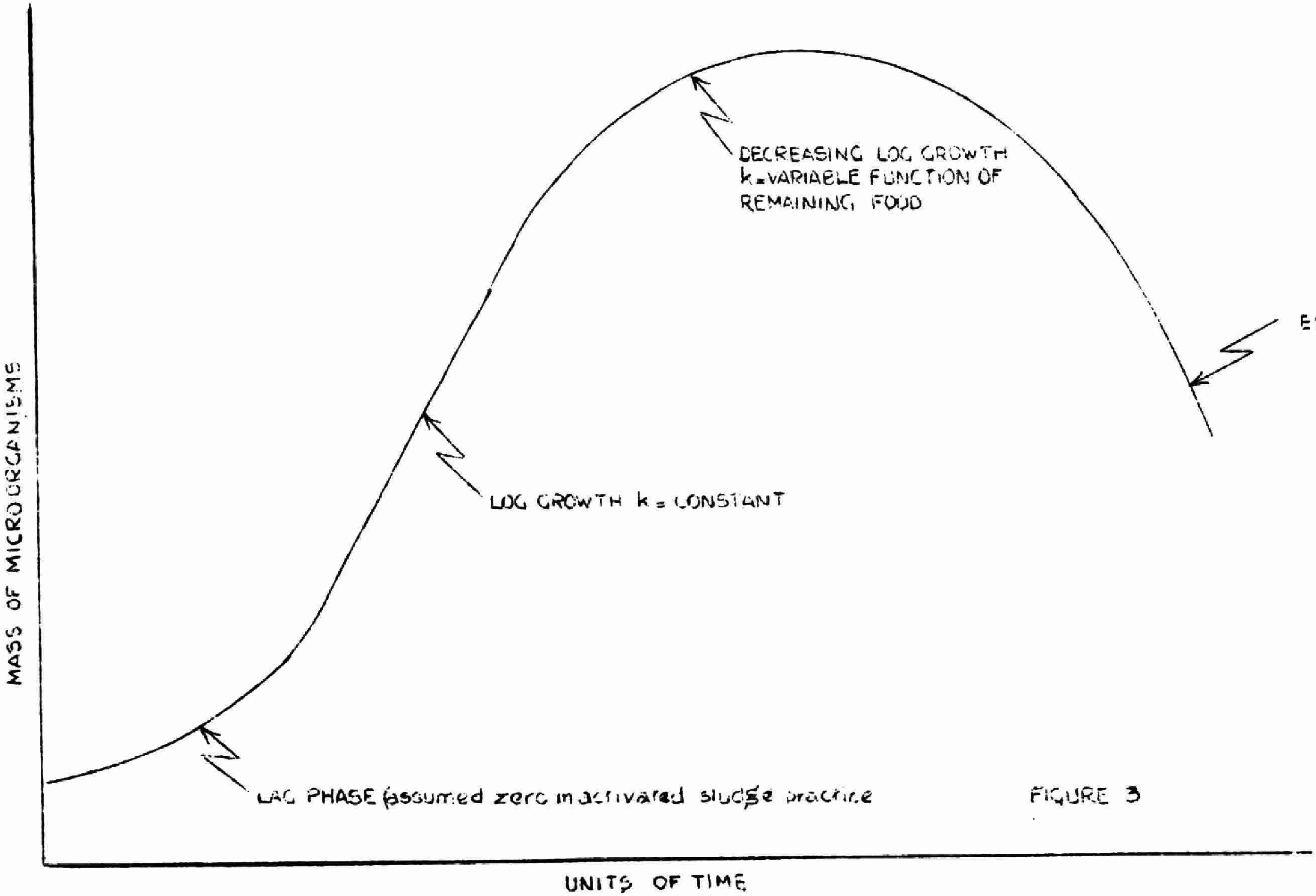


FIGURE 3

PROBABLE TREATMENT MECHANISMS IN ACTIVATED SLUDGE PROCESSES
(after Porges)

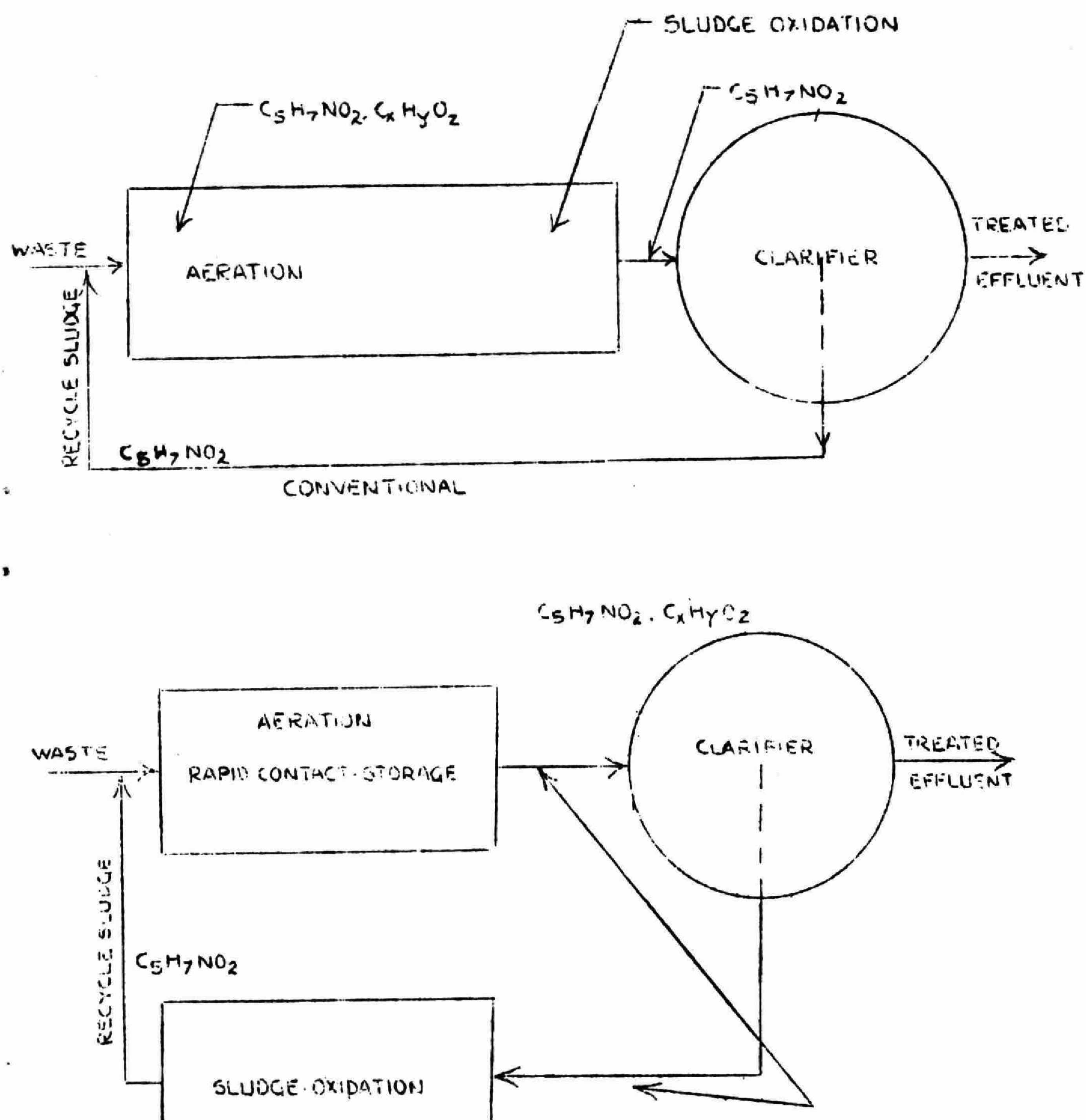


FIGURE 4

There is evidence that storage is also related to the efficiency of contact during mixing and to the BOD available to be removed. Katz (25) has shwon that the initial removal of BOD per unit mass of activated sludge decreases as the sludge concentration increases. Further study is essential to establish initial removal ratios for various oxidation systems.

The log growth phase may be defined as that period during which regular and maximum multiplication of sludge cells is taking place. The generation time is defined as that interval during which one bacterium develops and completely divides into two cells. This results in a geometric progression of bacterial growth.

The rate of growth of organisms may be expressed by the formula

$$\frac{ds}{dt} = kS \qquad (3)$$

The generation time of the organisms may be related to k.

$$g = \frac{0.693}{k} \qquad (4)$$

Since S after any time t is equal to $S_o + \Delta S$ and the amount of cell material produced is proportional to the amount of organic matter removed

$$\Delta S = \frac{aLr}{1.42S_o} \qquad (5)$$

1.42 is the theoretical factor for converting ultimate BOD to cell material. The integrated form of eq. (3) may be expressed

$$\log \left(1 + \frac{aLr}{1.42S_o}\right) = kt \qquad (6)$$

In the mixed microbial systems generally considered k is a function of the mean generation time of the culture. Since k is theoretically correct only for the viable count, errors will usually accrue through the use of total or volatile suspended solids measurement which includes both living and dead cells in addition to amorphous matter present in the sludge.

At the end of the log growth phase a negative acceleration phase exists where cellular division occurs at less frequent intervals (k is variable). It has been shown by several investigators (29) (30) that the mean generation time, g, and hence k is BOD concentration dependent below a limiting substrate level. A mean k, representative of overall process performance, may be related to microbial food supply as shown on Fig. 6.

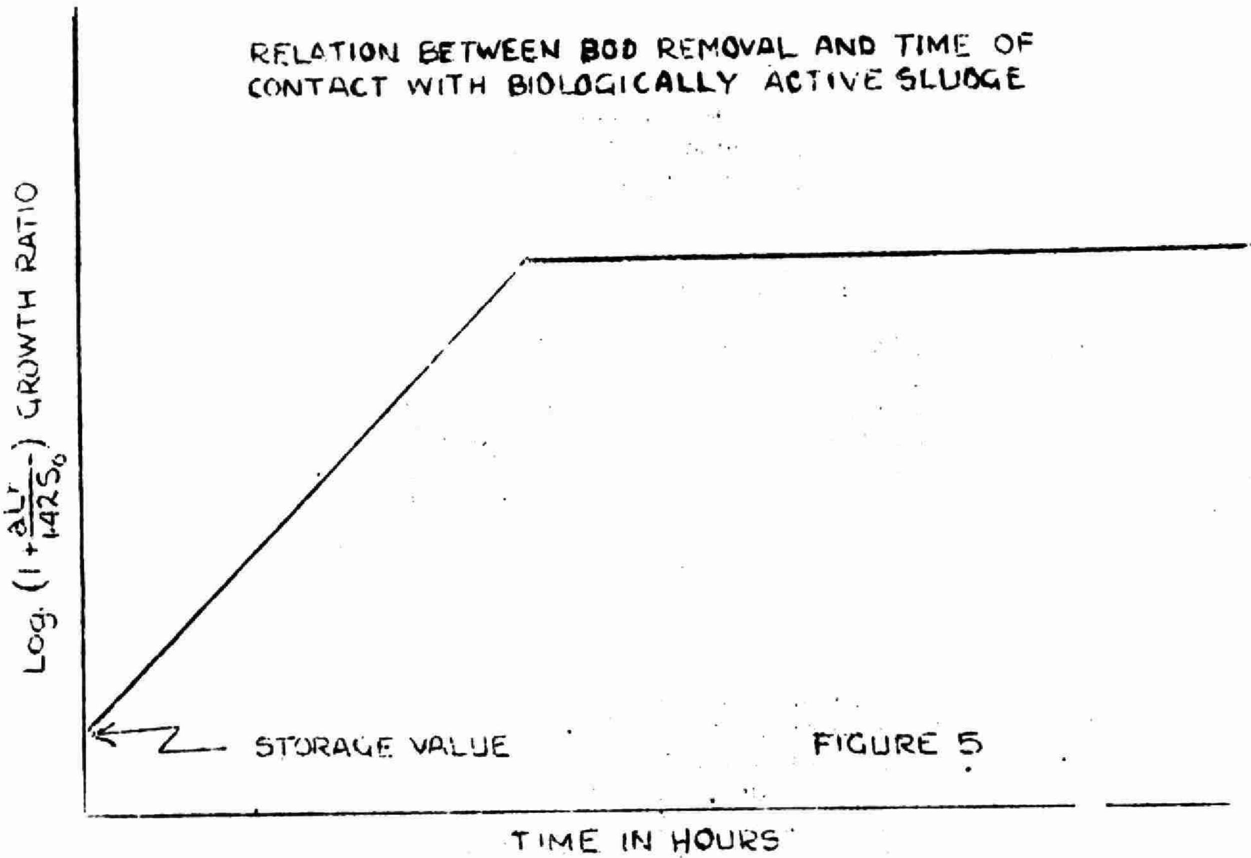


FIGURE 5

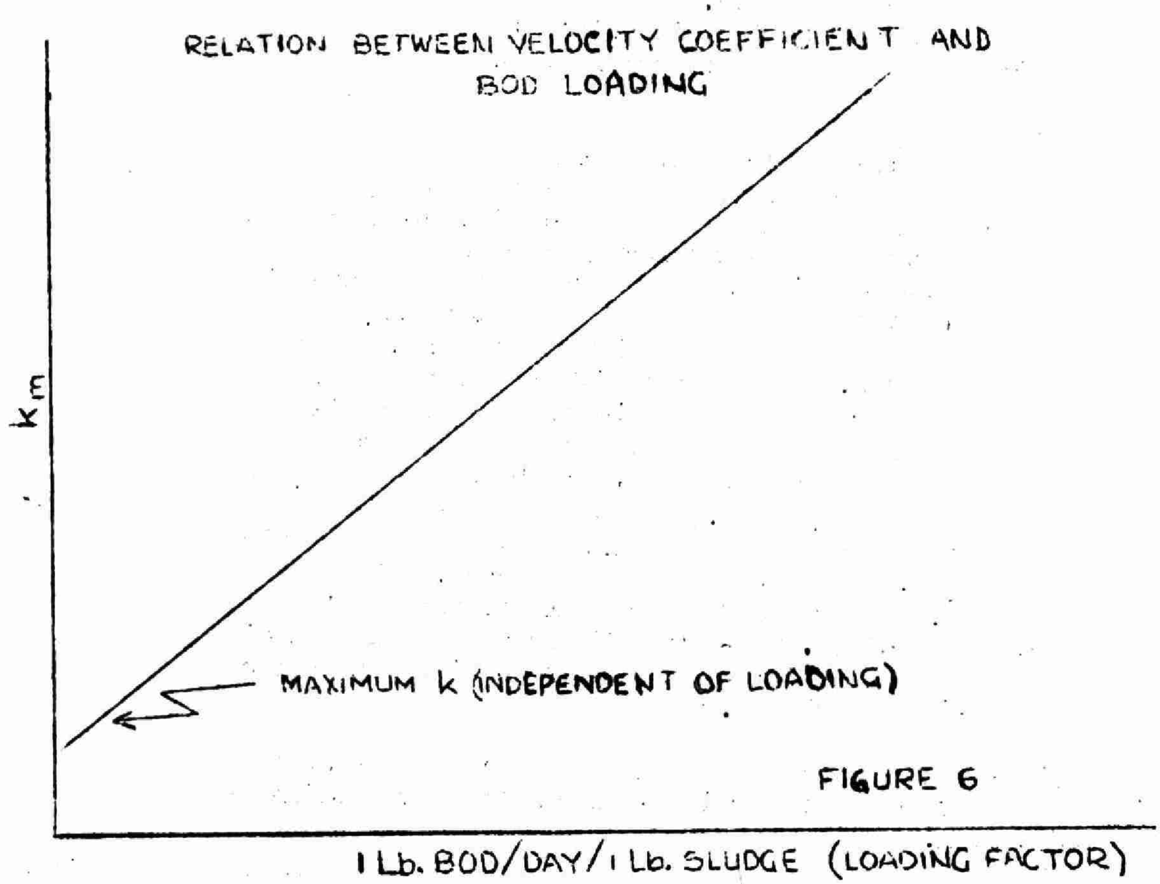


FIGURE 6

In the endogenous phase of the process there is little or no BOD removal and the sludge concentration is being decreased through endogenous respiration at a greater rate than growth through syntheses.

Application

It may be generalized that the efficiency of BOD removal in the activated sludge process is a function of the aeration time, the active sludge solids concentration and the BOD loading. It is therefore convenient to relate efficiency to a loading factor involving the aforementioned variables (31) (32) (33). This loading factor expressed as lbs BOD per day per lb aeration sludge may be computed from the equation

$$f = \frac{24\ f_a}{S_a t\ (1 + r)} \qquad (7)$$

From studies with glucose and peptone, Sawyer and Garrett (30) established maximum removal rates of 3.6 # BOD per day # solids at 10°C, 11.6 # BOD per day per #solids at 20°C and 20.8 # BOD per day per # solids at 30°C. Lower maximum removal rates have been observed in the treatment of pharmaceutical and cannery wastes. This loading factor employs mixed liquor suspended solids for convenience. Since only a portion (variable with different wastes) is active, microbial sludge maximum removals for particular systems are only representative for that particular waste.

The loading factor employed for process design should consider the total time the sludge mass has been undergoing aeration to encompass all four zones of activity previously described. Some process modifications such as contact stabilization employ a short aeration contact period of the waste with sludge for rapid removal of BOD (principally as storage) followed by a relatively longer aeration of the sludge alone for oxidation and synthesis. The loading factor computed for the waste aeration step alone would be primarily representative of storage while the loading factor based on the entire sludge mass would consider all process steps. Table 1 shows data from various waste oxidation systems. In conventional sewage treatment practice 90% BOD removal efficiency has been attained with a loading of 0.5 # BOD per day per # sludge. Increasing this loading to 4.0 # BOD per day per # sludge reduced the removal efficiency to 54%. 80 - 90% efficiency has been attained on cannery and pharmaceutical waste oxidation with loadings of 1-2 # BOD per day per # sludge.

Loading-efficiency data for any particular waste must be obtained by experimental investigations on that waste using well acclimated sludge.

Loading applied to the sludge is related to various secondary factors which influence the overall process performance. Many investigators have interpreted these effects in terms of sludge age which is related to the length of time the sludge has been undergoing aeration. Sludge age may generally be considered as the reciprocal of the loading factor. Gould (34) has defined sludge age as the mixed liquor suspended solids per suspended solids per day in the raw sewage. A more fundamental interpretation of sludge age was advanced by Heukelekian and Gellman (35) as the mixed liquor suspended solids per lbs BOD per day removed in the system.

Edwards (36) and Gould (37) showed the conventional process to have a sludge age of 3 - 4 days (endogenous phase) and the modified aeration process a sludge age of 0.2 days and 0.4 days in summer and winter respectively. They reported poor settling properties over the range 0.5 - 3.0 days. A generalized relationship was also defined in the NRC report (38) between the Mollman sludge index and sludge loading factor previously defined.

Haseltine (33) has summarized these findings; when oxidation lags adsorption, sludge settleability deteriorates; a further lag results in good settling qualities but poor removals. Excessive aeration into the endogenous zone results in pin-point floc and poor removals.

Interesting studies by McKinney (39) indicated that at high loading factors sludge does not flocculate and functions as a dispersed growth. Only when the sludge is brought down approaching the endogenous phase does flocculation occur. Flocculation of biological sludge is therefore interpretated as a function of the energy content of the system.

Busch (40) has attributed non-flocculant properties (poor settleability) to a young sludge population in the log growth phase.

While there is some doubt as to interpretation of the effects of high loadings on the overall process performance it is generally conceded that sedimentation and compaction of sludge is impaired when high loading factors are employed.

When the BOD loading per unit time is plotted against the BOD removal per unit time, a curve is obtained in which the removal approximates a linear function of the loading. At high loadings the removal approaches a limiting value such that increased loadings substantially affect no further reduction. Various graphical representations of loading-removal relationships are shown on Fig. 7.

A similar loading factor may be employed for the design of trickling filters. Since exact measurements of the quantity of active sludge solids are impractical, the loading factor is usually expressed as # BOD per day per cu.yd. of media. Maximum observed removals in filter operation are 3.1 - 3.3 # BOD per day per cu.yd.

BOD LOADING REMOVAL RELATIONSHIPS

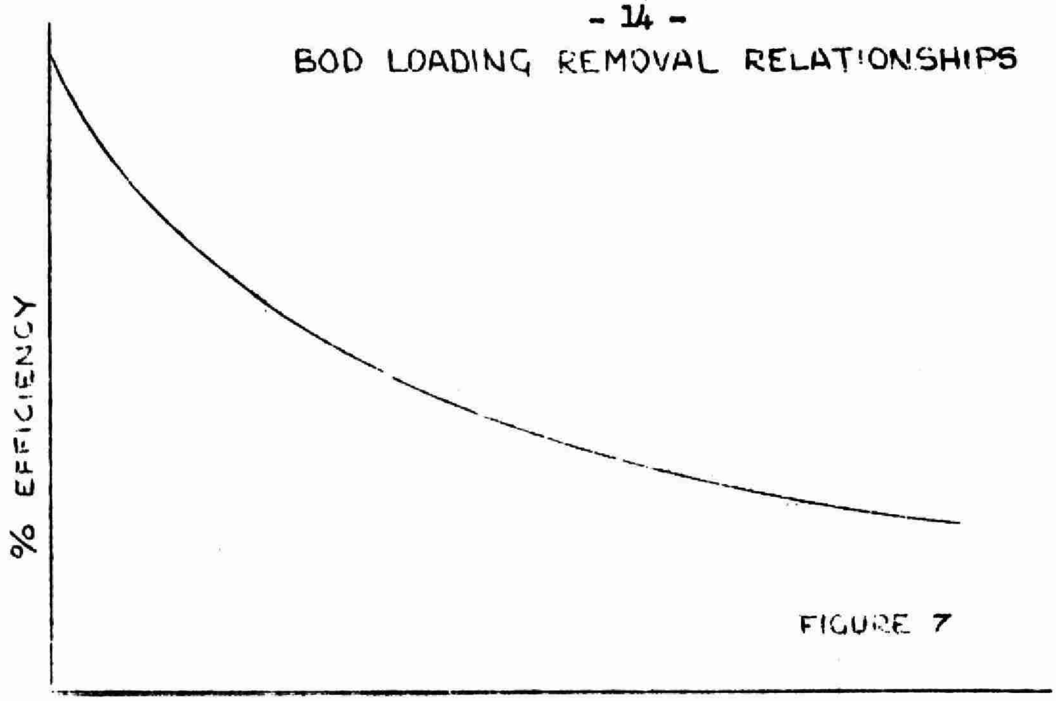


FIGURE 7

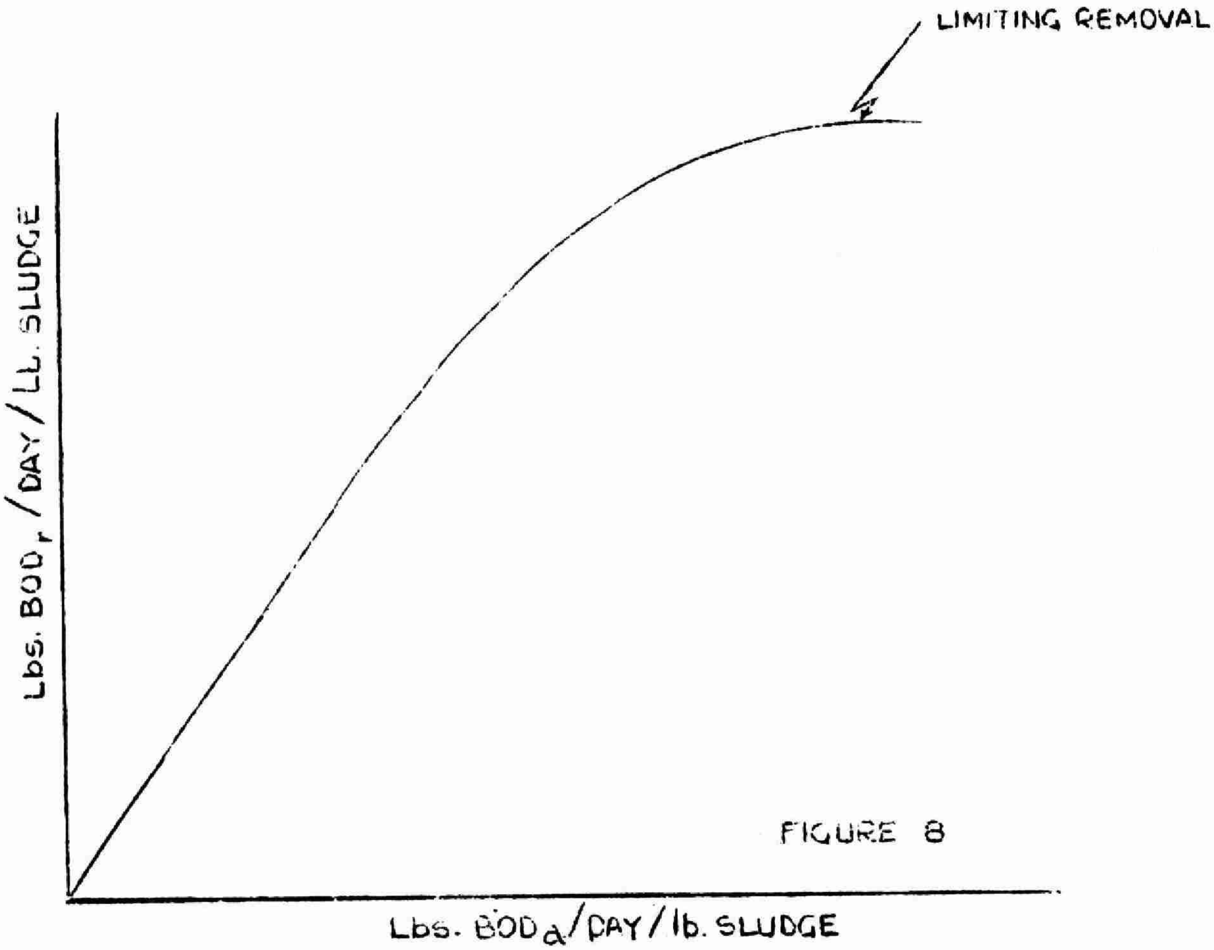


FIGURE 8

resulting in an overall process efficiency of 25 - 35% (41) (42) (43). Since the quantity of available sludge in a filter has been shown to vary from 8 - 12 # per yd^3 for low rate filters and 5.5. - 11 # per cu.yd. for high rate filters (44), the equivalent maximum removals are 0.2-0.4 # BOD per day per # sludge. Since the time of contact of BOD through a high rate trickling filter is 15-25 minutes, it is probable that the initial reactive capacity of the filter slimes exerts a major influence on filter performance.

Oxygen Utilization

As has been shown in eq. (1) and (2) oxygen plays an essential role in aerobic biological treatment. For optimum efficiency oxygen must be supplied at a rate equal to or greater than its rate of utilization. In the activated sludge process this is usually accomplished by diffusion from air bubbles injected into the liquid-sludge mass under turbulant conditions. In trickling filters oxygen is derived from air drawn into the bed due to the temperature gradient between the sewage and the ambient air and from oxygen dissolved in the incoming waste.

Oxygen utilization rate may be defined as the weight of oxygen consumed by a given weight of microbial sludge per unit of time. It is usually expressed as ppm per hour.

A linear relationship will exist between the sludge concentration and the oxygen utilized (45) (46) over the range of sludge concentrations usually employed.

$$r_r = k_r S \qquad (8)$$

In very high sludge concentrations ($>$ 10,000 ppm) the unit rate of oxygen utilization may decrease due to diffusional resistances (48).

The oxygen utilization rate characteristics of a sludge-liquid mass will be defined by the quantity of unoxidized organic matter present (nutrient) and the growth phase of the sludge (i.e. assimilation or endogenous respiration). Active respiration occurs in the presence of sufficient food in which oxygen is used by the sludge to obtain energy for the assimilation of organic matter producing CO_2 and H_2O. This shown by the general equation (1).

In addition to the above oxidation the sludge produced by the assimilation of organic matter is continually oxidized by its own mass. Hoover (48) has defined this as endogenous respiration. This oxidation is defined by Eq. (2) and illustrated in Fig. 9.

The rate of oxidation of organic matter as shown in Eq. (1) is 10-20 times the rate of auto-oxidation as shown in Eq. (2). Endogenous respiration is frequently defined as a percent per day of the sludge solids under aeration. This would

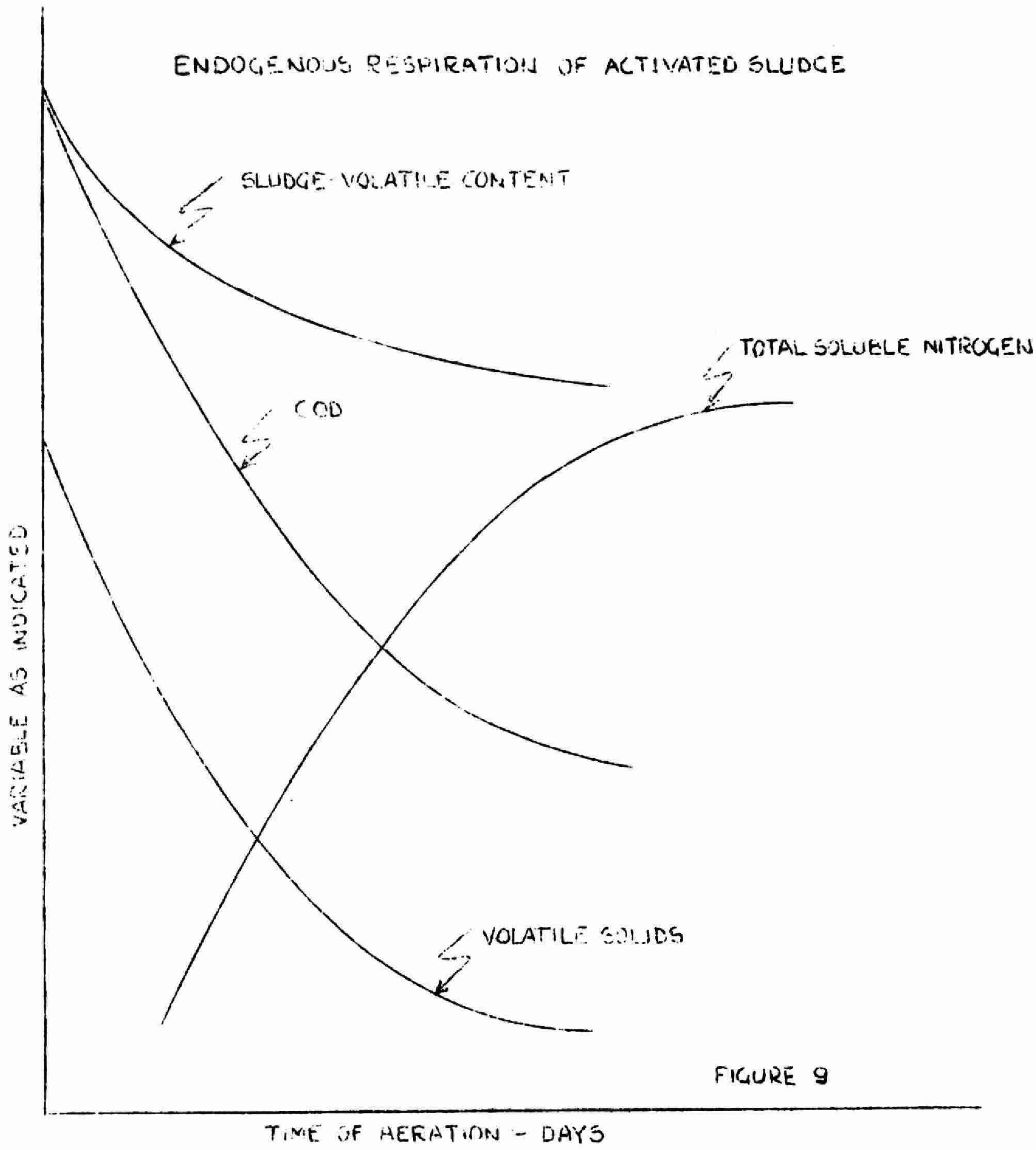

ENDOGENOUS RESPIRATION OF ACTIVATED SLUDGE
SLUDGE VOLATILE CONTENT
TOTAL SOLUBLE NITROGEN
COD
VOLATILE SOLIDS
VARIABLE AS INDICATED
TIME OF AERATION - DAYS

FIGURE 9

correspond to a constant rate of oxidation per unit of sludge. Actually the oxidation rate decreases with time due to the fact that the cell constituents differ in ease of oxidation. Hutchens has shown that this rate of decline for many micro-organisms is logarithmic in nature.

The oxygen utilization rate characteristics for several systems is shown in Table 1.

The total oxygen requirements for a biological system may be related to the quantity of organic matter removed and the concentration of sludge solids according to Eq. 9 and illustrated on Fig. 10.

$$O_2 = (1-a)L_r + bS \qquad (9)$$

The constants for this relationship must be experimentally evaluated for any particular waste. Caution must be exercised in the interpretation of Eq.9 when organic matter (BOD) is stored in the sludge system since this relationship is based upon a synthesis-oxidation balance. A similar relationship was derived by Smith (49) for the oxidation of domestic sewage.

The oxygen utilization characteristics of a system for process design may also be derived from a statistical analysis of utilization rates obtained at various loading levels. Statistics are applicable to the analysis of data which involves variation and provides a method for the significant interpretation of these data. The data is expressed in terms of a range of values encompassed by a stipulated probability of occurrence. The probability of occurence may be obtained graphically from a statistical plot on normal or logarithmic probability paper. A probability of occurrence (usually 90-95%) of oxygen transfer and blower design. The equipment is then slected such that at this value oxygen will be supplied to meet the demand rate 90-95% of the time. The probability of occurrence of BOD removal from the system will usually parallel the oxygen demand probability curve in accordance with Eq. 1 and 2.

It has been shown that when the oxygen concentration in the mixed liquor is greater than 0.2 - 0.5 ppm the rate of bacterial respiration is independent of oxygen concentration. When the oxygen centration is below this value, the system becomes oxygen dependent and the rate of BOD removal is decreased.

Warburg (51) and Pasveer (52) defined a mathematical relationship for oxygen diffusion into microbial cells which is a function of floc size, diffusivity, oxygen utilization rate and external concentration of dissolved oxygen (driving force). Sludge cells tend to clump hence to decrease the quantity of oxygen which can be transferred to them by an increase in resistance to transfer. High degrees of agitation will disperse the sludge clumps and increase the transfer rate to the cells for metabolism. By decreasing its mean floc radius,

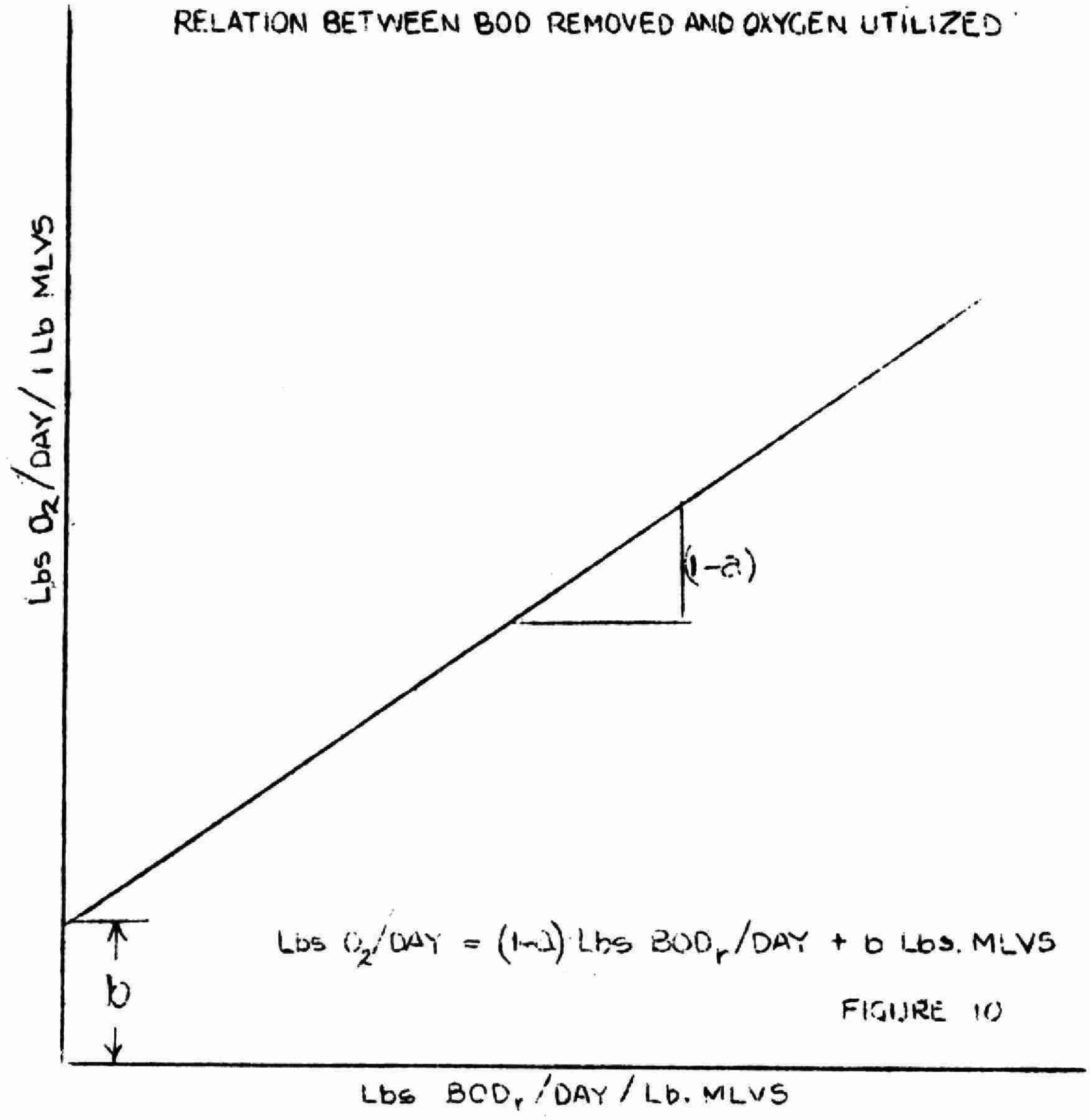

RELATION BETWEEN BOD REMOVED AND OXYGEN UTILIZED
Lbs O2/DAY/1 Lb MLVS
(1-a)
b
Lbs O2/DAY = (1-a) Lbs BODr/DAY + b Lbs. MLVS
Lbs BODr/DAY/Lb. MLVS

FIGURE 10

a greater surface is exposed for oxygen transfer and the degree of oxygen penetration is increased. This has the net result of increasing the unit rate of oxygen utilization. The maximum turbulence desired in a system may be defined as that power input which will not excessively shear the floc particles for subsequent settling. Turbulence and power input to the aeration system is frequently expressed as Horsepower absorbed per 1000 gallons of tank capacity.

Sludge Production

As illustrated in Eq. (1) the quantity of bacterial sludge produced will be proportional to the BOD removed in the process. Additional sludge for disposal will be contributed by inert suspended solids present in the waste. The total excess sludge produced by an oxidation system may therefore be assumed to be composed of microbial protoplasm, non-oxidizable organic matter, stored organisms and inorganic solids.

The quantity of microbial sludge produced by a system can be estimated by a material balance around the system employing Eq. (1) and (2) and illustrated on Fig. 11.

$$\text{Excess biological sludge} = aL_r - bS \quad (10)$$

('a' has been found to vary from 50 - 75% of the BOD removed by the system (assuming no storage)

Sawyer (52) has shown that the expected growth of new sludge is 50-60% of the dry weight of organic food. The data of Gellman and Heukelekian (35) show a yield of 0.5 # of volatile solids per # BOD_s fed to the system.

The presence of inert suspended solids removed in the system will increase the total quantity of sludge for disposal and Eq. 10 should be modified.

$$\text{Excess sludge} = aL_r - bS + C \quad (11)$$

The theoretical quantity of sludge produced is directly proportional to the BOD removed. The portion of the sludge which will be consumed in the process by oxidation (endogenous respiration) will be a function of the solids concentration and the time of aeration. At lower temperatures the rate of endogenous respiration is reduced and less sludge synthesized is oxidized.

Nutritional Requirements

Efficient and successful biological oxidation of organic wastes requires a minimal quantity of nitrogen and phosphorus for the synthesis of new cell tissue. In addition, trace quantities of several other elements such as potassium and calcium are required. These elements are usually present in

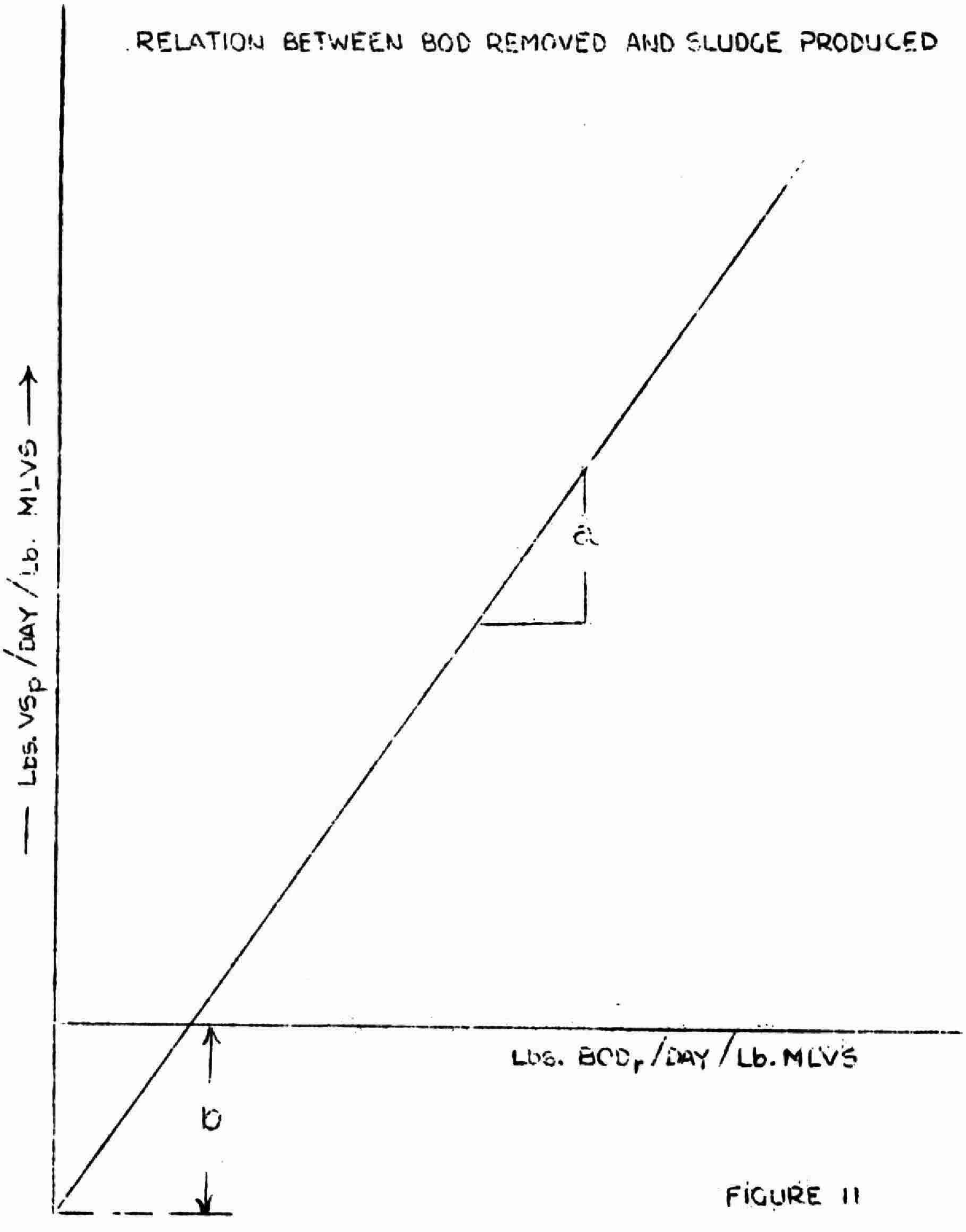

RELATION BETWEEN BOD REMOVED AND SLUDGE PRODUCED
Lbs. VSp /DAY /Lb. MLVS
Lbs. BODr /DAY /Lb. MLVS
a
b

FIGURE 11

natural waters in sufficient quantity to satisfy the requirements for bacterial metabolism. Nitrogen and phosphorus, however, are frequently deficient in waste substrates and must be fed as a nutrient supplement to the system to attain optimum efficiency.

The nitrogen cycle in biological waste treatment is shown below

$$\begin{array}{l} \text{Organic Nitrogen} \\ \downarrow \\ BOD + NH_3 + O_2 \text{ -------- Bacterial Cells} + CO_2 + H_2O \\ \qquad\qquad\qquad\qquad\quad \text{(Organic Nitrogen)} \\ \qquad\qquad\qquad\qquad\qquad \downarrow + O_2 \\ \qquad\qquad\qquad\qquad\qquad NH_3 + CO_2 + H_2O \\ \qquad\qquad\qquad\qquad\qquad \downarrow + O_2 \\ \qquad\qquad\qquad\qquad\qquad NO_2 \\ \qquad\qquad\qquad\qquad\qquad \downarrow + O_2 \\ \qquad\qquad\qquad\qquad\qquad NO_3 \end{array}$$

As may be observed, some nitrogen will be recovered and reused in the system due to the endogenous respiration and oxidation of cell tissue with a resultant release of ammonia to solution.

Nitrogen and phosphorus are important constituents of microbial cell structure and are present in the form of proteins and amino acids. Cell nitrogen will vary from 6 - 15% and phosphorus from 2 - 5% on a dry weight basis for most microorganisms of importance in waste treatment practice. Studies of Helmers and Sawyer (53) showed that for optimum process efficiency a minimum nitrogen content of 7% and a minimum phosphorus content of 1.2% by weight of the total volatile solids should be maintained. Recent investigations by Porges, et al. (23) revealed that while the cell nitrogen was 12 - 14% in the endogenous phase storage in the active growth phase reduced the nitrogen content to 7%.

Nitrogen in the form of ammonia, nitrite and nitrate and some forms of organic nitrogen are available to the organisms for synthesis. Soluble inorganic phosphorus and most organic phosphorus are available for microbial usage. When a nutritional supplement is required for a biological process, ammoniacal nitrogen and soluble phosphorus salts are generally used since they are most readily assimilable. It is usually not advisable to add nitrates, because they serve as a secondary source of oxygen for the organisms. In secondary settling tanks where the available dissolved oxygen may be depleted, nitrates are reduced and nitrogen gas is formed, resulting in a floating sludge.

Because many activated sludges contain an appreciable inert and amorphous fraction the critical nitrogen content may be quite low. For example, a biological sludge from a pulp and paper waste containing a large percentage of stable organic matter had a critical nitrogen content of 3.5% based on the total volatile solids. By comparison, the nitrogen content of an average domestic sewage biological sludge is 7.5% based on the total volatile solids.

Nutritional requirements may be expressed as a fraction of the total volatile solids, as lbs of N or P per 100 # BOD removed in the process or as a $\frac{BOD}{N}$ or a $\frac{BOD}{P}$ ratio.

Nitrogen and phosphorus requirements may be more rigorously computed from a material balance based on the maintenance of a minimum nitrogen and phosphorus content in the biological sludge produced in the system.

Nitrogen may be fed to a system as a gas (anhydrous ammonia) as aquous ammonia or as a dry feed of an ammonium salt. Phosphorus may be solution fed as phosphoric acid or dry fed as a phosphate. The selection of a feed system for any given installation should be determined by a comparative cost study.

Sedimentation and Flotation

Sludge-liquid separation is an integral part of biological oxidation processes. Consideration must be given the physical character of the sludge solids and the effect of process variations on these characteristics (for example, anticipated loading variations, temperature, pH, etc.),

The concentration of active sludge solids which can be maintained in the aeration basins is limited by the settling and compaction characteristics of the biological sludge in secondary settling tanks.

The two factors which must be considered are the rate of sludge settling and compaction and the rate and nature of the biological decomposition in an anaerobic environment (clarifier). Both of these factors are initimately related to the chemical nature of the waste being treated and to the loading characteristics of the sludge system as previously described.

For example, an activated sludge from a food processing waste could not be maintained in a final tank for long periods due to its high activity and gas production. As a result, the maximum sludge concentration attainable was 0.4 to 0.7%. By comparison, an activated sludge from a pulp and paper waste could be maintained for extended periods in the final settling tank due to its low activity and non-gas forming properties. Concentrations as high as 3.0% could be attained.

Special consideration must be given the selection and design of final clarifiers for separation of biological sludges. Density currents are created in final tanks due to the difference in specific gravity of the sludge mass entering the unit and the clarified liquor in the unit. Design factors have been discussed by Sawyer (55) and Anderson (56).

The use of flotation for sludge-liquid separation permits a higher solids balance to be maintained in the system independent of sludge settling and compaction characteristics. Experimental studies on activated sludges treating various wastes revealed that mixed liquor solids can be concentrated to 2 - 3% solids by weight employing pressure flotation.

The Character of Activated Sludge

The synthesis of activated sludge is shown by Eq. (1) employing ammonia as a source of nitrogen. The cellular material can be represented by the empirical formula $C_3H_7NO_2$ developed by Hoover (20). This formula is representative of the ratio of the primary element constituents of activated sludge. It is representative of the statistical average composition of the complex organic compounds constituting cell material.

Studies by Helmers, et al, (53) on various industrial wastes produced a sludge of 1.02% phosphorus content and 8% nitrogen content with the general formula $C_{118}H_{170}O_{51}N_{17}P$ Ignoring the phosphorus content, this sludge has the formula $C_7H_{11}NO_3$

In accordance with Eq. (2) the ultimate oxygen demand of cell material is 1.42 grams per gram of cell structure. If the volatile solids content of activated sludge is assumed to be cell material (not true for all industrial wastes) the ultimate BOD and the COD of microbial sludge should be 1.42 grams per gram.

Hoover (57) found an empirical factor of 1.25 O_2 per gm of dry weight solids. This is equivalent to 1.36 g O_2 per gm dry weight volatile solids for a sludge of 8 percent ash (61).

The heat of combustion of activated sludge used in the treatment of milk waste was found to be 10,300 BTU per lb. of volatile solids (22). This compares for the value of 10,000 BTU per lb. of volatile solids reported by Fair (62), for domestic sewage activated sludge. The heat of formation of activated sludge volatile solids can be estimated as 27.3 k cal. per emperical mole ($C_5H_hNO_2$) or 435 BTU.

The volatile solids of activated sludges will vary depending on the nature of the waste being treated. A pure microbial sludge will generally vary from 90-94% volatile (63). The volatile content of dairy waste sludge was shown to be 92% by Hoover (62). Studies on cotton Kiering, rag rope and brewery wastes by Sawyer (64) showed a volatile solids content of 72-89 percent. As the sludge solids are increased in a system, the volatile content will decrease due to the increased endogeneus respiration and the increase of inorganic matter in the sludge mass as shown in Fig. 3.

Factors Affecting Process Operation and Control

Various physical and chemical factors must be considered in the design of biological oxidation systems. The more important variables are temperature, pH, and toxic ions. The rate of bacterial growth (generation time) and the respiration rates of microorganisms are greatly influenced by temperature (65) (66) (67). The enzyme systems of the sludge mass will be affected by pH, since each enzyme system has a specific pH range (68). The presence of zinc, copper, chromium, nickel and cadmium as well as some other non-metalic substances will seriously impair the efficiency of the process (69).

Process Design

In order to illustrate the application of the aforementioned concepts to process design a specific example is presented.

Example

An organic waste has the following average characteristics. (For simplicity no consideration will be given in this example for variability in waste flow or strength)

BOD, ppm	-	980
Flow, mgd	-	0.94
available nitrogen, ppm as N		5.0

It is required that the BOD removal efficiency be 90%

Design Criteria:

Return sludge = 8000 ppm = Sr (based on sludge compaction vs decomposition studies)

Mixed Liquor Suspended Solids = 2500 ppm = S_a

Mixed Liquor Volatile Suspended Solids = 2100 ppm

Average endogenous respiration rate = 8% per day (based on volatile solids)

Calculations:

BOD_5 loading = 0.94 x 980 x 8.34 = 7650 lbs per day

BOD_5 removed = 7650 x 0.90 = 6900 lbs per day

$$\text{Recycle ratio} = \frac{S_a}{S_r - S_a} = \frac{2500}{8000-2500} = 0.45 = r$$

Recycle Flow = 0.45 x 0.94 = 0.42 mgd

(The computed recycle ratio assumes no solids in the raw waste. The build-up of active solids through the aeration system is neglected in the calculation)

Aeration Tanks:

From an experimental of BOD loading vs efficiency (Fig 11) the allowable loading factor is 1.0 lbs BOD per day per lb sludge.

$$\text{Lbs BOD per day per lb sludge} = \frac{24\ L_a}{S_a T(1+r)} = 1.0$$

Where T is the detention time in hours based on (Q + R) therefore

$$T = \frac{24\ L_a}{1.0\ S_a(1+r)} = \frac{24 \times 980}{1 \times 2500(1+0.45)} = 6.5 \text{ hrs}$$

$$\text{volume of aeration tanks } \frac{(Q+R)T}{24} = \frac{(0.94+0.42) \times 6.5}{24} = 0.37 \text{ mg}$$

If contact stablization is to be employed, data on the storage capacity must be obtained for design of the aeration tanks. The stabilization tank required will then be the difference between volume of the aeration tank and the total aeration volume required for the process.

Air Requirements:

From laboratory or pilot plant studies, a relationship such as Fig. 10 was derived (assumed no storage)

lbs O_2 per day = 0.48 lbs BOD_5 removed per day + 0.08 x 1.42 x lbs MLVS (1)

$$= 0.48 \times 6900 + 0.08 \times 1.42 \times 0.37 \times 8.34 \times 2100$$
4050

$$\text{oxygen utilization rate } \frac{\text{lbs } O_2 \text{ per day}}{V \times 8.34 \times 24} = \frac{4050}{0.37 \times 8.34 \times 24} = 55 \text{ ppm per hr}$$

Sludge Production:

From theoretical considerations that the ultimate BOD of a waste equals the sum of the oxygen utilized and the sludge produced by microbial growth, the following equation can be developed:

BOD ultimate removed = O_2 utilized + sludge produced (2)
Subtracting (1) from (2), converting to 5-day BOD units and introducing suitable conversion factors yields
lbs VS per day = 0.70 lbs BOD_5 removed per day - 0.08 lbs MLVS
= 0.70 x 6900 - 520
= 4300 lbs per day

$$\text{total solids produced} = \frac{4300}{0.85} = 5050 \text{ lbs per day}$$

Nutritional Requirements

From experimental studies critical nitrogen content = 7% of the net biological solids

Total nitrogen required = 0.07 x 4300 = 300 lbs per day.

Nitrogen available in waste = 5 ppm = 40 lbs per day..

Required nitrogen = 260 lbs per day.

The phosphorus requirement may be similarly computed.

Symbols

S - biological sludge solids

t - detention time, hrs

a - fraction of BOD removed which is synthesized

L_a - applied BOD, ppm

L_r - BOD removed, ppm

k - velocity coefficient of bacterial growth

g - generation time, hrs.

r - sludge recirculation ratio, $\frac{R}{Q}$

r_r - oxygen uptake rate ppm per hr

k_r - unit oxygen uptake rate, mg per hr per gm sludge

b - endogenous respiration, percent per day

C - inert suspended solids

Q - raw waste flow, mgd

R - recirculated sludge flow, mgd

f - BOD loading factor, lbs BOD per day per lb aeration sludge

TABLE 1

Biological Oxidation of Organic Wastes

Waste	Process	BOD Loading #/day/#MLSS	BOD raw ppm	MLSS ppm	Aeration Det's hrs	Return Sludge %	% BOD Reduc.	Ref.
Sewage	Conventional	0.228	153	2050	6.34	35	90	33
Sewage	High rate	2.08	132	530	2.92	20	67.5	33
Pulp and Paper	Conventional	0.30	183	2910	3.85	33	91.2	16
Pharmaceutical	Conventional	1.60	1556	3292	3.75	100	89.0	6
Cannery	Conventional	2.56	630	2500	4.8	-	81.6	1
Cannery	Contact Stabiliz.	1.28	600	3220	3.0	100	84.0	2

[1] The BOD loading to the aerator alone is 12.4 lbs BOD per day per lb sludge composed principally of cellular storage.

TABLE 11

Observed Respiration Rates in Biological Oxidation Systems

Waste	Respiration	Rate mg O_2/hr/gm sludge	Ref
Sewage	Active	10 - 20	(58) (59) (60)
Sewage	endogenous	1.85 - 9.8	(58)
Dairy	active	40 - 45	(57)
Dairy	endogenous	4 - 10	(57)
Cannery	active	35	(1)
Pharmaceutical	active	76 (ave. max. recorded)	(6)
Pulp and paper	active	10 - 15	(16)

References

1. Eckenfelder, W.W. and Grich, E.R., Plant Scale Studies on the Biological Oxidation of Cannery Wastes, Presented 10th Ind. Waste Conf., Purdue Univ., May 1955.

2. Eckenfelder, W.W., Pilot Plant Investigations of Biological Sludge Treatment of Cannery and Related Wastes, Proc. 7th Ind. Waste Conf., Purdue Univ., May 1952

3. Eckenfelder, W.W. and Grich, E.R., Biological Oxidation of Cannery Wastes, Pres. Biological Waste Treat. Conf., Manhattan College, April 1955

4. Eldridge, E.F., Sew Wks. Jour., 13, 1, 105, Jan. 1941

5. McKinney, R.E. and Weichlein, R.G., Water and Sew. Wks., 101, 3, 123, March 1954

6. Dryden, F.E. et al, Treatment of Pharmaceutical Wastes by High Rate Activated Sludge, 10th Ind. Waste Conf., Purdue Univ., May 1955

7. Kaufman, S., Relationship of Biochemical Oxygen Demand in a Treated Industrial Effluent Proc. 9th Ind. Waste Conf., Purdue Univ. 1954

8. Trebler, H.A. and Harding, H.G., Two Stage High Rate Trickling Filters for Dairy Waste Treatment, Proc. 4th Ind. Waste Conf., Purdue Univ., 1948

9. Harding, H.G. and Trebler, H.A., Biological Oxidation of Dairy Wastes, Pres. Biological Waste Treatment Conf., Manhattan College, 1955

10. Kountz, R.R., Dairy Waste Oxidation Plant Design, Pres. Biological Waste Treatment Conf., Manhattan College, April, 1955

11. Horton, J.P. and Trebler, H.A., Recent Developments in the Design of Small Milk Waste Disposal Plants Proc. 8th Ind. Waste Conf., Purdue Univ., 1953

12. Majewski, F., The Treatment of Wastes at the Rohm and Haas Co. Proc. 8th Ind. Waste Conf., Purdue Univ., 1953.

13. Dickerson, B.W., Treatment of Powder Plant Wastes, Proc. 6th Ind. Waste Conf., Purdue Univ., 1951

14. Degnan, J.M., Merman, R.G. and DeMann, J.G., Pilot Plant Investigations of the Biological Filtration of Refinery Wastes, Proc. 7th Ind. Waste Conf., Purdue Univ., 1952

15. Baker, R. and Weston, R.F., Biological Oxidation of Refinery Wastes, Presented Biological Waste Treatment Conf., Manhattan College, 1955

16. Eckenfelder, W.W. and Moore, T.L., Waste Works Points Way for an Industry, Engineering News Record, Dec. 6, 1954

17. Moore, T.L. and Kass, E.L., Biological Oxidation of Pulp and Paper Wastes, Pres. Biological Waste Treatment Conf., Manhattan College, 1955

18. Smith, D.B. and Lackey, J.B., Factors Influencing Development of Biological Floc, Pres., Biological Waste Treatment Conf., Manhattan College, 1955

19. Knaysi, G., Elements of Bacterial Cytology, 2nd Ed. Comstock Pub. Co., Ithaca, New York, 1951

20. Hoover, S.R. and Porges, N., Assimilation of Dairy Wastes by Activated Sludge 11. The Equation of Synthesis and the Rate of Oxygen Utilization, Sew. and Ind. Wastes 24, 3, 306, March 1952.

21. Placak, O.R. and Ruchhoft, C.C., Studies of Sewage Purification XB11, The Utilization of Organic Substrates by Activated Sludge, Sew. Wks. Jour. 19, 5, 423, May 1947

22. Weston, R.F. and Eckenfelder, W.W., Application of Biological Treatment to Industrial Wastes, Presented Fed. of Sew. and Ind. Wastes, Cincinnati, Ohio, Oct. 1954.

23. Porges, N. et al, Biochemical Oxidation of Dairy Wastes V11, Oxidation Assimilation and Storage, 10th Ind. Waste Conf., Purdue Univ., 1955

24. Keefer, C.E. and Meisel, J., Activated Sludge Studies 11 Efficiency and Performance under Various Operating Conditions, Sew. and Ind. Wastes Jour., 22, 1518, Dec. 1950

25. Katz, Wm.J., The Mechanism of Adsorption of Activated Sludge, PhD thesis, Univ. of Wisconsin, 1953

26. Kountz, R.R., Private Communication

27. Ruchhoft, C.C. et al, Studies of Sewage Purification XI The Removal of Glucose from Substrates by Activated Sludge, Sew. Wks. Jour., 12, 1, 27, Jan. 1940

28. Gellman, I. and Heukelekian, H., Studies of Biochemical Oxidation by Direct Methods, 11 Oxidation and Purification of Industrial Wastes by Activated Sludge, Sew. and Ind. Wastes, 25, 10, 1196, Oct. 1953

29. Penfold, W.J. and Norris, D., The Relation of Concentration of Food Supply to the Generation Time, Jour. Hygiene, 12, 527, 1912

30. Garrett, T.M. and Sawyer, C.N., Kinetics of Removal of Soluble BOD by Activated Sludge, Proc. 7th Ind. Waste Conf., Purdue Univ. 79, 51, May, 1952

31. Fair, G.M. and Thomas, H.A. Jr., The Concept of Interface and Loading in Submerged Aerobic Biological Treatment Systems, Jour. and Proc. Inst. Sew. Purif., Part 3, 235, 1950

32. Eckenfelder, W.W. and O'Connor, D.J., The Aerobic Biological Treatment of Organic Wastes, Proc. 9th Ind. Waste Conf., Purdue Univ., May 1954

33. Haseltine, T.R., A. Rational Approach to the Design of Activated Sludge Plants, Pres. Biological Waste Treatment Conf., Manhattan College, 1955

34. Gould, R.H., Sewage Aeration Practice in N.Y.C., Proc. ASCE, Vol. 79, Sep. 307, Oct. 1953

35. Gellman, I. and Heukelekian, H., Studies of Biochemical Oxidation by Direct Methods, 11 Oxidation and Purification of Industrial Wastes by Activated Sludge, Sew. and Ind. Wastes, 25, 10, 1196, Oct. 1953

36. Edwards, G.P., Factors Affecting the Efficiency of Activated Sludge Plants - A Discussion, Sew. Wks. Jour., Vol. 21, p 640, July 1949

37. Gould, R.H., Sewage Disposal Problems in the Worlds Largest City, Sew. and Ind. Wastes, 25, - 155, Feb. 1953

38. National Research Council, Sewage Treatment at Military Installations, Sew. Wks. Jour., 18, 791, Sept. 1946

39. McKinney, R., Biological Flocculation, Pres. Biological Waste Treatment Conf., Manhattan College, 1955

40. Busch, A.W. and Kalinske, A.A., Utilization of the Kinetics of the Activated Sludge Process for Process and Equipment Design, Pres. Biological Waste Treatment Conf., Manhattan College, 1955

41. Fischer, H.J., The Present Status of Biofiltration, Water Wks. and Sew., Oct. 1942

42. Walton, G., High Rate Trickling Filter Performance, March 1943, under direction of State Health Comm., Upper Mississippi River Basin, Sanitation Agreement

43. Velz., C.J., Basic Law for the Performance of Biological Beds, Sew. Wks. Jour. 20, 4, July 1948

44. Heukelekian, H., Relationship Between Accumulation and Biological Characteristics of Film of a Bio-Filter and a Standard Filter, Sew. Wks. Jour., 17, 1, Jan. 1945

45. Eckenfelder, W.W. Jr., Aeration Efficiency and Design, Sew. and Ind. Wastes, Vol. 24, p 1221, Oct. 1952 and p 1361, Nov. 1952

46. Nixon, A.E. and Gaden, E.L., Oxygen Transfer in Submerged Fermentation, Ind. and Eng. Chem. Vol 42, p 1792, Sept. 1950

47. Dawson, P.S.S. and Jenkins, S.N., The Oxygen Requirements of Activated Sludge Determined by Manometric Methods, Sew. Wks. Jour. 21, 4, 643, July 1949

48. Hoover, S.R.

49. Smith, D.B. Aerobic Biological Stabilization of Organic Substrates, Sew. and Ind. Wastes Jour., Sept. 1952

50. Hober, Hitchcock et al, Physical Chemistry of Cells and Tissues, Blakiston Pub. Co.

51. Pasveer, A., Distribution of Oxygen in Activated Sludge Floc, Sew. and Ind. Wastes 26, 1, 28, Jan. 1954

52. Sawyer, C.N., Nutrition and Synthesis, Pres. Biological Waste Treatment Conf., Manhattan College, 1955

53. Sawyer, C.N., et al, Nutritional Requirements in the Biological Stabilization of Industrial Wastes, Sew. and Ind. Wastes 24, 4, April 1952

54. Helmers, E.N., et al, Nutritional Requirements in the Biological Stabilization of Industrial Wastes, Proc. 6th Ind. Waste Conf., Purdue Univ., Feb. 1951

55. Sawyer, C.N. Final Clarifiers and Clarifier Mechanisms, Pres. Biological Waste Treatment Conf., Manhattan College, April 1955

56. Anderson, N.E., Final Settling Tanks, Sew. Wks. Jour. 17, 50, 1945

57. Hoover, S.R. et al, Assimilation of Dairy Wastes by Activated Sludge, Sew. and Ind. Wastes Jour., 23, 2, Feb. 1951

58. Sawyer, C.N. and Nicols, M., Activated Sludge Oxidations, 11 A Comparison of Oxygen Utilization by Activated Sludges from Four Wisconsin Communities, Sew Wks. Jour., 11, 3, 462, May 1939

59. Studies of Sewage Purification, Sew. Wks. Jour., 10, 4, 661, July 1938

60. Grant, S., Hurwitz, E. and Mahlman, F.W., The Oxygen Requirements of the Activated Sludge Process, Sew. Wks. Jour., 2, 2, 228, April 1930

61. Hoover, S.R., Biochemical Oxidation of Dairy Wastes, Sew. and Ind. Wastes Jour., 25, 2, Feb. 1953

62. Hoover, S.R., Biochemical Oxidation of Dairy Wastes, Presented 9th Ind. Waste Conf., Purdue Univ., May 1954

63. Porter, P.L., Bacterial Chemistry and Physiology, John Wiley and Sons, N.Y.

64. Sawyer, C.N., et al, Nutritional Requirements in the Biological Stabilization of Industrial Wastes, Proc. 6th Ind. Waste Conf., Purdue Univ., Feb. 1951

65. Sawyer, C.N. and Nichols, M.S., Activated Sludge Oxidation Effect of Sludge Concentration and Temperature upon Oxygen Utilization, Sew. Wks. Jour. 11, 1, 51, Jan. 1939

66. Sawyer, C.N. and Rohlich, G.A., Activated Sludge Oxidations IV The Influence of Temperature upon the Rate of Oxygen Utilization by Activated Sludges, Sew. Wks. Jour. 11, 6, 946, Nov. 1939

67. Wuhrmann, K., High Rate Activated Sludge Treatment and its Relation to Stream Sanitation, Sew. and Ind. Wastes, 26, 1, 1, Jan. 1954

68. Heukelekian, H. and Gellman, I., Studies of Biochemical Oxidation by Direct Methods II Effect of Certain Enviromental Factors on the Biochemical Oxidation of Wastes, Sew. and Ind. Wastes, 23, 12, 1546, Dec. 1951

69. Ludwig, M.F., Oswald, W.J. and Gotass, N.B., Manometric Technique for Measurement of BOD, Series 44, No. 2 San. Eng. Lab., Inst. of Eng. Research, Univ. of Cal., Berkeley, Cal., June 30, 1951

TREATMENT OF WASTE FROM SLAUGHTERHOUSES AND POULTRY DRESSING

By

R. RUPERT KOUNTZ

Professor of Sanitary Engineering
The Pennsylvania State University
UNIVERSITY PARK, Pennsylvania

When stream pollution must be abated economically and simply the treatment of waste water from small slaughterhouses and poultry dressing plants operating regularly or intermittently poses a special problem in contrast to the large complete meat products plant with special processing and rendering operations. Ordinarily, the small plant does not have a maintenance staff and the number of employees is at a minimum. Thus, any waste treatment operations will be of secondary importance to the processing of the product. Biological methods, if used in these plants, must be simple to operate and, if possible, semi-automatic.

Realizing this problem, the Pennsylvania Sanitary Water Board appropriated funds to The Pennsylvania State University's College of Engineering and Architecture for a study and evaluation of the waste problem from small slaughterhouses. The State Department of Health rendered assistance to this work by providing one of their staff Sanitary Engineers and a mobile field laboratory. A pilot plant installation was erected for the purpose of this study. The problem of waste water treatment from the poultry dressing plants was investigated at the University under the sponsorship of the United States Department of Agriculture, Agricultural Marketing Service. Data for the poultry study were gathered from the plants operating in Pennsylvania.

I. Slaughterhouse Waste

Biological Oxidation

The activated sludge process was not included in this study because of the intensive foaming encountered in the laboratory trials before building the pilot plant. With more dilute wastes or wastes having a significant fraction of sanitary sewage there should be no difficulty in employing this process. In work subsequently done by the author with dairy wastes the activated sludge process worked quite well and also very economically as a batch-process technique.

With waste strengths of 1500-2600 ppm (700-1200 ppm BOD with blodd excluded) BOD the usual style of trickling filter will not provide satisfactory treatment, without two or more stages, or else a high recycling ratio. Intermittent slaughtering schedules permit the conventional filter to dry out between uses and thus damage the biological flora in the filter. Tests in this study yielded less than 10% reduction in BOD using a conventional six-foot deep filter. The two to three inch stone originally tried was removed and replaced with "rice" and "buckwheat" anthracite coal to a depth of six feet. During five months of operation the coal filter approached a BOD reduction of 40% without recycling. Lack of time and funds did not permit further investigation of this unit, although it would appear to have use as a pre-treatment device before dischaging waste to a municipal sewer. The treatments described are for a single application at a rate of 2.0 mgad.

Obviously this is a ten-fold overload in regard to weight of BOD per unit volume of filter medium but such a rate is necessary to obtain hydraulic distribution.

If activated sludge and conventional trickling filter methods are unsatisfactory and finer filter media increases the degree of treatment, then the obvious solution is very fine media or a sand filter. Sand filters (24 inches deep on 6 inches of gravel) were built from washed river sand and operated similarly to the intermittent sand filters in early sewage plants. Waste was applied at a rate of 200,000 gallons per acre per day in four doses at two hour intervals and yielded a reduction of 95% in the summertime and 85% in the wintertime, when two sand filters were operated in series. A single filter yields 85% and 60% respectively. The waste is applied quickly from a dosing siphon so as to flood the filter surface. It is recommended that the underdrains be free outfalls and without traps, to aid in possible ventilation. Naturally, the waste should be screened and settled to reduce the filtermat on the sand surface. Rotary distributors were tried but found to cause ponding at the above dosing rate, and also required much greater maintenance than the filter-flooding application method.

Recycling was investigated but is not recommended because of the higher maintenance and operating costs. Filter maintenance is quite simple. Aside from an occasional light raking to remove any "mat," it is recommended that the top two inches of sand be removed and replaced with new sand at least once a year. The effluent from this treatment has a clear pale-straw color.

<u>Septic Tank Treatment</u>

Septic tanks have been used in many instances as a receptor of slaughterhouse waste before disposal by means of a tile field. In an effort to assess the degree of reduction offered by anaerobic action a limited laboratory study was made using samples of waste from normal slaughtering operations.

Three 16-liter carboys were used as septic tanks and seeded with sewage plant digester sludge. Quantities of waste were added at seven-day intervals so as to displace 10, 25 and 50% of the volume of carboy, and this system of waste addition was performed for eight months. During this time the pH of the carboys remained at 7.4 although highly alkaline waste was added, and there was no increase in the volume of sludge.

The average reduction in BOD is given in Table 1.

TABLE 1

BOD REDUCTION IN SEPTIC TANKS

Displacement	One Day	Three Days	Seven Days
10%	29%	64%	93%
25%	22%	51%	78%
50%	10%	29%	55%

Septic tanks produce a definite reduction in the pollution load of slaughterhouse waste and satisfactory reduction can be obtained if a relatively large tank size can be justified.

Chemical Treatment

Chemical treatment is feasible in instances where land area is limited, and neighbors are in close proximity. The operation of the plant is simple and can be carried out without laboratory control.

The hypochlorite-alum process developed in this work is based on the fundamental work developed and published by Halvorsen. It will be recalled that his application of chlorine at the Hormel plant (in Minnesota) was made without adjusting the pH of the waste to the protein iso-electric point (pH:4.3) and this would help account for the partial treatment obtained. In the Pennsylvania process filter alum is used to lower the pH to the proximity of the iso-electric point and the alum possessed the additional virtue that the use of grossly excess amounts would not produce a lower pH than 4.3. Further, the order of addition of the chemicals does not affect the efficiency of BOD reductions, but the addition first of hypochlorite does yield a more efficient chemical dosage. Chlorine gas was not investigated nor suggested since the cost and dangers of using it are too great. The chlorine compounds studied were calcium hypochlorite, chlorinated lime and sodium hypochlorite solution, and all worked equally well.

The hypochlorite-alum treatment of slaughterhouse waste will produce 95% or better reduction in BOD values of 1000-3000 ppm, but the reduction drops off rapidly to 60 to 70% as the amount of process cooking in the plant increases. Hypochlorous acid will precipitate fresh animal proteins almost completely, but because of protein hydrolysis due to cooking, the amount of original proteins capable of being precipitated is reduced and the amount of BOD reduction correspondingly decreases. The protein coagulation and precipitation is immediate and the sludge consolidates to a volume of 20 gallons per hog and 50 gallons per steer, leaving about 85% of the waste volume as a colorless, clear effluent which is decanted with an adjustable effluent pipe. These data are intended for a fill-and-draw type of plant which is much simpler for a small slaughterhouse. The average dosage of calcium hypochlorite used was three ounces per hog and 10 to 15 ounces per steer. The amount of alum used depended on the pH and alkalinity of the water supply but will range from 10 to 20 pounds per 1000 gallons of waste. In the absence of pH measurements (after adding alum) a sufficient dosage will be shown by a clear colorless supernatant in contrast to a tan color when under-dosed.

The sludge produced (98% water) was dewatered and dried on under-drained sand beds and under favorable weather conditions could be removed in five to seven days. There is no odor to the material and eventually it oxidizes to a hard black inert plastic-like substance. One advantage of this sludge is that rain cannot re-wet it after an air exposure of two to three days. A variation in the effluent system involves constructing the sludge beds of sand underlaid with graded gravel and under-drain tiles. The tank contents (supernatant first) are drained to the bed with a two foot head of applied liquid, and finally the sludge. This set-up can be operated at a two gallon per minute per square foot rate for the entire waste volume.

In the event any sludge accidentally reaches the stream there is no harm to fish life as toxicity tests were made with it using two-inch blue gill sunfish. A one percent sludge concentration in the aquarium water did not affect them in seven days contact.

11 Poultry Dressing Waste

Poultry dressing waste is very similar to the slaughter-house waste except for the matter of feathers. For this study it was assumed that all feathers would be screened from the waste before leaving the plant. The type of operation in regard to manure and blood disposal will greatly affect the strength of the waste. With blood and manure removed the BOD will be approximately 500-600 ppm, but when both are included it can easily be 3000-3500 ppm.

For this investigation chickens were assumed to have a live weight of 3.5 lbs. and a dress weight of 2.5 lbs. Water usage (waste volume) was found to have an average value of one gallon per pound of live weight of birds processed (3.5 gallons/bird). Under average conditions with good housekeeping the average wieght of BOD was found to be 25 lbs. per 1000 chickens.

In preparing these cost estimates of both the initial construction cost and the annual operating expenses, it was necessary, in order to simplify the calculations, to make various basic assumptions. It is believed, in view of the assumptions used, that the relative values shown are correct, whereas various authorities may differ on the actual assumed design and cost values.

In general the estimates show that the cheapest system to install and operate is spray irrigation. The next cheapest is subsurface tile field, and the most expensive are the trickling filter installations. In the case of the filters recycling of the waste reduces the capital investment and does not markedly increase the operating cost in spite of the continuous pumping required. Municipal sewage disposal is comparable to the tile field and recycling trickling filter costs and is to be recommended in view of the freedom from operation, maintenance, and responsibility. Activated sludge was not considered in this study because of the numerous systems and different items of equipment which might be employed for this process. It is the feeling of the author that, in general, the activated sludge process, if standardized for this type of waste, should prove cheaper to operate than either of the filter installations.

For estimation of disposal by spray irrigation a basic application rate of 10,000 gallons per acre per day was employed. Basically the principle of application involved for irrigation systems would apply twice the basic rate on alternate days and thus allow the sprayed area a resting period of approximately 36 hours. The sump size was designed so as to operate the sprinklers 15-20 minutes out of each hour. The cost of the sewer from the plant to the spray field was not taken into consideration in these estimates. The area and dosing rates involved are for an eight hour dressing operation per day. It was assumed that the spray area contains a crop of pasture grass, alfalfa or similar cover crop. The laterals supplying the spray nozzels are sloped so as to drain back to the pump sump when pumping ceases and thus prevent freezing in winter weather. It is assumed that an ice-cap will cover the area during severely low temperatures and that this ice-cap will melt slowly in the warmer weather without objectionable run off.

For the tile field installation, a soil having a percolation rate of five minutes per inch of water soakage was assumed to be available. If the percolation rate is considerably less than this value it would be necessary to increase the tile field installation proportionately. The tile field laterals had a maximum length of 100 ft. and were located on 10 foot centers.. The pipes were located in 12 inches of gravel in a 36 inch wide trench. This tile field was designed to be dosed four times per day with an automatic siphon. The cost of the sewer from the plant to the siphon chamber was not included in this estimate.

The available data in the literature on the calculation of municipal sewer service charges for the amount to be charged to industries is confusing and conflicting since it not only involves the strength of the waste and its volume, but also the accessed valuation of the industry itself. It was decided to assume a constant to be applied to the domestic sewage volume rate to yield the annual charge for poultry dressing plants.

The trickling filter installation was divided into two types: no recirculation and a recirculation rate of 4:1. In both cases it was assumed that a filter depth of 6 to 8 feet would be employed. The method of arriving at the total construction was to develop first the cost of the filter itself and then to add to it 75% - 80% for the cost of sedimentation tanks, pumps, and piping. The acre-foot of stone media required for these units was based upon the formula provided in the report of the National Research Council of May, 1946. Commonly prevailing engineering costs estimates were employed for the filter components.

In all of the above installations except municipal disposal the annual cost was computed by means of the following formula:

$$CC = C + O/r + \frac{C}{n}$$

where CC is the capitalization cost, C is the construction cost, O is the operating cost, r is the interest rate, n is the number of years of useful life or tax-write-off period. In this case r was 0.03 and n was 15 (years). The annual cost shown in this estimate was obtained by dividing the capitalization cost by the number of useful years (15).

For this comparison of costs a waste volume of 25,000 gallons per day with a strength of 800 ppm BOD is assumed. Spray irrigation, sub-surface tile field, trickling filters and municipal sewer system were evaluated. The construction cost of the first three was, respectively, $6000, $20,000, and $52,000. With recirculation, the trickling filter installation would cost $22,000. Computed annual costs were respectively: $3,300, $5,400, $13,000 and $9,000. The estimated annual sewer service charge was $4,900.

If land was available the low cost, and simplicity of operation and maintenance would favor the spray irrigation system. The spray irrigation and the tile field system would each require approximately three acres of ground area. Where sewers were available they would be preferable, in spite of the cost differential, because of the freedom from operation responsibility and its attendant problems.

In general summary, the method used would be evaluated by these five criteria:

1. The first cost of construction must be low.

2. Operating costs must be resonable.

3. The process must be simple.

4. Mechanical equipment should be held to a minimum to prevent shutdown due to mechanical failures and to cut maintenance costs.

5. Operational duties should be simple and not require much time, careful control or unpleasant tasks.

Acknowledgments

Much of this information was taken from a complete formal report, "Department of Engineering Research Bulletin No. 62" which terminated and fulfilled the terms of the research contract between the University and the Sanitary Water Board. The other two authors of Bulletin No. 62 were Robert E. Stiemke, formerly Professor of Sanitary Engineering, the Pennsylvania State University, and now Director of the School of Civil Engineering, Georgia Institute of Technology; and Thomas Iezzi, Senior Sanitary Engineer, Bureau of Engineering Pennsylvania Department of Health. As is always the case, numerous other University staff members aided in completing this project, as did a number of graduate students in Sanitary Engineering, and space does not permit listing all of them.

THE INTEGRATED TREATMENT of METALLURGICAL WASTES

By

L. E. LANCY, Ph. D.
Consulting Engineer in Metal Finishing

ELLWOOD CITY, Pa.

SYNOPSIS

The waste effluent from metal finishing plants contains numerous toxic compounds. The treatment of this waste before discharging it is a serious problem affecting the metal working industry. When evaluating the problem of waste treatment, it is found that the treatment of the contaminated rinse waters is the main issue. A simple method for the elimination of this type of pollution is introduced in the form of the integrated waste treatment system. Few specific examples of this treatment method are discussed.

INTRODUCTION

Among the industries discharging harmful wastes, the metal finishing trade is an important element. The chemicals employed in the make-up of metal processing solutions are extremely toxic to aquatic life. Another factor contributing to the seriousness of the question is the fact that the industry, especially the electroplating trade, is made up of a large number of relatively small plants dispersed everywhere where metal working industry is established. The economical burden of waste treatment is naturally much heavier for the smaller establishments both insofar as investments for treatment facilities are concerned and also because it requires the time of the scarce technically skilled help.

Evaluation of the polluting wastes from Electroplating processes.

The polluting wastes discharged by the typical electroplating plant may be divided in two general categories, such as: 1. concentrated and 2. dilute wastes.

1. Concentrated wastes are the spent acid pickling solutions, bright dips, passivating solutions, alkali cleaners, stripping solutions, etc. Generally these are process solutions, which lost their usefulness due to a high build up in either:

1. metallic salts;
2. organic materials, such as oils;
3. broken down and expended chemical compounds.

The regeneration of these process solutions usually is economically unjustified.

11. Dilute wastes are the diverse rinse waste effluents coming from the electroplating process. Some of the process solutions employed contain such highly toxic compounds, that eve trace quantities carried by the rinse water have to be considered toxic.

The evaluation of a particular waste treatment problem will depend to a great extent on the local conditions. If it is only the harmful effect of the wastes on the sewers and on the facilities of the local sewer works which has to be avoided, possibly only the concentrated wastes will have to be treated. On the other hand, if the receiver of the waste effluent is a stream, both the concentrated and dilute wastes will require treatment. Complete treatment of the dilute wastes is required also when the potential hazard to the sewerage treatment plant is considered.

The treatment of the concentrated wastes is a relatively simple procedure. The dumping of process solutions occurs only after reasonably long periods of use; the total quantities are not too large; some of the wasted solutions may be used to effect chemical treatment on others help neutralize each other. The chemical reactions involved are simple and a reasonably sized holding tank will allow a treatment frequency of only once or twice weekly.

It is believed that the real problem in connection with metal finishing waste treatment is the treatment of the dilute wastes.

We are dealing here with comparatively large quantities of waste. Profuse rinsing is a prerequisite of a sound finish because:

1. A film of dissolved chemicals, on the work in process which when reacting with the chemicals contained in the next process solution might lead to a precipitate on the surface to be finished. Some of the effects of insufficient rinsing could be porosity of the metallic or non metallic deposits, lack of adhesion, blistering of the deposit, spotting, tarnishing cloudy films, etc.

2. Continuous drag-in of foreign chemical compounds, would soon pollute the processing solution next in the line.

Waste treatment adds to the operating costs.

One finishing plant will usually employ a number of different process solutions; the rinse waters thus are contaminated by different chemical compounds, which will require different but specific chemical treatments. It becomes necessary then to segregate the waste waters according to the subsequent chemical treatment cycle they will be subjected to, and collect them for treatment.

Continuous treatment lines are not accepted by many of the Sanitary Authorities mainly because: 1. large variations in flow rates and chemical loads; 2. the extremely high toxicity of the waste, even in trace concentrations; 3. the toxic nature of some of the chemicals used for the treatment; 4. the time required for some specific reactions to progress to completion; 5. the lack of sensitivity and sometimes dependability of automatic control instruments.

The segregation and collection of these wastes requires large containers, actually several set of containers for:

1. collection;
2. treatment;
3. stand-by;
4. settling;
5. blending and discharge.

A reasonable number of pumps, chemical feeders, mixers, flow meters, and control instruments are also needed. Technical supervision, some manual and maintenance labor, and the chemicals consumed, added to the amortization cost of the physical plant constitute the operating expenses of the treatment plant.

The Integrated Waste Treatment System

Analyzing the problem as stated in connection with the treatment of the dilute plating wastes we might draw the following conclusions:

1. The pollution problem is due to the discharge of large quantities of rinse waters contaminated by a relatively low concentration of toxic chemical compounds.

2. This waste is not due to some chemical by-product which is a necessary result of the metal finishing process; rather it is caused by the requirement of repeated washing during the processing cycle.

From these considerations it follows, that if we could eliminate the toxic compounds before they are washed off we could meet the requirements, for profuse rinsing without causing pollution. It is necessary then to integrate the waste elimination steps into the processing sequence and establish the treatment as an organic part of the whole process.

The objectionable chemical compounds may be removed from the work in process before they could reach the sewer by either recirculating the rinse waters through ion-exchangers or by chemical treatment preceeding the rinsing steps.

The integrated Waste Treatment System is based on chemical treatment methods and the general conception may be described as: chemical treatment of the objectionable toxic compounds and their removal from the work in process-preceeding the rinsing with running water.

The chemical treatment solution is kept in a closed system and it is not wasted as a rule, but may be discharged after prolonged use. The treatment wash station is an integral part of the finishing line and it is connected to a larger treatment solution reservoir. The treatment solution is constantly recirculated, the chemicals consumed in the treatment process are replenished and the precipitated salts removed through settling or filtration. The treatment solution contains considerable excess of the chemicals used for the treatment. This feature avoids the necessity of close control, maintains a more even level of available chemicals regardless of fluctuations in the drag-in rate and in some cases accelerates the anticipated chemical reactions. Since the treatment solution is not expendable the higher concentration of reagents maintained does not imply wasteful consumption of the treatment chemicals.

The choice of the chemical reaction to be adapted for this type of treatment has to be such, that it suits the finishing cycle while fulfilling the objective of toxic waste elimination.

The requirements for a satisfactory treatment solution may be enumerated as follows:

1. it should not tarnish, discolor or stain the work;

2. it should not harm the functional qualities of the finish such as: corrosion resistance, activity for receiving subsequent electrodeposits, paintability and paint adhesion, etc.;

3. it should give an instantaneous reaction with the toxic compounds since the chances for harmful dragout into the subsequent running water rinse will depend on the concentration level in the treatment solution;

4. it should lead to a precipitate or gaseous breakdown product to eliminate undue chemical build up and the need for frequent dumping.

Dependent on the chemistry of the particular treatment to be used and also to some extent on the receiver of the final effluent, the treatment system may consist of one or two steps with as many different treatment solutions. As an example we could mention high and low pH cycles, reduction and subsequent precipitation steps, etc.

Evaluation of the integrated method of waste treatment

The advantages of the Integrated Waste Treatment System are numerous and probably decisive for the electroplating trade.

1. The capital outlay for treatment equipment is but a small fraction of the productive equipment cost.

2. The waste treatment is integrated into the finishing line, thus no separate treatment plant is required.

3. The floor space occupied is small and may be further minimized by occupying space overhead or below floor level.

4. Some reduction in chemical consumption is achieved especially when in a conventional batch plant large quantities of wastes have to be subjected to low pH treatment and subsequent neutralization.

5. The need for close chemical control is eliminated due to the wide limits allowed when working with a constant excess of treatment chemicals.

6. No separate personnel is required for the operation of the treatment system. Simple test methods approximating the concentrations of chemicals is sufficient and allow the integration of the waste treatment plant into the regular duties of the supervisory and operating labor usually employed.

7. Reduced quantities of rinsing water may be employed due to the better rinsability of the work after treatment and the reduction in contaminants.

8. The rinse waters are free of hight concentration of dissolved and suspended solids, the color and clarity are excellent in comparison to the effluent from a conventional treatment plant.

9. The effluent is far more free of toxic compounds than is the case with the average conventional treatment plant. The reason for this is simple; it is easier to work with an excess of treatment chemicals in a closed recirculated system especially when it involves the precipitation of trace quantities of heavy metal complexes.

Specific examples of integrated waste treatment

1. Treatment method after a cyanide type of plating solution:

The toxic compounds to be eliminated are the cyanide radical and the heavy metal ions, such as copper, zinc, cadmium. The oxidation of the cyanide complexes through chlorination is one of the simplest, cheapest and fastest chemical treatment methods and may be employed in the integrated system very advantageously. A free chlorine excess of 30-80 ppm is used at a pH of 9-10.5. Chlorine gas or a hypochlorite solution as the source of free chlorine is equally satisfactory. The underlying chemical reaction is thoroughly explored and it may be assumed to go through in two steps:

1. $NaCN + 2\ NaOH + Cl_2 \rightarrow NaCNO + 2NaCl + H_2O$.

This first step is a very rapid reaction converting the cyanides into cyanates, compounds of considerably lesser toxicity. With further additions of free chlorine the second reaction proceeds at a somewhat lower rate of speed. At the stated pH, with the excess chlorine stipulated at room temperature, in about 2-4 hours, the cyanates are broken down into nitrogen and carbon dioxide gas according to the assumed formula:

2. $2\ NaCNO + 4\ NaOH + 3\ Cl_2 \rightarrow 2\ CO_2 + 6\ NaCl + N_2 + 2\ H_2O$.

The relatively high chlorine excess accelerates the breakdown of the cyanates and allows the quantitative precipitation of the toxic heavy metal salts. In the event that the treatment follows copper plating from a Rochelle salt solution, sufficient quantities of calcium chloride or lime has to be added to the treatment solution to effect the complete precipitation of the copper.

The chlorination type treatment solution does not affect the appearance or corrosion resistance of the deposit nor does it alter the surface activity of a copper deposit insofar as the adhesion of subsequent nickel plating is concerned. A distinct improvement in rinsability is achieved if comparing rinsing after the treatment with washing after plating is an installation without the incorporated treatment step.

A typical integrated treatment line following plating from a cyanide type electrolyte consists of a treatment wash station in the processing line following the plating step. A larger treatment solution reservoir is also provided and this is in a pumping recirculatory connection with the treatment wash station. The provision of the reservoir allows a larger quantity of treatment solution in constant use, reducing the fluctuation in chemical composition and provides settling facility for the precipitated metallic salts. The treatment wash solution as it is recirculated between the treatment wash station and reservoir tank is constantly enriched with chlorine gas and caustic soda or a hypochlorite solution to replenish the chemicals consumed.

Non toxic salts such as sodium chloride, sodium carbonate, etc., slowly accumulate in the treatment solution. Every 2-4 months depending on the particular installation, the treatment solution should be discarded and a new treatment solution made up. A holding tank is usually provided for this purpose and also for periodic draw off for systems using the hypochlorite method of chlorine feed. The use of this holding tank allows leisurely time for analysis, reduction of the excess chlorine, precipitation of possible traces of copper or other heavy metal, adjustment of pH and slow bleeding off of the clear effluent.

Automatic control instrumentation based on pH control and depending on the redox potential can be used. The redox potential is a dependable indication of the quantity of the available free chlorine. The potential depends also on the pH, thus it is necessary to control the pH to be able to use the electrode system for the automatic control of the chlorine feed.

111. Treatment after chromium plating, chromic acid anodizing, dichromate type passivating dips, etc.

A two step process is usually employed. The first treatment insures the reduction of the hexavalent chromium to the trivalent state while the second treatment serves for the precipitation of the chromic salts.

Generally, sulfur dioxide gas is used for the reduction phase of the treatment. There are a number of important considerations making sulphur dioxide the preferred reducing agent in this reaction, these are:

1. ease of handling, adjusting the rate of flow, etc;

2. the greater driving force of this reaction allows a wide pH range-- from acidic to slightly alkaline-- for instantaneous reduction to take place, considering the usual excess of reducing agent in solution;

3. the sulfurous acid formed as the gas is absorbed in the solution regulates the pH effectively eliminating the need for separate acid additions;

4. the basic chromic sulfate formed will require smaller quantities of alkali for the subsequent precipitation.

The second treatment step used for the elimination of chromium waste consists of a slightly alkaline wash solution containing traces of reducing agent, such as sodium hydrosulphite ($Na_2 S_2O_4$), to maintain a reducing potential and eliminate the possible traces of hexavalent chromium not reached in the first treatment. A sodium carbonate, lime solution at a pH of 6-8 may be employed.

The probable chemical reduction of the hexavalent chromium with SO_2 gas is expressed as follows:

1. (a) $SO_2 + H_2O \longrightarrow H_2SO_3$

2. (b) $2H_2CrO_4 + 3H_2SO_3 \rightleftarrows Cr_2(SO_4)_3 + 5H_2O$

3. $Na_2Cr_2O_7 \cdot 2H_2O + 3SO_2 \rightleftarrows Cr_2(OH)_2(SO_4)_2 + Na_2SO_4 + H_2O$.

It will depend on the particular process on hand at what pH the reduction reaction should take place. While a pH of 2-3 is harmless for a treatment after chromium plating, a pH near neutral is required after chromic acid anodizing, or dichromate passivation of brass, zinc, cadmium, etc.

The speed of the reaction depends on the pH and excess reducer available while an increase in temperature also accelerates the reduction. The hydrosulphite ion has an even greater reducin g potential for hexavalent chromium compounds and it may be assumed to accomplish instantaneous reduction at an alkaline pH with only a 10-20% excess of the stoichiometric equivalent.

In a typical treatment layout, the first treatment wash follows the chromium plating, possibly after a drain station which serves to reduce the chemical dragout. The second treatment is next in the line and is followed by a running water or spray rinse. Both these treatment wash tanks are connected through a pump with a larger treatment solution reservoir and are constantly recirculated. The purpose of the treatment reservoir here is simply to expand the usually small holding capacity (100-200 Gal) of the wash station in the line and thus level off possible large fluctuations in the chemical concentration.

The sulfur dioxide is added through a porous stone or lead pipe diffuser after passing through a pressure regulating valve, flow meter, gas dryer and vacuum breaker. The chemical consumption in the second treatment solution is very small. Only the chromic salts dragged in from the first treatment step are precipitated here. Manual replenishment of the chemicals once daily is usually sufficient. The insertion of a filter in the recirculating line will constantly remove the small amounts of precipitate formed and perpetuate the usefulness of the second treatment solution.

The first treatment solution is allowed to build up to a concentration of 1-2 lb./gal. chromic acid equivalent in chromic salts and is then pumped to a neutralization tank. The neutralization and precipitation of the chromic salts is affected by the additions of dry lime and the resultant slurry is pumped to a sludge bed for drying. The by-product dry sludge is of commercial value.

The rate of sulphur dioxide flow and pH may be easily controlled automatically by the use of instrumentation based on the redox potential of the solution. Manual control is also easy; it is sufficient to use a spot test to approximate the excess reducer present. Simple pH paper test may take care of the second treatment wash solution.

SUMMARY

A simple treatment of plating waste is made possible for even the smallest plant without incurring great expenses. Neither the physical plant, nor the operating expenses are of sufficient magnitude to affect the economy of operations. All metal finishing plants could be designed in the future to completely eliminate all toxic waste, regardless of the lower standards allowed by the local conditions; the cost of waste treatment is small and well worth the benefits derived in the process. Better rinsing can be achieved, allowing a reduction in the water consumption rate. Cleaner, stain-free finishes may be had even with shapes notorious for trapped chemicals. The most outstanding difference is noticed after chromium plating, the usual chromic acid drying stains are all eliminated and the plating racks may be maintained with an "as new" appearance. The chances for contamination of the process solutions is eliminated. The need for better housekeeping teaches better working habits, improves efficiency and reduces chemical waste.

Water Quality Criteria for Aquatic Life

Clarence M. Tarzwell

Robert A. Taft Sanitary Engineering Center

Bureau of State Services

Public Health Service

U. S. Department of Health, Education, and Welfare

Cincinnati, Ohio.

The lakes and rivers of North America have played a very important role in the opening and development of the continent. In our Great Lakes we have a fresh water resource far surpassing any other in the world. Our rivers and hundreds of thousands of inland lakes are outstanding in their many uses and support a diversity of the most valuable fishes to be found anywhere. Perhaps it is because of this great wealth in aquatic resources, which many considered to be inexhaustible, that we have been so remiss in their protection and conservation. Their importance is only now coming to be generally appreciated. The great increases in population since 1900 and the manifold increases in the volume and variety of water uses have shown that in some areas the supply of water is definitely limited. As with other resources we find that value varies directly with demand and inversely with supply. In the western areas which recently suffered from a severe drought it was found that when local drinking water supplies dry up water will be purchased at any necessary price, however high it may be.

What is true for drinking water is also true in some measure for aquatic life resources. We have already found that as the demand for desirable fishing increases and the supply diminishes, the amount paid for such recreation becomes greater. The development of the country has drastically reduced or eliminated fishing waters in extensive areas. Deforestation, fire, overgrazing, and unwise agricultural practices have increased surface runoff and decreased seepage causing floods, intermittent flow, the drying up of springs, erosion, silting and the filling of stream beds. Removal of streamside vegetation has promoted bank erosion, the widening of streams, and warming of the water. Industrial and other pollution has blocked fish migration and has rendered many areas unsuitable for fish. These practices which alter or destroy the aquatic habitat are the chief cause of the decline of aquatic life resources. The surest way to eliminate a species or group of species is to destroy their habitat or produce environmental conditions unfavourable for them. The only way to maintain a species is to protect and maintain environmental conditions essential for and conducive to its growth, reproduction and well being.

Protection and conservation of aquatic life is not a simple task. Some have questioned its value and feasibility.

Our fisheries are now an important resource. The commercial fisheries of the United States and Alaska have an annual production of almost five billion pounds (1) This crop represents a high protein resource which can be expected to increase in value. While commercial fisheries utilize a great deal of equipment and employ large numbers of people, their economic worth is only a fraction of that of sport fishing. In 1955 there were more than 17 million licensed fishermen in the United States. There are several million additional fishermen who fish in the Great Lakes and in marine waters where a license is not required. According to the National Survey of Fishing and Hunting (2), sport fishing in the United States has an annual value of almost two billion dollars. Within the next 100 years the number of fishermen and the value of the fishery will increase several fold if the resources can be preserved.

In comparing the beneficial uses of a stream, there has often been a tendency to underestimate the wildlife and recreational values and to take a short rather than a long view. When evaluating our fisheries resources we should consider the returns not just for one year but over the centuries because these resources are renewable. The aesthetic, recreational, and health values of our waters are difficult to measure, but they are great. The recreational industry is a large one and is expanding every year. In a few states it is the first ranking industry and in many others it is of considerable importance. In the industrial state of Michigan it is reputed to rank second. As our population increases there will be an ever growing demand for and use of our forests, parks, preserves, wilderness areas, and streams, where people can engage in water sports and "get back" to nature and relax. It is believed that our aquatic life resources and the aesthetic value of our lakes and streams, which are largely inseparable, are well worth our earnest and sincere efforts to preserve them.

The objective of water quality criteria for the protection of aquatic life is to preserve or restore environmental conditions essential for its growth, reproduction , and well being. If these requirements are known and understood, criteria can be set up which will achieve this objective. If habitat requirements are not fully known, criteria can only be based on the best information available and changed whenever the need is indicated by new information.

Under our present state of knowledge a suitable water cannot be defined in chemical terms alone. There are several reasons for this situation. Different species of fishes and the organisms in their food chain vary widely in their sensitivity to dissolved materials. We do not know the effects onaquatic life of various concentrations of many materials individually or in combination. Mixtures of materials often have effects different from those of the individual components. Further, we do not know minimal lethal levels for many materials or their mixtures, nor do we know the most favourable concentrations of materials essential for the organisms. Perhaps the best definition that can be given of suitable fish habitat is--"A suitable fish habitat is one which produces a satisfactory fish crop." The adequacy of a fish crop is judged by its quality and the pounds produced per unit of surface area. Commonly, productivity and suitability are judged by catch per unit effort, growth rate, condition factor, quality of the flesh, and the size and species composition of the catch. In fisheries management an effort is made to manipulate the environment so that conditions are made more favorable for the desired species and less favourable for those not wanted.

While our knowledge of the habitat requirements of fishes is far from complete, enough information is now available so that some criteria and procedures can be set up which will be of value in the maintenance of a satisfactory environment and production of a suitable crop. However, much research is still needed to obtain all the information essential for the solution of this problem.

The environmental requirements of fishes may be roughly grouped under four main headings, (1) a favorable water supply; (2) suitable spawning facilities; (3) an adequate food supply for all age groups; and (4) good pools and shelter. In the abatement and control of pollution we are chiefly concerned with the first requirement, a favorable water supply. Natural waters have widely varying physical and chemical properties. The suitability of any water for fish life depends on its quantity, permanency, and quality; that is, its temperature, the concentration of dissolved atmospheric gases, salts and other minerals, and suspended solids.

As here used water pollution is the addition of any material or waste to a water in such quantities that it interferes with, lessens, or destroys a beneficial use. In this regard perhaps the simplest definition of pollution is "too much." For example, if "too much" is not added, the discharge to a stream of organic matter such as sewage has a fertilizing effect which is beneficial to fish production. However, when the capacity of the stream to utilize organic materials is exceeded so that unfavorable environmental conditions are produced and a beneficial use is damaged, such a discharge becomes pollution. It is evident, therefore, that water quality criteria for the protection of aquatic life must entail some quantitative measurements. Before criteria can be set up we must know or have some measure of how much is "too much" for those species we wish to protect at all stages in their life history and in waters of different quality. These criteria must insure environmental conditions favorable to all life activities and to general well being --mere survival is not enough. These environmental factors will be discussed in some detail.

Environmental Factors

Temperature

As a group, aquatic animals of the temperate zone are adapted to fluctuations in temperature between 32° and 90° F. Not all can withstand this range and some can withstand higher and some lower temperatures for a time. The range of temperature which can be tolerated by different species varies considerable as does their ability to withstand sudden changes or to acclimate themselves to unusual temperatures. Each species has a preferred range of temperature within which it does best and a zone above and below this in which it can survive for short periods. Proper acclimatization enables certain species to survive at temperatures which would be fatal under conditions of sudden exposure.

Fish have a rapid rate of adaptation to high temperatures (3) but adaptation to lower temperatures proceeds at a much slower rate. When suddenly exposed to higher temperatures fish can withstand much higher temperatures in summer than in winter. As the summer season develops, changes in upper lethal temperatures reflect the major changes in water temperature, rising with ascending temperatures and falling as the water cools in the fall. Brett (3) reports that the lethal temperature for the bullhead rose from 29.1° C. on May 12 to 35.3° C. by July 8. Brett (4) also found that there is a considerable difference in the time required for completion of acclimation with respect to heat tolerance at each level of temperature. It has been shown that some species exhibit geographic differences in their resistance to high temperatures while others do not (5). The writer noted a bass kill in a southern Michigan lake in June 1936 when the water reached 94° F. during an unusually hot period. However, a temperature of 96° F. in Wheeler Reservoir in 1938 appeared to have no lethal effects. The difference may have been due to a different acclimation history. It was observed that a temperature of 108° F. killed all the fish in a pond near Savannah, Georgia, in 1945. Allowable peak temperatures brought about by some unnatural cause may, therefore, be somewhat different in different portions of the country, increasing from north to south.

Members of the family Salmonidae are cold water forms. Brook trout seem to do best in streams, the summer temperatures of which range between 52 and 68° F. (6) (7). While trout can survive much higher temperatures for short periods, streams having such temperatures are not first class trout streams. The writer found brown and rainbow trout surviving a peak temperature of 83° F. in the South Branch of the Pere Marquette River of Michigan in 1930. Brook trout survived peak temperatures of 81° and 82° F. in the East Branch of the Black River on successive days in July 1931. Fry (8) reported the upper lethal temperature for young brook trout (12 to 14 hours exposure) to be about 77.5° F. Such high temperatures are more favorable for minnows and suckers which increase greatly in numbers and compete for food and space with the trout (9). The result is that trout comprise a very small portion of the total fish population of the stream and supply little fishing even though the overall productivity of the stream may be great.

Four fish population studies made in the East Branch of the Black River of Michigan indicated that trout made up only 9.6 percent of the total population. Legal sized trout comprised only 0.9 percent of the total number of fish taken in the study areas. In the neighboring Pigeon River, another stream having temperatures above 75° F., trout comprised 15 percent of the total fish population in the areas counted (9). In a nearby cold stream, the West Branch of the Sturgeon River, trout represented 96 percent of the total population. In trout streams having high peak summer temperatures, suckers and minnows comprise the bulk of the fish population. Thus, while temperatures higher than the optimum and high temperatures of short duration (75° to 82° F) may not kill trout, they produce environmental conditions more favorable for the coarse fishes, which increase at the expense of the trout population. This fact must be taken into consideration in the establishment of temperature criteria for the cold water species. Such criteria must be based on optimum conditions and not on temperatures tolerated by trout. It is belived that for good trout production in streams subject to invasion by coarse species, temperatures should not exceed 68° F.

Since deforestation, overgrazing, unwise land use, removal of streamside shade, and erosion have already caused the warming of streams to such an extent that the amount of trout water has been seriously reduced, and since trout fishing is in highest demand, it is belived that no wastes of significant heat content should be discharged into a trout stream if the stream is to be maintained for trout.

Favorable temperatures are especially important at spawning time for both cold and warm water species. It is well known that bass spawn in the spring when the water temperature exceeds 60°F. If the water is unnaturally warmed to this temperature for a period, spawning may be induced too early in the season. Then if waste discharges are discontinued over a weekend, water temperatures may drop into the 50's with the result that guarding males leave the nests, the eggs are infested with fungi, and no young are produced. Fluctuations of water temperature above and below 60° F. during the spring are detrimental to bass production.

A change in water temperature may affect the aquatic fauna directly or indirectly. While the change may be within the thermal tolerance of the fish, it may so alter environmental conditions that they become unfavorable for essential food organisms and certain life history stages of the fish, or the change may make them more favorable for competitors or predators. Temperature changes will directly affect the metabolic rate, growth, and reproductive processes. They may result in increased or decreased food production, interfere with spawning, or change an important part of the fauna, thereby altering the quantitative makeup of the population.

Although high summer temperatures have been considered of outstanding importance because of their possible lethal effects, it is believed that unnaturally high winter temperatures may be equally important. In the temperate zone the aquatic biota have evolved under conditions of quite wide differences in seasonal temperatures. For example, the eggs of some daphnia have to be chilled or frozen before they hatch. Many other organisms go through resting stages or specific stages of development at certain seasons. Some of the diatoms, for example, are abundant only at temperatures below 50° F. Other forms appear only at certain times of the year and there is a succession of forms with the seasonal changes. At present we have little conception of the changes which might be brought about by permanently elevating stream temperatures. A large portion of the biota might be changed and the whole food chain disrupted. For this reason consideration should be given to upper temperature limits during the winter season. This consideration may require increasing attention as the atomic energy industry develops. Temperatures should not be raised to levels that induce spawning at unnatural times if there are periodic drops in temperature, and they should not be such that they interfere with the development of important organisms in the fish food chain. Considerable study is needed before this problem can be approached intelligently.

Waters of significant heat content should not be discharged into a stream in such a manner that they create a temperature block across the stream. Further, an abrupt change of more than 9° F. may affect fishes adversely even if of short duration.

For a well rounded warm water fish population in the Ohio valley area it is believed that peak summer temperatures should not exceed 93° F. at any time or place. In the south such peak temperature probably should not be above 96°F. This means that in general temperatures will be considerably below these levels. While several species can withstand higher temperatures (100° to 103° F.) for very short periods, 93° and 96° F. represent critical levels for most species in the designated areas. Further, while fish may, through certain adaptations, survive abnormally high temperatures for short periods, they cannot complete their life history at such temperatures. For good production, therefore, temperatures within a favorable range are required.

Settleable Solids and Turbidity

Studies carried out in connection with trout stream improvement investigations in Michigan indicated that sand bottoms are almost barren of benthic organisms and that the addition of sand or silt to rubble or gravel bottom streams greatly decrease stream productivity (9) (10) (11). In fact, shifting sand in quantities so small as to be unnoticed by casual observation can decrease the production of macro-invertebrates by drifting into the spaces between the gravel and thereby decreasing the areas for attachment and cover. It is believed that no inert inorganic, sandy, or other similar wastes should be added to a rubble, gravel bottom stream as such deposition may not only decrease the supply of desirable stream bottom insects but also seriously limit spawning of most nest-building fishes. Studies of the effects of mining wastes in California have shown that salmon select clear water for spawning and that the deposition of silt results in smothering of the eggs (12). Quantitative bottom samples taken in a series of similar streams in California showed that the average number of food organisms was always less in mined areas when inert inorganic materials were discharged to the stream than in nonmined areas (13). On the Scott River, samples from the silted area averaged 36 organisms per square foot, whereas those from the clean stream bottom above the mine averaged 249 per square foot, or 7 times as many. Similar studies (14) have shown that hydraulic mining wastes are detrimental to salmon and trout production. These and wastes from placer mining and from stamp mills and washing operations may completely choke a stream causing it to flow in a shallow sheet over the accumulated deposits. Further, debris dams created by such operations can eliminate the salmon by blocking migration.

From results of studies in various parts of the country, it is apparent that erosion silt is a major stream pollutant and that it produces environmental conditions unfavorable for the reproduction and growth of fishes. Since the character of the stream and its bottom are of prime importance in determining the harmful effects of erosion silt, it is not possible to establish numerical criteria for settleable solids which are universally applicable. In some streams considerable amounts do very little additional harm, while in gravel rubble bottom streams even small amounts, as has been noted, reduce food production and limit spawning. It is belived that criteria on settleable solids should be established to protect environmental conditions in the stream, though they will vary from stream to stream, depending on local conditions.

Turbidity is usually due to solids which settle out slowly or to colloidal materials which may remain in suspension over long periods. The studies of Irwin (15), Wallen (15A), and others at Oklahoma A and M have shown that turbidity must be very high before it exerts a directly harmful effect on fishes. In some tests (15) direct reactions to turbidity did not appear until it reached 20,000 p.p.m., and for one species not until it reached 100,000 p.p.m. Most individuals of all species endured exposure to more than 100,000 p.p.m. for a week or longer but finally died at turbidities of 175,000 to 225,000 p.p.m. Fishes which succumbed to these turbidities had the opercular cavities and gill filaments clogged with silty clay particles.

In Oklahoma Buck (16) carried on pond studies to determine the effects of turbidity on growth rate. At the end of two growing seasons the average total weight of fish in clear ponds was about 1.7 times that of those in ponds of intermediate turbidities and approximately 5.5 times greater than those in muddy ponds. Of the three species used, large mouth bass were most affected by turbidity. The effect on plankton production was even more striking since the average volume of net plankton in clear ponds during the 1954 growing season was 8 times greater than in ponds having intermediate turbidity and 12.8 times greater than the yield in most turbid ponds. However, catfish survived better in muddy ponds. Game fish feed by sight and in turbid waters, they are at a disadvantage when competing with such fish as carp, buffalo, and carp suckers which employ a vacuum cleaner type of feeding. Turbidity can, therefore, bring about a quantitative and qualitative change in the fish fauna. In addition, metallic or sharp particles may kill fishes by causing abrasive injuries to the gills or by clogging the gills and respiratory passages.

Suspended solids and turbidity prevent light penetration, decrease photosynthesis, and thus limit algal production. Since algae are the basic material in the food pyramid, turbidity adversely affects fish production in an indirect manner. In most streams settleable solids and turbidity are largely due to soil erosion. Until erosion is brought under control, little can be done toward clearing up the streams. Reduction of turbidity is a difficult and long time problem which must be carried out in cooperation with soil conservation, agricultural, and forestry interests. In the meantime, however, efforts should be made to control or eliminate other sources of settleable solids and turbidity. Lagooning can be effectively used to remove settleable solids and turbidity from many wastes. Such procedures are essential on all clear streams and they should be initiated in conjunction with efforts to reduce turbidity and settleable solids through control of soil erosion.

Turbidity standards must be somewhat local in their application as they will depend on the area and type of stream. It is possible to set up relatively simple turbidity standards which can be readily checked for compliance by field tests. Turbidity standards might state that a certain percentage of the incident light at the surface shall reach a stated depth between 11:00 A.M. and 1:00 P.M. The depth selected would depend on the depth to which the regulatory agency felt the photosynthetic zone should extend. Different types of water differ in their capacities to absorb light. Water transparency is affected by the suspended matter, including the plankton, and by stain or color. In water of the clarity of usual municipal supplies, 9.5 percent of the solar energy present at the surface reaches a depth of 6 feet. Born (39) states that the limit for growth for the higher aquatic plants lies between 2.5 and 3.5 percent of the total surface energy at bottomdepth, but that it rapidly declines below 4 percent where severe etiolation occurs in submerged seed plants. There is some evidence that certain algae can grow at levels of 1 percent of the incident light, but it is not definitely known how much light is required for them to produce more oxygen by photosynthesis than they use in their respiration. While criteria will vary with the area they can be kept relatively simple. For example, a criterion for a particular area might state -- under conditions of brilliant sunlight at or near noon 4 percent of surface incident light shall reach a depth of 6 feet. Incident light and light at any given depth can be readily read by means of a photometer fitted for underwater use.

pH

The pH of a water may exert a direct effect on fish if it is very high or very low due to strong bases or mineral acids. It may have an indirect effect through its influence on the toxicity of certain materials such as HCN, H_2S, ammonia, heavy metals, etc. Longwell and Pentelow (17) found that the toxicity of NaS solutions to brown trout was influenced markedly by variations in pH, the toxicity increasing as the pH became lower. The heavy metals are considerably more toxic at lower pH levels probably because they are more soluble. Ammonia becomes rapidly more toxic as the pH is raised above 8.2. The toxicity of a number of weak inorganic and organic acids, including hydrocyanic, hypochlorous, hydrosulfuric, carbonic, and tannic, is increased by lowering the pH.

Extreme pH values of 4 and 10 or slightly above have been tolerated by resistant fishes in certain areas. Some levels at which fish have been killed experimentally are: trout, 9.2; bluegills, 10.5; roach, pike, carp, and tench, 10.4 to 10.8. Fish mortality has been observed within a few hours at pH levels of 3.4 to 4. However, certain fish have been acclimated to live for considerable periods at pH levels as low as 4.5 to 4.2.

Studies of acid bog lakes (18) have shown that yellow perch, brown bullhead, bluegill, and pike can live at a pH of 4.4. Ellis (19) states that the pH of streams generally ranges between 7.4 and 8.5 with an over-all range of 6.6 to 9.0, while bog streams and lakes vary from 4.0 to 6.0. He states that in most uncontaminated freshwater streams pH values range from 6.5 to 8.5.

Sudden or wide fluctuations in pH are undesirable. While fish can withstand pH levels as high as 9.5, it is undesirable to have the pH maintained continually between 9 and 9.5 when this level is due to the addition of caustic wastes. Such pH conditions are entirely different from and more harmful than the naturally occurring but brief higher levels which may be as high as 10 or 10.5. These natural high pH levels are produced by photosynthesis due to the removal of CO_2 and they are always accompanied by high D.O. levels. High pH intereferes with oxygen uptake of some marine and freshwater fishes and may limit their ability to survive at low oxygen tension (20). At values below 5 and above 9, the pH seriously affects the ability of some fishes to extract oxygen from the water. This ability varies with the species; with bass and crappie the pH can be lowered to almost 4 before their ability is affected (21) (22). In general, fish are able to extract oxygen best at pH levels from 7.0 to 8.5, but such fish as perch, bass, crappie, goldfish, trout, and green sunfish have a wide range of tolerance. The blunt nose minnow and one of the shiners, Notropis whipplii, were found to be very sensitive as they can extract oxygen best at pH 7.0 to 8.0 (20). Some fishes can survive rapid changes in pH. Laboratory studies (21) have indicated that goldfish withstood changes from 7.2 to 9.6, black bass from 6.6 to 9.3, and sunfish from 7.2 to 9.6. The amount of dissolved oxygen is a determining factor as to whether or not these changes can be tolerated (21).

In the range from 5 to 9.5, pH as such has not been shown to be detrimental to fishes. However, changes in this range can drastically affect the toxicity of certain materials, and they also influence the ability of fish to absorb oxygen from the water. Further, it has been noted that in the more productive streams pH usually falls in the range from 6.5 to 8.5. At pH levels above and below these values some of the essential minerals become unavailable. Thus, while pH in the range from 5.0 to 9.5 is not in itself directly harmful to fishes and this range may be used in setting up water quality criteria, from the standpoint of productivity, it is recommended that every effort be made to keep pH values in the range of 6,5 to 8,5.

Dissolved Oxygen

There are a host of environmental and other conditions which influence or determine the solubility of oxygen in water, the amount of dissolved oxygen favorable to fish life, and the minimum amount needed for existence. In fresh waters, temperature is the most important factor affecting the solubility of oxygen. Dissolved solids are rarely present in sufficient amounts to have an appreciable influence. Several environmental conditions may influence the optimum amount of oxygen required by fish or interfere with the obtaining of oxygen by the fish or may change or increase their minimum need for oxygen. Among these are temperature, pH, CO_2, and dissolved solids.

Temperature increases within the range favorable to fish are accompanied by a progressively higher metabolic rate and a continuous increase in the oxygen uptake. Wiebe and Fuller (23) found that at 25° C. the oxygen consumption of largemouth black bass was 282 percent of that at 15° C. At 20° C. it was 177 percent of the consumption at 15° C. This is in accord with the van't Hoff law which states that for any chemical change the rate of reaction is increased between 2- and 3-fold for every 10° C. increase in temperature. Temperature is of outstanding importance in the determination of environmental requirements since the oxygen consumption increases as temperature rises whereas solubility of oxygen decreases. Because the annual range in temperature of streams of the temperate region may be as much as 28° C., oxygen consumption at peak temperatures may be several fold what it is at minimum temperatures, whereas at peak stream or lake temperatures the water will hold only about half as much oxygen as it does at minimum temperatures. Graham (24) found that for speckled trout the rate of oxygen uptake increased with increasing temperature up to the ultimate upper lethal temperature, if sufficient oxygen were available. Water containing less that 75 percent of the air saturation level of oxygen reduced the activity of speckled trout at all temperatures, and above 20° C.(68° F.) fully saturated water is required to allow the full scope of activities. Several other investigators have also found that the oxygen requirements of fishes become greater with increases in temperature (25) (26) (27).

Temperature also markedly affects dissolved oxygen concentrations which are lethal to various species of fish. Burdick (28) found that smallmouth bass died in 5 to 9 hours at oxygen concentrations of 0.7 p.p.m. to 1.17 p.p.m. at temperatures of 52° F. to 72° F. There was also some variation in the turnover time for different species of fishes. At 55°F. and oxygen concentrations of 1 to 2 p.p.m. the turnover times were as follows: brook trout, 1-3/4 hours; brown trout, 2-1/2 hours; and rainbow trout, 3 hours. At 69° F. to 71° F. these fishes turned over in approximately the same time at oxygen concentrations of 2.3 to 3.4 p.p.m.

Several other environmental factors also interfere with oxygen uptake or increase the oxygen requirements of fishes. High and low pH levels interfere with the ability of fishes to absorb oxygen from the water. High CO_2 concentrations interfere with the utilization of dissolved oxygen. Fry and Black (29) found that the common sucker, with its CO_2 sensitive blood, was unable to remove oxygen from water containing CO_2 tensions which did not hinder the respiration of bullheads, the latter possessing blood with a very low sensitivity to CO_2. Under pollutional conditions fish generally require more oxygen (45) (46) (20). At low dissolved oxygen levels fish succumb to concentrations of toxic materials which they can tolerate at high dissolved oxygen levels.

Many studies have been made in attempts to determine the lowest D.O. levels tolerated by different species of fish. Gutsell (30) reported that some brook trout could endure, for a short period, an oxygen concentration as low as 1.2 p.p.m.; however, some asphyxiation occurred at a D.O. content of 2.5 p.p.m. Smallmouth black bass lived for a time at 0.4 p.p.m. D.O. Wiebe (22) found that some fish can withstand sudden wide changes in the concentration of oxygen and that they can live in water supersaturated with oxygen. The increase in D.O. was followed by a slowing down of the respiratory movements. Fry (31) states that at 49° F. the ultimate minimal tolerance of brook trout for dissolved oxygen is 0.9 p.p.m. Gardner and King (32) reported the asphyxial level of trout to be 1.1 p.p.m. D.O. at 6.5° C. and 3.4 p.p.m. at 25° C. Thompson (33) on the basis of field studies, reported that carp and buffalo lived in water having 2.2 p.p.m. D.O. However, he found a variety of fishes only when there was over 4 p.p.m. of oxygen and the greatest variety of fishes were present when the D.O. was 9 p.p.m. He found that fish died overnight in water containing less than 2 p.p.m. D.O. Ellis reported (19) that goldfish, perch, catfish, and other species of freshwater fishes when maintained in water of constant flow, composition, and temperature (20° to 25° C.) showed respiratory compensation in both volume and rate when the dissolved oxygen was reduced to slightly below 5 p.p.m.

In addition to those environmental conditions which influence the oxygen requirement, there are several physical, chemical, and physiological conditions which influence the ability of fish to extract oxygen from the water, its need for oxygen , and its ability to resist low oxygen levels. First, it must be realized that ability to extract oxygen from the water and to resist low D.O. levels varies with the species. It is well known that dogfish, carp, and gar can survive at much lower D.O. levels than trout and several other fishes. Some fishes are more efficient in the extraction of oxygen or their blood is not as sensitive to the presence of CO_2.

The amount of oxygen required by fishes is determined in part by activity. It is generally recognized that a man lying in bed does not breathe as deeply or require as much oxygen as one digging a ditch. It has been reported that from two to four times as much oxygen is required by a fish when it is active as when it is quiescent (24) (26) (34). Under actual stream conditions a fish must maintain its position against the current, find, pursue, and catch its food, avoid its enemies, and reproduce. All these activities require oxygen in such amounts that D.O. levels at which the fish can just survive are unsatisfactory. Age, size, and season are also of importance. In general, fry and younger fish have a higher metabolic rate and require more oxygen than adults (35) (36). Because of increased activity and their physiological condition fish require more oxygen at the spawning season. Studies carried out in our laboratories indicate that D.O. requirements are different at other times of the year and further, the physical condition of the fish is of outstanding importance in determining requirements and the minimum level tolerated. An actively feeding, rapidly growing fish requires considerable more oxygen than one which feeds very little. Since growth is rapid in the fry to fingerling stage it is expected that for many species D.O. requirements will be higher at this period. Eggs deposited in bottom materials require higher D.O. concentrations than do adult fish. Since the current through the bottom materials is slow, the amount of water flowing by the eggs per unit of time is small and thus it must contain more D.O. to provide needed requirements.

Through acclimation, resistance to low D.O. levels may be increased. Fry (31) reports that through acclimation the lethal dissolved oxygen level can be reduced to about one-half the corresponding value for trout accustomed to air-saturated water. Lower dissolved oxygen levels can be tolerated for considerable periods through an increase in respiration rate and volume of water pumped, reduced activity and food consumption, and an increase in blood haemoglobin (37) (38). By means of such adaptation fishes may live for considerable periods at reduced oxygen concentrations without apparent harm. This does not mean, however, that they can complete their life cycle at such levels. Further, ability to live more or less indefinitely at low oxygen levels does not mean that some of their physiological processes have not been altered so that their well being and growth are adversely affected. It has been reported (4) that the bullhead is unable to become acclimated to increased temperature when D.O. levels are low whereas it becomes rapidly acclimated at normal D.O. levels. Dissolved oxygen levels adequate for growth, reproduction, normal activities, and well being are considerably higher than levels which can be tolerated for extended periods through acclimation and compensation.

Studies of the oxygen requirements of fishes fall into two categories: laboratory investigations, where as many as possible of the variables are controlled, the factor under study is varied, and the effects on fishes directly observed for a relatively short period; and field studies, where the variable in question is measured in different sections of the stream and is related to the fish population in various areas. Both types of study have certain advantages and disadvantages. It is very difficult to relate laboratory results to field conditions, while in the field studies, factors other than the variable in question (dissolved oxygen concentration) might have a bearing upon results. It is believed that the best approach is to carry on both laboratory and field studies so that they supplement each other. In the interpretation of laboratory findings, it must be recognized that fish are usually held under favorable conditions and it is necessary to realize that all findings are not applicable to natural conditions.

The Lytle Creek studies (40) and other field studies have indicated dissolved oxygen concentrations at which fish and their food supply can maintain themselves. Twenty-four hour studies were made on Lytle Creek at all seasons of the year at selected stations to determine D.O., CO_2, pH. and temperature. Such studies or a continuous record of dissolved oxygen are essential for investigations of D.O. requirements as there are great diurnal and seasonal variations in oxygen concentration. Fish populations and growth rate studies were made over a two-year period (41) (42) in order to relate them to environmental conditions and their seasonal variations in different portions of the stream. Uncontrolled variables encountered in stream studies usually make it difficult to be certain that differences in fish populations are caused by oxygen concentration alone. However, it is believed that variations in oxygen concentration were the important variable in Lytle Creek since fish appeared first in the riffles of the upper zone of recovery and were found first in the pools much farther downstream. Since fish were not present in the pool immediately below the riffles or between them, it is believed this difference is due to D.O. as other limiting factors probably would not change so rapidly. In streams having a considerable biological oxygen demand there are marked differences in D.O. in the pools and riffles. In studying a section of the Scioto River, it was found that the D.O. at the tail of a large pool was 0.1 p.p.m. while about 200 yards downstream, water which had passed over a wide shallow riffle on one side of the stream contained 5.6 p.p.m. oxygen. Some 20 feet from the riffle in the main flow of the river there was 2.5 p.p.m. of oxygen.

In streams polluted with organic wastes, toxic material such as H_2S, NH_3, and CH_4 may be formed by anaerobic decomposition. The H_2S may escape or be fairly rapidly used by certain bacteria such as Beggiotoa, Thiothrix, and Sphaerotilus (43). Usually much of the NH_3 is converted to NO_3 and both of these materials are rapidly utilized by the dense growths of algae in the recovery zone (44). Most of the CH_4, which is not very toxic, escapes as a gas. Thus, while toxic materials may be formed, it is possible that they do not exert a marked effect on the fish.

Determination of the oxygen requirements of fishes and establishment of suitable dissolved oxygen criteria are especially difficult tasks. A great many studies have been made of the oxygen requirements of fishes. Investigators have not always used a uniform approach. In fact, there has been great diversity in the species studied, the conditions under which they were studied, the experimental methods used, the objectives of the study, the caliber of the investigation, and the interpretation of results. Consequently, data obtained have varied widely and have not always been in agreement. Short time studies carried out in aquaria at low temperatures with resistant fishes which are not fed indicate only that certain fishes can survive very low concentrations of dissolved oxygen for limited periods. It should be recognized that mere survival is not enough and that the minimum dissolved oxygen level should be one suitable for the continuous maintenance of a satisfactory fish crop. Minimum D.O. levels at which some species of fish can, through adaptation, resist death by asphyxiation for a time are not adequate for completion of the normal life cycle. Oxygen levels must be continuously adequate for the general well being of the fish and the maintenance of fish food organisms. Before adequate criteria can be established it is essential, therefore, to know the environmental requirements of the fishes since the objective is to provide suitable conditions for them.

Concentration of dissolved oxygen is often expressed as weekly, monthly, or sometimes daily, averages. Such values are not satisfactory as they do not indicate environmental variations and may actually be misleading from the standpoint of the continued existence of the fish. It is the extreme variations which may become limiting and which are the most important for indicating unfavorable habitats.

Some D.O. criteria have been set up as percentages of saturation. This procedure is deemed undesirable because over the range of temperature observed in our natural waters, 50 percent of saturation may mean 7.3 p.p.m. oxygen or 3.5 p.p.m. As temperature increases the amount of oxygen which can be held by the water decreases, whereas the amount required by the fish increases. It is believed that criteria for dissolved oxygen should be expressed in parts per million by weight.

Findings in Lytle Creek have indicated that in a stream section in which the oxygen concentration is usually above 5 p.p.m., the occurrence of concentrations below 5 p.p.m., but not below 3 p.p.m. for a few hours, does not have an adverse effect upon a well rounded warm-water fish population. Minnows and other coarse fishes were found in the section where minimum D.O. levels dropped to 2 p.p.m. or slightly below. On the basis of these studies and other pertinent data it is believed that for a well rounded warm-water fish population, dissolved oxygen concentrations must not be below 5 p.p.m. for more than 8 hours of any 24-hour period and at no time should they be below 3 p.p.m. For the maintenance of a coarse fish population dissolved oxygen concentrations should not be below 5 p.p.m. for more than 8 hours of any 24-hour period, and at no time should they be below 2 p.p.m.

The salmonoid fishes are not usually found in streams where minimum dissolved oxygen concentrations are lower than 4 to 5 p.p.m. For normal feeding and adequate growth at least 5 p.p.m. dissolved oxygen are required. Successful development of eggs and fry require a minimum of 6 p.p.m., while for the full range of activity for brook trout and perhaps for other members of the family, 7.6 p.p.m. are required at 15° C. and full air saturation at 20° C. and above (31). It is believed, therefore, that for good salmonoid production dissolved oxygen concentrations should not be less than 6 p.p.m.

Carbon Dioxide

Carbon dioxide may influence the toxicity of other materials or it may in itself be harmful if present in sufficient quantities. Alabaster and Herbert (48) found that CO_2 was not toxic to rainbow trout within a 12-hour exposure at concentrations up to 30 p.p.m. but was toxic at 60 p.p.m., and that period of survival decreased as the concentration increased. The presence of CO_2 in concentrations from 15 to 60 p.p.m. was found to reduce the toxicity of ammonia. Higher concentrations are toxic; 100 to 200 p.p.m. can be rapidly fatal to moderately susceptible fresh water fishes in well oxygenated water. Fifty to 100 p.p.m. can cause distress and may be lethal. Both marine and fresh water fishes vary greatly in their resistance to CO_2. Wells (49) reports that resistance of fishes to harmful conditions varies with the species, with age or size and weight, with the condition or physiological state of the individual, and with the season. He found that practically all the fishes with which he worked were least resistant just after the breeding season-- June, July, and August-- and most resistant before it-- March, April, May(50). Powers (51) has shown that the ability of marine fishes to extract oxygen at low concentrations was adversely affected by moderate amounts of CO_2 which lowered the pH. The investigation of Black, Fry, and Black (52) demonstrated the influence of CO_2 on the utilization of oxygen by 16 species of fresh water fishes. It was found that oxygen in the respired water at the time of death was higher when the tension of CO_2 was increased. The ability to take up oxygen in the presence of CO_2 varied with the species. Powers and co-workers found (53) that fish are able to absorb oxygen at a low oxygen tension through a wider range of CO_2 tension than is found in the natural waters in which they live. Most workers have found that naturally occurring levels of CO_2 are not detrimental to fishes. It is believed that concentrations under 30 p.p.m. in the absence of other adverse factors will have no harmful effects on most species. The majority of investigations indicate that CO_2 becomes rapidly harmful at concentrations of 100 to 200 p.p.m. Surber (54) found that concentrations between 55 p.p.m. and 78.5 p.p.m. in hard water at pH 6.9 to 7.0 caused a decided increase in the loss of eyed eggs and the number of deformed trout fry. Concentrations up to 43 p.p.m. apparently hand no harmful effect.

Dissolved Solids

Natural, unpolluted waters of lakes and streams have in solution small amounts of the anions CO_3^{--}, Cl^-, SO_4^{--}, smaller quantities of NO_3^-, PO_4^{---}, NH_4^+, and NO_2^-, and traces of many others. The metallic cations are Ca^{++}, Mg^{++}, Na^+, K^+, Fe^{++}; Mn^{++}; and traces of several others. These materials exert a physiological and osmotic effect to which organisms have become adpated. In fact, these dissolved materials are required by the organisms. Rawson (55) found a positive correlation between the total solids in fresh waters and the average standing crop of plankton and bottom fauna. The type of rock formation and soil largely determines the concentration of dissolved solids in a water but erosion may be of considerable importance. Pollution may also be a factor. During the period from 1906-07 to 1934-43, the average amount of dissolved solids in Lake Erie increased from 133 to 165 p.p.m. whereas those in Lake Superior remained unchanged (56) (57).

Criteria for dissolved solids have little meaning if the purpose of the criteria is the protection of aquatic life, unless the materials to be considered as dissolved solids are specified. It is apparent that salts of Hg, Cu, Ag, Zn, Pb, and Cd will have a much different effect on fishes than will equal concentrations of salts of Ca, Na, Mg, and K. In general when total dissolved solids are referred to in relation to water quality criteria, it is the salts of these relatively nontoxic earth metals which are believed to be under consideration. Unnatural concentrations of these salts may effect aquatic life in two ways. If the solution of salts is physiologically unbalanced, one of them may exert a direct toxic effect. If they are physiologically balanced, that is, each is present in quantities sufficient to antagonize any toxic effects of one or more of the others, they may occur in such concentrations that they exert an osmotic effect. Wiebe (58) points out that the osmotic pressure that fish can tolerate depends to a large extent on acclimatization. Fish acclimated to the extremely soft waters of East Texas cannot survive when subjected to salinities to which the fish of the Pecos River are continually exposed.

Texas rivers (58) range in total dissolved solids from 45 to 4,810 p.p.m. Wiebe found as much as 28,000 p.p.m. of chloride in a stream where fresh water fish were supposed to live. However, Young(59) indicates that when dissolved solids reach 11,000 p.p.m. only certain fish can tolerate them indefinitely. The ability to resist high concentrations of dissolved solids varies with the species. While some fishes move from marine to fresh water or from fresh to sea water, some species have been reported as being unable to resist concentrations above 3,000 p.p.m. Young reported that Na_2CO_3 in concentrations about 800 p.p.m. was unfavorable for catfish. Huntsman (60) reports that in the Quill lakes of Saskatchewan, which have a total solids content of 16,550 p.p.m., there is a resident fish population of somewhat limited extent. It is believed that total dissolved solids in concentrations up to 3,000 p.p.m. can be tolerated by most fishes, if the materials in solution are the relatively non-toxic earth metals and are physiologically balanced.

Chlorides

The amount of chlorides is often considered as a measure of salinity or of total dissolved solids. When dealing with sea water, which is fairly uniform and the composition of which is known, chlorides can be taken as a measure of salinity or dissolved solids. This does not hold, however, for oil field brines and other wastes. Oil field brines differ drastically from one another and from sea water and many wastes contain large quantities of salts other than chlorides.

The chloride ion as such does not have much significance from the standpoint of toxicity to aquatic life. The cation is so much more important that the chloride anion is not generally considered. This is especially true with chlorides of the heavy metals such as mercury, copper, zinc, etc. Even with salts of the relatively nontoxic earth metals the toxicity of their chlorides is evidently attributable to the specific toxicity of the cations present and not to any toxicity of the chloride ions. Since the cations vary greatly in their toxicity to fish and are governing in the determination of toxicity, it is obvious that the chloride ion content of a mixture of salts is not a reliable index of toxicity.

Physiologically balanced mixed salt solutions such as sea water may be harmful to freshwater organisms because of their excessive over-all salt content and osmotic pressure rather than the specific toxicity of any particular ions present. Provided that the salts and other substances dissolved in water are balanced against each other so as to exclude any individual toxic effects, certain hardy freshwater fishes can tolerate waters of osmotic pressure equal to those of their own bloods and even higher for extended periods. Other freshwater fishes, however, have been reported unable to tolerate balanced salt solutions with concentrations of 2000 to 4000 p.p.m. It is not known whether a typical freshwater fish can complete a normal life history in water of relatively high osmotic pressure, nor is it known how osmotic pressure affects the life processes of other freshwater organisms. It is, therefore, impossible at present to define the maximal safe osmotic pressure of a freshwater environment. Presumably, the tolerable osmotic pressure entails a salt concentration far higher than the limits imposed by industrial and municipal requirements. When we are dealing only with different concentrations of a particular salt mixture such as sea salt, the composition of which is known and uniform, the chloride content of the solutions (which is easily determined) can be a useful index of osmotic strength. However, when we are dealing with mixed salt solutions of unknown and varying composition (such as oilwell brines and other industrial wastes), their chloride ion content is not a reliable index of osmotic strength. For example, an industrial waste brine containing a large amount of sodium sulphate can be much more active osmotically than another brine with a much higher chloride ion content which contains only sodium and calcium chlorides. It is impossible when dealing with mixed wastes to generalize as to the relationship between chloride ion concentration and osmotic, toxic, or over-all pollutional strength. It is believed, therefore, that chloride ion criteria have no practical significance as far as aquatic life is concerned.

Fluorides

Studies at our laboratory in Cincinnati have indicated that fluoride ions do have toxic properties in their own right. Further, they appear to have a cumulative effect. In 10-day tests it was found that the TL_m value for potassium fluoride was 64 p.p.m. It is believed that for good fish production the fluoride content should not exceed 5 p.p.m.

Toxic Materials

There is a great deal of literature dealing with the toxicity of various pure chemicals to fishes. The great majority of investigators have used different approaches and have carried out their studies with a variety of fishes, using different types of waters for dilution. Several compilations, reviews, or bibliographies of these studies have been made (38), (61),(62), (63), (64), (67). An examination of these papers clearly indicates that there is great variation in toxic levels reported by various investigators for selected pure chemicals. This variation is especially evident in the California report (61).

The quality of the receiving or dilution water, which is often not reported by some of those investigating toxicity, is of outstanding importance in determining toxicity of a particular material or waste. Several environmental factors may influence toxicity, such as: temperature, CO_2, D.O., pH, alkalinity, hardness, turbidity, and dissolved materials. Certain dissolved materials may significantly affect the toxicity of a waste through their synergistic or antagonistic action or through complexation, percipitation, or other action. In the case of ferro- and ferricyanide solutions, sunlight is of importance as photo decomposition of these materials occurs with the production of toxic HCN (65). The heavy metals are considerably more toxic at low pH since they are more soluble in acidic solutions. In hard waters at higher pH they are precipitated or changed in other ways to become much less toxic. It has been found that beryllium and uranium are 60 to 80 times more toxic in soft waters than in hard water (66). Ellis (38) and other investigators have found that ammonia becomes rapidly more toxic at pH values above 8.0. Calcium antagonizes the toxicity of many of the heavy metals whereas some of them are synergistic with each other and become considerably more toxic when mixed; examples are Cu and Zn, Cu and Cd, and Zn and Ni (67).

The toxicity of many of the metal-cyanide complexes is greatly influenced by pH. Doudoroff (68) has reported that fish can withstand 1,000 times as much nickel cyanide complex at pH 8 as at pH 6.5. Among the metabolites, including weak acids and bases, it is the molecule and not the ion which appears to be toxic. Thus weak acids such as HCN and H_2S become more toxic as the pH is lowered and dissociation depressed, whereas weak bases such as NH_4OH become more toxic as the pH is raised.

In general, materials are more toxic at higher temperatures and at low dissolved oxygen levels. Carbon dioxide may, through its effects on pH, render some materials more toxic or it may serve to make others less toxic. Complexation, precipitation, oxidation, dissociation, recombination, or buffering action must also be considered. The influence of water quality and other environmental factors on the toxicity of various materials has been summarized by Tarzwell (69).

The character of the receiving water can cause wide variations in the toxicity of many materials to fishes. Reference to the literature on the toxicity of specific pure chemicals is of little value for determining the toxicity of a complex waste containing these and other materials. Such an approach neglects water quality, which is of particular importance, as well as synergism and antagonism, oxidation, precipitation, complexation, and other actions which may occur in the stream and may greatly influence the toxicity of a waste in a particular stream. Numerical standards for toxicity of specific pure chemicals have little value and can be misleading. From the standpoint of industry they may be very undesirable. If a regulatory agency sets numerical criteria for the heavy metals and other substances which are to be applied over a wide area, they must be set so low that allowable concentrations are not detrimental to aquatic life under those conditions at which they are most toxic. For example, criteria for nickel cyanide wastes discharged into an acid stream would have to be set so low that the HCN formed from the wastes would not be toxic, whereas in an alkaline stream the criteria could be much higher as an increase of one and one-half pH units from 6.5 to 8.0 decreases the toxicity of this material over 1000 times. Copper is much less toxic in hard waters than it is in soft water with a low pH; variation may be as great as 200 times.

It is believed that the best approach to this problem is to make bio-assays with the total waste, using for dilution, water from the receiving stream at the point where the waste is to be discharged. In this way the many variables which influence the toxicity of that particular waste in that stream are taken into consideration and safe disposal or dilution rates can be determined. With certain exceptions (some of the insecticides and other materials whose toxicity is not influenced by water quality), water quality criteria for toxic materials when applied over wide areas should not be expressed as numerical values. It is believed that a tailor-made approach should be used where toxicity of the waste can be determined for the particular receiving stream at the point of discharge. When the toxicity of a waste is determined in this way allowable concentrations for that particular situation can be expressed as p.p.m. or as dilution ratios. Such an approach also permits evaluation and comparison of the toxicity of wastes from different industries along the stream.

Summary and Conclusions

The establishment of water quality criteria for the protection of our valuable aquatic resources is a complicated and difficult problem. Since the basic objective of water quality criteria for the protection of aquatic life is to provide or preserve environmental conditions essential for the survival, normal growth, reproduction, and well being of aquatic organisms, a knowledge of the environmental requirements of these organisms is essential for the establishment of such criteria. Many of the activities of man have modified the aquatic environment. Among these are deforestation, unwise agricultural practices, overgrazing and pollution. Our aquatic resources which produce billions of dollars yearly in revenues from sport and commercial fishing are a renewable resource worthy of our best efforts for preservation.

Siltation due to erosion has been and is a major pollutant. The solution of this problem by means of erosion control must be a cooperative effort among those agencies dealing with water, soil, and other natural resources.

While all the environmental requirements for aquatic life are not now known, application of the data presently available can be used effectively in the setting up of some criteria. As more data become available existing criteria can be modified and others set up in order to meet the problem more adequately.

The quality of the receiving water is particularly important in determining the effects of many wastes. Among the factors influencing the toxicity of pollutants in a particular receiving water are temperature, CO_2, D.O., pH, alkalinity, hardness, and dissolved materials. Other factors which may modify the toxicity of a waste are complexation, precipitation, oxidation, synergy, and antagonism.

In view of the many factors which may influence the effects of pollutants in different streams, it is believed that in most situations numerical criteria which are to apply to extensive areas can be set only for temperature, D.O., and pH. With a few exceptions, such as the insecticides and certain other materials, it is believed a tailor-made approach should be used in setting criteria for toxic wastes. This approach would consist of bio-assays of the waste in question, using for dilution, water from the receiving stream taken from the area into which the waste is to be discharged. Such bio-assays would take into consideration the variables which influence toxicity of that particular waste and can be used with appropriate application factors to indicate safe concentrations, or the amount of dilution required.

Criteria for settleable solids and turbidity will depend largely on local conditions and will vary with the stream and the area.

When considering large areas pH values should not fall below 5 or exceed 9.5, but for good fish production it is desirable that they be maintained between 6.5 and 8.5.

For a well rounded warm water fish population dissolved oxygen levels should not be below 5 p.p.m. for more than 8 hours in any 24 hour period and at no time should they be below 3 p.p.m. If a coarse fish population only is desired minimum levels may fall to 2 p.p.m. For good production of Salmonoid fishes a minimum of 6 p.p.m. appears to be required. However, trout can live and reproduce in waters where the D.O. content may drop to 4 or 5 p.p.m. but the survival of eggs and fry and the productivity is usually not so high.

It is suggested that in the northern portion of the country peak temperatures for warm water fishes should not exceed 93° F. In the southern portion of the country fish are better acclimated to higher temperatures and can withstand peak temperatures of 96° F. or higher. While trout can stand peak temperatures of 80° F. to 83° F. for short periods, best production is attained in streams having summer temperatures of 60° F. to 68° F.

Allowable concentrations of toxic complex wastes for each stream or situation should be determined by means of bio-assays and safe dilutions estimated by the use of application factors or by other means.

Literature Cited

1. Anderson, A.W., and E.A. Power
1955 Fishery statistics of the United States for 1952. U.S.Dept. of Interior, Fish and Wildlife Service. Statistical Digest, 34, pp 1-345.

2. Annon
1956 National survey of fishing and hunting. A report on the first nationwide economic survey of sport fishing and hunting in the United States during 1955. U.S. Govt. Printing Office, Washington, D.C., pp 1-50.

3. Brett, J.R.
1944 Some lethal temperature relations of Algonquin Park fishes. Univ. of Toronto Studies, Biol. Ser.No. 52, Pub. Ont. Fish. Res. Lab. No. 63, pp 1-49.

4. Brett, J.R.
1946 Rate of gain of heat-tolerance in Goldfish (Carassius auratus). Univ. of Toronto Studies, Biol. Ser. No. 53. Pub. Ont. Fish. Res. Lab. No. 64, pp 1-28.

5. Hart, J.S.
1952 Geographic variations of some physiological and morphological characters in certain freshwater fish. Univ. of Toronto Studies, Biol. Ser. No. 60, Pub. Ont. Fish. Res. Lab. No. 72, pp 1-79.

6. Embody, George C.
1927 An outline of stream study and the development of a stocking policy. Cont. Agric. Lab., Cornell Univ.

7. Creaser, Charles W.
1930 Relative importance of hydrogen ion concentration, temperature, dissolved oxygen, and carbon dioxide tension on habitat selection by brook trout. Ecology, Vol. 11, No. 2, pp 246-262.

8. Fry, F.E.J., J.S. Hart, and K.F. Walker
1946 Lethal temperature relations for a sample of young speckled trout, Salvenius fontinalis. Univ. of Toronto Studies, Biol. Ser. No. 54, Pub. Ont. Fish Res. Lab., No. 66, pp 1-35.

9. Tarzwell, Clarence M.
1936 Environmental improvement in trout streams. A problem in applied ecology. Doctorate Thesis, pp 1-238. Univ. of Michigan Library, Ann Arbor,Mich.

10. Tarzwell, Clarence, M.
1932 Trout stream improvement in Michigan. Trans. Am. Fish, Soc., Vol. 61 (1931) pp 48-57.

11. Tarzwell, Clarence M.
1937 Experimental evidence as to the value of trout stream improvement in Michigan. Trans .Am. Fish. Soc., Vol. 66, (1936) pp 177-187.

12. Smith, Osgood R.
1940 Placer mining silt and its relation to salmon and trout on the Pacific coast. Trans. Am. Fish. Soc., Vol. 69, (1939), pp 225-230.

13. Taft, A.C., and Leo Shapovalov.
1935 A biological survey of streams and lakes in the Klamath and Shasta National Forests of California. U.S. Bur. of Fisheries. Mimeographed Report, pp 1-36.

14. Sumner, Francis, and Osgood R. Smith
1940 Hydraulic mining and debris dams in relation to fish life in the American and Yuba Rivers of California. California Fish and Game, Vol. 26, No. 1, pp 1-22.

15. Irwin, W.H., and James H. Stevenson
1951 Physiochemical nature of clay turbidity with special reference to clarification and productivity of impounded waters. Bull. Okla. Agri. and Mech. College, Biol. Ser. No. 4, Vol. 48, No. 4, pp 1-54.

15A. Wallen Eugene I.
1951 The direct effect of turbidity on fishes. Bull. Okla Agri. and Mech. College, Biol.Ser. NO.2, Vol.48, No. 2, pp 1-27.

16. Buck, D. Homer
1956 Effects of turbidity on fish and fishing. Okla. Fish. Research Lab., Report No. 56, pp 1-62.

17. Longwell, J., and F.T.K. Pentelow
1938 The effect of sewage on brown trout (Salmo trutta). Jour. Exp. Biol., Vol. 12, pp 1-12.

18. Jewell, M.E., and Harold Brown
1924 The fishes of an acid bog lake. Trans. Am. Microscopical Soc., Vol. 43, No. 2, pp 77-84.

19. Ellis, M.M.
1944 Water purity standards for fresh water fishes. U.S. Fish and Wildlife Service. Special Sci. Report, No. 2, Mimeographed Report, pp 1-15.

20. Wiebe, A.H., A.M. McGavock, A.C. Fuller, and H.C. Markus
1934 The ability of fresh-water fish to extract oxygen at different hydrogen-ion concentrations. Physiol. Zool., Vol. 7, pp 435-448.

21. Wiebe, A.H.
1931 Notes on the exposure of several species of pond fishes to sudden changes in pH. Amer. Microscop. Soc., Vol. 50, pp 380-393.

22. Wiebe, A.H.
1932 Notes on the exposure of several species of fish to sudden changes in the hydrogen-ion concentraion of the water and to an atmosphere of pure oxygen. Trans. Am. Fish. Soc., Vol. 61 (1931) pp 216-224.

23. Wiebe, A.H., and Arno C. Fuller
1934 The oxygen consumption of largemouth black bass (Huro floridana) fingerlings. Trans. Am. Fish. Soc., Vol. 63, (1933) pp 208-214.

24. Graham, J.M.
1949. Some effects of temperature and oxygen pressure on the metabolism and activity of the speckled trout, Salvelinus fontinalis. Can. Jour. Res. D. 27, pp 270-288.

25. Chapman, W.M.
1938 The oxygen consumption of salmon and steelhead trout. Wash.Dept. Fish., Biol.Rept. Vol. 37A, pp 1-22.

26. Fry, F.E.J., and J.S. Hart
1948 The relation of temperature to oxygen consumption in the gold fish. Biol. Bull., Vol. 94,pp 66-77.

27. Wells, N.A.
1935 The influence of temperature on the respiratory metabolism of the Pacific killifish, Fundulus parvipinnis, due to size, season, and continued constant temperature. Physiol. Zool., Vol. 8, pp 318-336.

28. Burdick, G.E., Morris Lipschuetz,Howard F.Dean, and Earl F. Harris.
1954 Lethal oxygen concentrations for trout and smallmouth bass. N.Y. Fish and Game Jour., Jan. pp 84-97.

29. Fry, F.E.J., and E.C. Black
1938 The influence of carbon dioxide on the utilization of oxygen by certain species of fish in Algonquin Park, Ontario. Anat.Rec. 72 (Supplement 1938):47.

30. Gutsell, James S.
1929 Influence of certain water conditions, especially dissolved gases on trout. Ecology, Vol. 10, pp 77-96.

31. Fry, F.E.J.
1951 Some environmental relations of the speckled trout (Salvelinus fontinalis). Rept.Pro.N.E.Atlantic Fish Con.

32. Gardner, J.A., and G. King
1922. Respiratory exchange in freshwater fish. IV. Further comparison of goldfish and trout.Biochem.Jour., Vol. 16, pp 729-735.

33. Thompson, D.H.
1925 Some observations on the oxygen requirements of fishes in the Illinois River.Bull.Nat.Hist.Sur., Vol.15, Art.7, pp 423-437.

34. Spoor, W.A.
1946 A quantitative study of the relationship between the activity and oxygen consumption of the goldfish, and its application to the measurement of respiratory metabolism in fishes.Biol.Bull., Vol. 91, pp 312-325.

35. Packard, W.H.
1907 The effect of carbohydrates on resistance to lack of oxygen. Amer.Jour.Physiol., Vol. 18, pp 164-180.

36. Privolnev, T.I.
1947 Critical pressure of oxygen in water for various ages of the young, Salmo salar, Docklady. Akad. Nauk. USSR, Vol. 58, p. 1197. Chem. Abs., 46:4685 (1952).

37. Black, E.C.
1951 Respiration in fishes. Publ. Ont. Fish. Res. Lab., No. 71, pp 91-111.

38. Ellis, M.M.
1937 The detection and measurement of stream pollution. Bull. Bur. Fish, Vol. 48, No. 22, pp 365-437.

39. Born, W.S.
1932 Ecological and physiological studies on certain aquatic angiosperms. Contrbs. Boyce Thompson Inst., Vol. 4, No. 4, pp 425-496.

40. Tarzwell, Clarence M., and Arden R. Gaufin
1953 Some important effects of pollution often disregarded in stream surveys. Proc. Eighth Ind. Waste Conf., Purdue Univ., Eng. Bull. Ser. 83: pp 295-316.

41. Katz, Max, and Arden R. Gaufin
1953 The effects of sewage pollution on the fish population of a midwestern stream. Trans. Am. Fish. Soc., Vol. 82 (1952), pp 156-165.

42. Katz, Max, and W. Charles Howard
1955. The length and growth of 0-year class creek chubs in relation to domestic pollution. Trans. Am. Fish. Soc., Vol. 84 (1954), pp 228-238.

43. Winogradsky, S.
1888 Beiträege zur morphologie und physiologie der bakterien.
I. Zur morphologie und physiologie der schwefelbakterien. A. Felix, Leipzig.

44. Gaufin, Arden R., and Clarence M. Tarzwell
1956 Aquatic macro-invertebrate communities as indicators of organic pollution in Lytle Creek. Sew. Ind. Wastes, Vol. 28, No. 7, pp 906-924.

45. Downing, K.M.
1954 The influence of dissolved oxygen concentration on the toxicity of potassium cyanide to rainbow trout. Jour. Exp. Biol., Vol. 31, pp 161-164

46. Townsend, L.D. and H. Cheyne
1944 The influence of hydrogen ion concentration on the minimum dissolved oxygen toleration of the silver salmon. Oncorhynchus kisutch (Walbaum), Ecology, Vol. 25, pp 461-466.

57. Westfall, B.A.
1945 Coagulation film anoxie in fishes. Ecology, Vol. 26, pp 283-288.

48. Alabaster, J.S. and D.W. M. Herbert
1954 Influence of carbon dioxide on the toxicity of ammonia. Nature, Vol. 174, p. 404.

49. Wells, Morris M.
1918. The reactions and resistance of fishes to carbon dioxide andcarbon monoxide. Bull. Ill. State Lab. Nat. Hist., Vol. 11, Article 8, pp 557-571.

50. Wells, Morris M.
1916 Starvation and the resistance of fishes to lack of oxygen and to KCN. Biol. Bull, Vol 31, pp 441-452.

51. Powers, E.B.
1922 The physiology of the respiration of fishes in relation to the hydrogen-ion concentration of the medium. Jour. Gen. Physiol., Vol. 4, pp 305-317.

52. Black, Edgar C., F.E. J. Fry, and Virginia S. Black.
1954 The influence of carbon dioxide on the utilization of oxygen by some freshwater fish. Canadian Jour. Zool., Vol. 32, pp 408-420.

53. Powers, Edwin B., Howard H. Rostorfer, Lula Mae Shipe, and Theresa Hickman Rostorfer
1938 The relation of respiration of fishes to environment. XII. Carbon dioxide tension as a factor in various physiological respiratory responses in certain fresh water fishes. Jour. Tenn. Acad. Sci., Vol. 13,No. 3, (July 1938), pp 220-245.

54. Surber, E.W.
1936 Effects of carbon dioxide on the development of trout eggs. Trans. Am. Fish. Soc., Vol. 65(1935), pp 194-203.

55. Rawson, D.S.
1951 The total mineral content of lake waters. Ecology, Vol. 32, No. 4, pp 669-672.

56. Clarke, F.W.
1924 The composition of the river and lake waters of the United States. U.S. Geol. Surv. Prof. Paper, No. 135, pp 1-99.

57. Leverin, H.A.
1947 Industrial waters of Canada, Dept. Mines and Resources, Canada, Report 819, pp 1-109.

58. Wiebe, A.H., J.G. Burr, and H.E. Faubion
1935 The problem of stream pollution in Texas with special reference to salt water from the oil fields. Trans. Am. Fish. Soc., Vol. 64 (1934), pp 81-86.

59. Young, R.T.
1923 Resistance of fish to salts and alkalinity. Am. Jour. Physiology, Vol. 63, No. 2, pp 373-383.

60. Huntsman, A.G.
1922 The Quill Lakes of Saskatchewan and their fishery possibilities. Cont. Can. Biol., No. 9.

61. California Water Pollution Control Board.
1952 Water quality criteria. State Water Pollution Control Board, Pub. No. 3, pp 1-512.

62. California Water Pollution Control Board.
1954 Water quality criteria. Addendum No. 1. State Water Pollution Control Board Pub. No. 3, Addendum No. 1, pp 1-164.

63. Mackenthun, Kenneth M.
1952 Selected review of the literature on toxic materials affecting biological life in streams and sewage treatment processes. Wis. Comm. on Water Pollution. Mimeographed Report pp 1-37.

64. Doudoroff, Peter, and Max Katz
1950 Critical review of literature on the toxicity of industrial wastes and their components to fish. I. Alkalies, acids, and inorganic gases. Sew. and Ind. Wastes, Vol. 22, No. 11, pp 1432-1458.

65. Burdick, George E., and Morris Lipschuetz
1950 Toxicity of ferro- and ferricyanide solutions to fish, and determination of the cause of mortality. Trans. Am. Fish. Soc., Vol. 78, (1948)pp 192-202.

66. Tarzwell, Clarence M., and Croswell Henderson
1956 The toxicity of some of the less common metals to fishes. Transactions of a Seminar on Sanitary Engineering Aspects of the Atomic Energy Industry held at the Robert A. Taft San. Eng. Center, Dec. 6-9, 1955, TID-7517, Part 1A, pp 286-289.

67. Doudoroff, Peter, and Max Katz
1953 Critical review of literature on the toxicity of industrial wastes and their components to fish. II. The metals as salts. Sew. and Ind. Wastes, Vol. 25, No. 7, pp 802-839.

68. Doudoroff, Peter
1956 Some experiments on the toxicity of complex cyanides to fish. Sew. and Ind. Wastes, Vol. 28, No. 8, pp 1,020-1,040.

69. Tarzwell, Clarence M.
1957. The use of bio-assays in relation to the disposal of toxic wastes. Trans. Third Ont. Ind. Waste Conf. (1956), pp 117-124.

THE DISPOSAL OF RADIOACTIVE WASTES

By

I.L. OPHEL

Division of Biology, Atomic Energy of Canada Ltd.

CHALK RIVER, Ontario

The question of radioactive waste disposal occupies many people's minds to-day. Nuclear power is now a reality, and some have painted an alarming picture of atomic power plants springing up over the continent and spreading their mysterious radioactive wastes into the environment. This view overlooks the fact that the atomic energy industry is already a very large one - in fact in the U.S.A., it is the largest single industry, with a capital investment exceeding five billion dollars. This huge industry is handling its wastes at the present time in a safe and effective manner. It is true that a widespread development of nuclear power will create further waste disposal problems, but they are problems that can be solved by application of knowledge already gained.

The mysterious nature of radioactivity is due to its newness and novelty rather than any inherent properties. Radioactivity is surprisingly easy to detect - using a high voltage supply, a gas-filled Geiger tube and an electronic recording device, it is possible to measure millionths of a gram of most radioactive isotopes with amazing accuracy. It is true that radioisotopes can be tolerated only in small amounts in the environment, but since the production of waste radioactive materials, even from large installations, can be measured in grams per day, the disposal problem remains in proportion.

Because of the time available for this talk, we will consider only the treatment and disposal of liquid wastes. This does not mean that gaseous and solid wastes are not important, but even though we confine ourselves to liquids many aspects of their treatment and disposal can only be mentioned briefly.

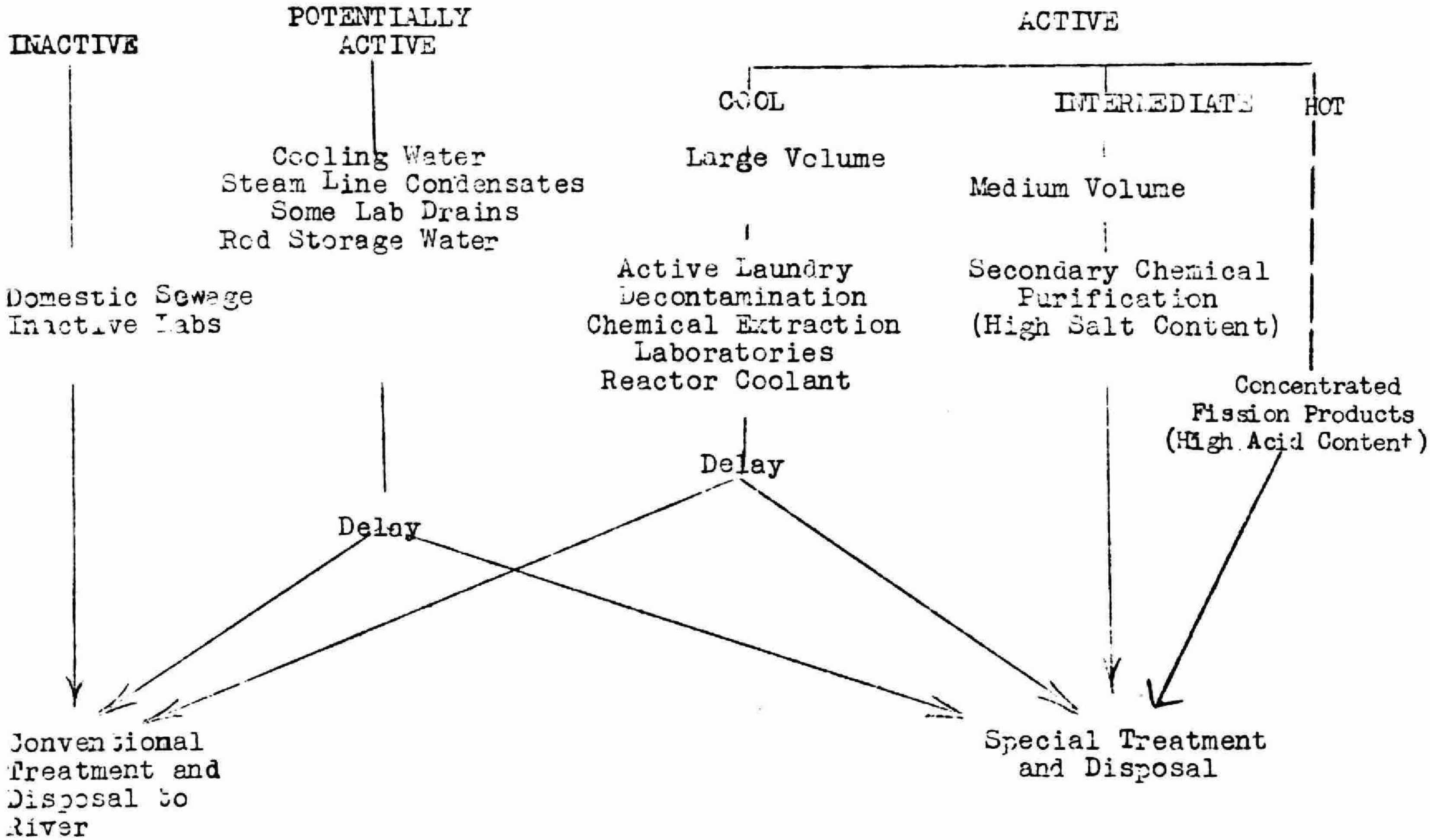
Types of Waste Found in the Atomic Energy Industry

An atomic energy project like any other industry produces many different kinds of waste. These can be classified and subdivided in many ways. Fig. 1 shows one classification of the main types and the major sources of waste.

Treatment and Disposal of Wastes

(1) Inactive

These are given conventional treatment (e.g. Imhoff tanks) followed by chlorination and disposal to river.



CLASSIFICATION OF MAIN TYPES OF RADIOACTIVE WASTES

Figure 1

(2) Potentially Active

Wastes of this type require a delay tank system to hold the liquid until it has been tested for radioactivity. A further requirement is a 'flexible' pumping and piping layout so that, depending of the result of the laboratory analysis, the wastes can be diverted to inactive or active disposal.

(3) Active

For slightly active or 'cool' wastes the same requirements of delay and flexibility in the pumping system are necessary. Most of these wastes are of large volume and normally low in radioactivity.

The reactor coolant is unique in that it contains no fission products, but only induced radioactivity caused by neutron irradiation of the dissolved salts as the water passes through the reactor. Over 95% of the induced radioactivity has a half-life or less than one day and the only other radioisotope of significance is radiophosphorus (P^{32}) with a half-life of approximately 14 days. These characteristics make this type of waste particularly amenable to treatment by delay - several days delay causes a considerable reduction in radioactivity due to decay.

Under some circumstances, it is possible for normally cool wastes such as the active laundry effluent, the decontamination wastes and the reactor coolant to become more radioactive. An example would be the development of a leak in a reactor, such as occurred in the Chalk River NRX reactor in Devember 1952, during which the coolant water became contaminated with fission products. In such cases, the segregation of wastes at their source and a flexible pumping set-up means the wastes can be diverted from their normal disposal - the river - and given special treatment.

The 'intermediate' and 'hot' active wastes contain fission product activity in such amounts and of such a nature that they cannot be disposed of into streams or even large rivers.

"Intermediate' wastes are probably the most difficult of the wastes encountered. They are often of considerable volume, their radioactivity is such that they require careful handling and they often have a considerable content of non-radioactive dissolved material which may complicate treatment.

However, they can be handled in one of two ways depending on the non-radioactive material present. The first of these is disposal of specially prepared soil pits where the radioactive cations are retained by the negatively charged soil particles. Before soil disposal these wastes may require preliminary treatment by ion-exchange or chemical destruction to remove undesirable extraneous compounds. A second method involves incorporating the wastes into special non-leachable concrete blocks which can be buried in the ground or disposed into deep ocean water.

'Hot' wastes which are highly radioactive and of small volume are kept as long as possible in special delay tanks to take advantage of radioactive decay. They can be best disposed of by incorporation into a fused ceramic or glass-like product in which the radioactive ions are tenaciously held by ion-exchange mechanisms and the fused nature of the material reduces leaching of radioactivity to a minimum. These blocks can be stored in remote disposal areas to await the decay of the radioactivity.

Effects of Disposal to Streams and Rivers

The Chalk River Project like many other atomic energy installations has taken the view that a minimum amount of radioactivity should be disposed into streams and rivers. This policy of course means that any possible effects are greatly reduced. At Chalk River the limited disposal of fission products to the Ottawa River results in concentrations of radioactivity far below the permissible levels allowed in water for life-time consumption. No radioactivity has ever been detected in the water supply of Pembroke which is about 20 miles downstream from the project.

It is known that some plants and animals can concentrate some radioactive ions even from very dilute solutions. This possibility, and the fact that incomplete mixing of the effluent with the river water could occur, resulting in uneven dilution of materials, has meant the establishment of continuous survey of the river and the plants and animals living in it. Thousand of specimens of fish, plants, invertebrates and sediment are collected each year and assayed for radioactivity. Continuous sampling of the plant effluent entering the river is carried out.

The years have shown that the early fears were unfounded. There has been no accumulation of radioactivity in the river organisms during the years in which the project has been in operation. A detectable amount of radioactivity is found in the river organisms each summer immediately below the project outfall. This is due to an uptake of radio-phosphorus from the reactor coolant. In the fall this radioactivity disappears due to the lowered metabolism of the animlas and the short life of the radio-phosphorus. Despite these results, the biological survey programme - as with all programmes designed for public health protection - continues to be carried out.

Conclusion

This has been a very brief survey of the problems concerned with radioactive waste disposal. By utilizing the established waste disposal principles of segregation and reduction of wastes at their source; by taking advantage of the natural properties of the waste materials (i.e. radioactive decay and usually cationic form) and by following an intensive and continuous sampling programme, it is possible to dispose of radioactive wastes safely and effectively.

RECOVERY AND USES OF GRAIN DISTILLERY STILLAGE

By

C.S. Boruff
Technical Director

J. M. Van Lanen
Asst. Research Director

Hiram Walker & Sons, Inc. and Affiliates,

PEORIA, Illinois.

and

C. T. Carson
Vice President, Production

Hiram Walker & Sons, Ltd.,

WALKERVILLE, Ontario, Canada.

Introduction

Grain stillage recovery and utilization is undergoing continuous research both in individual distilling companies and through collaborative programs with others. These investigations have led, over the years, to an industry-wide increase in recovery efficiencies and a corresponding reduction in the amount of stillage wasted. These developments are reviewed in the present paper, with particular emphasis upon the commercial applications of grain distillers byproducts in industry and agriculture.

Potential Wastes

The unit processes involved in the conversion of grain to beverage alcohol and whiskey are briefly outlined in Figure 1 and have been discussed in detail elsewhere (3,4,5, 9,15). Detailed studies on the sources and potency of potential wastes from a modern distillery practicing complete stillage recovery also have been published recently (3,5).

Distillery wastes have a potential pollution load of about 50 population equivalents per bushel mashed. Hence a 5,000 bushel plant practicing no "stillage to feed" recovery would have a pollution of about 250,000 population equivalents. The main potential waste from a grain distillery is the stillage. Other sources of pollution load in a grain distillery, such as clean up waters, cooker blow-downs evaporator tail waters, etc., are minor in comparison to the potential load from stillage.

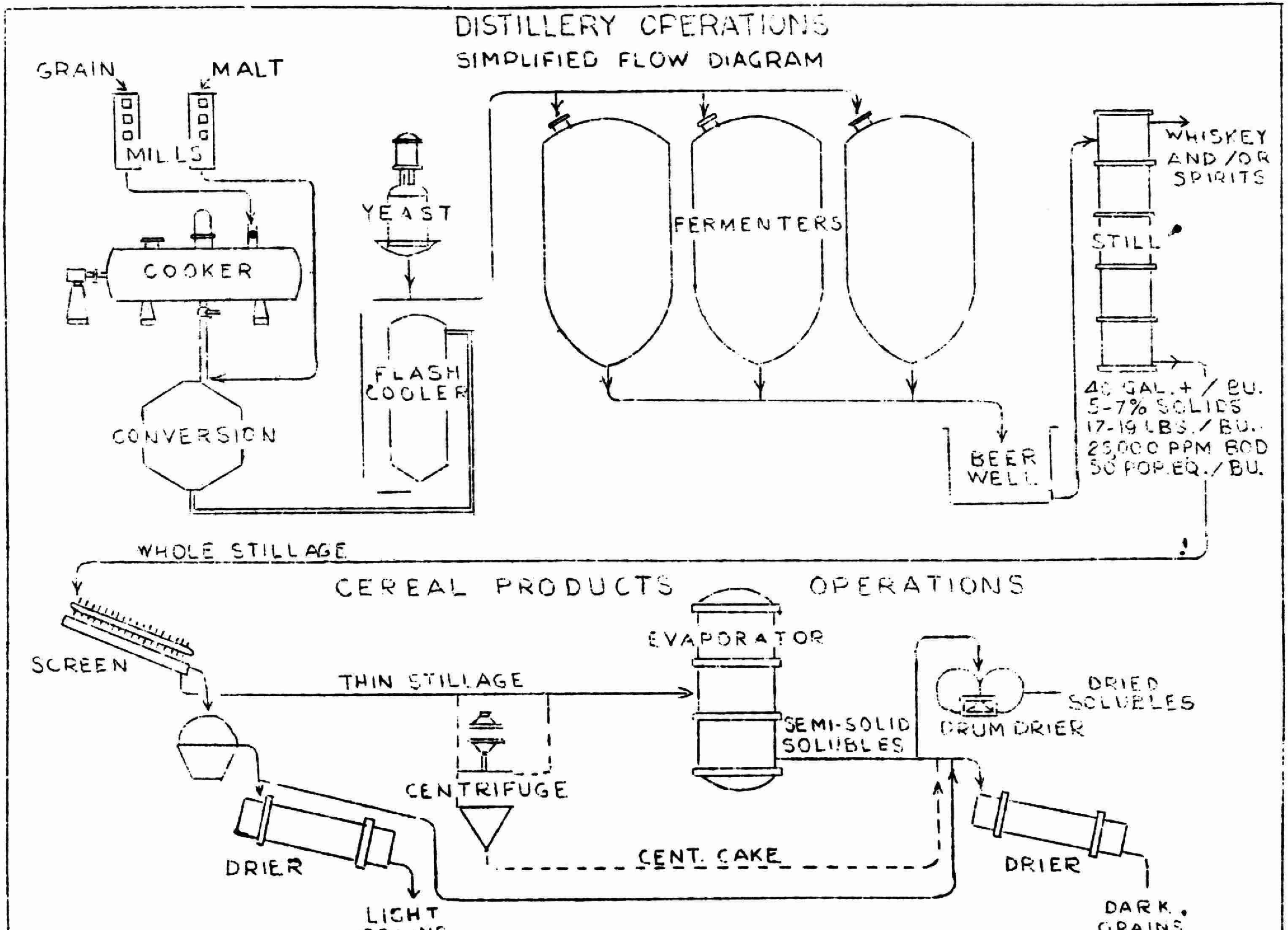

DISTILLERY OPERATIONS
SIMPLIFIED FLOW DIAGRAM
GRAIN
MALT
MILLS
COOKER
CONVERSION
YEAST
FLASH COOLER
FERMENTERS
STILL
WHISKEY AND/OR SPIRITS
BEER WELL
40 GAL.+/BU.
5-7% SOLIDS
17-19 LBS./BU.
25,000 PPM BOD
50 POP.EQ./BU.
WHOLE STILLAGE
CEREAL PRODUCTS OPERATIONS
SCREEN
THIN STILLAGE
CENTRIFUGE
EVAPORATOR
SEMI-SOLID SOLUBLES
DRUM DRIER
DRIED SOLUBLES
DRIER
LIGHT GRAINS
CENT. CAKE
DRIER
DARK GRAINS

FIGURE 1

Complete stillage recovery reduces the pollution load to 1 to 3.5 population equivalents per bushel mashed (3,5). A few U.S. Distillers practicing complete stillage recovery but located on small to dry-run streams also treat their final plant effluent (3,5,9,15).

Situation in Early 1930's

We would like to direct your attention to the grain distillery waste problem as it existed in Canada and U.S. in the early 1930's. In those days the common practice was to discharge the waste to streams or feed the wet slop, with hay, to steers chained to feed troughs. It required one steer per bushel of grain mashed. This practice of feeding whole stillage was purely a waste disposal method and possessed its own pollution, stench, fly and waste problems. A few distillers screened their stillage. Some sold the wet screenings while others dried the recovered screenable solids and fed or wasted the screened effluent. Those that investigated or tried evaporating screen stillage and drying the syrup with the screenings, that is, complete stillage recovery (as, for example, in the distillery in Corbyville in 1924), found costs in excess of the market price of the recovered feed.

Defining the Program

In view of the above situation, the advent of repeal in U.S., and desires in both our countries to eliminate these wastes from surface streams, a number of distillers in Canada and the U.S., and we are glad to say Hiram Walker was a pioneer in this field, gave this project priority. The feed value of the stillage, at 5 to 6% total solids content, appeared too valuable to use as a fertilizer or dispose of as a waste. Therefore, these lines of investigation were soon discarded. The problem as visualized in the early 1930's resolved itself into the following four related but distinct segments:

1. Develop cheaper methods of complete stillage recovery.
2. Determine the proper roles of distillers dried grains, and variations of this product, in animal nutrition through laboratory and feeding experiments and practical feeding demonstrations.
3. Promote the results of research findings on the proper usage of distillers feeds and thus develop a demand market in place of the cheap feed "filler" category in which this product found itself at that time.
4. Justify the capital investment for recovery facilities and services which in the 1930's approximated 1.0 million dollars for a 5,000 bushel plant. Today, this investment would be considerably more.

Activating The Program

Activating the above program required extensive laboratory, pilot plant and engineering studies, market surveys and evaluations, and extensive feeding trials by distillers, agricultural experimental stations and feed mixers. In the United States, these studies were accelerated by the formation in 1945 of a Distillers Feed Research Council sponsored and financed by a number of the grain distillers.

After many trials and tribulations and considerable capital investment, distillers in Canada and the United States today are, in the main, recovering their stillage to various distillers feeds for incorporation, by feed mixers, into final feeds and concentrates. The market developed for these products is such that grain stillage recovery is today accomplished at a profit.

Let us now direct our attention to the developed uses of the various distillers feed products that are on the market today because, as in other endeavors, market acceptance spells the difference between profit and loss operations.

Distillers Dried Grains

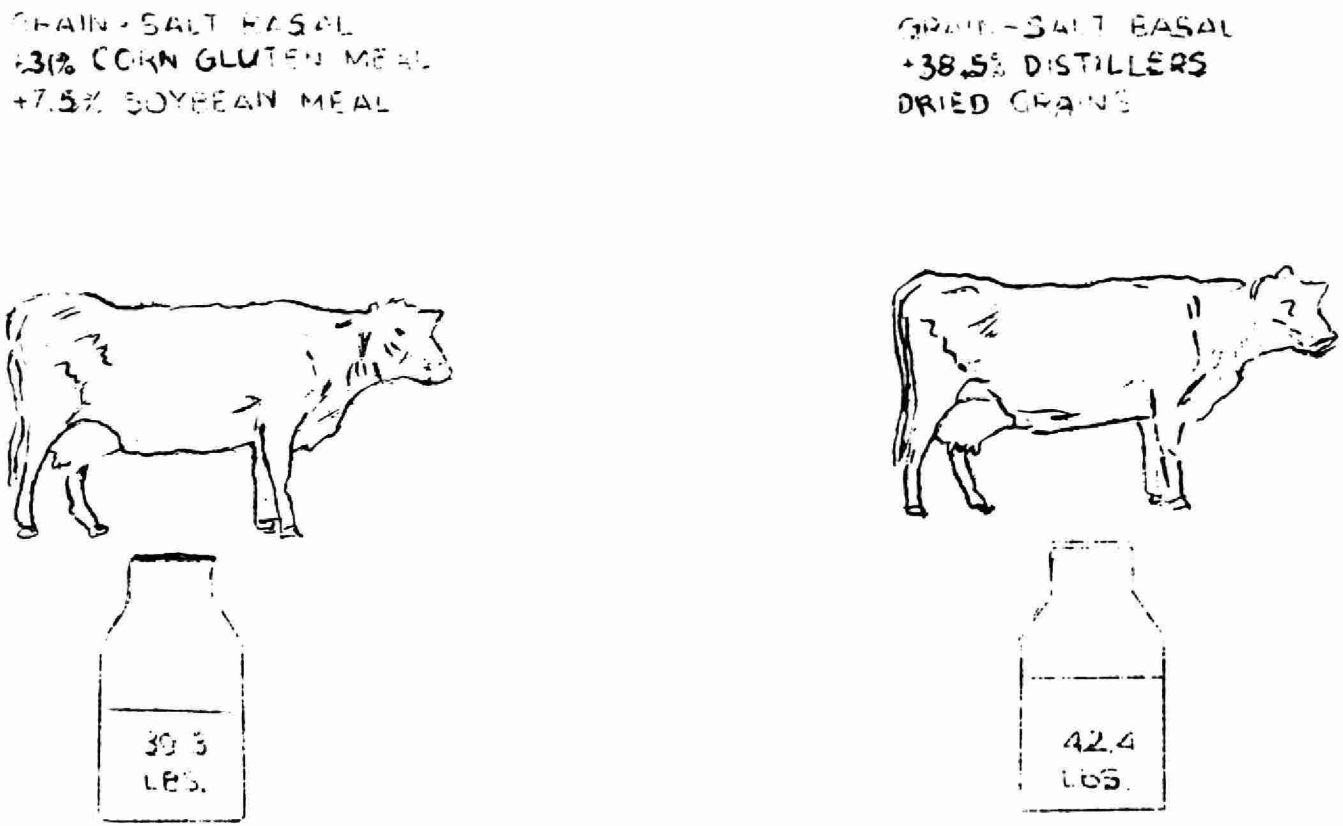
Distillers Dried Grains, the dried screenings from stillage, and Distillers Dried Grains with Solubles, the dried whole stillage, find their main use as a bulky protein-fat-vitamin supplement in dairy feeds. This is due mainly to findings that they increase milk production beyond that of other supplements of equal or higher price. Figure 2 summarizes an experiment conducted at Cornell University which is a typical demonstration of this effect. Note that an equal weight of Distillers Dried Grains replaced corn gluten meal and soybean meal with an increase in the daily production of fat-corrected milk. They also are used in lesser tonnage in beef cattle supplements and to a limited extent in poultry rations. Distillers Dried Grains with Solubles possess a fat, protein and vitamin content about 3 times that of the original grain because during fermentation only the starch, amounting to about two-thirds of the grain, is removed. This product also contains residual dried yeast.

Distillers Dried Grains possess an 85% toal digestible nutrient (TDN) content which exceeds that of competitive feeds, such as soybean oil, corn gluten, cottonseed, linseed, meat and fish meals and brewers grains.

Figure 3 illustrates the value of distillers grains as a supplement in steer feeding. The steers represented by that animal on the left side of the figure received all the roughage and corn they would consume. For each 100 bushels of corn fed, the average gain was 476 pounds. The steers

FIGURE 2

FEEDING OF DISTILLERS FEEDS TO DAIRY CATTLE



AVERAGE DAILY PRODUCTION OF FAT-CORRECTED (4%) MILK

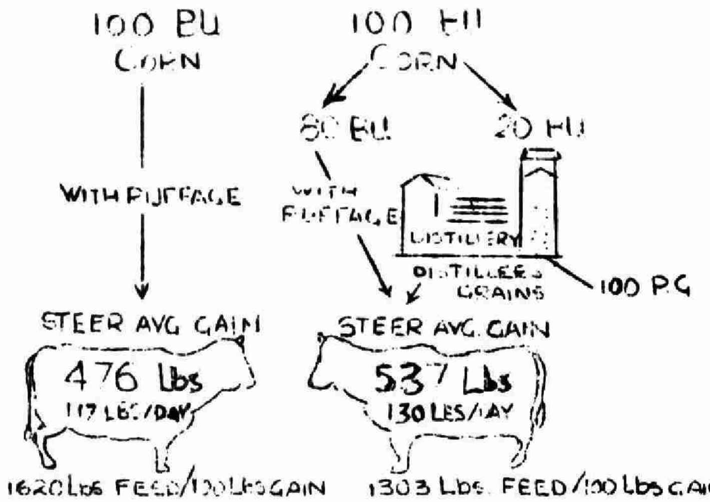
REFERENCE - Loosli, J. K., Proc. 6th Distillers Feed Conf., March 15, 1951, p.7

FIGURE 3

SUPPLEMENTAL VALUE OF DISTILLERS GRAIN IN FEEDING STEERS

THE '80-20' DEMONSTRATIONS

Garrigus and Ruf *



* COMBINED RESULTS OF 2 DEMONSTRATIONS AS SUMMARIZED BY SCHAIBLE, FEEDSTUFFS, NOV. 12 1949

represented by the animal on the right were fed 80 bushels of corn, roughage in the same manner as the first group and the distillers feeds recovered from processing the remaining 20 bushels of corn through the distillery. Even though this second group was fed a lower total poundage of feed, the average gain was 537 pounds, or 61 pounds over the group receiving corn and hay (1,16). Many other feeding trials (1,8) show that distillers feeds as a supplement to grain-hay feeding take back to the farm a higher nutrient value than would be obtainable from the original grain.

The above is explainable on the basis of balanced feeding. In an average livestock and poultry ration there should be about 1 pound of protein for each 6 pounds of energy foods. In raw cereal grains there is less than 1 pound of protein to each 6 pounds of energy foods. When cereal grains such as corn are fed without supplements, part of the energy producting food -- the starch and fat -- is wasted in order that the animal may get the necessary quantity of protein, vitamines, etc. Supply of these high protein feeds is limited. The distilling industry helps alleviate this shortage by making high protein-fat-vitamin concentrates from grain. Grain distillers, therefore, are truly grain processors and not grain wasters. In Canada and in the U.S., since 1938, with the exception of two short, heavy production periods, the price of distillers grains has exceeded the price of corn on a per ton basis, and rightly so from a nutrition point of view.

Distillers Dried Solubles

Hiram Walker, through its research, was the first to produce and market Distillers Dried Solubles (U.S. in 1939; Canada in 1952). This product is now produced by a number of other distillers.

Distillers Dried Solubles, the evaporated and drum dried portion of stillage which is a concentrate of the solubles from the grain and yeast, finds its main use in poultry, turkey, swine, calf starter and grower mixed feeds and concentrates. In addition to its semi-predigested nutrients from the fermented grains, it contains noteworthy quantities of the water-soluble vitamins from the grain and from the yeast used. It is low (2%) in crude fiber content. Distillers Dried Solubles are also being used in pet, furbearing animal, fish and bee foods.

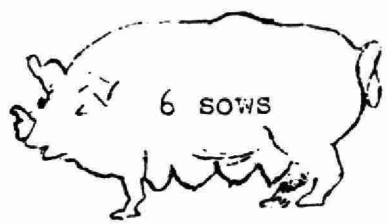
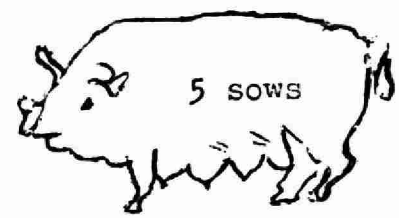
Distillers Dried Solubles, as a protein-vitamin supplement, stretch materials in short supply and / or more expensive ingredients, such as dried milk, dried whey, meat, fish and yeast. It has been found especially useful in modern high vegetable protein (low animal protein) rations which basically are low in certain nutritional factors.

Figure 4 illustrates one of many feeding experiments on the use of Distillers Dried Solubles in swine rations. Increased gains secured by incorporating dried solubles in feeds for sows and pigs from weaning to market weight, with resultant lower unit feed consumption, has been proved many

FEEDING OF DISTILLERS DRIED SOLUBLES TO SWINE[xx]

Gestation-Lactation; Dry Lot

Distillers Dried Solubles Replacing Meat Scrap

	Basal Ration + 10% Meat Scrap	Basal Ration[x] + 10% Distillers Dried Solubles
		
Average Pigs per Sow	9.2	11.4
Pigs weaned per Sow	5.5.	7.4
Percent weaned	60	65
Avg. 56 Day Litter wt., Lbs	178	224
Daily Lbs.Feed, Lactation period, Sow + Litter	13.2	12.4

DISTILLERS DRIED SOLUBLES GIVE

1. More pigs farrowed per sow.
2. More pigs raised per sow.
3. Greater weight gains.
4. Less total feed.

FIGURE 4

x Basal ration corn, soybean meal, vitamins and minerals.
xx Krider, U. of Ill., 4th.Conf.Distillers Feeds, DFRC, p.24, 1949

times in the feed-lot under general farm conditions.

Distillers Dried Solubles has been shown to contain demonstrable (by feeding tests) but as yet chemically unidentified growth, reproduction and lactation factors (1,3,8,10,12,13,14,17). Since its introduction, Distillers Dried Solubles, with a few exceptions, has sold over the price of Distillers Dried Grains and corn but well under competitive supplements, such as dried milk products, meat-scrap, fish products, yeast, etc.

Other Studies

Studies have been reported on the effect of using various grains and manufacturing processes on the physical properties and chemical and vitamin content of distillers feeds (4,5,6,7). The role of these products in producing balanced poultry and livestock rations has been covered in a number of publications of the Distillers Feed Research Council, Inc., of 1232 Enquirer Bldg., Cincinnati, Ohio, and elsewhere (1,2,5 8,10,12,13,16).

Production Tonnages

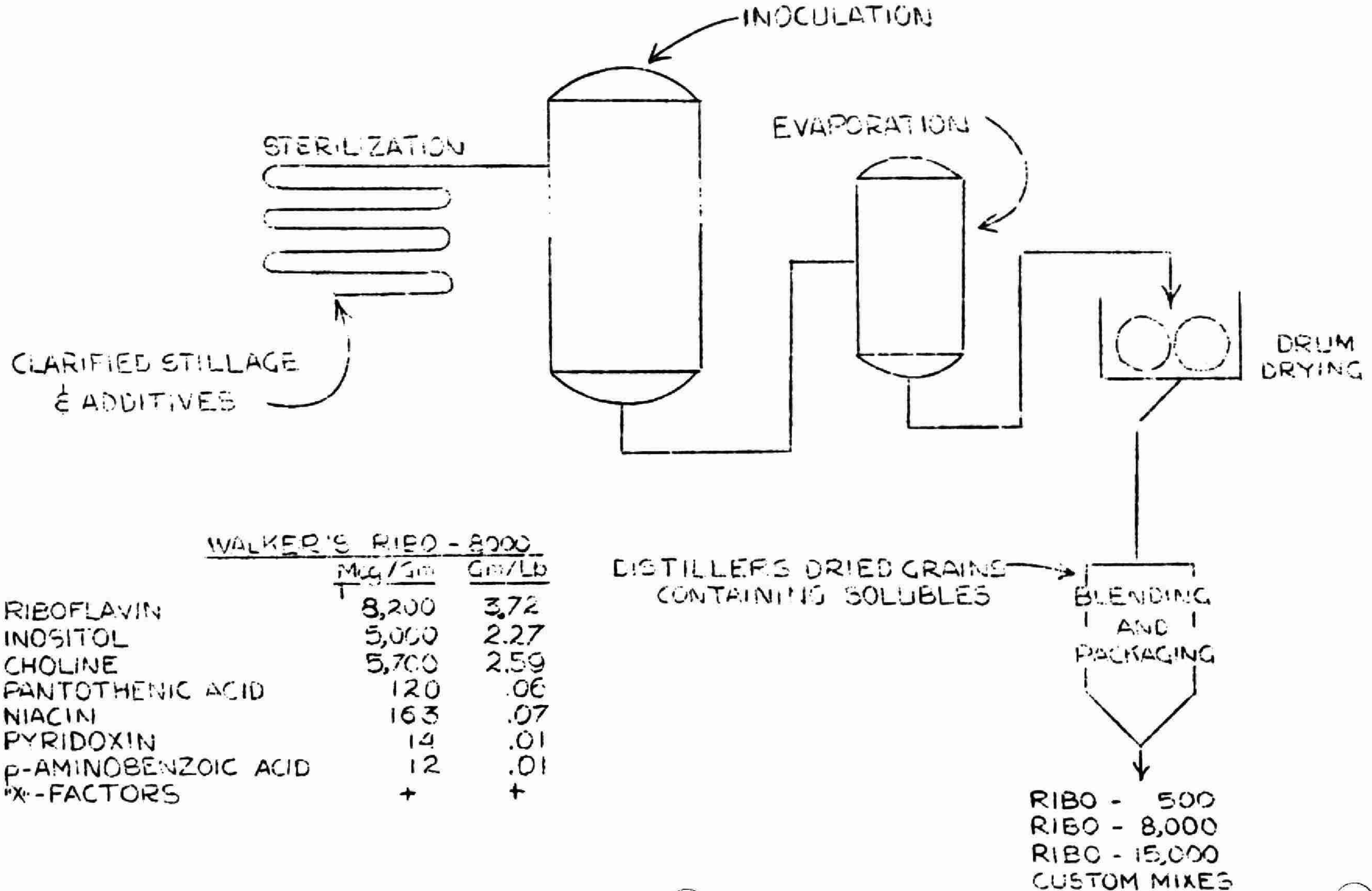
The production of distillers feeds in Canada and the U.S. in recent years is summarized in Table 1. No annual data are available on the production of wet distillers feeds in the U.S. but a survey in 1949 showed that of all grain stillage produced, 85% was recovered as dried feeds, 14% was fed wet and only 1% wasted (4,5). By 1953, however, the U.S. data on grains used and dried distillers feeds recovered show an average of 16 pounds of dried feeds per 56 pound bushel of grain processed. Since the theoretical recovery is between 16 and 18 pounds, depending on grain used, etc., one can conclude that little to no significant quantity of distillers feeds was sold wet or stillage wasted. In 1954 the gross income from dried distillers feeds in Canada totaled $2,174,869 for 37,297 tons for an average of $58.31 per ton. Sales of 24,491 tons of wet feeds totaled $29,833 for only $1.22 per ton wet weight, or $17.88 per ton at the moisture content of Distillers Dried Grains ($1.22 x 88/6 = $17.88). In other words, it has definitely become profitable to dry distillers grain byproducts. It is estimated that the 244,900 tons of total dried distillers feeds produced in the U.S. in 1954, a low production year, brought a gross income of about $18,000,000 for an average of about $74.00 per ton, f.o.b. distillery.

Additional Uses for Stillage

For years grain distillers have used stillage as a yeast growth stimulant. This, along with the fact that may micro-organisms grow well in stillage, directed attention to the use of stillage and/or Distillers Dried Solubles as a medium for the biological production of certain chemicals. Today, Distillers Dried Solubles is a common constituent in media for

FIGURE 5

REFERMENTATION OF GRAIN STILLAGE TO RIBOFLAVIN FOR POULTRY AND LIVESTOCK FEEDS



WALKER'S RIBO - 8000

	Mcg/Gm	Gm/Lb
RIBOFLAVIN	8,200	3.72
INOSITOL	5,000	2.27
CHOLINE	5,700	2.59
PANTOTHENIC ACID	120	.06
NIACIN	163	.07
PYRIDOXIN	14	.01
p-AMINOBENZOIC ACID	12	.01
"X"-FACTORS	+	+

the production of certain antibiotics and biologicals. As a result of a number of years of study in the Hiram Walker Central Research Department, stillage was first reprocessed or, as we call it in Peoria, refermented to new products in a small plant built in 1950. The first products to reach the commercial stage were a series of riboflavin feed supplements. Figure 5 briefly outlines the process by which riboflavin concentrate is produced in submerged, aerobic fermentation equipment in Hiram Walker's new, larger Vitamin Plant placed in operation in January 1954. Laboratory and commercial studies also have been conducted on the production of fungal amylase as a saccharification replacement for barley malts. This process appears to be feasible.

Table 2 summarizes the commercialization of products from stillage at our Peoria plant as they have been developed over the past 16 years.

Summary

The processes for manufacturing the various distillers feeds have now become satisfactorily efficient and the market has been sufficiently developed to make their production a profitable operation. Use as supplements in mixed feeds has kept pace with production except during exceptionally high alcohol production periods. During low production periods there is a great demand for distillers feeds, because replacements are usually in short supply and more costly. The modern distiller is constantly striving to get the best alcohol and feed yields possible from the amount of grain processed. There exists, therefore, a definite profit incentive for pollution abatement through total stillage and waste reclamation.

In conclusion, during the past 25 years we have seen, through the application of the various sciences and marketing procedures, the main distillers waste, namely, stillage, converted from an unpopular and unprofitable waste to a series of demand feed supplements, the recovery and marketing of which is profitable to the distiller. This change, along with other intra-plant changes, also means that this pollution load has been taken out of our surface water resources. Distillers are, and we think rightly so, very proud of their contribution to cleaner streams and to the feed and food economy of our two nations.

References

1. Anonymous, Distillers Feeds, Their Importance to the U.S. Economy, Distillers Feed Research Council, Inc., Cincinnati, Ohio, 1951. (A compilation of research and demonstration data.)

2. Bauernfeind, J. C., and Boruff, C.S., Fermentation By-Products as Animal Feeds, Am. Miller 72, No. 1, 132; No. 2, 53; No. 3, 50 (1944)

3. Boruff, C.S., and Blaine, Russell K., Grains Distillery Feeds and Wastes, Sewage and Ind. Wastes 25, No. 10, 1179 (1953).

4. Boruff, C.S., Recovery of Fermentation Residues as Feeds, Ind. Eng. Chem. 39, 602 (1947)

5. Boruff, C.S., Grain Distilleries, Ind. Eng. Chem. 44, 491 (1952)

6. Boruff, C.S., Our Products - Animal Feed Products of the Distillery Industry, 2nd Distillers Feed Conference (DFRC) Feb. 27, 1947, p. 4

7. Boruff, C.S., and Kolachov, Paul J., A survey of the Chemical and Vitamin Analysis of Distillers Feeds Produced in 1947, 3rd Distillers Feed Conf. (DFRC) Feb. 24, 1948, p. 93

8. Carpenter, L.E., The Modern Distilling Industry and Its Feeds, Feedstuffs 27, No. 9, p.30 (Feb. 26, 1955)

9. Carson, C.T., Treatment of Distillery Wastes, Municipal Utilities (Toronto) p. 66, Sept. 1950

10. Couch, J.R., et al, Distillers Dried Solubes in the Diet of Chicks, Proc. 10th Distillers Feed Conf. (DFRC) March 3, 1955, p. 47, also Feedstuffs 27, No. 17, p. 32 (April 23, 1955)

11. Loosli, J.K., Turk, K.L., and Morrison, F.B., The Value of Distillers Feeds for Milk Production, Dairy Science 35, No. 10, 868 (1952)

12. Norris, L.C., Recent Progress on Unidentified Growth Factors in Distillers Dried Solubles and Other Feed Supplements, Proc. 10th Distillers Feed Conf. (DFRC) March 3, 1955, p. 39, Feedstuffs 27, No. 17, p. 32 (April 23, 1955)

13. Rasmussen, R.A., Distillers Feeds in Animal Nutrition, Chemurgic Digest 8, No. 1, 8 (1949)

14. Rasmussen, R.A., et al, The Dual Nature of the Unidentified Chick Growth Promoting Activity of Distillers Dried Solubles, Proc. 9th Distillers Feed Conf. (DFRC) March 10, 1954, p. 29

15. Rudolfs, W., Industrial Wastes, Reinhold Pub. Co., N.Y., 1953, ACS Monograph Series #118, Chapter 6 (Boruff) The Fermentation Industries, p. 99-131.

16. Schaible, P.J., The Grain Distilling Industry and Its Feeds, Feedstuffs 21, No. 46, p. 20 (Nov. 12, 1949)

17. Smiley, K.L. et al, Biosynthesis of Riboflavin, L. Bulgaricus Factor, and Other Growth Factors, Inc. Eng. Chem. 43, 1380 (1951)

TABLE 1

SALES OF DISTILLERS FEEDS IN CANADA AND U.S.

	Canada			U.S.		
	Dried Grains and Dried Grains with Solubles, Tons x x x	Wet Grains, Tons	Value of Dried Feeds, $	Dried Grains, Tons	Dried Grains with Solubles, Tons	Dried Solubles, Tons
1934	x	x	38,469	x	x	0
1935	x	x	44,546	x	x	0
1936	x	x	76,667	x x	240,400	0
1937	x	x	162,932	x x	230,400	0
1938	x	x	166,242	x x	149,400	0
1939	x	x	174,491	x x	148,600	500
1940	x	x	276,662	x x	163,100	500
1941	x	x	231,909	x x	205,900	600
1942	x	x	460,987	x x	341,700	3,700
1943	x	x	524,849	x x	339,300	17,600
1944	28,058	x	703,661	285,400	131,200	27,300
1945	26,627	4,043	774,440	352,600	195,400	85,500
1946	20,331	3,245	552,193	133,400	83,600	105,900
1947	21,412	4,301	743,616	157,400	148,700	105,200
1948	24,225	4,480	1,160,095	130,100	147,800	73,200
1949	21,238	5,295	1,207,616	86,900	188,200	57,800
1950	21,894	6,597	1,150,982	91,300	188,600	85,200
1951	25,629	21,849	1,310,024	199,700	288,600	145,600
1952	24,675	20,327	1,657,587	65,000	184,600	82,600
1953	29,424	21,408	1,922,972	40,000	116,200	29,500
1954(1)	37,297	24,491	2,174,869	69,100	121,900	53,900

x Quantity data not available.
x x Until 1944 tonnage included with Dried Grains with Solubles.
x x x Includes some Dried Solubles production starting in 1952.
(1) Tentative data.

C. S. BORUFF 1955.

TABLE 2

WALKER PRODUCTS FROM STILLAGE

PRODUCT	YEAR OF DEVELOPMENT
Corn Distillers' Dried Grains with Solubles	1934
Walker's Stimuflav	1939
Walker's Ribo-8000	1950
Walker's Ribo-15,000	1952
Walker's U.S.P.Riboflavin	1954

DIFFUSION CHARACTERISTICS OF THE ST. LAWRENCE RIVER AT MAITLAND

by

F. A. Reid

Du Pont Company of Canada Limited

Introduction

Between 1951 and 1953, Du Pont Company of Canada Limited purchased a large site fronting on the St. Lawrence River, near Maitland Ontario, and constructed a plant for the manufacture of the two basic ingredients from which nylon yarn and staple fibre are made. Selection and acquisition of this site recognized that the Du Pont Company of Canada would likely manufacture other items at that location, and one step has already been taken in this direction by the current construction of a plant to manufacture "Freon".

Time and a considerable amount of money were spent to assure that neither pollution of the river nor of the atmosphere would result from our manufacture. To this end, Dr. Ruth Patrick of the Philadelphia Academy of Natural Sciences carried out a survey of the marine life in the river at this point, and the Ontario Research Foundation under Dr. A. E. R. Westman was engaged to perform test work on existing air pollution. Dr. Morris Katz, our Canadian air pollution consultant, guided the test program and activities. Similar surveys are intended for the future to ensure that no adverse effect results from plant location.

Most chemical plants have waste streams which cannot be employed, initially at least, in the manufacture of by-products. At Maitland Works, small amounts of certain wastes, suitably treated at considerable expense, have been routed through an eight-inch, one thousand foot stainless steel line laid at the bottom of the river, to be released for dispersion in deep, rapidly moving water.

During the summer of 1954, a program was initiated to establish the characteristics of the dilution of this particular effluent throughout the water in the St. Lawrence. The object was not only to confirm that conditions in the river were satisfactory to health authorities, but to gain general knowledge of the diffusion which exists at that point. Such information was important to the design of future manufacturing facilities at this site. This test work proceeded through June and July and at the end of July, little information had been obtained except that it had been established beyond any doubt that the running of tests in a river such as the St. Lawrence was an extremely difficult task.

Typical of the difficulties encountered was a mischance which occurred when an aircraft and two occupants were engaged to observe and photograph dispersion of highly visible fluorescein dye released under certain conditions at the outfall. Ground parties were equipped with portable radio and tests had previously been run to verify that communication with the set installed in the plane was possible. In the interval between this check and the test day, made necessary by inappropriate weather, the radio set in the plane was removed and another substituted which could not be tuned to the same wave length. As a result, the plane arrived half an hour early, and followed and photographed a completely valueless preliminary release of dye.

After several such tests had failed to yield desired results, and with fall approaching, it was decided to plan one much more elaborate test than any yet attempted, and make every possible provision to ensure successful results.

If the experience gained in the preliminary work and during the test itself could be summarized in a single theme, this theme would be: "Detailed Planning is required". Because this entire test was conceived and carried out in less than one month, certain initial work was necessarily abbreviated, but no effort was spared to ensure that the test itself would not be jeopardized through lack of preparedness.

Initial Planning

In the basic planning for this test, it was recognized at an early date that the location of the stainless steel outfall was not accurately known and this would have to be determined and a record kept for any future test. Consideration of several alternatives indicated that the only foolproof method of locating this outfall was to do so through the use of a diver.

With this point established, the remainder of the test was designed to derive as much value as possible from the presence of a diver at the bottom of the river.

Because the assembly of test personnel was expensive and difficult, it was hoped to complete the work in a maximum of two days and if possible, in one day.

The first step in organizing the test was to consult, as far as practical in the limited time available, as many specialists on the subjects of river flow and prevention of stream and lake pollution as possible. Advantage was taken of the Company's association with E.I. du Pont de Nemours & Co. Inc., and preliminary and reasonably complete discussion of the major test techniques was held with Dr. Berry, A. V. DeLaporte and O. V. Ball of the Ontario Department of Health, and with Dr. Patrick in Philadelphia. At this time also, tentative arrangements were made for attendance at the test by a representative of Dr. Berry's Department. One of the main targets in those discussions was to learn of existing techniques which could be used and to determine what additional information beyond the immediate answers required could be obtained at the same time with a minimum of additional cost and effort.

At the conclusion of this preliminary work, it was considered that the major structure of the test would comprise the following items:-

(a) Location of outfall by the diver and description of the appearance and path taken by the effluent (dyed so as to be visible) after its emergence.

(b) Triangulation of the outfall position for any future work.

(c) Determination of dilution at various distances down-stream from the outfall by a total of 3 techniques:-

(1) Direct measurement by conductivity meter probe held by diver in the trace (effluent was an electrolyte).

(2) Chemical measurement performed on liquid samples taken at same location and time as the conductivity reading (sucked up through garden hose).

(3) Calculation based on effluent and river flow rates and measurement of dimensions of trace by the diver.

Final Planning and Test Preparations

Following initial contacts and discussions, a preliminary test plan was laid out. This was discussed with the Maitland personnel who had carried out previous tests in the river and with Mr. W. Viner, the engineering representative of the diving firm (A.F. Simpson, of Brockville, Ontario).

The importance of this step cannot be overstressed. Mr. Viner appreciated most fully the problems involved and the need for comprehensive planning and he contributed in a great degree to selection of final test techniques. He was in a position to specify floating plant requirements, and to forecast problems which would be encountered in anchoring a barge close to the traffic lane in the river, the degree of visibility likely to be experienced at the bottom of the river, and the need for devices to guide the diver in the area of the test.

Following major revision of the original outline, the proposed program was discussed with all test personnel, drawn mainly from our Company's Engineering Department in Montreal.

A secondary discussion was then held with the Maitland personnel and Mr. Viner. At this point, drawings of all pieces of equipment, together with a schedule for their preparation and testing, were released.

Great importance was attached to the provision of spares for certain essential test equipment. Typical of the results achieved were two sources of power for a conductivity meter which was employed and the ultimate provision of four portable generators on the barge to supply power to tape recording equipment, underwater light and P.A. system.

Sketches were made of the barge showing allocation of space to the diving crew and to the test crew and the position of all test equipment was established. On completion of this work, a description of the entire test was issued, covering the duties of all personnel, sequence of events, and scheduled times for significant steps.

An additional preliminary technique was employed when the group leader of each test cell was required to submit an outline of his phase of the work, together with his sheets for recording of data and graph paper prepared to allow plotting of results as they would be obtained during the test.

It was necessary to arrange contacts with all key personnel to allow postponement of the test which was scheduled for Monday August 30, in case of bad weather, and all personnel were instructed to report to the Hotel Manitonna in Brockville at 8:00 P.M. on Sunday evening prior to the test.

On the Saturday prior to the test, heavy equipment was loaded on the test barge west of Brockville and it was moved over the week-end to the Company dock at Maitland. Final checks of the construction and adequacy of all test equipment, calibration of the conductivity meter and check-running of the sample suction pump were carried out at this time.

On Sunday night, all personnel were present including the diver (Mr. Arthur Simpson) and Mr. Viner, to be coordinator of the diving effort, together with C. E. Simpson, representative of the Ontario Department of Health. Test procedures were again reviewed in detail and final revisions were made and recorded on individual copies in writing. Some shifts in the assignment of personnel to the boats were found necessary at this point in order to assure that all members of these crews were experienced in handling small craft.

Sketch No. 1 shows the general area of the test and Sketch No. 2 is a more detailed presentation of the test area and the immediate shore line, showing proposed barge and test positions. The following sections will clarify the points which arise upon inspection of these sketches.

<u>Test Organization</u>

The organization of the test group was as follows: Test coordinator was myself, located on the barge. A main log recorder was also located on the barge. His entire function was to see that all watches were synchronised and that all significant happenings were recorded. This technique became extremely valuable in the afternoon of the test when it was necessary to estimate diving time on the second dive.

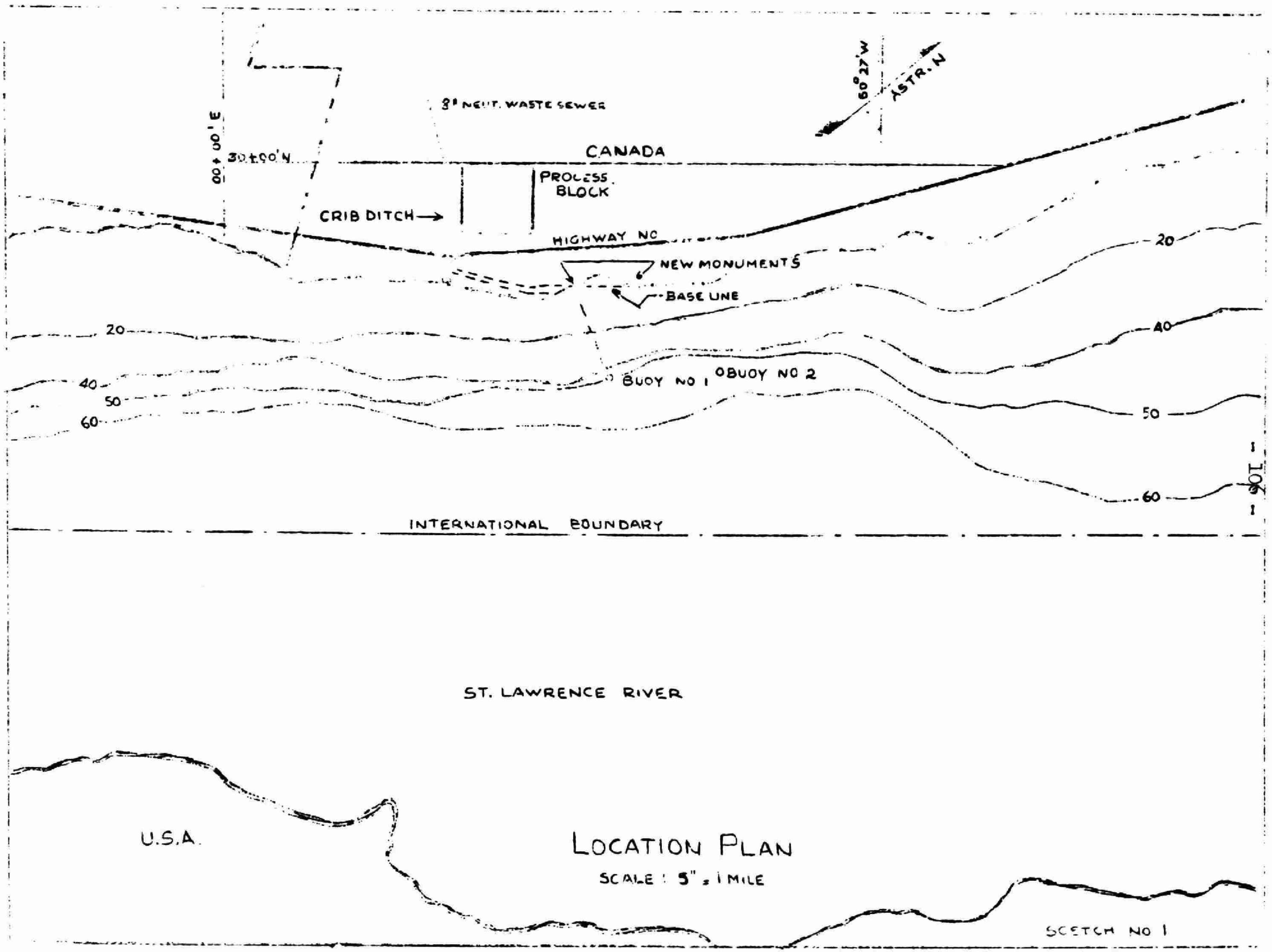
A shore party coordinator was located at the shore "walkie-talkie" at the last manhole on the effluent line. Two instrument men were assigned to instruments located on the permanent monuments at the shore line.

One man was assigned to measure the flow of effluent to the line and to ensure as far as possible that the composition and quantity of this effluent did not vary too greatly throughout the test period. Prior arrangements had been made with the Production Department of the plant that such conditions would likely be maintained during the test day. One man was assigned to control and measure the addition of fluorescein dye at precalculated rates into the effluent through a manhole several hundred feet up-stream of the last manhole. He also measured temperature of the effluent at the last manhole and took samples at this point at twenty minute intervals.

Two boat crews comprising two men each were used and these men were employed on the barge in intervals between boat work and to provide transportation between barge and shore. One man was assigned to the "walkie-talkie" on the barge and to aid in conductivity meter operation. One was assigned to operation of the sample pump on the barge and one to conductivity meter operation.

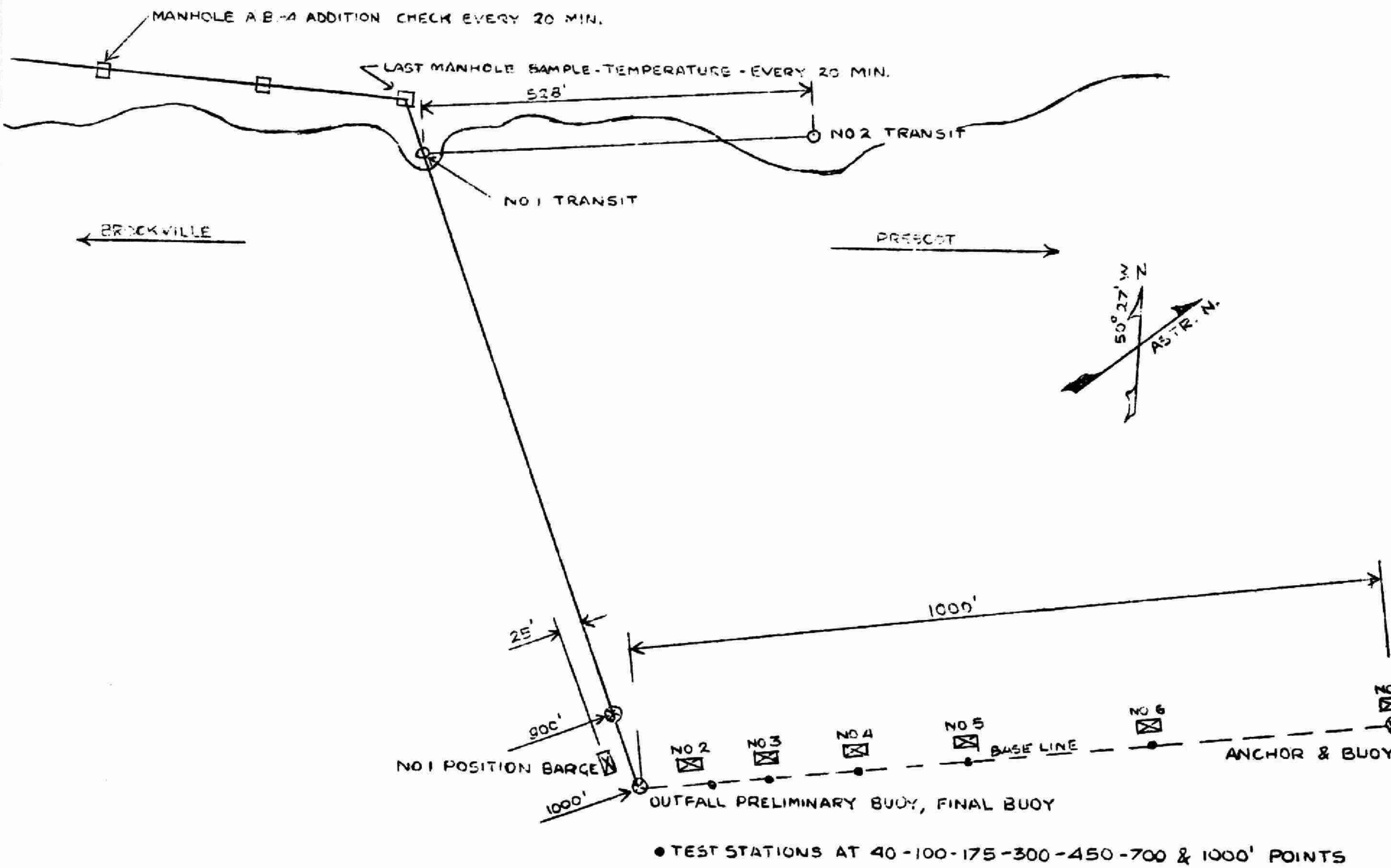
All personnel carrying out repetitive functions synchronised watches with that of the main log recorder and logged all significant occurrences. Throughout the test, P. A. Communication was maintained between W. Viner and the diver and both conversations were recorded on a tape recorder. In addition, the main log recorder periodically orally reported the time on the recorder.

Total test personnel, including five from the diving firm, amounted to twenty people, of whom approximately fifteen were graduate engineers.



8" NEUT. WASTE SEWER
60°27'W
ASTR. N
00+00'E
30+00'N
CANADA
PROCESS BLOCK
CRIB DITCH
HIGHWAY NO
NEW MONUMENTS
BASE LINE
20
40
50
60
BUOY NO 1
BUOY NO 2
INTERNATIONAL BOUNDARY
ST. LAWRENCE RIVER
U.S.A.
LOCATION PLAN
SCALE: 5" = 1 MILE
SCETCH NO 1

LAY OUT of TEST ON PROCESS EFFLUENT
MAITLAND WORKS AUG. 30 1954



SCETCH NO 2

Test Procedures

Prior to test day, survey parties established the absolute location of the newly constructed permanent monuments and from drawings covering the design of the effluent line, calculated instrument readings to be used in triangulating the estimated position of the outfall. A dry run involving a single boat crew, which would on test day position a mooring buoy, was made to determine difficulties to be encountered and to establish a rough schedule on this phase of the test, as it was considered to be one of the most significant and difficult tasks.

The test party assembled at the main gate of the plant at 5:30 A.M. The weather was overcast and a light east wind was raising light waves on the river. The shore and boat parties immediately commenced work necessary to position a marker buoy at the estimated location of the outfall. The remainder of the personnel obtained test equipment and set it up on shore or located it suitably on the barge.

The marker buoy was successfully positioned at approximately 7:30 and the barge was anchored about 40 ft. inshore of the marker and approximately 25 ft. upstream at 9:00 o'clock. The diver immediately started to dress and at 9:55 entered the water. The addition of dye, after some unexpected difficulties, was started at 9:50. It had been estimated from the effluent flow, line diameter and length that this dye would reach the outfall about fifteen minutes later.

The diver reported on reaching the bottom that it was hard, smooth and sandy with little plant life, but with several fish. Very great difficulty was experienced by him in locating the line. The strength of the current at this point in the river was most unexpected. Due to its effect on the diver's lines, he found it necessary to crawl on hands and knees at any time when he wished to move upstream. The depth had previously been measured at 46 ft., and the barge was close to the edge of the traffic lane in the river. The large wakes of passing freighters gave considerable trouble, with the diver being tossed on his back on one occasion as a result of the violent pitching of the barge.

After guidance from above by means of one of the buoy lines used later in the test, the diver finally found the line 35 minutes after reaching the bottom. His first action was to clamp the outfall buoy line to the stainless line at the outfall, and the No. 1 boat then tightened the line on the buoy as much as possible.

He then described the conditions at the outfall, particularly the appearance and path taken by the fluorescein-dyed effluent.

A transcription of the actual conversation with the diver is included at this point, as follows:-

"I think, Arthur, about the very first thing you should do now you are there is to try and clamp that clamp onto her. How about that? .... Good show."

"Now first of all, what sort of condition is the end of the line in, Art?"

"Just as it was when I laid it."

"Good. Now, the next question. Has the pipe been lying in a silted-in trench or what?"

"No, in the clear on top of the bottom."

"Is the whole pipe clear of the bottom Arthur?"

"Yep."

"Good. O.K. now Arthur, what's the story about the dye as you see it, and where are you looking at it from?"

"I am on the upstream side of the pipe, almost at the end of the pipe. The dye is coming out .... approximately, oh it's on a curve, curving downstream, ... and fanning out about 5 ft. from the end of the pipe and it's starting to funnel out and at the 10 ft. mark it has funnelled out to an area of about 3 ft. in diameter and the stream is rather elliptical, or round sort of, more or less."

"Hello Art. This is Frank Reid here. Is it fanning out fairly steadily?"

"Yes, it is fanning out very steadily and even in two or three feet, I can see a big difference in the dilution of the dye as it is coming out of the pipe."

"Is it tending to hold its position or does it appear to be going up into the water or is it staying horizontal?"

"No, it is rising slowly and the angle of rise..... is about 2 ft. in 15."

"That is, the angle of rise is about 2 ft. in 15?"

"That's right."

"And it is about, can you tell us again what dimension is it at 10 ft. approximately downstream?"

"Will you say that again?"

"What is the diameter of the trace 10 ft. downstream from the outfall?"

"........... about 2 or 2½ ft. in diameter, nearly 3 ft."

"O.K. then. As far as I am concerned, you can attach the outfall buoy line."

"O.K. Say, the fish are swimming right up to the mouth of that thing."

"That's good information. Go ahead."

"........ I am shooing them off."

"Have you got her all secured, Art?

"Yep, she's all secured."

"Good show! "

Time record- 10:51

"Arthur, listen- are you going to be able to see that trace, that dye trace some 50 ft. downstream or will it be necessary to add more dye so that it will still be visible even with the dilution that is taking place down there?"

"Yeah, you might add more dye, that's right. O.K......"

"Is that a level bottom there or sloping bottom, or any rocks?"

"No, nothing. Perfectly level bottom ...."

"....... I can see fish, I can see plenty of fish...... As far as I can tell, these are ideal conditions for mixing down here. I will sketch it when I come up."

"The gentlemen here are dancing and screaming with joy! We would like to hear more of THAT stuff."

Light reaching the bottom, even on the dull day, gave better viewing conditions, in his estimation, than that obtained from an under-water light which had been supplied, and this equipment was removed from further use.

A calibrated thermometer which had been attached to his equipment was then used to measure the temperature of the water one yard upstream of the outfall and of the effluent 4" inside the line. This thermometer was then passed up to the No. 1 boat.

An under-water camera was dropped to him by letting it slide along the outfall buoy line and several pictures were taken of the emerging effluent. Unfortunately, these pictures were so completely underexposed as to be without value whatever.

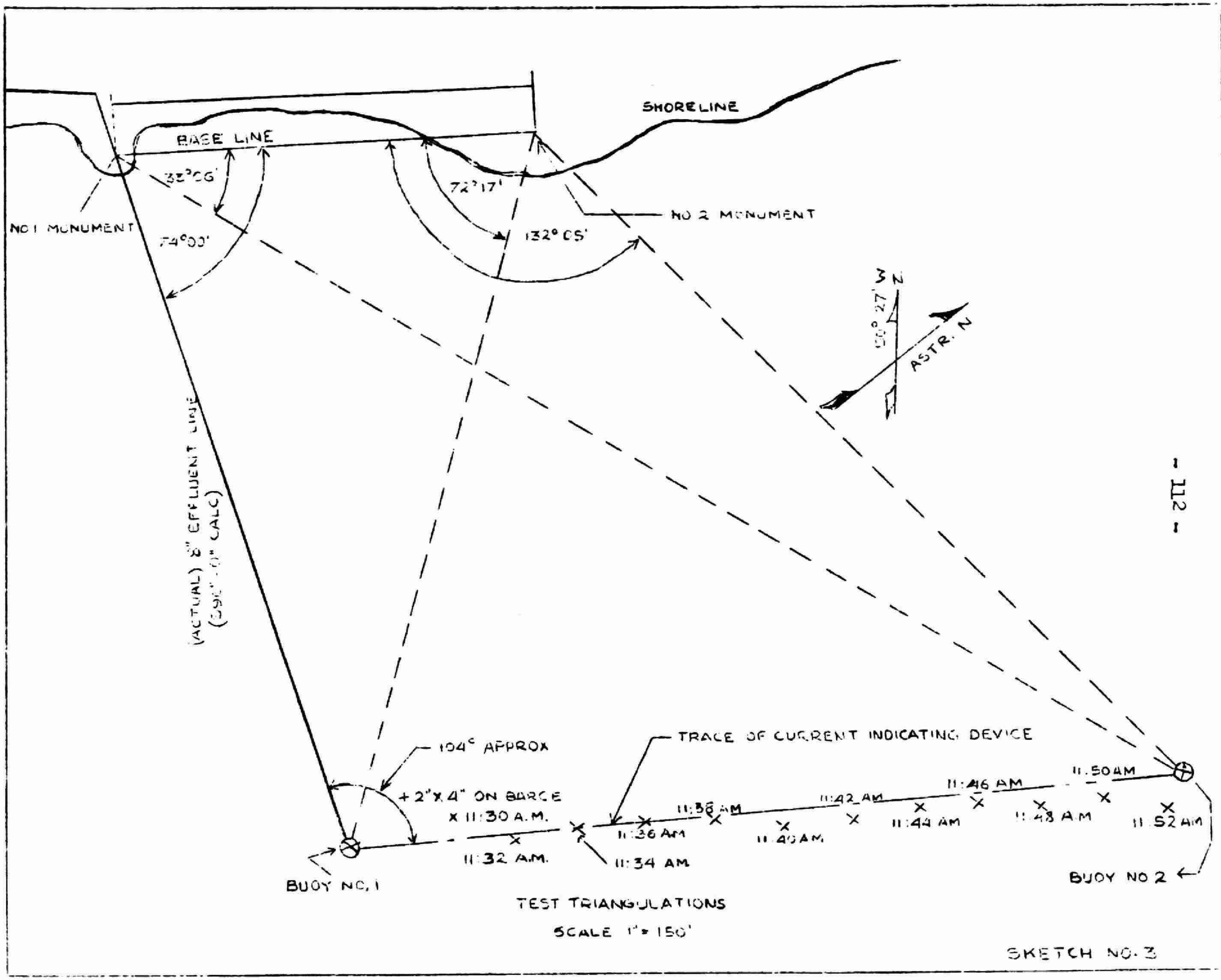
The upstream end of a thousand foot nylon sash cord line called the "base line" was then dropped to him and was permanently clamped to the outfall. At this point, the diver commenced his return to the barge.

The No. 1 boat carrying the rolled-up base line then manoeuvred out of position. The No. 2 boat swung in close to the outfall buoy and prepared to release a vaned float device so designed that its very large plywood vanes would hang in the river current approximately 6 ft. above river bottom. The float on this device contained a flag to allow tracking from shore. It was released after alerting the shore survey parties and on release, moved down the river with the flag duplicating the flow pattern in the river likely to be followed by the effluent. Carefully synchronised triangulations were made by both instrument parties at two-minute intervals, allowing the flow pattern in the river and its speed to be plotted as shown in Sketch No. 3.

Upon release of the vaned device, the No. 1 boat moved in behind it and proceeded down-river in its wake, paying out the base line as necessary. On reaching the thousand foot point, the No. 1 boat dropped the downstream base line anchor to which the downstream buoy line had been attached and the No. 2 boat recovered the vaned device. A permanent base of reference, closely approximating the probable effluent path, had thus been established for the diver's use.

Following lunch, the barge was repositioned at a point 70 ft. downstream and 50 ft. inshore of the outfall buoy, fluorescein dye addition was resumed at triple the rate used in the morning, and the diver went over the side at 2:15 carrying one end of the 1200 ft. "fanning line". At the end of this line was a stainless steel clamp followed with 10 ft. of stainless steel wire, and it carried aluminum markers suitably coloured and marked with test station numbers. These had been spaced roughly logarithmically at distances of 40, 100, 175, 300, 450, and 700 ft. from the outfall end. The rolled-up portion of this line required tending by the No. 1 boat during its use by the diver. He located the outfall with no difficulty and after attaching the "fanning line" clamp, prepared to receive the combined conductivity and sampling line probe. A very great deal of difficulty was then experienced in obtaining a satisfactory prime on the part of the sampling pump. Forty-five minutes elapsed before this difficulty was overcome and the sample probe was received by the diver.

He was then directed to move downstream to the first test point at 40 ft. and holding the fanning line at the No. 1 marker, he was instructed to pace off the full width of the trace and comment when he passed over the base line. He was also asked to estimate location of the centre point and the vertical height of the trace at that point.



SHORELINE
BASE LINE
33°06'
74°00'
72°17'
132°05'
NO 1 MONUMENT
NO 2 MONUMENT
10° 27' W
N
ASTR. N
(ACTUAL) 8" EFFLUENT LINE
(390'-0" CALC)
104° APPROX
+ 2"x 4" ON BARGE
x 11:30 A.M.
TRACE OF CURRENT INDICATING DEVICE
11:32 A.M.
11:34 AM
11:36 AM
11:38 AM
11:40 AM
11:42 AM
11:44 AM
11:46 AM
11:48 AM
11:50 AM
11:52 AM
BUOY NO. 1
BUOY NO 2
TEST TRIANGULATIONS
SCALE 1" = 150'
SKETCH NO. 3

He then assumed position at the centre line of the trace and held the sample probe upstream of his person progressively 1 ft., 2 ft. etc. from the bottom, commenting at what point on his person the probe was being held. At each test position, the conductivity meter operator balanced his bridge and recorded conductivity of the sample, allowing interpretation and plotting. The liquid sample crew drew off the estimated hose purge volume of liquid and then filled a sample bottle. The probe could then be moved to a new test position.

On completion of the vertical traverse of the centre line, a traverse was made on the horizontal centre line working from the vertical centre line inshore with test points one pace apart. The diver's pace and height were measured later.

On completion of work at this station and inspection of conductivity meter results, it was apparent that dilution was very much greater than had been expected and, in fact, concentrations at this point approached the threshold of sensitivity of the meter (150:1). As a result, rescheduling of further work immediately became necessary and it was decided to run a test 10 ft. from the outfall and a third test one yard from the outfall. This was completed as rapidly as possible because a very heavy rain was falling accompanied by winds up to 18 m.p.h., and because the diver was showing signs of fatigue. He returned to the barge at 4:15 and it was then moved back to the Company dock.

Final triangulation was made on the outfall buoy, the outfall buoy line was attached to the fanning line as the buoy was removed and the No. 1 boat proceeded to shore paying out the fanning line. This fanning line was left in position and it has been established that test crews can pick it up inshore, proceed to the outfall end, using it as an anchor line, can blind-sample the effluent trace at will so long as wind direction is substantially down-river.

General Results

Monitoring samples taken at the last manhole were measured using the conductivity meter to determine the strength of the effluent compared with that selected for instrument calibration. A plot in time of this relationship allowed corrections to be made to the apparent strengths of effluent trace obtained during the test by the conductivity meter.

Plotting of vaned device triangulations indicated that river speed at the 40 ft. level was 2400 ft. per hour in a direction roughly parallel to the north shoreline. Velocity in the effluent line was calculated at 4,280 ft. per hour and the starting temperature differential between the effluent and the river was 4.2°C. This differential at emergence had dropped to 1.1°C.

No appreciable temperature gradient was found to exist in the river. Surface temperature was 21.9°C and all other readings, taken at 10 ft. intervals, were 21.7°C.

It was established that fluorescein dye in concentrations of 1 in 93,000 is completely visible with and without artificial light on the bottom of this river on a dull day. It was adequately visible in concentrations of one part in 5 million in the morning and was invisible diluted 1 in 5.4million. In the afternoon, using a 1,000 watt light, it was completely visible diluted one part in 51 million.

Diffusion Results

It was intended to chemically analyse all liquid samples taken on the barge as a check against conductivity meter determination. Unavoidable delays were experienced in arranging a satisfactory test and results obtained were completely unreliable. Conductivity meter readings at each station were plotted and dilution at the centre line of the trace at each of the three test points was calculated. (See Sketch No. 4)

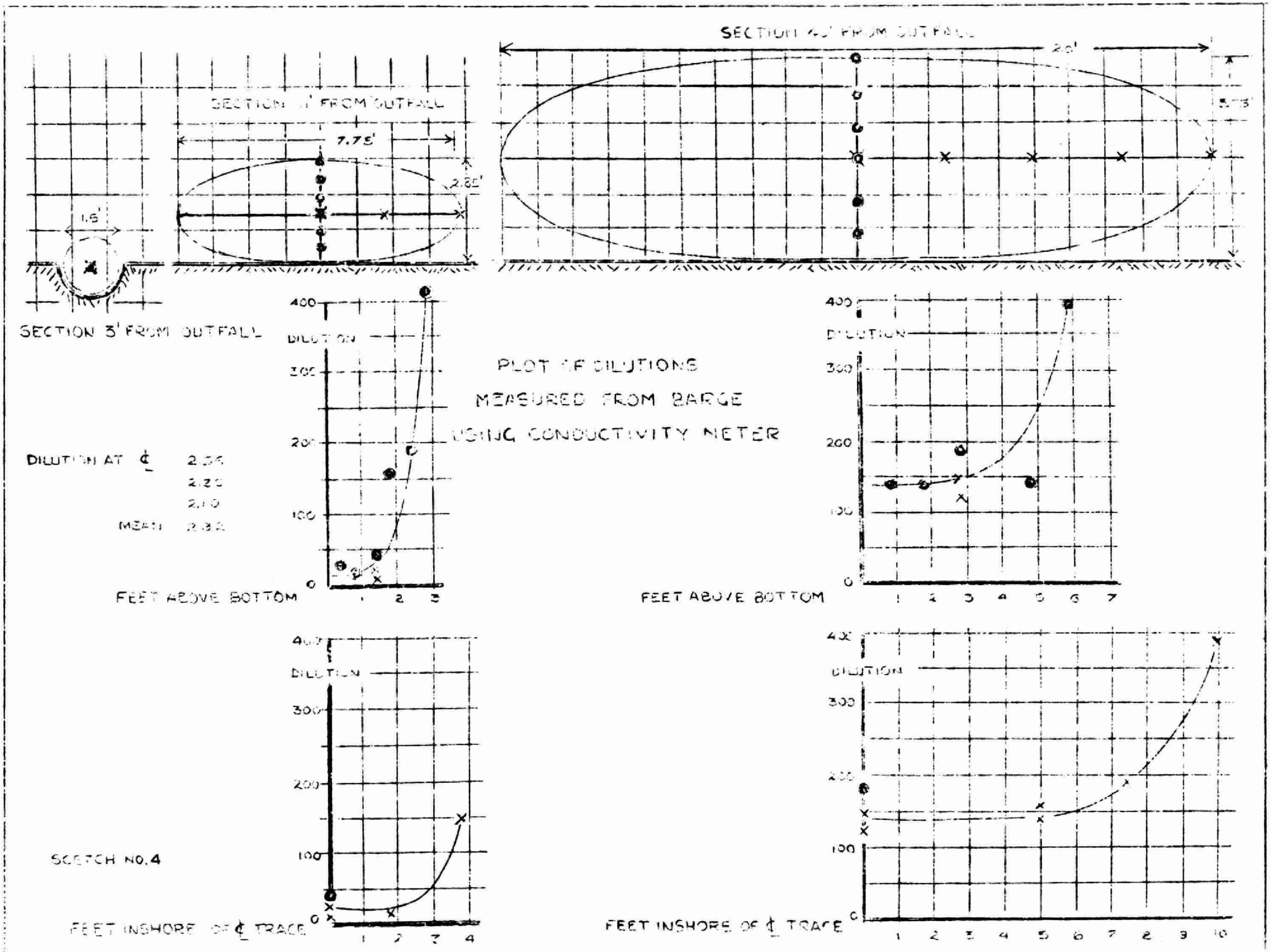
Knowing the rate of flow in the river and in the effluent line- assuming the effluent trace was at all times elliptical in cross-section and using the dimensions of this trace as taken from the diver's description on the tape recorder - it was possible to calculate dilution at each of the test points.

Sketch No. 5 attempts to portray the path taken by the effluent, and is based on the diver's recorded descriptions and answers to questions posed him when he returned to the surface.

The results of these two methods of determining diffusion are as follows:

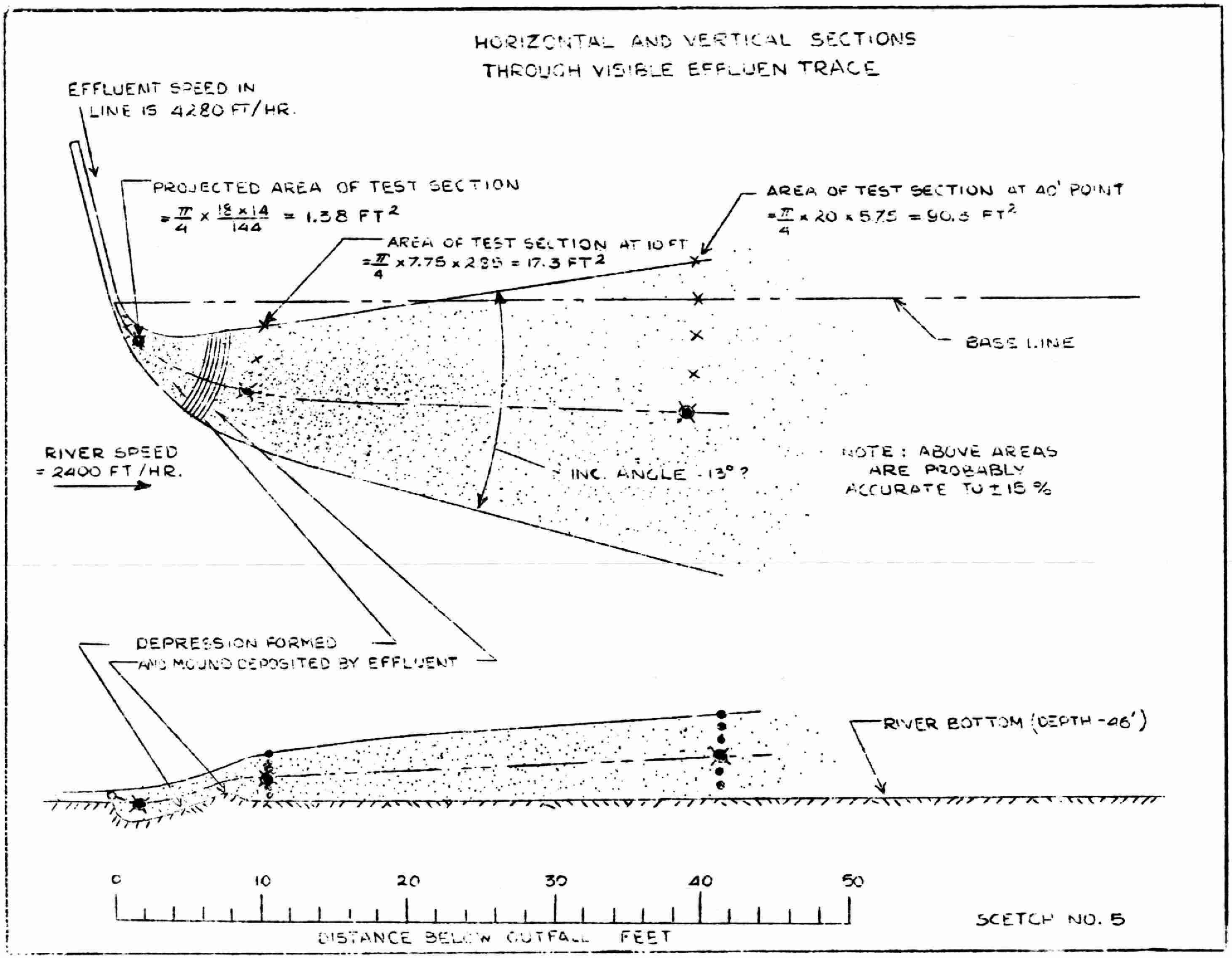
Distance Below Outfall Feet	Diffusion- Minimum at Centre of Trace by Conductivity Meter	Diffusion- Average by calculation of areas and flows
3	2.3:1	2.2:1
11	20.5:1	27.5:1
40	145:1	145:1

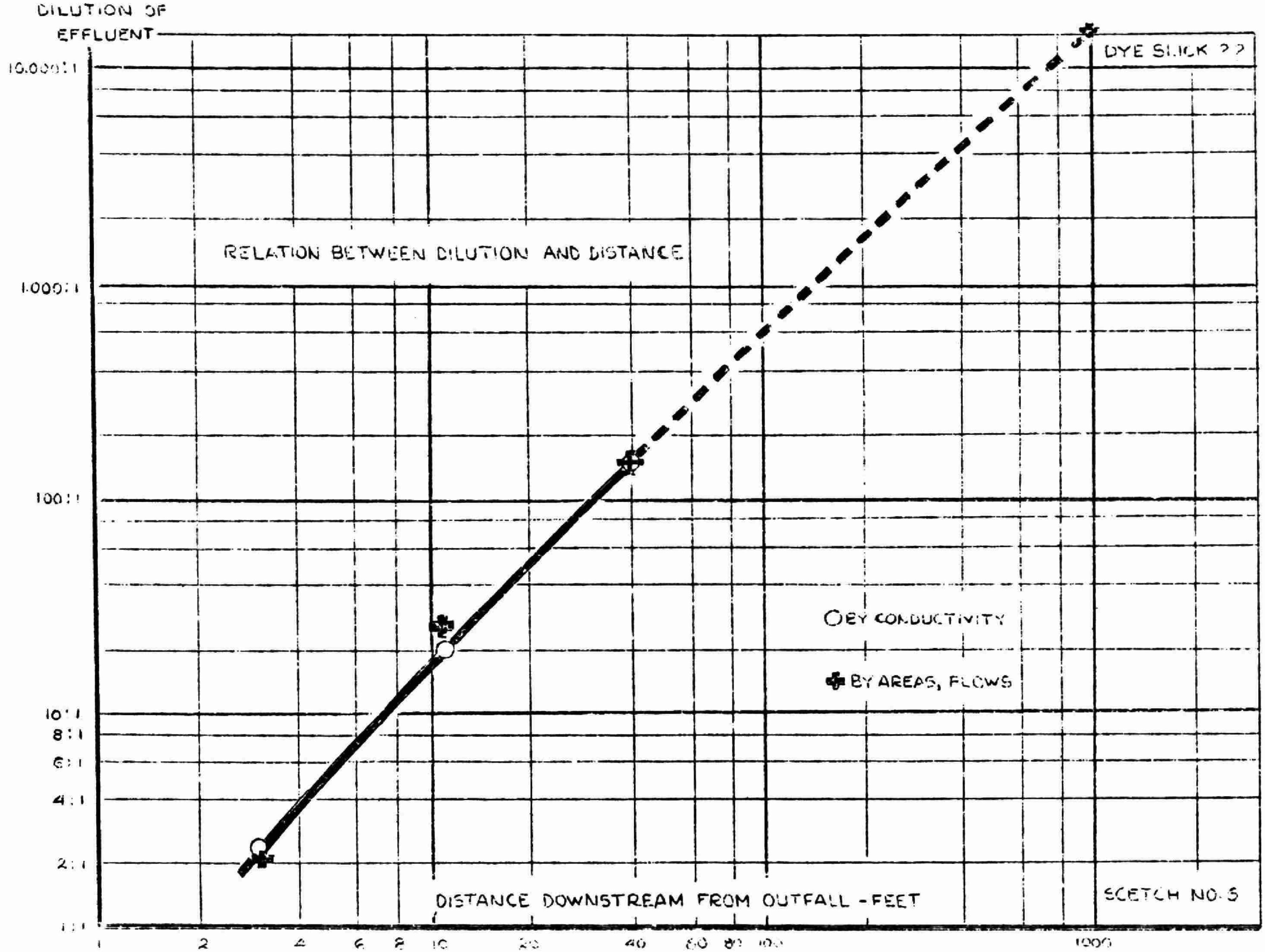
These points are plotted on Sketch No. 6 and the remarkably good agreement between the two techniques is evident.



SECTION 3' FROM OUTFALL
FROM OUTFALL
7.75'
2.85'
1.5'
20'
PLOT OF DILUTIONS
MEASURED FROM BARGE
USING CONDUCTIVITY METER
DILUTION
FEET ABOVE BOTTOM
FEET INSHORE OF ℄ TRACE
SCETCH NO. 4

- CTT -


HORIZONTAL AND VERTICAL SECTIONS
THROUGH VISIBLE EFFLUEN TRACE
EFFLUENT SPEED IN
LINE IS 4280 FT/HR.
PROJECTED AREA OF TEST SECTION
$= \frac{\pi}{4} \times \frac{18 \times 14}{144} = 1.38 \text{ FT}^2$
AREA OF TEST SECTION AT 10 FT
$= \frac{\pi}{4} \times 7.75 \times 2.85 = 17.3 \text{ FT}^2$
AREA OF TEST SECTION AT 40' POINT
$= \frac{\pi}{4} \times 20 \times 5.75 = 90.3 \text{ FT}^2$
BASE LINE
RIVER SPEED
= 2400 FT/HR.
INC. ANGLE - 13° ?
NOTE: ABOVE AREAS
ARE PROBABLY
ACCURATE TO ± 15 %
DEPRESSION FORMED
AND MOUND DEPOSITED BY EFFLUENT
RIVER BOTTOM (DEPTH - 46')
0
10
20
30
40
50
DISTANCE BELOW OUTFALL FEET
SCETCH NO. 5


DILUTION OF EFFLUENT
10,000:1
1,000:1
100:1
10:1
8:1
6:1
4:1
2:1
1:1
DYE SLICK ??
RELATION BETWEEN DILUTION AND DISTANCE
O BY CONDUCTIVITY
BY AREAS, FLOWS
DISTANCE DOWNSTREAM FROM OUTFALL - FEET
SCETCH NO. 5
1
2
4
6
8
10
20
40
60
80
100
1000

Extrapolation to the 100 ft. point (500;1) seems justified, and consideration of one of the closing incidents of the test may allow still wider extrapolation:- The No.2 boat, on picking up the base line downstream buoy, observed a dye slick in the water at the thousand foot point. If it is assumed that this was evidence that the effluent trace completely filled the river vertically at this point and the ratio of its long axis to its short axis remained constant, it can be calculated that the dilution at that point was in the order of 14,000:1. It is interesting to see that this point plots quite nicely on a continuation of the graph of dilution versus distance.

Discussion of Results.

The unusually high rate of dilution was completely unexpected. Perusal of all available existing information allowed an estimate before the test that dilution at the thousand foot point might lie somewhere between 18:1 and 5-:1. It was quite evident from the diver's comments that conditions for rapid mixing were optimum at this location in the river. It is thought that the high dilution rate can be linked with the absence of any temperature differential in the river as it is believed that this absence is fairly clear indication that the river water is intermixing completely from top to bottom under the flow conditions that exist.

TWO YEARS OF AIR POLLUTION SURVEY IN SARNIA

By

B. C. NEWBURY, B. Sc., A.R.I.C.

Research Fellow
Department of Chemistry
Ontario Research Foundation

Last year, two papers to this conference (1,2) outlined the history and organization of the Sarnia Project. Continuous data for a period of over two years are now available, and, while much remains to be done, especially with reference to the organic and minor pollutants in the air, it is possible to discuss a pattern for the major pollutants in the Sarnia basin and to compare these findings with data published for other cities. It is too early to assess the effects of changes made by local industry which has invested over four million dollars in pollution control devices during the short life of the investigation. During the two years under review, industrial production has increased and the weather patterns of the two years are far from identical. In fact, we have reliable evidence from other sources that the meteorological conditions alone resulted in significantly lower pollution levels in 1954 compared with 1953. Any reduction in pollution levels at Sarnia, therefore, during 1954 cannot at this stage be accredited to the work of the pollution Subcommittee although a simple addition of the amounts of pollution suppressed by various means leaves no doubt that without the efforts of the Subcommittee conditions would have been much worse.

Figure 1 is a general map of the Sarnia area showing the geographical distribution of the various areas - industrial, commercial and residential.

Figure 2 shows the location of sampling stations to which we shall refer from time to time during the discussion of our findings.

Dustfall

Dustfall is one of the most widely measured types of pollution mainly because of the simplicity of the equipment required. Almost any type of vessel can be (and has been) used

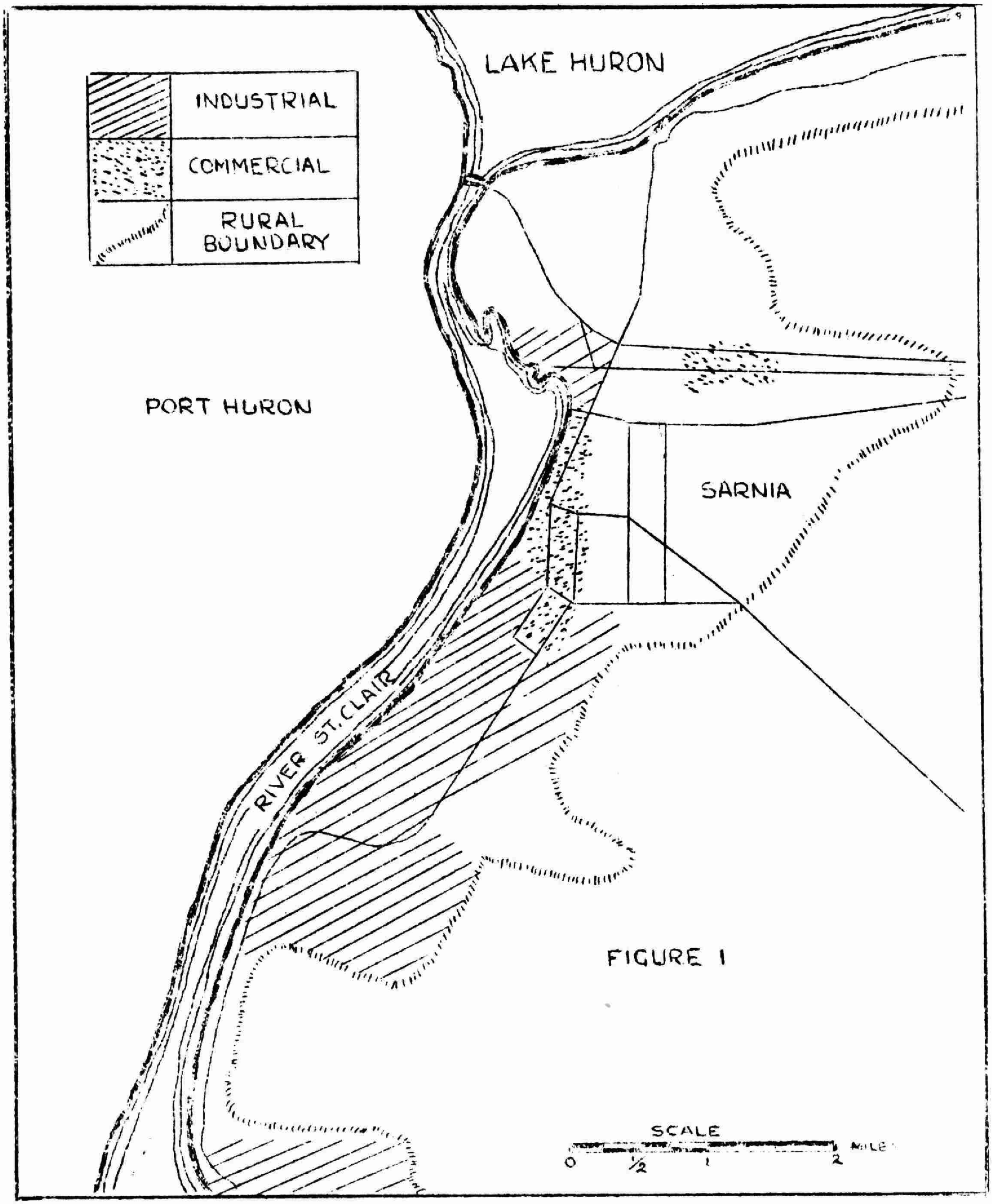

LAKE HURON
INDUSTRIAL
COMMERCIAL
RURAL BOUNDARY
PORT HURON
SARNIA
RIVER ST. CLAIR
SCALE
0 ½ 1 2

FIGURE 1

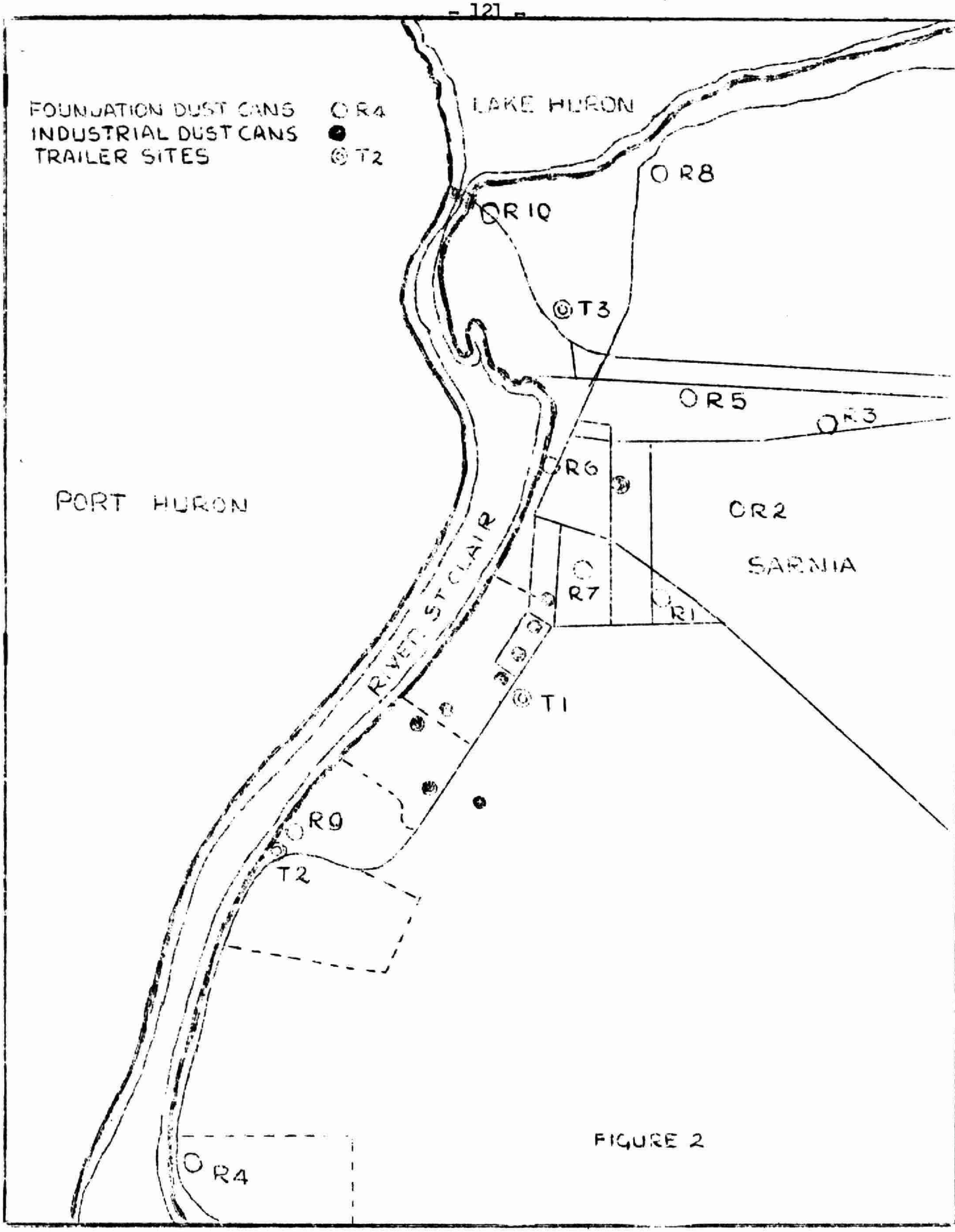

FOUNDATION DUST CANS
R4
INDUSTRIAL DUST CANS
TRAILER SITES
T2
LAKE HURON
R8
R10
T3
R5
R3
R6
PORT HURON
R2
RIVER ST CLAIR
SARNIA
R7
R1
T1
R9
T2
R4

FIGURE 2

to collect the falling dust, and no attempt at standardization or correlation of the results has been made. The data collected are thus only of value in comparing areas where similar equipment and similar techniques have been used. Although many of the data have been published, details of its collection are usually omitted and inter-city comparisons are meaningless. The collectors used at Sarnia are copies of a collector developed for the Detroit-Windsor Survey as a result of wind tunnel experiments and the Sarnia results are comparable with those published for Windsor and Detroit. In order to extend the usefulness of the data, parallel exposures of the Detroit Can and the Toronto Funnel Collector are being made at Sarnia and Toronto and a sample can has been sent to England, where it will be exposed alongside the English Collector. If it should prove possible to obtain reliable correlation factors, many more comparisons will become possible. At present, a limited number of results indicate that the Toronto Collector gives values which are less than 40% of the values obtained with the Detroit Can.

Figure 3 shows the distribution of dustfall over the Sarnia area for the two-year period. Plotting the two years separately, we find that the averages in the industrial area were 90 and 114 tons/square mile/ month for 1953 and 1954 respectively, while the commercial-residential area averages were 56 and 52 tons/square mile/month. It is assumed that differences in meteorological conditions must be responsible for the increase in the industrial area with a simultaneous decrease in the residential area.

The Isopleths in Figure 3 are drawn at 25-ton intervals but no significance should be attached to the choice of these intervals which are purely arbitrary. The industrial area is seen to vary from heavy to moderately heavy pollution, and the dustfall decreases steadily out towards Lake Huron and the London Road areas where dustfalls of less than 50 tons/square mile)month were recorded. The continuation of the 50-ton isopleth northwards to include Front and Christina Streets is an indication of well-defined local sources in this area. For comparison, Windsor is reported to have dustfalls of 69 tons in the business-residential areas, falling to 28 tons in the semi-rural residential areas.

The monthly variation of dustfall over the two-year period is shown in Figure 4. A feature of this curve is the spring peak which appears to be a common phenomenon for Ontario. Normally, there is a winter maximum due to the heating load in cold weather and a summer minimum, although the difference is less marked in areas using natural gas or oil heating than in areas using predominantly coal heating. Dividing the year into four 3-month seasons, we find the quarterly dustfall rates, starting with the December-February period, to be 30, 45, 34 and 32 tons respectively. The first period is the heating period, the second and fourth periods are periods of adverse weather conditions, while the river shipping is substantially

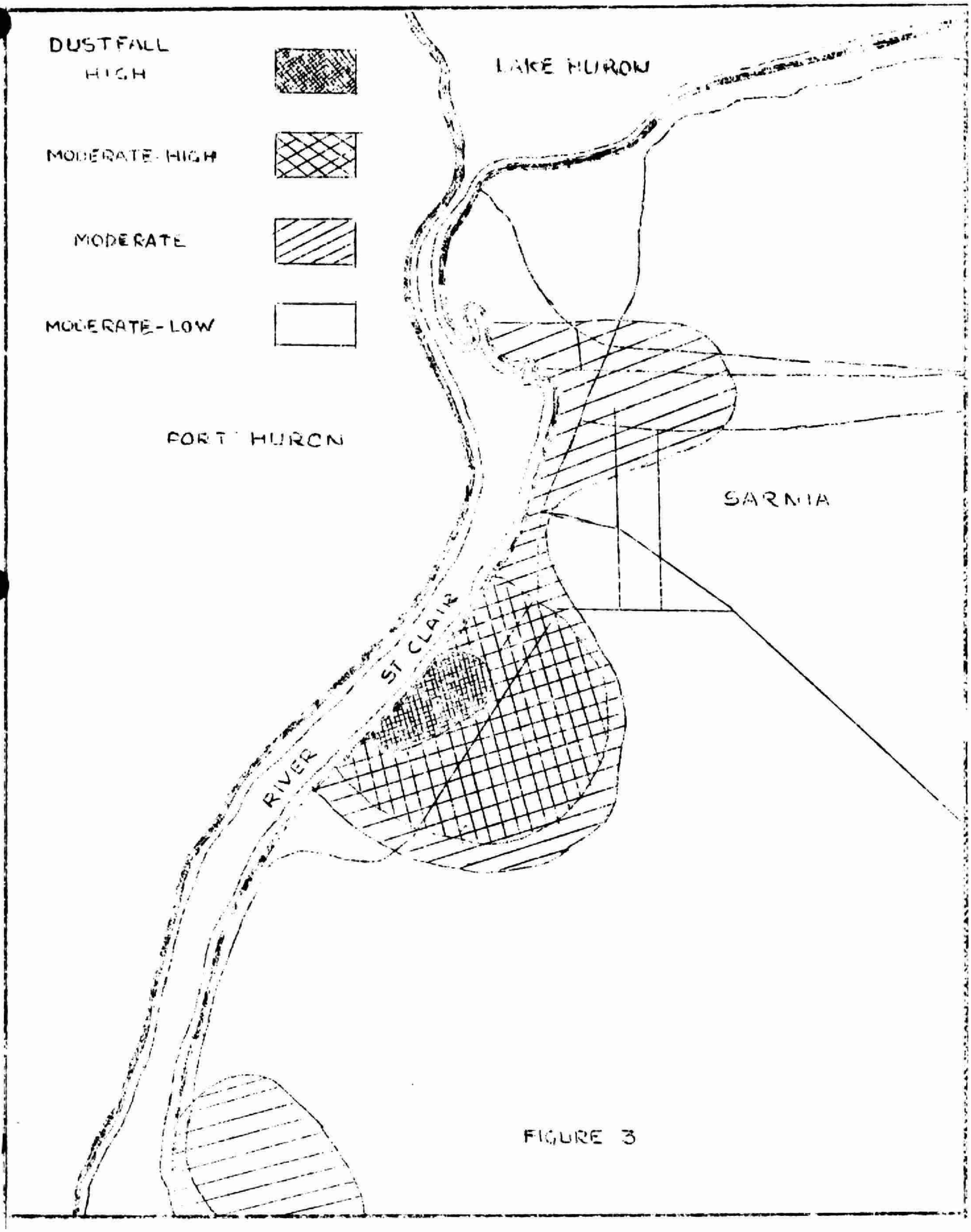

DUSTFALL
HIGH
MODERATE-HIGH
MODERATE
MODERATE-LOW
LAKE HURON
PORT HURON
SARNIA
RIVER ST CLAIR

FIGURE 3

ANNUAL VARIATION OF INSOLUBLE DUSTFALL

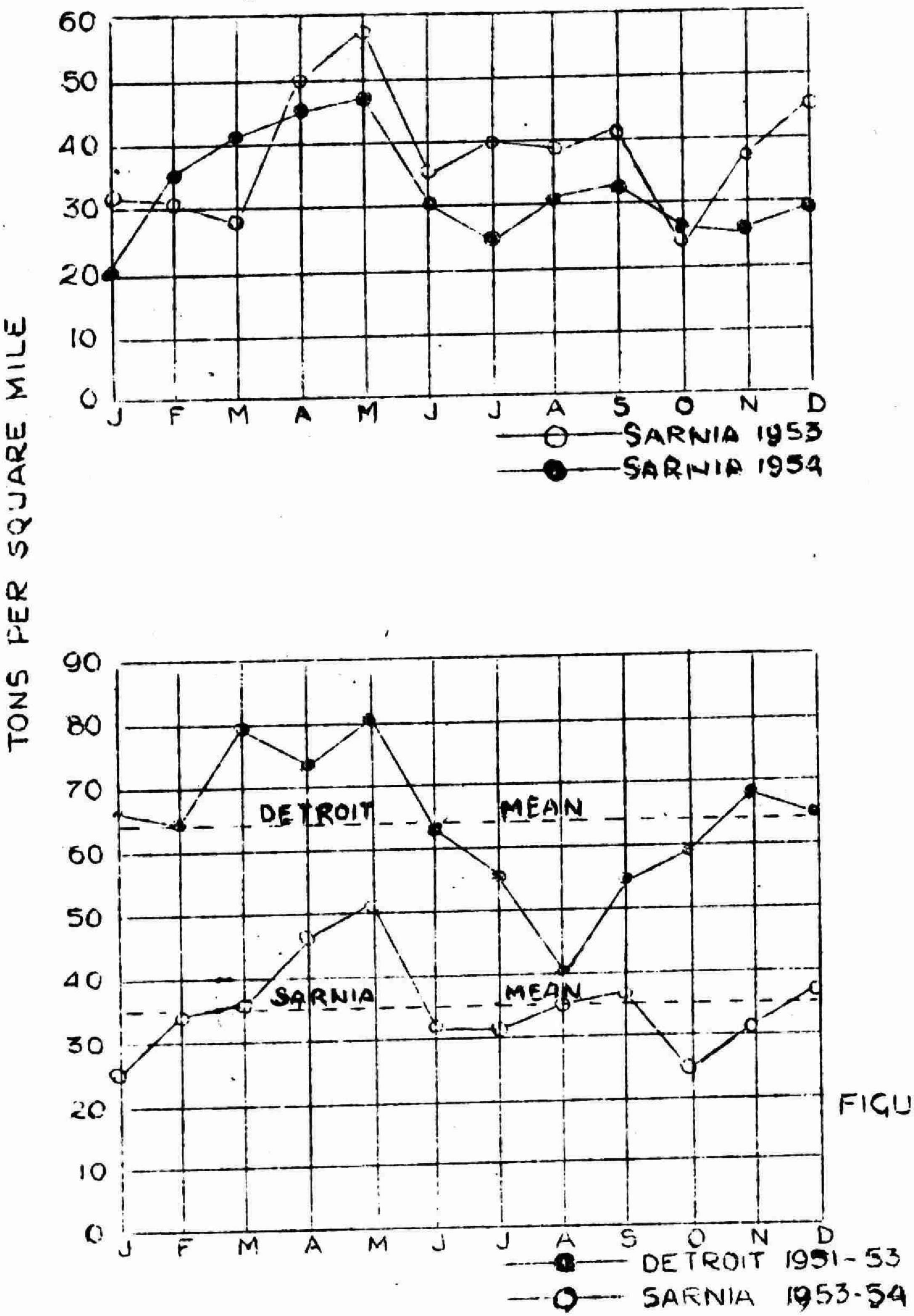


FIGURE 4

constant during the last three periods. There is at present no logical explanation of these observations although the same pattern has been observed at Windsor, Detroit and Toronto.

Analyses of the dust collected shows that the bulk of the deposit is mineral ash (15-30 tons), followed by combustible matter (6-20 tons), soluble materials (6-20 tons) and tars (1 ton or less). The mineral ash has been further analyzed and has been found to contain about 60% silica (9-18 tons/ square mile)month). Amongst the metals found were iron (14%), aluminium (4%), copper (2%) and lead ½%). Some samples were also found to contain fluorides and others cadmium. Further work on the fluoride, cadmium and lead is in hand.

Aerosols

Two methods have been used to measure the crosol concentrations in the Sarnia area. One unit samples the air at 60 c.f.m. for 24 hours and collects a sample large enough to be weighed and analyzed, while the other has a sampling rate of 2 c.f.m. and produces a stain on a filter paper which is assessed by photoelectric means. These methods are complementary and there is no theoretical basis for any correlation between their results. However, if the particle size distribution is constant, then there will be a correlation between the high volume weight readings (which responds mainly to the larger particles) and the low volume stain readings (which are most influenced by the sub-micron size particles). A fair degree of correlation has been found for Sarnia results so that we could, if necessary, convert data from one system to the other. However, the procedure introduces some error into the results.

High Volume Samples

The first high volume sample runs were made with the object of determining the effect, if any, of the start-up of a catalytic cracking unit. Runs before and after the start-up were found to have no significant difference, nor has any significant change been noted in subsequent runs. The average values recorded show that Sarnia has a relatively low level of aerosol pollution, lower in fact than any of the following: Baltimore, Cincinnati, Donora, and Windsor. Table 1 gives the published data for the above cities and for Sarnia.

TABLE 1

Aerosol Concentrations in Grams/Million Cubic Metres

	Down 'Town (Business Area)	Residential	City Limits
Baltimore	0.87	-	-
Cincinnati	-	0.28	-

Cont'd

	Down Town (Business Area)	Residential	City Limits
Donora	0.74	-	-
Windsor	0.21	0.15	0.08
Sarnia	0.15	0.08	0.05

It is of interest to note that during the lethal London Smog of 1952, averages of the order of 2.5 grams were recorded and that the peak concentration reach 4.4. grams/million cubic metres.

While these averages are fairly constant, it must be appreciated that the daily variations can be quite large due to the influence of meteorological conditions so that while the averages for the downtown area and city limits are 0.15 and 0.05 respectively, the downtown area can give readings between 0.46 and 0.03 while the city limits can give values up to 0.29. Obviously only long-term averages can reflect the trueconditions.

The objection to aerosols stems mainly from two properties. One is the soiling power - what the paint technician knows as "covering power" and the other is the ability of the particles to gain access to the lungs. In both cases, size is the predominant factor and while the high volume sampler is of value in determining the amount of matter in the air, another method, sensitive to the sub-micron particles is required to measure aerosols in terms of their effect on the general public. This is done by the Hemeon Sampler which draws a small volume of air through a filter paper, leaving a stain. This stain is then evaluated by the difference in loss of light transmission through the clean and exposed papers. The unit, the COH, is an unfamiliar unit to most people. It is the optical density of the stain produced by 1000 linear feet of air. The COH measurement is very sensitive to particles of the order of 0.1 micron, and hence measures the concentration of those particles which cause soiling of clothing, drapes and decorations, reduce visibility and may play a hitherto unsuspected part in the incidence of many lung diseases. Beaver (3), in his report to the British Parliament, gives statistical data showing that the 1952 death rate per 100,000 for England and Wales for bronchitis and pneumonia were: cities over 100,000 population-109, 50,000-100,000 population - 93; urban areas under 50,000 population - 84; rural areas - 68. It has also been shown that morbidity and mortality rates for respiratory diseases are higher in the northeastern areas of British cities than in the southern and westerly areas, and this may be a reflection of the high pollution levels due to the predominantly south-westerly winds. There is also a growing body of opinion that the incidence of lung cancer is affected by pollution and, while no medical survey is being made in Sarnia, the trend of the aerosol pollution is being watched with interest.

COH values for aerosols are only available at present for Pittsburgh, Pennsylvania (3.1) and Columbus, Ohio (3.0). Sarnia's values, ranging from 1.55 in the residential area to 0.56 at the city limits, confir m the cleanliness of the area.

Since the Hemeon Sampler gives a reading every two hours compared with every 24 hours for the High Volume Sampler, it is possible to evaluate the effect of meteorological variables on the aerosols.

Diurnal Variation

Under certain meteorological conditions, pollution tends to build up during the evening and study of the daily cycle of pollution will indicate whether high concentrations of smog are likely. Table 2 gives the average pollution levels throughout the day. It will be seen that there are two peaks, one at midnight and one around sunrise with a minimum at midday. However, since the peak values are less than twice the minimum value, the build-up of pollution is not serious and extensive periods of smog are not to be expected.

TABLE 2

Diurnal Variation of Aerosols (COH Units)

Time	0001/ 0200	0200/ 0400	0400/ 0600	0600/ 0800	0800/ 1000	1000/ 1200	1200/ 1400	1400/ 1600	1600/ 1800
COH Units	1.66	1.58	1.49	1.78	1.54	1.24	1.18	1.27	1-48

Time	1800/ 2000	2000/ 2200	2200/ 2400
COH Units	1.57	1.74	1.73

Effect of Wind Direction

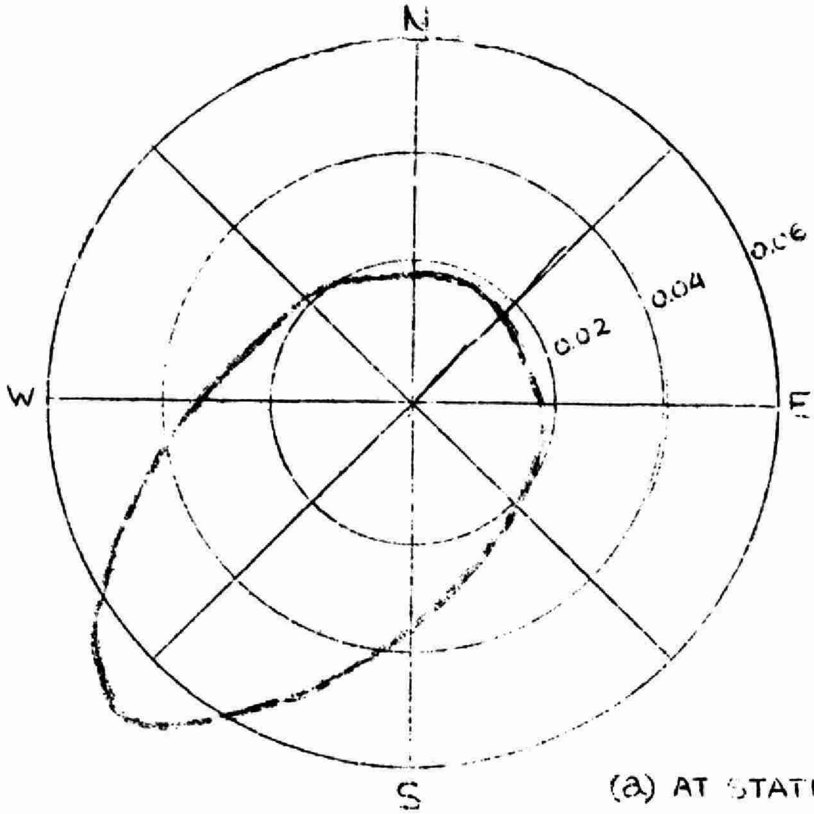
Winds from the southern quadrant are usually warm winds passing over relatively cool ground (4). Under these conditions, the lower strata of air become cooler than the higher levels so that convection and vertical mixing are retarded. Conversely, north winds are normally passing over relatively warm land whereby the lower layers become warmer and are carried aloft by convection. In this way, pollution is removed from the surface air. It is of interest to find out whether these mechanisms of stability and convection can influence the pollution levels over a city. For this purpose we have selected two stations R1 and T2 which are approximately equal distances from the centre of the high pollution area, one to the south and the other to the northeast. Taking average over a period to eliminate the influence of daily fluctuations, we find that a north wind comes in over Sarnia (at T3) with an average aerosol content of 0.43 COH units. Passing over the sources of pollution (including the commercial area), it reaches T2 with a pollution content of 0.63 COH units. This is the highest reading obtained for any wind direction at T2 except for a value of 0.95 COH units obtained during calm periods. The southwest wind approaches Sarnia with an initial reading of 0.53 COH units and, by the time it reaches R1, the value has risen to 2.76 units which is the average of 232 individual readings. Obviously the stability of the wind is a potent factor in determining its capacity to disperse pollution and the above data should be of great value in future town planning.

Sulphur Dioxide

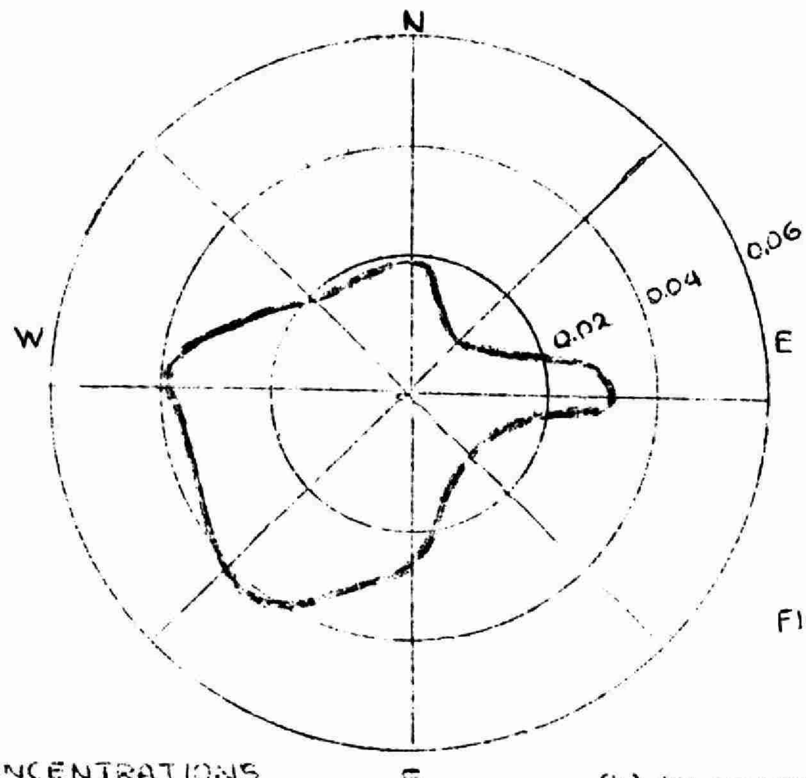
Sulphur dioxide is the commonest of the gaseous pollutants since it is produced by almost every combustion process. It can also be released in large quantities from chemical plants such as smelters and oil refineries. Furthermore, it is probably by far the commonest cause of vegetation damage. Plants of all kinds are damaged by SO_2 and some of the "leafy" plants such as lettuce, spinach and alfalfa can be damaged by a few hours exposure to concentrations well below 1 part per million. For this reason, continuous monitors of the sulphur dioxide in the atmosphere have been kept running during the past two years. The records show that the average concentration in the residential area is 0.03 parts per million which is between one-half to one-third of the comparable figures for Windsor, Cincinnati and Baltimore. However, gratifying though these results may be, the objection to sulphur dioxide lies more in the concentration-time relationship during the periods of fumigation. The limits of plant damage are not known precisely since investigations of plant response are affected by such variables as amount of sunlight, rate of plant growth and differences in plant feeding. The lowest concentration claimed to affect vegetation is 0.15 p.p.m. for an exposure of 8 hours. This, then, we have taken as our yard-stick, but on no occasion during the past two years has this danger point been exceeded in the residential area. Concentrations as high as 1.0 p.p.m. have been recorded momentarily and concentrations above 0.25 p.p.m. have been recorded but only for 10 minutes These concentrations and times are insufficient to cause visible damage to plants and it now appears probable that after the gas has blown away, plants are well able to assimilate these small amounts of sulphur and make a complete recovery.

While R1 was chosen because it seemed the logical place to expect the maximum pollution, it is useless for the purpose of estimating the contributions of individual sources of pollution. For this reason, site T2 was chosen for the trailer unit and polar diagrams have been constructed to show the average concentration of SO_2 with wind direction for both locations. Figure 5 indicates that at R1 most of the SO_2 is received from a southwesterly direction. At T2, however, the individual contributions of groups of industries to the north, E

EFFECT OF WIND DIRECTION ON MEAN SULPHUR DIOXIDE CONCENTRATION AT TWO LOCATIONS



(a) AT STATION R 1



(b) AT STATION T 2

FIGURE 5

(HOURLY MEAN CONCENTRATIONS OF SO_2 IN P.P.M).

west, southwest and east are clearly defined. You will see that the contribution of the Round House to the east is brought out very clearly. This figure, incidentally, is based on data collected in 1953 and we hope to repeat this experiment in the near future to determine whether the pattern has been changed significantly by the improvements made by the industries.

Hydrogen Sulphide

The Hemeon Sampler, which is used to evaluate the soiling properties of the aerosols can be used to record concentrations of hydrogen sulphide by removing the aerosols in a pre-filter and filtering the air through a lead acetate impregnated paper. Hydrogen sulphide is a relatively poisonous gas but seldom exists in the atmostphere in dangerous quantities except near certain industries, including petroleum refining. It has a very noticeable smell which can be detected at about 0.1 p.p.m. (100 parts per billion). At this concentration, it rapidly tarnishes silver and blackens lead paints. The minimum concentration detectable with our equipment is 1 part per billion and, during 2400 hours of observation, a concentration of 10 p.p.b. was recorded for 6 hours only. The maximum concentration was 70 p.p.b. recorded on a still calm night in July 1954. A breakdown by wind direction shows that positive results, which were obtained for about 20% of the sampling time, occur with all wind directions except east. There must be, therefore, a number of sources spread over the industrial area, and even if it is decided to attempt to reduce the sulphide pollution, no single change is likely to change the conditions appreciably.

Shipping

The St. Clair and Detroit Rivers are reputed to carry the heaviest water-borne traffic in the world. Even to the casual observers, the smoke produced by these vessels seems worthy of attention, so, during last summer, observations were made of all the ships passing Sarnia during two 2-hour periods daily. The periods of observation were dictated by the normal shift work of the observers who undertook the 2-hour periods during their spare time. The periodswere distributed over sixteen hours of daylight and there is no evidence of any bias in the results. In all, 426 observations were made, logging the Ringelmann Number of the smoke and the name of the vessel, and from the data the following conclusions were drawn.

1. Taking Ringelmann Number 2 as the maximum pollution desirable, the smoke was logged as Ringelmann No. 2 or less for 44% of all transits. A breakdown according to firing methods shows that for oil-fired vessels 89% of the transits were satisfactory, for stoker-fired vessel 58% and for hand-fired vessels only 20% were satisfactory.

2. It is agreed that continuous operation at Ringelmann No. 2 is impossible and that hand-fired boilers will make more smoke than other types. On this basis, the International Joint

Commission has laid down objectives for the three classes of firing and we find that 45% of all the ships on the St. Clair river fail to meet these objectives, the worst offenders being the hand-fired vessels (56%), followed by stoker-fired (42%), and the best behaved, the oil-fired vessels (26%).

3. Although the current under the Blue Water Bridge is 6 knots, and it had been claimed that ships would be sailing under full steam against the current, there is no evidence that ships proceeding upstream make more smoke than ships sailing with the current.

At present, a high percentage of the ships in these waters are obsolete and no modernization is contemplated since the shipping companies propose to lay down new vessels soon to take advantage of the St. Lawrence Seaway. The only improvement to be expected for some time therefore, is that resulting from improved control by the firemen. Windsor and Detroit have shown that the percentage of transits giving Ringelmann No. 3 or over can be reduced from 55% to 35% by constant pressure on the operators, and it is hoped to make a similar improvement in Sarnia. It has not been possible to assess the contribution of the ships to the pollution measured at Sarnia and it may be that the contribution is not significant. There is, no doubt, however, of the psychological effect of dense black smoke billowing from passing ships on the public's willingness to cooperate to clean up the city.

Other Aspects

During the course of our analyses, we have confirmed the presence of fluorides, lead and cadmium. These are all potentially dangerous pollutants. While the amounts found give no cause for alarm - they can be identified in trace amounts in most places - further work is proceeding on the concentration, distribution and origin of these compounds in order to be forewarned of any approach to physiologically significant concentrations. We are also preparing to assess the nature and amount of hydrocarbons in the atmosphere in Sarnia. Air pollution damage to vegetation is spreading rapidly around the large cities of the world and there is evidence pointing to the use of oil and gasoline fuels as being the cause. Whether these hydrocarbons need to undergo pyrolysis in an engine is not known and therefore the effect of normal unavoidable refinery and petrochemical losses is unknown. Much work remains to be done on this subject.

Conclusion

Our results so far show that Sarnia is relatively clean for an industrial city. Its pollution levels are probably only 30-50% of those of such cities as Pittsburg, Columbus, Windsor and Baltimore. The expenditure of several million dollars by the industry of Sarnia to install and operate pollution-preventing devices is proof of their intention to maintain and, if possible, improve existing conditions. Only by this means can the Chemical Valley continue to expand and prosper without spoiling the living conditions of those who work in the factories. Pollution is an insidious disease and needs constant attention. It grows imperceptibly until one day comes disaster - a disaster such as befell London in December 1952 and prompted Guy Murchie (5) to write:

> "..... By the third day, old people with asthma or bronchitis began to get frightened, and oxygen tents were in great demand. Blondes were turning into brunettes. An Airplane that managed to make an instrument landing at Croydon got lost between the runway and the ramp. Blind men were helping as street guides in the city, firemen groped in front of their engines, while dock police were busy trying to rescue those who had walked off wharves into the thames and could be heard calling and blubbering hopelessly somewhere in the filmy water. People in theaters could not see the stage from the sixth row and projected moving pictures could not penetrate to the screens. Sounds of choking could be heard everywhere, mingled with distant church bells and the muffled clanging of ambulances. The whole city seemed to be suspended in the sky, floating in a cloud-cool, dank, inviolate."

REFERENCES

(1) A. D. McRae. First Industrial Waste Conference, 1954, p. 1

(2) B.C. Newbury. First Industrial Waste Conference, 1954, p. 80

(3) Sir Hugh Beaver. Committee on Air Pollution Report. H.M.S.O. Cmd. 9322, p. 9

(4) B.C. Newbury. Meteorology and Air Pollution. To be published

(5) Guy Murchie. "Song of the Sky". Houghton Mifflin Company, New York, 1954

CONTINUOUS CULTURE OF SACCHAROMYCES FRAGILIS

By

STEIN S. HEGBOM

Ontario Research Foundation.
Toronto, Ontario

A problem which has been of interest to the dairy industry for a long time is the possibility of a more effective utilization of cheese whey. Although it is of rather low nutritional value both to human beings and animals, the producer usually takes back most of it for a low value livestock feed. During the peak season, however, the farmers do not require quite all the whey for animal feed and so other means of disposal must be found.

The Department of Public Health objects strenuously to the practice of dumping whey in streams and so, in some cases, the excess whey has caused an increase in disposal costs due to increased sewage capacities.

A great deal of research into the economic utilization of cheese whey has been done and some processes have been developed, such as the production of lactose, whey powder, etc. However, from the point of view of most cheese factories whey is still a waste product, as the market demand for these products is rather limited.

For these factories, therefore, the development of economic processes the products of which are in demand on the market, is highly desirable.

A consideration of the chemical composition of the whey, being rich in amino-nitrogen, lactose, vitamins and other growth-factors, immediately suggests microbial transformation of the constituents into stable and useful products.

This approach opens a wide variety of possibilities ranging from the manufacture of vitamins, etc. to the production of protein.

The work on cheese whey performed at the Ontario Research Foundation deals with the latter aspect, by continuous production of fodder yeast. This product would eventually be used to enrich low grade animal feeds, both with respect to protein, and vitamin-content.

The kineticd of yeast growth conforms at least over quite a large range to well-defined mathematical laws, a fact which is extremely useful in the elucidation of the conditions to be employed in continuous production.

For a better understanding of the principles of continuous biological oxidations, yeast growth in a batch culture and its kinetics will be briefly dicussed.

Fig. 1 illustrates a typical graph obtained for yeast growth in a batch culture. The 3 dotted lines divide the graph into 4 parts. During the first period which, for obvious reasons is called the lag phase, the yeast level for a time falls below the value at which it was seeded. Then growth slowly commences. The rate of growth changes rapidly, until all the cells are in a state of constant division. At this point the graph moves into the log phase -- so called because the growth is exponential. Beyond the log phase is the transition phase in which the over-all rate of growth slows down. Hence the graph falls rapidly off towards the stationary phase in which hardly any growth occurs and the graph becomes horizontal.

Continuous culture is a further development of batch growth. In this work the commencement of the process is actuallly batch-wise, and so experiments that elucidate yeast levels and rates of growth are of major importance.

For various reasons the part of the graph that is of most interest for a continuous process is the linear portion, which enables the theoretical maximal flow under continuous conditions to be calculated.

As already has been mentioned, in the log phase, the organisms are in a steady state of reproduction, and so the rate of increase of mass is proportional to the instantaneous mass.

Thus:

$$\frac{dm}{dt} = km$$

K = growth constant

m = mass/litre (dry wt.)

t = time

Integrating: $\ln m = kt + \ln m_o$

i.e : $m = m_o e^{kt}$ --------- (i)

In this state of binary fission the multiplication can also be represented by the equation:

$m = m_o 2^{t/g}$ ------------ (ii)

where g = regeneration time of the organism (in hours), i.e., the time taken for the concentration of cells to double itself.

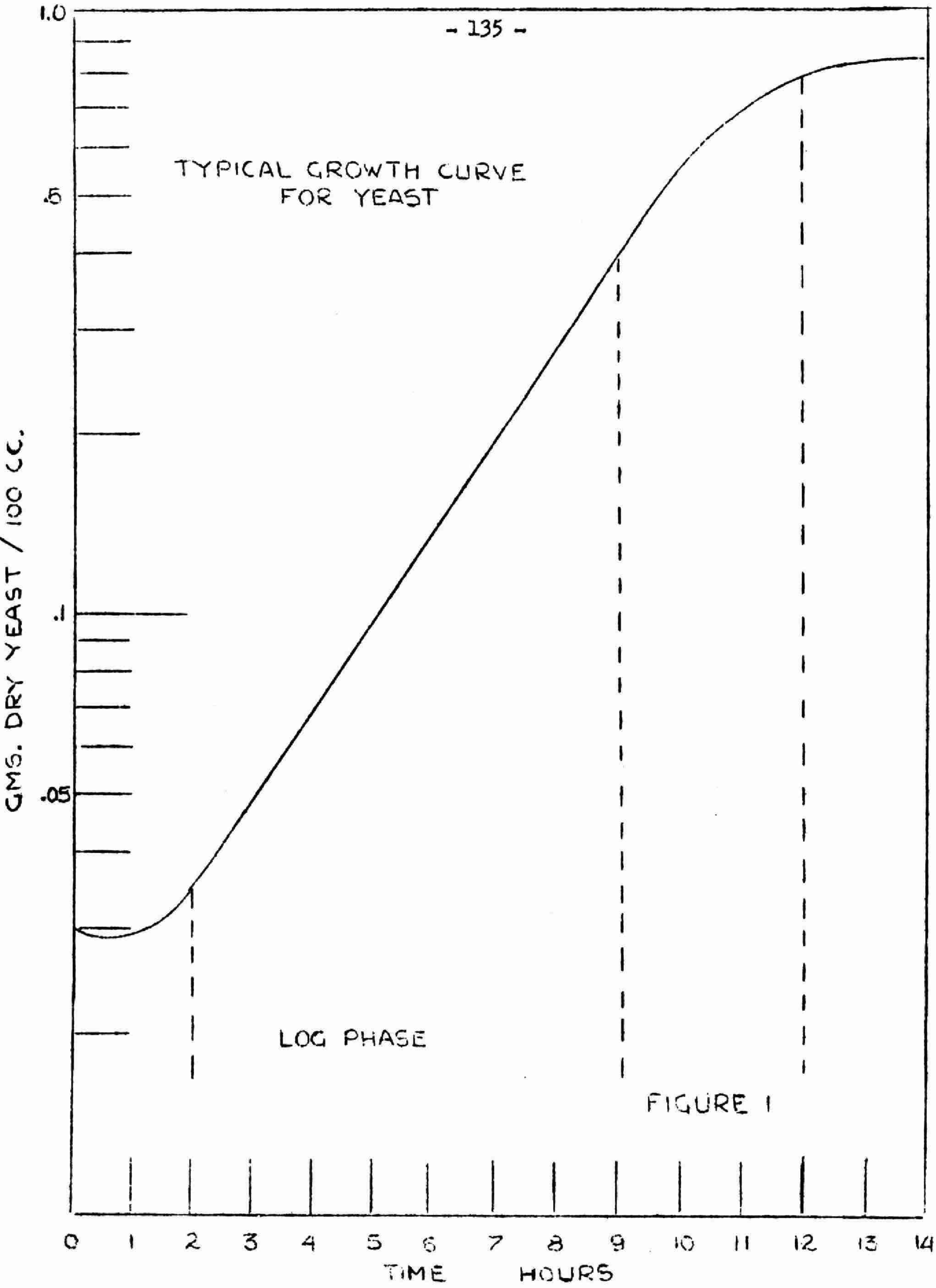

TYPICAL GROWTH CURVE
FOR YEAST
GMS. DRY YEAST / 100 CC.
1.0
.5
.1
.05
LOG PHASE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME HOURS

FIGURE 1

Equating (i) and (ii): $k = \frac{\ln 2}{g}$ -------(iii)

If we have a fermenter of effective volume V litres, then, under conditions of continuous flow at a rate of R litres/hour, the rate of change of population at any time may be represented as:

$$\frac{dm}{dt} = km - \frac{R}{V}m \text{ ------------(iv)}$$

If flow is adjusted to the maximal theoretical rate, there is no resultant change of mass in the fermenter.

i.e.: $\frac{dm}{dt} = 0$

Then: $k = \frac{R}{V}$ -----------(v)

Using equation (iii): $R = \frac{\ln 2}{g} \times V$ ---------(vi)

The factor $\frac{V}{R}$ is often denoted H = hold-up time and represents the time taken, at no change of population, to pass through the fermenter a volume of medium equivalent to the working volume of the fermenter.

Thus the interrelation between rate of growth and hold-up time by equation (v) becomes:

$$K = \frac{1}{H}$$

In this work equation (vi) has been used most frequently, not only because it comprises both the interrelated quantities R and V, but also because of it simplicity. V is a pre-determined, constant factor and g can be measured directly from a standard batch-graph. Another advantage of this approach is that the maximal yeast-level, which must be attained for maximal efficiency of the fermenter, can be obtained without much difficulty.

Another mathematical approach in this respect is offered by the integrated form of equation (iv):

$$m = m_0 e^{\frac{(kV - R)t}{V}}$$

or: $\frac{m}{m_0} = e^{\frac{(kV - R)t}{V}}$ (vii)

This equation is advantageous over equation (vi) in that it, at least to some extent, indicates what happens at different values of R.

It is readily seen that if $k < \frac{R}{V}$

Then $$e^{\frac{(kV - R)t}{V}} = < 1$$

and so $m < m_o$

and so, in the course of time, the concentration in the tank will fall to an infinitesimally low value.

On the other hand, if $K > \frac{R}{V}$ then

$$e^{\frac{(kV - R)t}{V}} = > 1$$

and so $m > m_o$

This means theoretically that at sub-maximal rates of flow a stable equilibrium will be set up, which is desirable.

$k = \frac{R}{V}$ would be the ideal state of affairs, but although the rate of flow can be adjusted fairly closely to fit this condition, experimental errors are appreciable and so, in order to obtain a stable equilibrium in the fermenter, the general view is that R should be somewhat lower than the theoretical maximal value.

For a commercial process it is important that the process be as efficient as possible, i.e. that the daily output with the available equipment be maximum. It is also important that the organisms utilize the nutrients efficiently and completely.

Some points to note in this connection are:

(1) High working volume relative to the total volume of the fermenter.
(2) High concentration of organisms in the effluent.
(3) High rate of growth
(4) High efficiency in the utilization of the nutrients of the medium
(5) Inexpensive and plentiful raw material, to which as little nutrients as possible have to be added
(6) The process must be continuous over a long period of time.

For continuous propagation of Saccharomyces fragilis on cheese whey these points are answered as follow:

Theoretically (1), (2) and (3) should be as high as possible in order to give the highest output with the available fermenter space. But in practice a compromise must be found for they are all tied up with each other, in such a way that they cannot all be maximal at the same time.

Thus, the higher the concentration of yeast cells in the overflow, the richer must the feed-medium be with respect to nutrients. The more concentrated the feed-whey is, the stronger is the tendency for frothing, and so the effective volume of the fermenter decreases. Also, it is found that at a high concentration of cells the rate of growth of the organism is lower than at a low yeast-level.

Considering each point separately:

(1) Milk whey containing 4% lactose may support the growth of up to 24 gms. of yeast (dry wt.)/litre. However, aeration of this concentrated solution produces very heavy frothing. In fact, German workers found the foam-pad so extraordinarily heavy that they could maintain 1/3 useful volume only, even though antifoam agents were added.

However, on diluting the whey, i.e. when working at lower yeast levels, the frothing decreases rapidly. In our experiments the whey has been diluted to 5-6 times its original volume with water. In some of these experiments we have had a working capacity of 4/5 of the total volume of the fermenter, with only small, periodic additions of lard oil as antifoam. This value would probably be too high for a large scale fermenter, but a value of 3/5 - 3/4 appears very reasonable.

Thus the effective volume is doubled relative to the case where the undiluted whey is used, the advantage of which is obvious.

(2) The rate of growth has been found to be affected in the main by three factors only.

Temperature, of course, has a great effect in this respect. For a Saccharomyces the optimum temperature is normally ca. 30°C. However, with S. Fragilis it is found that an increase in temperature of 7-8°C. is very beneficial.

This fact is well illustrated by Fig. 11 which shows that such a raise in temperature decreases the regeneration time by 1/2 hour. At the same time it is seen that a variation of pH over as wide a range as 2 pH-units has no effect on the rate of growth. Also as regards other environmental factors the growth rate of this yeast is remarkably independent.

The second factor involved in determining the rate of growth is the actual condition and amount of the seed yeast.

This fact is illustrated by Fig. 111 which shows the interrelation between rate of growth and rate of seeding in such a way that the rate of growth is decreased as the rate of seeding is increased. Also, the seed-yeast must be in a healthy condition, otherwise the rate of growth is slowed down.

The exact nature of the third factor is unknown. All we know is that it is some growth factor found in CSL.

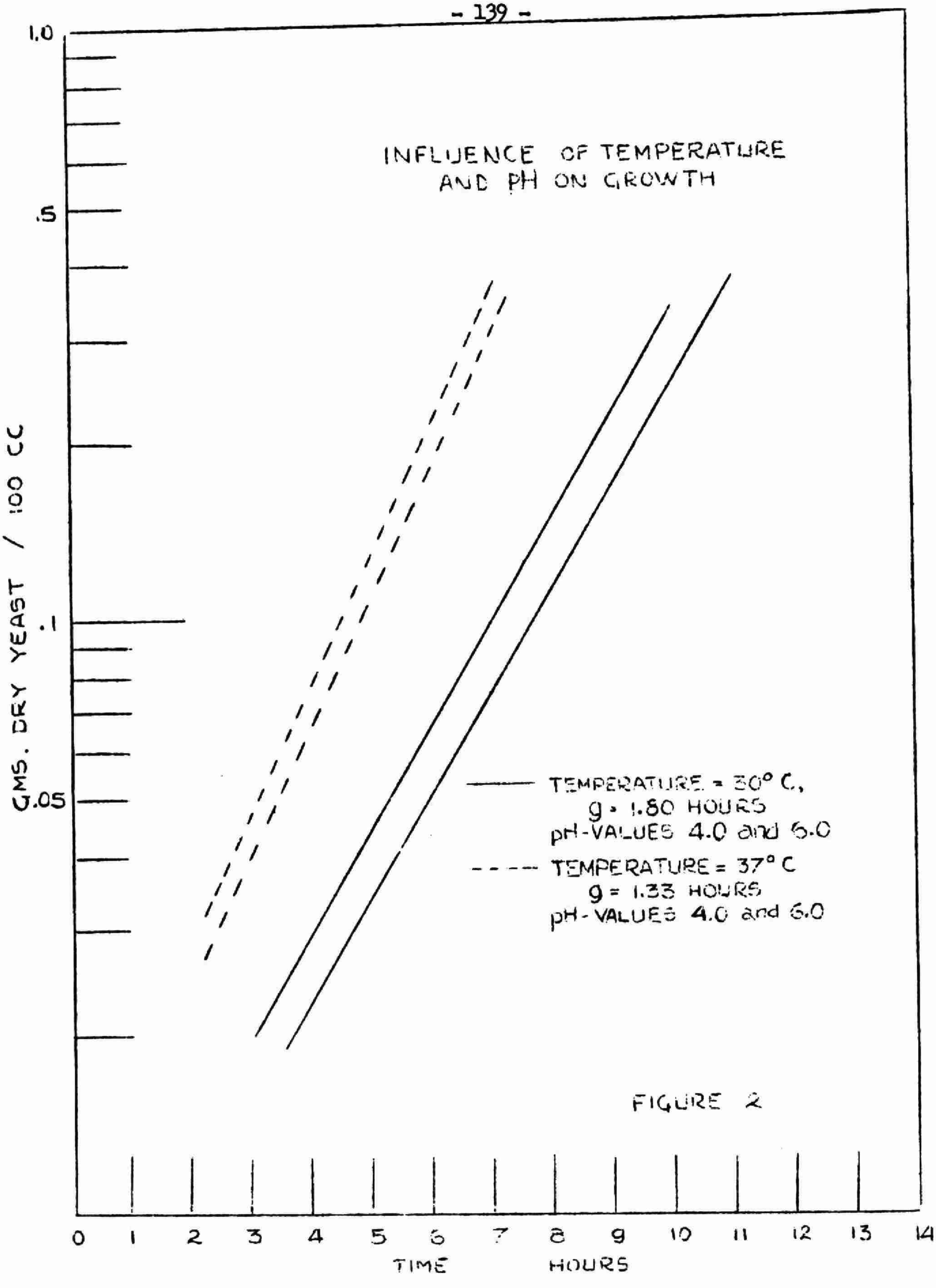

INFLUENCE OF TEMPERATURE
AND pH ON GROWTH
GMS. DRY YEAST / 100 CC
1.0
.5
.1
.05
TEMPERATURE = 30° C,
g = 1.80 HOURS
pH-VALUES 4.0 and 6.0
TEMPERATURE = 37° C
g = 1.33 HOURS
pH-VALUES 4.0 and 6.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
TIME HOURS

FIGURE 2

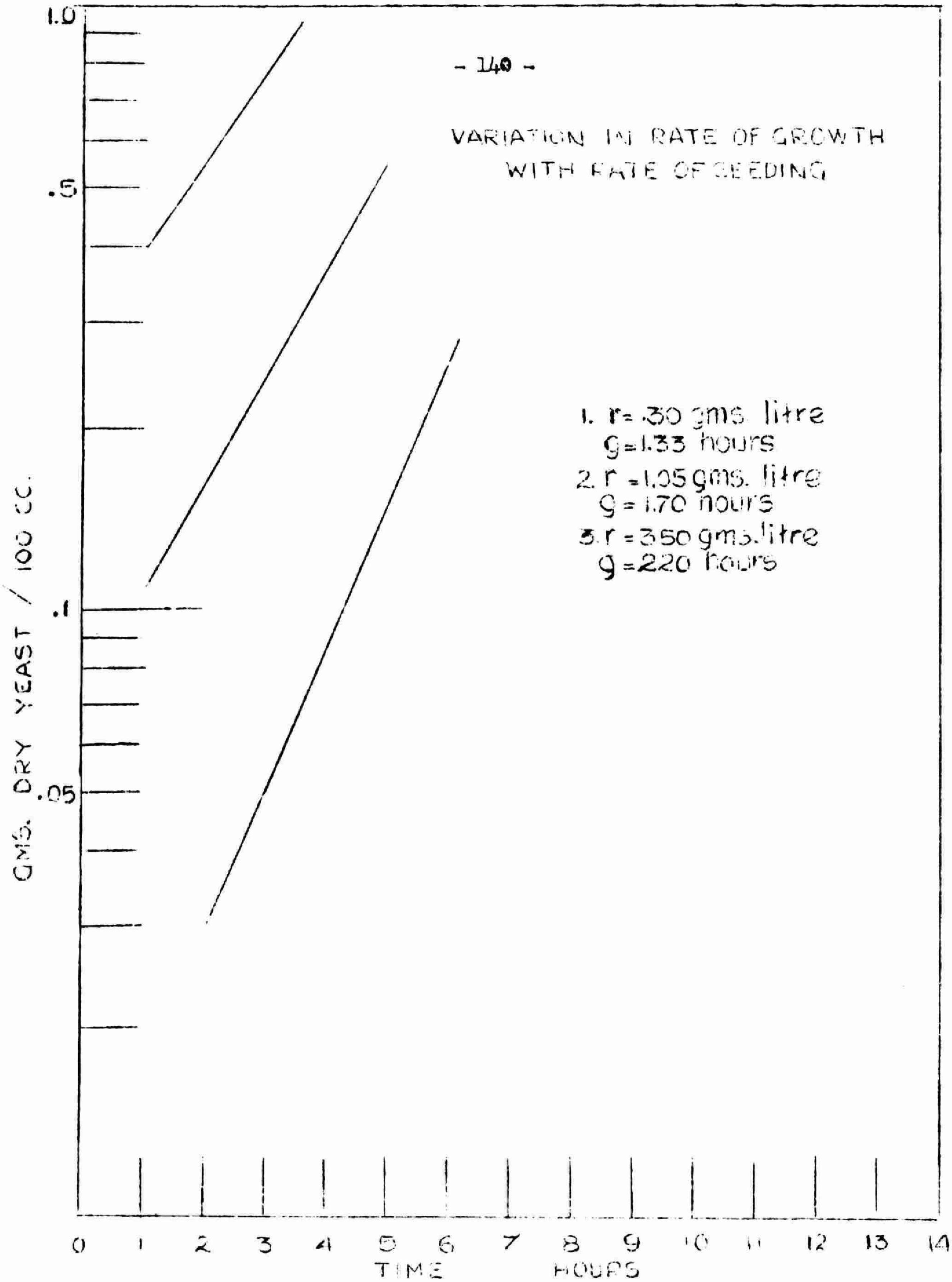

VARIATION IN RATE OF GROWTH
WITH RATE OF SEEDING
1. r= .30 gms. litre
g=1.33 hours
2. r =1.05 gms. litre
g = 1.70 hours
3. r =3.50 gms. litre
g =2.20 hours
GMS. DRY YEAST / 100 CC.
1.0
.5
.1
.05
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME HOURS

FIGURE 3

As indicated on Fig.lV, addition of 1/2% of CSL to the dilute whey decreases the regeneration time nearly by another 15 minutes.

At a dilution of the whey of 1:4, a temperature of 37° - 38°C. and with the addition of 1/2% CSL, the regeneration time is 1.1 hours when the rate of seeding is .3 gms. of yeast (dry weight)/litre. This rate of growth is extremely high, almost approaching that of bacteria. It corresponds to a hold-up period of 1.60 - 1.75 hours, and so in 24 hours a volume of dilute medium corresponding to ca. 14 times the working volume of the tank, can be fermented.

(3) Under conditions of maximal rate of growth and flow the yeast level to be expected is 3 gms. of dry yeast/litre of medium. In addition to this comes ca. 4-5 gms. of lactalbumin/litre of undiluted whey, which should be heat precipitated and separated before the fermentation stage.

It may be possible -- at least theoretically -- to maintain a somewhat higher level in the fermenter by decreasing the rate of flow, but there is some indication that this is not so, and that we run into the phenomenon of cycling, which is a steady fluctuation between an upper and a lower yeast-level. If so, the average yeast output will be lower than at near-maximal rates of flow. Also, the protein content of the yeast, normally 53-55% decreases to < 50% beyond the exponential phase. So on the whole it seems best to work in the exponential phase. In all this work considerations are based on a level of 3 gms. dry yeast/litre.

(4) The efficiency on the nutrients should be as high as possible and is in fact very good. The factors under consideration are lactose (i.e. whey), phosphates, nitrogen, magnesium and CSL.

Lactose, both a source of energy and cell matter, is most important in this respect. It is completely assimilated under conditions of continuous flow if its concentration in the feed is lower than corresponding to an efficiency of 33% on the dry yeast produced. This value is very low, but economizing with the carbohydrate can be induced by decreasing the concentration of sugar in the feed. Under such conditions the yeast level remains constant while the efficiency on the lactose utilized increases. In this way efficiencies of over 52% (dry yeast wt./wt. lactose) have been recorded and even higher %-age values can probably be obtained.

Acids such as lactic acid, which are present, do not seem to be of much importance, as it appears that the yeast preferentially assimilates the lactose completely. Only then does it utilize the acids. The rate at which it does so seems to be lower than for lactose, and so they are of little interest as nutrients.

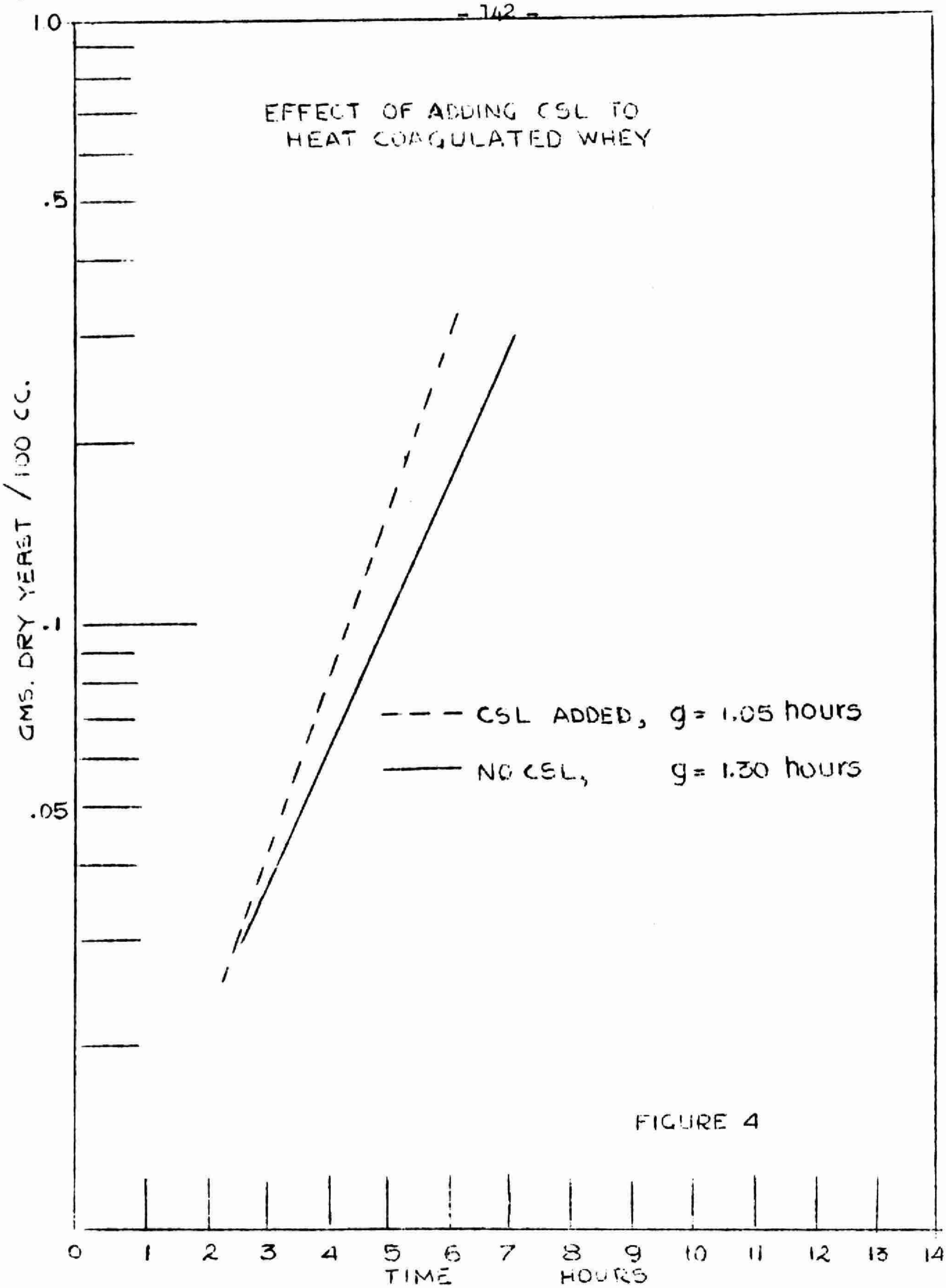

EFFECT OF ADDING CSL TO
HEAT COAGULATED WHEY
GMS. DRY YEAST /100 CC.
1.0
.5
.1
.05
CSL ADDED, g = 1.05 hours
NO CSL, g = 1.30 hours
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME HOURS

FIGURE 4

Nitrogen will be supplied either as $(NH_4)_2SO_4$ or as urea. At the yeast level chosen the former source of nitrogen does not result in a decrease in pH that necessitates a regulation of pH, a fact that simplifies operation considerably. In fact, under continuous conditions the pH-value remains at or near 4.7 which is an ideal value.

The whey-CSL medium contains nitrogen in available form. Under the desired conditions it supplies ca. 60% of the nitrogen assimilated by the yeast. Nitrogen added in the form of $(NH_4)_2SO_4$ is utilized immediately and completely, and a favourable point is that if it should be in short supply for some reason, the yeast level is not affected, but the protein-content of the yeast decreases.

Under the desired conditions 0.15 lbs. of $(NH_4)_2SO_4$ must be added/lb. of yeast (dry wt.) produced to give a protein content of 53-55%.

At the low yeast-level used the medium contains enough Mg and P, and so no expense is required for these nutrients.

The amount of CSL to be added must be fixed arbitrarily. In our experiments 0.5% has been added, but this is in excess of the required amount.

An interesting nutritional point is the fact that abnormal growth can be induced by using a feed deficient either in phosphorus or in nitrogen. The cells are definitely morphological variants and no infection. Their appearance is that of elongated pseudo mycelial cells, joined together like strings of sausages. The change into the abnormal form takes place rapidly and almost completely. Reversion to the normal parental form takes place on sub-cultering in a rich medium.

So far attempts at inducing this condition in a whey-medium have been unsuccessful, as it is rich in N and P. However, such a state would be highly desirable as both rate of growth and yeast level increase in this condition.

(5) Whey satisfies the condition that it is inexpensive, and the cost of raw materials to be added will be l w. Only $(NH_4)_2SO_4$, CSL and antifroth agent in small quantities are required in this respect. The total amount of raw material is plentiful. However, it is distributed between many cheese factories, and the daily amount available at each of them is small. Thus, during the flush season only 10-30,000 lbs. of whey, averaging ca. 20,000 lbs., are produced at each factory. This amount is low for an economically satisfactory method.

(6) We have had the process working continuously for a period of time exceeding 4 days. The process was working well at the end of this period, and, although no definite statement

about prolonged growth can be made, there seems to be no reason why it should discontinue.

Some data are available for comparison with the expected results for this method: C.O. Reiser suggests a method for continuous production of Torula yeast from starch wastes. A 46,000 gal. fermenter, at a hold-up time of 4 hours, would produce 9,100 lbs. of dry yeast/day.

J. Demmler and co-workers tried to produce fodder-yeast from whey by a continuous method, using different yeasts, S. fragilis excepted, but were unable to maintain the yeast-level, which after an unspecified time fell to 1/2 - 1/3 of the desired level. Scaling their maximal results to fit a 46,000 gal. fermenter, their daily output would be ca. 9,200 lbs.

Our daily output from the same fermenter would be 14,500 lbs. based on 3/4 useful volume of fermenter, 3 gms. dry yeast/litre in overflow, and a hold-up time of 1 3/4 hours. This gives a 60% more efficient utilization of the fermenter.

Summing up, the advantages of this method are as follows:

1. Relatively small fermenter space required.
2. High %-age yield of yeast at high protein-content on the nutrients.
3. Cheap raw-materials.
4. Simple operation.
5. Continuity of method.
6. High rate of growth.

Two disadvantages are:

1. Dilute medium.
2. Small quantities of whey available at each cheese factory.

References

(a) Agr. & Food Chem. Vol. 2, 2, Jan. 20, 1954.

(b) Die Milchwissenschaff, Heft 1, Jan. 1950.

PROBLEMS IN THE UTILIZATION OF MUNICIPAL WASTE

* BY *

L. A. CAMPBELL

RESEARCH FOUNDATION

TORONTO, ONTARIO.

SOME TIME AGO MR. HAROLD D. BRADLEY, THE STREET COMMISSIONER FOR THE CITY OF TORONTO, RETAINED THE SERVICES OF THE ONTARIO RESEARCH FOUNDATION, TO A LIMITED EXTENT, TO EXAMINE THE POSSIBILITIES OF UTILIZINE OR UP-GRADING THE VAST AMOUNT OF WASTE MATERIAL WHICH THE DEPARTMENT OF STREET CLEANING COLLECTS DAY BY DAY.

I DO NOT WISH TO INFER BY THIS THAT GOOD USE HAS NOT BEEN MADE OF MUNICIPAL WASTE IN THE PAST. ON THE CONTRARY, THE PRACTICE OF SANITARY LAND FILLING WITH REFUSE AND THE ASHES OF REFUSE, TO RECLAIM UNDESIRABLE TOPOGRAPHY BY TRANSFORMING IT INTO USABLE LAND HAS BEEN WIDELY USED IN TORONTO IN THE PAST WITH VERY PROFITABLE RESULTS BECAUSE THIS RECLAIMED LAND CONTINUES TO RETURN TO THE MUNICIPAL GOVERNMENT A STEADY REVENUE OF TAXES.

IT IS PROBABLY TRUE TO SAY THAT THE MOST USEFUL THING THAT CAN BE DONE WITH MUNICIPAL WASTE IS THE RECLAIMATION OF WASTE LAND BY THE SANITARY LANDFILL PROCESS, BUT IN ANY ONE CITY IT HAS ITS LIMITS. EVENTUALLY ALL THE RECLAIMABLE LAND BECOMES RECLAIMED: ALL THE HOLLOWS AND DIPS IN THE LANDSCAPE BECOME FILLED UP AND THE PROBLEM OF WHERE TO PUT THE MATERIAL BECOMES ACUTE. SUITABLE DUMPING PLACES BECOME FARTHER AND FARTHER FROM THE SOURCE AND THE COST OF DISPOSAL SOARS.

IT WAS WITH THIS THOUGHT IN MIND THAT MR. BRADLEY FIRST PLACED THE PROBLEM BEFORE US. ALTHOUGH IT WAS WELL RECOGNIZED THAT INCINERATION OF MUNICIPAL REFUSE WHICH IS THE PRESENT PRACTICE IS AN EFFECTIVE AND INEXPENSIVE METHOD OF REDUCING THE BULK OF THE REFUSE AND MITIGATING ITS OBNOXIOUS PROPERTIES, THE POSSIBILITY DID EXIST THAT SOME OR ALL OF THE WASTE COULD BE PROCESSED IN A MANNER OTHER THAN INCINERATION SO THAT THE END PRODUCT WOULD BE MORE VALUABLE THAN THE PRODUCT OF STRAIGHT COMBUSTION.

THE FIRST WASTE PRODUCT TO WHICH WE GAVE ATTENTION WAS THE ANNUAL HARVEST OF LEAVES. MEMBERS OF THE DEPARTMENT HAD FOR SOME TIME BEEN AWARE OF THE FACT THAT IF THE LEAVES COLLECTED EACH FALL COULD PROPERLY PROCESSED TO LEAF MOULD, THERE WAS A VERY STRONG POSSIBILITY THAT IT MIGHT FIND A READY MARKET AMONG THOSE CITIZENS WHO PURSUE GARDENING AS A HOBBY. IF SUCH WERE THE CASE THEN IT WAS PROBABLE THAT THE COST OF DISPOSAL OF LEAVES COULD BE CUT CONSIDERABLY.

AT THE OUTSET IT SEEMED THAT, SINCE THE PRODUCTION OF LEAF MOULD HAS BEEN A COMMON ART FOR MANY HUNDREDS OF YEARS, OUR EFFORTS SHOULD BE DIRECTED TOWARDS AN ATTEMPT TO SPEED UP THE PROCESS OR TO ENHANCE THE PRODUCT FROM A PLANT NUTRITIONAL POINT OF VIEW. IT WAS CLEAR AT THE BEGINNING THAT THE POTENTIAL PRODUCTION FOR THE AREA ADMINISTERED WAS FIXED, THAT COLLEC tion of raw materials was sharply concentrated into a very short period of time, and that sales would be made largely in the spring and early fall. Hence a considerable storage time was indicated and storage requires land. The minimum land requirement would be that which was sufficient to hold the harvest from one fall until it was sold in the following spring and summer, providing that the process could be made sufficiently fast that the transformation from fallen leaves to leaf mould could be accomplished during the winter months. We soon found that despite anything we could do, (and this included adding such materials as ammonium salts, phosphorous compounds, lime, so-called bacterial activators), the heat of the summer following the harvest was needed, and it was necessary to operate on a tract of land big enough to hold at least two years harvest.

We also made an attempt to increase the organic nitrogen content by adding inorganic nitrogen and other salts. The results of this experiment are shown in the first slide.

Slide

Added	June 9		July 2		August 12	
	N	C/N	N	C/N	N	C/N
None	1.0	38.8	1.1	34.7	1.2	22.3
NH_4NO_3 (A)	1.8	19.9	1.6	16.8	1.4	17.3
Superphosphate (B)	0.9	39.8	1.2	26.5	1.0	24.8
Ash residue (C)	0.9	37.8	0.9	32.4	1.1	20.5
A + B	1.8	17.5	1.5	21.1	1.4	18.4
A + C	1.4	22.2	1.5	20.9	0.9	21.5
B + C	1.1	31.0	0.9	30.8	1.0	23.6
A + B + C	1.3	26.8	1.4	18.8	1.3	17.2

The leaves for this experiment were taken from a pile which had been harvested the preceding fall. Weighed amounts were mixed with the desired chemicals then placed in drums which were perforated at the bottom and which were raised above the ground on blocks. Twice, at monthly intervals, the contents were spilled out on mixing boards, stirred, sampled, and put back in the drums.

From the results, it is seen that in three of the four cases in which ammonium nitrate was added, although the nitrogen content was raised above the control, the material lost nitrogen during the two months the experiment was in progress. The percentage nitrogen of the control increased over the period. It was concluded from this that the addition of inorganic nitrogen was economically unjustified.

The procedure adopted at the present time in the production of leaf mould is this: the leaves are collected in the fall and taken to a spot in the Don Valley which is large enough to hold more than two years complete harvest. Here they are placed in long rows of about 12 feet square cross section and they are left for the winter. In the spring, as soon as it is feasible, the rows are turned by bulldozer and this turning is repeated throughout the summer and fall at monthly intervals if possible. The following spring it is shredded and screened to remove stones, sticks, glass, etc. and it is ready for bagging and sale.

Slides of production of leaf mould.

The leaf mould is of value not so much as a fertilizer since its nitrogen content is only about 1% but as a source of humus and

AS A SOIL CONDITIONER. IT IS OF PARTICULAR VALUE AS A MULCH OVER CLAY OR SANDY SOIL. IF USED AS A MULCH IT NOT ONLY PROTECTS THE SOIL FROM INTENSE AND RAPID DRYING OUT DURING DRY SPELLS, AND AGAINST EROSION AND PUDDLING DURING INTENSE RAINS, BUT AIDS IN KEEPING THE EARTHWORM POPULATION ON THE MOVE IN THE VERTICAL PLANE. THIS IS BECAUSE THE WORMS FIND IT AN EXCELLENT FOOD, AND THEY COME UP FOR IT AT NIGHT RETURNING DOWN AGAIN DURING THE DAY. THIS CONSTANT MIGRATION IS THOUGHT TO BE OF CONSIDERABLE VALUE, SINCE IT HELPS TO AERATE THE SOIL AND ESTABLISH A GOOD CRUMB.

IT IS POSSIBLE, OF COURSE, TO ADD FERTILIZER SUPPLEMENTS TO THE LEAF MOULD BUT THE DEPARTMENT HAS DECIDED AGAINST THIS PRACTICE IN THE BELIEF THAT IT IS NOT A FUNCTION OF THE MUNICIPAL ADMINISTRATION TO COMPETE WITH ESTABLISHED BUSINESSES. LEAF MOULD IS A PRODUCT WITH UNIQUE CHARACTERISTICS OF ITS OWN, AND IN THE ORDINARY COURSE OF EVENTS, NO ORGANIZATION IS AS LIKELY AS THE CIVIC ADMINISTRATION TO HAVE A SUPPLY OF IT.

THE NEXT WASTE PRODUCT TO WHICH WE TURNED OUR ATTENTION WAS GARBAGE. WE APPROACHED THE PROBLEM OF UTILIZING THIS MATERIAL NOT AT ALL IN THE MANNER OF DON QUIXOTE APPROACHING HIS WINDMILLS, BUT WARILY, LIKE A DOG EYEING A SPITTING CAT. BEFORE WE COULD DO ANYTHING AT ALL, WE FIRST HAD TO FIND OUT WHAT IT WAS WE WERE WORKING WITH. TO ACCOMPLISH THIS WE SET UP A SURVEY OF GARBAGE CAN CONTENTS WHICH AFTER 5 MONTHS YIELDED THE DATA SHOWN IN THE NEXT SLIDE.

AVERAGE COMPOSITION OF HOUSEHOLD GARBAGE

THIS SURVEY SHOWED THAT IN 100 LBS. OF HOUSEHOLD GARBAGE WE COULD EXPECT TO FIND ON THE AVERAGE 25.2 LBS. TABLE REFUSE, 17.4 LBS. PAPER WRAPPED AROUND TABLE REFUSE, 31.4 LBS. OF OTHER PAPER, 7.3 LBS. OF TIN CANS, 5.9 LBS. OF BOTTLES AND 12.8 LBS. OF UNCLASSIFIABLE MATERIAL. FURTHER ANALYSIS SHOWED THAT ONLY 23.4% OR 5.9 LBS OF THE TABLE WASTE PORTION IS SOLID MATTER SO THAT THE CONCLUSION IS UNMISTAKABLE THAT WHEN WE SPEAK OF UTILIZING HOUSEHOLD GARBAGE WE ARE REALLY FACING THE PROBLEM OF UTILIZING A VERY LOW GRADE OF WASTE PAPER.

OUR SURVEY ALSO GAVE US INFORMATION ABOUT THE AMOUNT WE COULD EXPECT PER PERSON. WE FOUND THAT THE AVERAGE OUTPUT OF REFUSE IS 3.18 LBS. PER PERSON PER COLLECTION. OF THIS 1.55 LBS. ARE PAPER. THERE ARE 104 COLLECTIONS PER YEAR. FROM THESE DATA WE MAY CALCULATE THAT FROM THE METROPOLITAN AREA OF TORONTO, WHICH IS A LOGICAL UNIT, WE MAY EXPECT TO GET FROM HOUSEHOLD GARBAGE ALONE, THE AMOUNTS SHOWN IN THE NEXT SLIDE.

100,000 TONS OF PAPER
AS WELL AS . . . . 11,700 TONS OF TABLE REFUSE SOLIDS
14,350 TONS OF TIN CANS
12,500 TONS OF GLASS

THESE FIGURES REPRESENT ONLY A MINIMUM FOR THREE REASONS, PARTICULARLY IF THE FUTURE IS BEING CONSIDERED.

(1) THEY DO NOT INCLUDE CONTRIBUTIONS FROM INDUSTRIES OR RETAIL ESTABLISHMENTS. IF THESE WERE INCLUDED IT CAN BE SAFELY ESTIMATED THAT THE PAPER WOULD BE AT LEAST DOUBLE THIS FIGURE.

(2) THEY DO NOT TAKE INTO ACCOUNT THE FACT THAT HOUSEHOLD GARBAGE GRINDERS ARE NOW LEGAL IN TORONTO. THIS MEANS THAT AS TIME GOES ON AND THEY BECOME MORE POPULAR AND WIDE-SPREAD IN USE, THE AMOUNT OF

TABLE REFUSE WHICH WILL FIND ITS WAY INTO THE GARBAGE WILL BECOME LESS AND LESS. PROPORTIONATELY PAPER WILL BECOME MORE AND MORE.

(3) THEY DO NOT TAKE INTO ACCOUNT THE GREAT INCREASE IN THE USE OF OIL AND IN THE FUTURE PROBABLY GAS, FOR HOME HEATING. THIS CHANGE IN HEATING HABITS REMOVES MANY INCINERATORS IN WHICH MUCH PAPER WAS FORMERLY BURNED IN THE HOME BUT WHICH NOW FINDS ITS WAY TO THE GARBABE.

THE FIRST QUESTION WHICH NATURALLY COMES TO MIND IS: "WHY NOT USE IT TO MAKE MORE PAPER?" ACCORDING TO MY COLLEAGUES IN THOSE INDUSTRIES WHICH USE WASTE PAPER, THE ESTABLISHED COMMERCIAL MECHANISMS FOR COLLECTING WASTE PAPER IS DOING ALL THAT IS NECESSARY, AND IT WOULD NOT BE CONOMICALLY FEASIBLE TO SORT ALL THE PAPER COLLECTED IN THE GARBAGE INTO GRADES SUITABLE FOR RE-USE. IT IS, HOWEVER, FEASIBLE AT TIMES TO PICK OUT AND BALE THE KRAFT CARTONS, AND THIS IS DONE WHEN IT IS WARRANTED. THIS SALVAGEABLE PORTION OF THE PAPER, HOWEVER, REPRESENTS BUT A VERY SMALL PORTION OF THE AMOUNT AVAILABLE.

NOW SINCE PAPER IS WOOD IN ANOTHER GUISE, IT FOLLOWS THAT THE PROBLEM OF UTILIZING THE PAPER IS THE SAME AS THE PROBLEM OF UTILIZING WASTE WOOD. THIS PROBLEM HAS RECEIVED A GREAT DEAL OF THOUGHT AND STUDY OVER MANY YEARS, BY MANY PEOPLE. WE DECIDED TO DO SOME PRELIMINARY AND EXPLORATORY WORK IN THE LABORATORY ALONG SOME OF THE LINES WHICH HAVE BEEN TRIED WITH WOOD WASTE, TO SEE IF ANY OF THESE MIGHT POSSIBLY HAVE MERIT WHEN APPLIED TO PAPER UNDER THE ECONOMIC CONDITIONS PECULIAR TO GARBAGE DISPOSAL.

IN GENERAL, TWO MODES OF ATTACK ARE POSSIBLE: CHEMICAL AND BIOLOGICAL. WE FIRST CONSIDERED THE POSSIBILITY OF CHEMICALLY SACCHARIFYING THE CELLULOSE OF THE PAPER. IT IS WELL KNOWN THAT CELLULOSE CAN BE HYDROLYSED EITHER BY STRONG ACIDS IN THE COLD, OR BY DILUTE ACIDS AT ELEVATED TEMPERATURES AND PRESSURES. IN MADISON, WISCONSIN, A MODIFICATION OF THE ORIGINAL GERMAN SCHOLLER PROCESS OF SACCHARIFICATION HAS BEEN DEVELOPED. THIS CONSISTS ESSENTIALLY OF PERCOLATING DILUTE SULPHURIC ACID THROUGH WOOD CHIPS AT ABOUT 400°F. THE ACID, AT THIS HIGH TEMPERATURE HYDROLYSES THE CELLULOSE TO GLUCOSE WHICH IS RECOVERED IN THE EFFLUENT AFTER NEUTRALIZATION AND EVAPORATION. I HAD THE GOOD FORTUNE OF BEING ABLE TO TALK WITH SOME PEOPLE WHO HAD HAD PERSONAL EXPERIENCE WITH THIS PROCESS AND THEY WERE UNANIMOUS IN THEIR PREDICTION THAT BECAUSE OF THE TENDENCY FOR TARS TO FORM AND PLUG UP THE EQUIPMENT WHEN PARTICLES OF WOOD SMALLER THAN DISCREET CHIPS WERE USED, IT WOULD NOT WORK WITH PAPER. IN VIEW OF THIS, WE DECIDED NOT TO EXPERIMENT WITH THIS METHOD, BUT INSTEAD TO LOOK INTO THE POSSIBILITIES WHICH THE GERGIUS PROCESS OF SACCHARFICATION MIGHT HAVE.

SLIDE

IN THIS PROCESS HYDROCHLORIC ACID CONCENTRATED TO A STRENGH 41% IS USED TO EXTRACT THE WOOD IN A COUNTER CURRENT FASHION. THE LIGNIN IF FILTERED OFF AND THE BULK OF THE ACID IS RECOVERED BY EVAPORATION AND CONDENSATION AND IS RE-USED. THE EVAPORATION OF THE LAST 20% TO DRYNESS IS DONE BY A SPRAY DRIER. THE RESULTANT POWDER IS GIVEN A MILD HYDROLYSIS AND THE SUGAR IS CRYSTALLIZED OUT OF THE SYRUP IN THE ORTHODOX MANNER.

WHEN WE CAME TO SIMULATE THIS PROCESS IN THE LABORATORY WE QUICKLY FOUND THAT WHEN 41% HYDROCHLORIC WAS PASSED OVER PAPER, THE SURFACE OF THE PAPER GELATINIZED AND SEEMED TO BECOME RATHER IMPERVIOUS TO THE ACID. AFTER SOME TRIALS THIS WAS OVERCOME WHEN WE FOUND THAT BY SUSPENDING THE PAPER IN 37% ACID, (THE STRENGTH AT WHICH IT IS ORDINARILY SOLD), THE PAPER

PEPTIZES READILY. THEN WHEN HCl GAS IS INTRODUCED AND THE STRENGTH RISES TO 41%, SOLUTION OF THE CELLULOSE IS VERY RAPID AND THE LIGNIN SEPARATES AND PRECIPITATES.

THE LITERATURE INDICATED THAT AFTER SOLUTION OF THE CELLULOSE IN THE ACID, THE PRODUCTION OF SUGARS WAS A FUNCTION OF THE TIME OF STANDING, AND THAT THE AMOUNT AT ANY TIME WAS THE RESULT OF TWO REACTIONS, ONE BY WHICH CELLULOSE WAS BROKEN DOWN TO SMALLER AND SMALLER UNITS, THE END BEING GLUCOSE, AND THE OTHER, BY WHICH THESE SMALLER UNITS REFORMED AGAIN INTO LARGER MOLECULES OF A CONFIGURATION DIFFERENT FROM GLUCOSE. MEASURED AS REDUCING SUGARS THERE WAS NO UNANIMITY BETWEEN OTHER WORKERS' RESULTS AND OURS AS THE NEXT SLIDE SHOWS.

IT APPEARED QUESTIONABLE IF THESE FIGURES REALLY REPRESENTED REDUCING SUGARS. TO SETTLE THIS POINT WE INVOKED THE TECHNIQUE OF PAPER CHROMATOGRAPHY AND WITH THIS TOOL WE WERE ABLE TO SHOW THAT NO GLUCOSE FORMED EVEN AFTER STANDING AT ROOM TEMPERATURE FOR 16 HOURS, UNTIL THE MILD HEATING INVOLVED IN THE VACUUM CONCENTRATION OCCURRED. AT THIS TIME SOME CELLOBIOSE WAS ALSO PRESENT.

WE SIMULATED SPRAY-DRYING BY POURING A SMALL VOLUME OF CONCENTRATED MATERIAL OVER A LARGE SURFACE UNDER HIGH VACUUM AND TEMPERATURES NOT OVER 40°C. THE POWDER OBTAINED WAS VERY HYGROSCOPIC AND EVEN AFTER PROLONGED VACUUM TREATMENT ANALYSED 10% BY WEIGHT OF HCl. WHEN FRESHLY PREPARED, IT WAS LIGHT GREY BUT IT TURNED BLACK AFTER A FEW DAYS STORAGE. THE INDICATIONS ARE THAT HYDROCHLORIC ACID IS VERY CLOSELY ASSOCIATED WITH THIS PRODUCT, PERHAPS EVEN CHEMICALLY COMBINED. WHEN THIS MATERIAL WAS REDISSOLVED IN WATER AND HYDROLYSED FOR 1/2 HOUR AT 15 LBS. PRESSURE, CELLOBIOSE WAS NOT LONGER PRESENT. WHEN THIS HYDROLYSATE WAS TREATED WITH THE PROPER ION-EXCHANGE RESINS AND THEN CONCENTRATED, A REASONABLY GOOD GRADE OF SUGAR WAS OBTAINED.

THIS PROCESS APPEARS TO BE TECHNICALLY FEASIBLE. THERE IS A STRONG POSSIBILITY THAT IT WOULD COMPARE FAVOURABLY WITH INCINERATION ECONOMICALLY EVEN TO-DAY, IF A STEADY USE FOR THE SUGAR WAS ASSURED, AND A MUCH STRONGER POSSIBILITY IN THE FUTURE WHEN PLASTICS DEVELOPMENTS MAY MITIGATE CORROSION PROBLEMS IN THE RECOVERY OF THE HYDROCHLORIC ACID. THREE THINGS ARE AGAINST IT: THE LIGNIN WHICH CONSTITUTES 30% OF THE PAPER HAS TO BE UTILIZED SEPARATELY, AND THE SPRAY DRIED POWDER FIXES TOO MUCH OF THE HYDROCHLORIC ACID. THE LATTER OBJECTION CAN PROBABLY BE OVERCOME BY STUDY, AND THE UTILIZATION OF LIGNIN IS SOMETHING WHICH IS CONSTANTLY BEING THOUGHT ABOUT, AND SOMEDAY NO DOUBT WE WILL HAVE MANY USES TO CHOOSE FROM. WE HAVE NOT WORKED ON THIS ASPECT OF THE PROBLEM BUT UNTIL A USEFUL OUTLET FOR THE LIGNIN IS ASSURED THIS METHOD OF UTILIZATION WILL NOT LIKELY BE SUFFICIENTLY ATTRACTIVE TO JUSTIFY LARGE CAPITAL EXPENDITURE.

ONE OF THE REASONS WHY IT IS DESIRABLE TO SACCHARIFY PAPER IN GARBAGE AS A STEP IN ITS UTILIZATIONS, IS THAT THE RESULTANT SUGAR IS UTILIZED SO READILY BY MANY ORGANISMS WHICH PRODUCE USEFUL ARTICLES OF COMMERCE - SUCH AS PROTEIN, ETHYL ALCOHOL, BUTYL ALCOHOL, ACETONE, LACTIC ACID, ACETIC ACID. WE MAY CALCULATE AS AN EXAMPLE THAT IF THE CELLULOSE FROM 200,000 TONS OF PAPER WERE COMPLETELY HYDROLYSED AND GROWN TO YEAST WE COULD HARVEST 30,000 TONS OF PROTEIN. HOWEVER, CELLULOSE AND TO A LESSER EXTENT LIGNIN, ARE BOTH DIRECTLY SUSCEPTABLE TO MICROBIOLOGICAL DEGRADATION, AND THE QUESTION NATURALLY ARISES "WHAT USEFUL PRODUCTS CAN BE PRODUCED MICROBIOLOGICALLY DIRECTLY FROM GARBAGE, WITHOUT AN INTERVENING HYDROLYSIS?"

ONE OF THE ANSWERS THAT IS FREQUENTLY OFFERED TO

SUCH A QUESTION IS THE SUGGESTION TO "COMPOST IT, THEN USE THE COMPOSTED MATERIAL AS FERTILIZER." THERE ARE SEVERAL DIFFICULTIES IN THE WAY OF THIS SOLUTION. FARMERS, FOR EXAMPLE, HAVE NEVER BEEN UNDULY ANXIOUS TO OBTAIN THIS TYPE OF MATERIAL AND IT IS DOUBTFUL IF HAULAGE CHARGES COULD BE RECOVERED BEYOND THE CITY LIMITS AND CERTAINLY THE MARKET WITHIN THE CITY LIMITS WOULD NOT BEGIN TO ABSORB THE POTENTIAL SUPPLY. MOREOVER, ALTHOUGH FOOD REFUSE MAY BE COMPOSTED WITH RELATIVE EASE, PAPER MAY NOT BE. THIS IS DUE TO AT LEAST TWO FACTORS: PART OF THE CELLULOSE IN PAPER IS REFRACTORY TO MICROBIAL ATTACH, AND PAPER CONTAINS NO NITROGENOUS NUTRIENT FOR THE ORGANISMS. TO PROPERLY COMPOST PAPER REQUIRES A FAIR LENGTH OF TIME AND THE ADDITION OF BACTERIAL NUTRIENTS. IT IS TRUE THAT IN GARBAGE WHERE THE RATIO OF PAPER TO TABLE REFUSE IS NOT TOO HIGH, COMPOSTING TO A SAFE CARBON-NITROGEN RATIO MAY PROBABLY BE ACHIEVED WITHOUT THE ADDITION OF NUTRIENTS BUT, AS I MENTIONED EARLIER, SINCE THE LIKLEHOOD IS, IN THE FUTURE, THAT THE RATIO OF PAPER TO TABLE REFUSE WILL GET HIGHER NOT LOWER, CONDITIONS FOR EASIER COMPOSTING ARE NOT READILY FORSEEN.

INDEED, IT IS NOT UNREASONABLE TO TAKE THE POINT OF VIEW THAT IF, IN THE FUTURE TABLE REFUSE IS TO FIND APPLICATION ON THE SOIL AS AN ORGANIC FERTILIZER, IT WILL DO SO VIA THE ROUTE OF ACTIVATED SLUDGE, SINCE THE SAME FACTORS WHICH TEND TO CUT DOWN THE TABLE WASTE PORTION OF THE GARBAGE HAVE THE EFFECT OF INCREASING THE SLUDGE RECOVERED IN THE SEWAGE.

ALTHOUGH COMPOSTING OF PAPER WHICH IS LARGELY AN AEROBIC PROCESS IS NOT LIKELY TO BE COMMERCIALLY SUCCESSFUL ON A LARGE SCALE, THE POSSIBILITIES OF AN ANAEROBIC FERMENTATION USING PURE CULTURES OF ORGANISMS TO PRODUCE USEFUL CHEMICALS FROM THE CELLULOSE AND ALSO LEAVING A COMPOST-LIKE MATERIAL OF LIGNIN AND NITROGENOUS MICROBIOLOGICAL REMAINS MUST NOT BE OVERLOOKED. WE KNOW FOR EXAMPLE, THAT IN THE RUMEN OF A COW THE INDIGENOUS FLOR CAN BREAK DOWN CELLULOSE TO SUGARS AND ACIDS WHICH MAY BE USED BY THE ANIMAL AS FOOD. WHAT IS THE POSSIBILITY OF PRODUCING SUCH A FERMENTATION IN A TANK? WORK AT OTTAWA AND ELSEWHERE HAS INDICATED THAT IT IS VERY DIFFICULT TO KEEP THE RUMEN ORGANISMS ALIVE OUTSIDE OF THE INTESTINAL TRACT AND FREE FROM RUMEN FLUID BUT OTHER WORKERS, HAVE INDICATED THAT SOME SUCCESS MAY BE ACHIEVED WITH SOIL ORGANISMS AT THERMOPHILIC TEMPERATURES. AT THE FOUNDATION WE HAVE MADE SOME PRELIMINARY EXPERIMENTS TO SEE WHAT SOME OF THE CONDITIONS FOR THE PRODUCTION OF VOLATILE ACIDS MIGHT BE. THE NEXT SLIDE SHOWS SOME TYPICAL RESULTS. THIS SLIDE SHOWS THE VOLATILE ACID PRODUCED FROM DAY TO DAY AS A % OF THE PAPER, IN A MEDIUM WHICH WAS ENRICHED TO DIFFERENT LEVELS WITH AMINO NITROGEN SUPPLEMENTS, pH ADJUSTED TO 7.8 AND HELD THERE BY SUSPENDED LIME, WITH TEMPERATURE HELD AT 55°C.

EFFECT OF AMINO N ADDITION ON VOLATILE ACID PRODUCTION

EXPRESSED AT % OF ACETIC ON PAPER

DAYS	% PEPTONE			% C.S.L.
	0	0.2	0.6	0.5
3	3.7	10.8	11.0	5.2
4	2.7	9.4	14.0	15.0
6	5.3	6.1	10.0	6.6

THESE DATA SHOW TWO THINGS: THAT SOME SORT OF ORGANIC NITROGEN IS A NECESSARY ADDITIVE; THAT UNDER THESE CONDITIONS A PEAK

ACID PRODUCTION WAS REACHED AFTER WHICH, THE ACID ITSELF WAS USED UP.

AN ATTEMPT WAS MADE TO ISOLATE A CAUSATIVE ORGANISM IN PURE CULTURE BUT THIS ATTEMPT WAS UNSUCCESSFUL.

THE HOPE THAT DIRECT FERMENTATION OF PAPER TO USEFUL PRODUCTS CAN BE BROUGHT ABOUT IS WELL FOUNDED, BUT BEFORE ANY WELL-CONTROLLED PROCESS CAN BE WORKED OUT, THE ANSWERS TO THE FOLLOWING QUESTIONS MUST BE FOUND: WHAT ORGANISMS ARE SUITABLE? CAN THEY WORK ALONE IN PURE CULTURE? WHAT ARE THEIR NUTRITIONAL AND ENVIRONMENTAL REQUIREMENTS? WHAT IS THE MINIMUM CHEMICAL OR PHYSICAL TREATMENT WHICH IS REQUIRED TO MAKE ALL THE CELLULOSE IN THE LIGNIN-CELLULOSE COMPLEX READILY AVAILABLE? TO ANSWER THESE QUESTIONS WILL TAKE A GREAT DEAL OF RESEARCH. WE MIGHT ALSO ASK OURSELVES THIS QUESTION - "WOULD IT NOT BE BETTER TO SEEK A WAY OF TREATING THE PAPER SO THAT THE ENERGY OF THE CELLULOSE WOULD BE ACCEPTABLE TO CATTLE, AND LET THESE ANIMALS FUNCTION AS PROTEIN FACTORIES IN THEIR TIME-HONOURED FASHION?

IT MUST BE APPARENT FROM WHAT I HAVE SAID THAT I AM NOT ABLE TO SUGGEST ANY SURE-FIRE PROCESS FOR TURNING GARBAGE INTO GOLD. IT MAY POSSIBLY BE THAT INCINERATION IS THE FINAL SOLUTION, BUT I DOUBT IT, BECAUSE INCINERATION IS DESTRUCTION AND THE GOAL OF AND THE CHALLENGE TO TECHNOLOGY IS NOT DESTRUCTION BUT CREATION.

*
***
*****
****
*****
***
*

OBJECTIVES FOR WATER QUALITY CONTROL IN ONTARIO

*
***
*

Adopted By The Pollution Control Board, May 5, 1953

By

Dr. A. E. Berry, Chairman

These objectives are for all waters in the Province of Ontario, and it is anticipated that in certain specific instances, influenced by local conditions, more stringent requirements may be found necessary.

GENERAL OBJECTIVES

All wastes, including sanitary sewage, storm water, and industrial effluents, shall be in such condition when discharged into any receiving waters that they will not create conditions which will adversely affect the use of these waters for the following purposes; source of domestic water supply, navigation, fish and wild life, bathing, recreation, agriculture and other riparian activities.

In general, adverse conditions are caused by:

(a) Excessive bacterial, physical or chemical contamination.

(b) Unnatural deposits in the stream, interfering with navigation, fish and wild life, bathing, recreation, or destruction of aesthetic values.

(c) Toxic substances and materials imparting objectionable tastes and odours to waters used for domestic or industrial purposes.

(d) Floating materials, including oils, grease, garbage, sewage solids, or other refuse.

(e) Discharges causing abnormal temperature, colour or other changes.

SPECIFIC OBJECTIVES

In more specific terms, adequate controls of pollution will necessitate the following objectives for:

(a) Sanitary Sewage, Storm water, and Wastes From Water Craft
sufficient treatment for adequate removal or reduction of solids, bacterial, and chemical constituents which may interfere unreasonably with the use of these waters for the purposes afore-mentioned.

Adequate protection for these waters, except in certain specific instances influenced by local conditions, should be provided if the coliform M.P.N. Median value does not exceed 2,400 per 100 ml. at any point in the waters following initial dilution.

(b) **Industrial Wastes**

(1) Chemical Wastes - Phenolic Type

Industrial waste effluents from phenolic hydro-carbon and other chemical plants will cause objectionable tastes or odours in drinking or industrial water supplies and may taint the flesh of fish.

Adequate protection should be provided for these waters if the concentration of phenol or phenolic equivalents does not exceed an average of 2 p.p.b. and a maximum of 5 p.p.b. at any point in these waters following initial dilution. This quality in the receiving waters will probably be attained if plant effluents are limited to 20 p.p.b. of phenol or phenolic equivalents.

Some of the industries producing phenolic wastes are: Coke, synthetic resin, oil refining, petroleum cracking, tar, road oil, creosoting, wood distillation, and dye manufacturing plants.

(2) Chemical Wastes, Other Than Phenolic

Adequate protection should be provided if:

(a) The pH of these waters following initial dilution is not less than 6.7 nor more than 8.5. This quality in the receiving waters will probably be attained if plant effluents are adjusted to a pH value within the range of 5.5 and 10.6

(b) The iron content of these waters following initial dilution does not exceed 0.3 p.p.m. This quality in the receiving waters will probably be attained if plant effluents are limited to 17 p.p.m. of iron in terms of Fe.

(c) The odour-producing substances in the effluent are reduced to a point that following initial dilution with these waters the mixture does not have a threshold odour number in excess of 4 due to such added material.

(d) Unnatural color and turbidity of the wastes are reduced to a point that these waters will not be offensive in appearance or otherwise unattractive for the afore-mentioned uses.

(e) Oil and floating solids are reduced to a point such that they will not create fire hazards, coat hulls of water craft, injure fish or wild life or their habitat, or will adversely affect public or private recreational development or other legitimate shore line developments or uses. Protection should be provided for these waters if plant effluents or storm water discharges from premises do not contain oils, as determined by extraction in excess of 15 p.p.m., or a sufficient amount to create more than a faint irridescence.

Some of the industries producing chemical wastes other than phenolic are: Oil wells and petroleum refineries, gasoline filling stations and bulk stations, styrene co-polymer, synthetic pharmaceutical, synthetic fibre, iron and steel, alkali chemical, rubber facricating, dye manufacturing, and acid manufacturing plants.

(3) Highly Toxic Wastes

Adequate protection should be provided for these waters if materials highly toxic to human, fish, aquatic, or wild life are eliminated.

Some of the industries producing highly toxic wastes are: metal plating and finishing plants discharging cyanides, chromium or other toxic wastes; chemical and pharmaceutical plants and coke ovens. Wastes containing toxic concentrations of free halogens and wastes containing resin and fatty acid soaps are included in this category.

(4) Deoxygenating Wastes

Adequate protection of these waters should result if sufficient treatment is provided for the substantial removal of solids, bacteria, chemical constituents, and other substances capable of reducing the dissolved oxygen content of these waters unreasonably. In addition to sewage some of the industries producing these wastes are: Tanneries, glue and gelatine plants, alcohol, including breweries and distilleries, wool scouring, textile, pulp and paper, food processing plants such as meat packing and dairy plants, corn products, beet sugar, fish processing and dehydration plants.

OBJECTIVES FOR WATER QUALITY CONTROL IN MANITOBA

By

L. A. KAY

Director, Bureau of Public Health
Engineering, Province of
Manitoba,
Winnipeg, Man.

The question of suitable objectives for water quality control has enamcured many responsible public health authorities; and in this regard, special mention might be made of the outstanding work of the Board of Technical Advisors to the International Joint Commission and the subsequent report of the Commission dealing with the pollution of boundary waters, and, more particularly, that section concerning water quality control objectives as set out in the 1951 publication.

In the consideration of any subject of broad general significance to the public health and well-being, it is essential that certain terms of reference, or limitations, be proposed - otherwise, the discussion may get out of control; and, secondly, it is very convenient to enumerate certain pertinent factors as points of common interest and attention, around which may be woven a sound framework of plausible fact, and from which, eventually, certain useful deductions and practical formulae may be drawn and devised.

It would appear that the International Joint Commission objectives excel in this latter regard, in that they propound a realistic but flexible set of standards for the comparative evaluation of the type and extent of pollution then under surveyance in the very important industrial waterways in the vicinities of the St. Clair, Detroit and Niagara Rivers, which, along with other bodies, form the International Boundary.

The significance of the objectives has already been discussed very fully by the previous speaker; therefore, may I suggest that we return to the original terms of reference of this paper and look briefly at conditions in the West.

The Manitoba Scene

A glance at a map of the country and at one of the Province of Manitoba would indicate a rather peculiar situation in this latter province:

(a) There are no International Boundary waters, as such.
(b) There are no major streams originating in Manitoba.

(c) The general topography forces the drainage in an Easterly then Northerly direction (except in the Eastern section where surface waters flow more or less directly North).

Looking at the picture another way, we find, then, in Manitoba, we are dependent on the neighboring provinces and states for the continuing initial good quality of our waterways.

For example, the Red River rises far to the South and enters the province via North Dakota. In this regard, both North and South Dakota and the State of Minnesota have co-operated in formulating a comprehensive pollution control program for what they refer to as the "Red River of the North". The Assiniboine River has its source in Saskatchewan, and after crossing into Manitoba, flows South then East, and the admixture of its waters with those of the Red follow the general trend towards the North. The smaller Souris stream rises in Saskatchewan, supplies water for the town of Minot, North Dakota, and re-enters Canada by way of the Manitoba section of the Border.

The water source for Winnipeg and environs is drawn from the Shoal Lake area of the Lake of the Woods. The huge watershed of this latter body is eventually drained to Northern Manitoba via the Winnipeg River and Lake Winnipeg. Another interesting example is the North Saskatchewan River which rises in Alberta, supplies water for one of the Battlefords, Prince Albert, and the town of The Pas (in Manitoba), and then joins the general conflux of drainage which eventually terminates in the northern muskegs and the Hudson Bay.

On a population basis, possibly 300,000 people (o.t of a total of less than 800,000 in the province) are supplied from the Greater Winnipeg Water District; another 40,000 are dependent on the Assiniboine and its tributaries; one small community now uses the Red River as a source, and a few towns, of course, utilize underground supplies.

About one-half of the total population is served through municipal or corporation systems from surface water sources, and another substantial percentage of rural dwellers presumably draw water from local streams, lakes and artificial dugouts. It may be seen, therefore, that the potability of the surface waterways is very important as far as the health and well-being of the majority of the Manitoba population is concerned.

The weather is an important environmental factor. It might be said that we have three seasons - winter, summer, and a short dawn-or-dusk type or zone in between each of the extremes. For field work purposes, we can divide the twelve-month survey year into a nominal ice-covered season, (say, December to April inclusive); a high flow period - extending from the end of June or July; and a more or less 'normal' summer-fall session when the flow of water may be expected to be reasonably constant.

The fact that surface drainage falls rapidly away from the centre of population and eventually disappears in the untenanted Northern reaches of the province or the salt water of Hudson Bay, means that strict enforcement of anti-pollution measures is at present generally unnecessary once the urban centres are in the background. A significant point is that we are not concerned with the possibility of transmitting dangerously contaminated waters to other states or provinces. Therefore, we are relieved of a tremendous burden of moral, if not actual, responsibility.

Thus, in brief, you have the picture in Manitoba - a keystone- shaped province dividing the country, with almost half its population located within a hundred miles radius of the City of Winnipeg; the rocks and evergreens of the Pre-Cambrian Shield intruding on the East and Northeastern areas; whilst, in the other direction, the great level prairies extend through and past the Province of Saskatchewan; rivers and streams which rise everywhere but in Manitoba, and eventually drain into the Northern muskeg, and an extreme of temperature which is popular only with the natives.

THE RELATIVE POSITION OF WATER QUALITY STANDARDS

Broadly speaking, if empirical standards of water quality were to be utilized in Manitoba, there would be created an unfair and non-uniform financial burden on half the sewered municipalities, including industrial townsites, in the province. Manitoba is economically young, very sparsely settled, and only now beginning to accentuate and encourage industrial expansion. The increasing significance of natural oil and gas reserves in the mid-western section may ultimately threaten the importance of the hitherto-leading grain, mineral, fish and timber resources; but, meanwhile, the patchwork application of water pollution control is relatively unsightly but effective.

Statutes

The authority for pollution control measures has been considered from the twofold angle of protection of the public health and conservation of a great natural resource. Regulations made pursuant to "The Public Health Act" ensure minimum hazard to the safety and well-being of the citizens - but strict and effective control of surface water usage as a medium for waste treatment and disposal is vested in a Provincial Sanitary Control Commission set up under the terms of "The Pollution of Waters Prevention Act" administered by the Department of Mines and Natural Resources.

This legislation is quite significant. In Part 1 provision is made for a requirement for the licensing of any agency discharging or draining any sewage or waste into any body of water. A second division deals with the organization and powers of the Provincial Sanitary Control Commission; Part 111 comprises the framework for enabling the creation of sewage disposal districts (e.g., The Greater Winnipeg Sanitary District), and another section deals with the resultant powers of sewage districts once they may be organized.

By this system of dual legislation and administration, the supervision of the installation of municipal waterworks and sewerage projects still remains with the Department of Health; but the onus of dividing the natural capacity of the surface water courses in an equitable manner is placed in the hands of an impartial Commission, which, in turn, is empowered to hire such engineering and other skills as are deemed necessary for the effective working of the Commission.

Policy

With the humble realization that laws in themselves are not always effective, and that too many rules and regulations may defeat the primary purpose of any legislation, it was decided to formulate a policy which might serve as an interim guide to the administration of an effective program; which could be used to evaluate the claims of user-agencies; and which would eventually result in the uniform and reasonable use of our surface water courses to the maximum economic limit without abuse, with minimum offense, and without undue jeopardizing of the natural beauties of the streams.

This policy was first published late in 1953, and may be re-examined and modified or enlarged at any time. Meanwhile, it serves:

(i) To explain,
- the need for diversified control
- the importance of conservation of this non-wasting asset
- the various types of claims for usage of the water potential

(ii) To propound,
- a general basis for administering statutes and regulations
- the need for tangible indices of pollution
- the importance of continuing river surveys
- a list of certain principles basic to the reasonable application of the program
- a scheme for the temporary or permanent down-grading or zoning of a "graded" water course
- standards for both effluents and diluting waters

(iii) To propose,
- the licensing of major user-agencies
- the grading of all larger water courses
- the preparation of detailed pollution indices
- the empirical definition of certain categories of municipal sewage treatment processes

AND (iv) To outline future planning,
- in regard to the Greater Winnipeg Sanitary District and other major agencies of concern
- concerning possible re-examination of relative statutes
- of surveys and grading of all pertinent provincial waterways.

Application

It may be seen that, in the practical application of a Manitoba pollution control program, it is proposed to utilize the better features of both generally recognized expedients of stream classification and of water quality standards without prejudice or discrimination one way or another. These methods are termed 'expedients' advisedly, since there is a danger that the too arbitrary enforcement of either of these control criteria may defeat the ultimate purpose of the entire program; and their use must be leavened by judicious interpretation in view of local conditions of economics, topography, population, etc.

It is granted, however, that the listing of objectives for water quality control is the essential base for the planning of an effective program. Further, we should be prepared to re-examine and alter these desirable standards from time to time along the lines dictated by the motivation of adequate protection of public health and well-being, the retention of desirable aesthetic conditions, the conservation of a great natural heritage, and the industrial economy of the province.

As the control program develops, the value of river surveys and subsequent classification or grading assumes increasing stature (although there may be some argument on this point). It is a fact that probably in every province and in every state there are streams and lakes which are hopelessly defiled and can never be recovered to their original state. The Control Commission recognizes this condition, and is prepared, failing any other practical solution, to down-grade such water courses permanently as unfit for potable water supply and any other normal usage other than waste disposal.

On the other hand, by setting a classification of a now attractive and useful stream at a higher grade, notice is served on industry and the public alike that it is the firm intention of the authorities to preserve the usefulness and attractive properties of that stream; and that while some abuse may have been allowed in the past, and notwithstanding the fact that some use may be made of the diluting and treating capacity of the stream in question, the degree of usage and the distribution of such benefits is a matter of governmental concern in the interests of the province as a whole.

TECHNICAL REQUIREMENTS FOR WATER CONTROL

There would appear to be a pre-disposition, especially among engineers and other skilled professionals, to become too enthusiastic over the technical intricacies of the solution of pollution problems, with the result that sooner or later an elaborate organization may be required to carry out the preliminary stages of an effective program.

Again, the many interesting features, especially in the industrial field, may sometimes overshadow the prime purpose of the investigation and survey in the avowed object of maintaining good water quality.

Self-Policing

In order to avoid these obvious difficulties, the Manitoba plan has been;

(i) to license major polluting agencies
(ii) in conjunction with industry, to formulate certain 'tracers' (such as phenol in the refinery business) the incidence and quantity of which can be readily examined by the use of procedures outlined in standard Methods.
(iii) To require the particular industry to provide its own technical staff and facilities for routine effluent and receiving water tests.

In this way, the technical staff of the Commission may be kept at a minimum, industry is protected by having a licence to do certain things and discharge wastes of certain types into the stream, self-policing is carried out by the concerned company, and by the use of a readily identifiable tracer, the periodic returns required from industry may be checked by infrequent concurrent dual sampling and subsequent analyses.

Industrial vs. Municipal Sewage

The water of a stream subject to contamination by raw municipal sewage may generally be re-conditioned and purified for domestic consumption without any particularly complex manoeuvres. The ability of the water course to re-stabilize itself is quite marked - particularly if there are any rapids or other obstructions present in the channel to create turbulence and assist in the aeration of the suspended materials.

On the other hand, the consideration of an industrial effluent is usually a much more comprehensive matter. In the first place, the user-agency is a private or corporate body rather than a public one; secondly, each individual plant seems to be able to produce a different and more complex waste than its predecessor or contemporary. In addition, some of the more obnoxious compounds in these industrial effluvia seem to be able to persist indefinitely without disintegration, and, in effect, without losing the power of disrupting normal potable water treatment procedures.

The complexity of the industrial problem emphasizes the fact that pollution control authority should be prepared to provide technical information and possibly consultative assistance to municipal user-agencies, but should ask industry to work out its own solutions whilst affording the latter some protection in the form of a licence to discharge waste, and definite guidance by incorporating in that licence the general and specific requirements in regard to effluent and diluting water quality.

Local Conditions

Some of the conditions peculiar to Manitoba may be utilized ultimately to some advantage in lessening the degree of required treatment for both industrial and domestic wastes. As noted at the beginning of this paper, there are no further "sanitary customers" for the water courses once the rivers and streams have proceeded beyond the larger centres of population.

The long period of ice cover, whilst detrimental to the process of natural pollution assimilation, may yet be found helpful to accommodate the off-season discharge of otherwise too concentrated high-B.O.D. pollution loads, although any planning in this regard will have to be done with a view to the prevalence and significance of local sport fishing. The substantial increase in velocity and volume of our rivers, due to spring runoff, undoubtedly assists in the periodic scouring of some of the channels which might otherwise be the source of warm weather offence and possibly health hazard. Unfortunately, another by-product of these high flow rates is the possibility of flooding which seems to have been a consistent menace in the last few years.

SUMMARY

In concluding this short talk on objectives for water quality control in Manitoba, I would like to refer to a statement contained in a publication of the U.S. Health Service entitled A COMPREHENSIVE PROGRAM FOR WATER POLLUTION CONTROL FOR THE RED RIVER OF THE NORTH BASIN. The statement follows;

> "The controlling water quality criteria for the main stem of the Red River of the North is the protection of the water supplies of the municipalities which are dependent on the stream as a source of water, while the controlling criteria of the remainder of the drainage basin varies with the use to which the waters are put."

The same principle is being followed in Manitoba, augmented by a policy of licensing major user-agencies and grading the more important water courses in the hopeful expectation that industry, the municipality and the private citizen are being given a reasonably fair share of the inherent value of this natural resource.

The subject of drouth and consequent low stream flows has purposely been omitted from this discussion. Much of our persuasive planning for municipalities and others is based on long-term implementation - usually of three to five years duration. In the meantime, severely curtailed river flows could be very awkward, if not troublesome. The terms of the Control Commission licences include a reference to this possibility and the fact that existing requirements might have to be drastically altered under such circumstances.

A CODE FOR MUNICIPALITIES FOR THE ADMISSION OF INDUSTRIAL WASTE TO SEWERS

by MR. D. P. SCOTT,
Deputy Commissioner
of Works, (Drainage
Division), Municipality
of Metropolitan Toronto.

(a) Domestic (b) Storm (c) Industrial

In recent years the rapid growth of our urban and industrial centres demands that adequate sewage treatment facilities be installed to preclude the pollution of our rivers and lakes which are the source of our water supply and are valuable recreational assets. With the growth in importance of sewage treatment has come research into methods to improve that treatment and reduce its cost. One of the major treatment problems has proven to be water-borne industrial wastes. Studies of this problem are being carried out across the continent, and several codes to control discharge of these materials have been recommended, adopted and rewritten by various centres in the past few months. Proposed codes have been discussed at many technical conferences such as this with increased concern and appreciation of the problem. Industrial waste then, and its control, is a matter of prime interest, not only to the body which must provide the treatment facilities, but also to industry itself which uses the municipal sewers and treatment plants.

It is the purpose of this paper to review the factors which should be considered in the establishment of effective regulations for controlling the discharge of industrial waste into municipal sewer systems. A review of existing regulations for municipalities on this continent and the problems associated therewith makes it apparent that a single regulation which will apply to all localities and situations cannot be drawn up because each individual case may differ somewhat, depending on the size of the municipality, the design of the sewer system, the number and type of industries and nature of the treatment plant or plants.

It is, perhaps, the duty of a municipality or sewerage district to accept and treat all liquid wastes originating within the tributary area which do not cause damage to sewers or affect treatment plant operation.

If, at times, a certain waste must be excluded, it should not be done on an arbitrary basis, but rather for sound and just reasons. In order to determine the acceptability of a waste, it is necessary for a comprehensive investigation to be undertaken. Some reasons for discharging all wastes, within acceptable limits, to the municipal sewerage system, are as follows:-

1. Better control is achieved in one combined plant, rather than in a number of separate smaller plants.

2. It is sometimes more economical to treat a combination of industrial wastes and domestic sewage than to treat each one independently.

3. It relieves industry, as much as possible, from the responsiblity of treating its wastes, which in most cases would require highly trained technical personnel.

Treatment in a large plant is invariably cheaper than in separate smaller units, because unit costs for both construction and operation are reduced as the size increases. In addition, it is sometimes beneficial to treat industrial wastes in association with domestic sewage because of dilution, flow equalization, blending and other factors.

Large treatment plants such as our Main Plant at Ashbridge's Bay warrant the employment of better qualified men than smaller plants; as a result, better operation and control is achieved. In very small industrial plants technical men qualified for the treatment of waste would usually not be available.

If industry is permitted to discharge its water-borne waste to the public sewer system, then it must be prepared to co-operate with the public agency in solving mutual problems which may arise. Whether industry is required to bear a fair share of the cost for treatment of its waste is a matter for decision by the municipality concerned. It is recognized that there should be some measure of control if industrial wastes are to be discharged to the municiapl system. Three alternatives which may be considered are as follows:

1. No restrictions whatsoever, and the indiscriminate discharge of all wastes

2. Detailed and inflexible regulations governing the discharge set out by the local municipality.

3. A set of minimum regulations, which would remain in effect unless special permission were granted.

Without regulations there is no protection for the municipal sewerage facilities and therefore the first alternative would not merit our further consideration.

The second alternative has been adopted by a number of municipalities, both in the United States and in Canada. In these instances the regulations are spelled out in detail and are justified particularly where the treatment plant is overloaded or the sewer system has inadequate capacity.

The third alternative is one which is gaining in popularity as it permits the maximum use of the municipal sewage treatment facilities, and at the same time permits such control as is necessary to gain the maximum efficiency in the operation of these works.

x x x

There are certain factors which must be included in any sewer regulation, and which should prove adequate without specific conditions and requirements. These are predicated on the principle that the regulatory agency would have the right to and would exercise its authority on the basis of factual information and sound judgment.

x x x

Experience dictates that restrictions on waste discharged to municipal systems should include a number, if not all, of the following:

1. No surface drainage to the sanitary system without special permission.

2. No solid materials which will tend to damage structures or settle out in the sewers.

3. No oils, tars, greases or other organic or inorganic material which will tend to cling to the sides of pipes thus impairing their capacity.

4. No oils, petroleum products or other inflammables or explosive materials.

5. No poisonous or toxic materials hazardous to life or plant operation.

6. No materials which may be destructive to sewers or plant structures.

7. No wastes which create noxious conditions that may cause the public any discomfort.

8. No material which will seriously disrupt the efficient operation of the treatment plant.

In the implementation of any Control Program certain information should be obtained, and certain requirements satisfied. An inventory of all industries and businesses, completely outlining the plant operation and the type and quantity of waste to be discharged is desirable, as well as right of entry for the purpose of inspection, sampling and flow measurement. The provision of a manhole on the outlet drain, or connection of the drain to a manhole on the street is sometimes necessary. Where wastes are deemed not acceptable, pretreatment or flow equalization may be required, or the right to prohibit discharge of wastes having a deleterious effect on sewers or sewage treatment plants must be reserved.

To underline the remarks and suggestions made, and to justify the expressed opinion that certain regulations are required, a brief summary of some case histories in the Metropolitan Toronto Area should be helpful.

DAMAGE TO SEWERS

Acid wastes from the plating operations of a battery manufacturer caused failure of a 9-inch vitrified tile drain, resulting in a road sinkage. Although the cement mortar in the joints was first affected, the pipe itself showed extensive corrosion. Where this drain dropped into a concrete horseshoe sewer, the effect of the acid waste was very evident in the spalling of the concrete downstream from the point of connection.

I have for exhibit, a piece of concrete pipe, which once formed a part of a sewer serving a fich-processing industry. The sulphuric acid used in recovery of fats reduced the pH of the plant effluent to 2.5, causing disintegration of the sewer invert and collapse of the pipe.

BLOCKAGE OF SEWERS

The chief offender in this respect is accumulation of fats and greases, which in many cases represents a direct loss to the industry discharging the material. When the accumulation of grease is coupled with collection of hair, wool etc. some serious blockages can result in short periods of time.

In one instnce lard from a food processing plant blocked a sewer flooding a neighbourhood, a dealer in cloth wipers, causing him considerable damage. In another case, wastes from a fellmongery, combined with that from a pork packer, regularly blocked the sewer serving them. Occasionally, whole hides of cattle and sheep have reached the screens of a sewage pumping station. One station had its screen blocked regularly by a gummy mass of vegetable oils, which was traced to the discharging firm who were not aquainted with their losses until they were notified of them. Intercepting equipment was installed shortly thereafter.

One company, due to loss of foundry sand from its operations, blocked a large sewer and caused flooding of several lateral sewers, as the sand deposit extended for several blocks downstream. Cost of removal, which was in excess of $1500, was charged to the offender by the City of Toronto, as is the custom in such cases.

DISRUPTION OF SEWAGE TREATMENT

Formation of scum blankets, composed of grease, fats, cattle hair, paunch manure etc. in digestion tanks can result if indiscriminate discharge of such material is not controlled to some degree. These blankets can become quite extensive and tough causing the digestion tank capacity to be greatly reduced and thus prevent effective treatment.

A small plant naturally is more sensitive, and therefore more vulnerable, to unusually heavy discharges of strong industrial waste. One of our small plants of 0.75 m.g.d. capacity, was at one time seriously handicapped by the discharge of calcium lignosulphonate. At another plant of 3.0 m.g.d. capacity, the total plant effluent was so affected by dumping of lye vats at a nearby soap factory that its pH was 11 and its 5 day B.O.D. rose to 2100 p.p.m. During the canning season, sludge pumping was tripled at this same plant.

Discharges such as these, unless controlled as to volume, strength and periods of discharge, cause equipment failures and can very soon put a small plant out of commission.

HAZARDS

Some wastes are definitely hazardous to personnel engaged in sewer maintenance and sewage treatment work. In this class are cyanide wastes, solvents, sulphides, gasoline, etc.

Gasoline, fortunately, does not frequently occur as a waste, but it does find its way into sewers by leakage or spillage and infiltration. One case of infiltration was caused by a leaking underground tank at a service ststion. The measured loss over a period of 36 hours was 1,500 gallons of gasoline which caused a very dangerous situation in a wide area, besides giving rise to headache and nausea among occupants of buildings with defective drain traps. Another similar instance occurred recently, when a leak in a pressure oil pipe line along the Don River allowed gasoline in quantity to enter an adjacent storm sewer. Fumes found their way into the sanitary system of a large factory nearby and thence passed into the sanitary sewer in a very highly explosive mixture. Fortunately the situation was corrected without incident.

At another of our smaller plants, personnel were seriously affected by solvent discharges from a paint factory. In addition, men have been overcome while working in sewers carrying waste from manufacturers of printing ink and from biological laboratories, although we now preclude a repetition of this by utilization of specialized testing equipment.

Discharges of toxic material to open watercourses constitute a hazard to children and to animals. In one case, an autopsy performed on three head of cattle found dead by a stream, and anlysis of the water disclosed cyanides in lethal quantities in the stream.

SUMMARY

Having examined in some detail specific cases of troublesome industrial wastes, let us consider the steps being studied by the Municipality of Metropolitan Toronto to institute some measure of control over them.

Regulations will have to take into account the existence of combined, sanitary, and storm sewers in this area. Since storm sewers discharge directly to watercourses, rivers or lakes, the material permitted to enter them will have to be rigidly controlled. At the peak of the dry season, quite frequently the only flow in some of our streams is that entering from sewers and sewage treatment plants, therefore the need for a high standard is self evident.

Discharge to sanitary and to combined sewers will be open to the consideration outlined earlier in this paper, that is, the proposed waste will be analyzed and its effect on the system as a whole taken into account.

Basically, then, some determination of what limits will be established is necessary. The Federation of Sewage Works Association, in its Manual of Practice No. 3, Municipal Sewer

Ordinances (1949) a Model Ordinance, outlines a foundation on which a code might be based. But variations will have to be incorporated to allow, perhaps under special permit, discharges in excess of the limits, if maximum use of the sewer system and treatment facilities are to be made, thus reducing to a minimum treatment installations operated independently of those under the control of the municipality.

From the determinations made to date, it would appear that the flows tabulated below might be accepted without question; flows beyond these limits require special consideration in each case, based on all local factors involved, that is the sewers and flows therein, the type of treatment plant, its capacity, the receiving waters for the effluent and other pertinent data - viz:-

1. Range of pH, 5.5 to 9.0 Temperature below 150°F.
2. <u>Effluents to Storm Sewers</u>:

5 day B.O.D.	10-20 p.p.m.
Suspended solids	350 p.p.m.
Cyanides, metallic salts, sulphides	5 p.p.m.
Mineral oils, tar, grease	10 p.p.m.
Phenols	5 p.p. billion

3. <u>Effluents to Sanitary Sewers</u>

5 day B.O.D.	300 p.p.m.
Suspended solids	350 p.p.m. (all passing ½" mesh)
Total fats by weight	100 p.p.m.
Cyanides, metallic salts, sulphides	5 p.p.m.
Mineral oils, tar, grease	10 p.p.m.
Phenols	5 p.p. billion

4. Provision by industry of facilities for sampling of waste waters, such facilities to be accessible to municipal authorities at any reasonable time.

The use of garburetors or garbage comminutors is prohibited in Metropolitan Toronto at the present time, due in part to lack of capacity in the seventeen sewage plants which serve the Metropolitan Area.

At present, our program is one of acquainting industry with the problem involved, and of the savings and benefits that may be derived through a sound approach to the entire matter of industrial waste discharge. Much remains to be accomplished, but progress is gradually being made towards the establishment of a by-law which will form a foundation on which will be built a code permitting a maximum and efficient use of the existing municipal sewage facilities, without unnecessary expenditure by either industry or the public at large.

AN EXAMPLE OF ASSOCIATION RESEARCH APPLIED TO AN INDUSTRIAL WASTE PROBLEM

- THE SULPHITE PULP MANUFACTURERS' RESEARCH LEAGUE, INC. -

- BY -

DR. AVERILL J. WILEY

TECHNICAL DIRECTOR

THE SULPHITE PULP MANUFACTURERS'

RESEARCH LEAGUE INC.

APPLETON, WISC.

RESEARCH AND DEVELOPMENT OF PROCESSES FOR TREATING INDUSTRIAL WASTES CAN USUALLY BE EXPECTED TO PRESENT DIFFICULT PROBLEMS AND THEIR SOLUTION IS APT TO BE EXPENSIVE, SINCE THESE EFFLUENTS ARE THE FINAL RESIDUES FROM MANUFACTURING OPERATIONS FOR WHICH NO PRACTICAL VALUE IS KNOWN, OR, ALTERNATIVELY, FOR WHICH THE COST OF RECOVERY EXCEEDS KNOWN VALUE. UNDER SUCH CONDITIONS, RESEARCH AND DEVELOPMENT ON INDUSTRIAL WASTE PROBLEMS MAY BE CONSIDERED A MATTER OF CHOOSING AS WISELY AS POSSIBLE FROM THREE PRINCIPAL PATHWAYS:

1. FINDING NEW AND GREATER BY-PRODUCT VALUES FROM THE RESIDUE, OR

2. REDUCING THE COST OF RECOVERING VALUES THEREFROM, OR FINALLY,

3. DEVELOPING PRACTICAL, ECONOMICAL, AND INOFFENSIVE METHODS FOR DISPOSAL.

SUSTAINED, WELL-COORDINATED RESEARCH AND DEVELOPMENT ARE REQUISITE TO THE SEARCH FOR AND THE ESTABLISHMENT OF WORKABLE PROCESSES. THE ORGANIZATION AND FINANCING OF RESEARCH ON AN ADEQUATE SCALE ARE OFTEN BEYOND REACH OF SINGLE INDUSTRY UNITS. YET, IF THEY ARE TO COMPLY WITH POLLUTION CONTROL MEASURES AND STILL REMAIN IN BUSINESS, THESE SINGLE INDUSTRY UNITS MUST FIND PRACTICAL ANSWERS WHICH WILL HELP TO MAINTAIN THEIR COMPETITIVE POSITION WITHIN THE INDUSTRY.

THE SUBJECT MATTER OF THIS PAPER OUTLINES ONE SUCH INDUSTRIAL WASTE PROBLEM FOR WHICH GROUP RESEARCH EFFORT

HAS ACCELERATED AND GREATLY ASSISTED IN THE DEVELOPMENT OF ANSWERS FOR THE ENTIRE MEMBERSHIP AT COSTS WITHIN REACH OF EVEN THE SMALLER CONCERNS.

The spent liquor from the acid sulphite pulping industry has been a critical problem since 1874 when the acid method of pulping was first put into commercial practice by Ekman in Sweden and by Mitscherlich in Germany. Both men were, even in those early stages of developing the pulping process, well aware of the disposal and utilization problem presented by that half of the pulp wood being dissolved and wasted to the nearest streams. Both men patented various schemes for utilizing spent liquor. In all the years of the more than 80-year history of this important segment of the pulp and paper industry, literally thousands of ideas have been proposed, researched, and have undergone various stages of development and of commercial practice. Yet we still do not have feasible processes available for processing more than a fraction of the spent liquor produced each day. True, there are a number of sulphite mills which have found use for a part or even all of the liquor individually produce and a good number now have disposal methods of treatment which they can employ with various degrees of efficiency, yet we have far to go to find processes applicable on an industry-wide basis.

The Sulphite Pulp Manufacturers' Research League was established in 1939 by a group of Mid-western sulphite pulp mills to help in obtaining workable answers to this specific waste problem. The resultant cooperative research effort by a group of competitive industry units is representative of a growing trend toward formation of business leagues or trade associations to conduct research and development on a scale which would not otherwise be possible for individual units. The S.P.M. Research League can point to the achievement of a modest degree of success in finding answers which have been usable by its member mills and work now in progress promises to yield new processes and also further improvement and economies in older ideas which can be put to work by the membership.

Organization Features and Advantages of Group Attack

It is our purpose to describe those organizational features and working methods of the Research League which may prove useful to others interested in establishing similar programs of association research.

From the legal standpoint, this organization can be defined as a business league for nonprofit research. It was originally established by twelve corporations operating fourteen pulp mills in the states of Wisconsin and Michigan. The concerns making up the membership were and continue to be highly competitive. The strains and stresses

OF THIS COMPETITIVENESS, ALTHOUGH EVIDENT IN THE BACKGROUND AT TIMES, HAVE BEEN LESS OF A PROBLEM FOR OUR RESEARCH LEAGUE THAN MIGHT HAVE BEEN EXPECTED. GOOD LEADERSHIP AT THE TRUSTEE AND AT THE TECHNICAL COMMITTEE LEVEL GOES FAR TOWARD RECOGNIZING AND ALLOWING FOR INTERESTS AND PROBLEMS OF INDIVIDUAL MEMBER CORPORATIONS, BUT OTHER FACTORS ALSO CONTRIBUTE TOWARD MINIMIZING OR ELIMINATING COMPETITIVE CONFLICTS. THE HEAVY PRESSURE FROM FEDERAL, STATE AND LOCAL STREAM POLLUTION AUTHORITIES AND FROM OTHER SOURCES HAS HELPED TO ESTABLISH A DEGREE OF FAMILY RELATIONSHIP. THIS HAS PROMOTED GROUP EFFORT. REAL ESPRIT DECORPS PREVAILS. POSSIBLY THIS COULD RESULT IN PART FROM OPPORTUNITIES TO GET TOGETHER FOR A GOOD CRY UPON OTHER SHOULDERS ALSO BURDENED WITH EFFLUENT DISPOSAL PROBLEMS, BUT PRINCIPALLY IT RESULTS FROM A GENUINE, CONTINUING INTEREST IN:

1. A COMMON NEED TO FIND A SOLUTION TO THIS WASTE PROBLEM WHICH HAS LONG SINCE REACHED A STAGE WHERE IT COULD THREATEN THE FUTURE OF THE SULPHITE PULPING INDUSTRY.

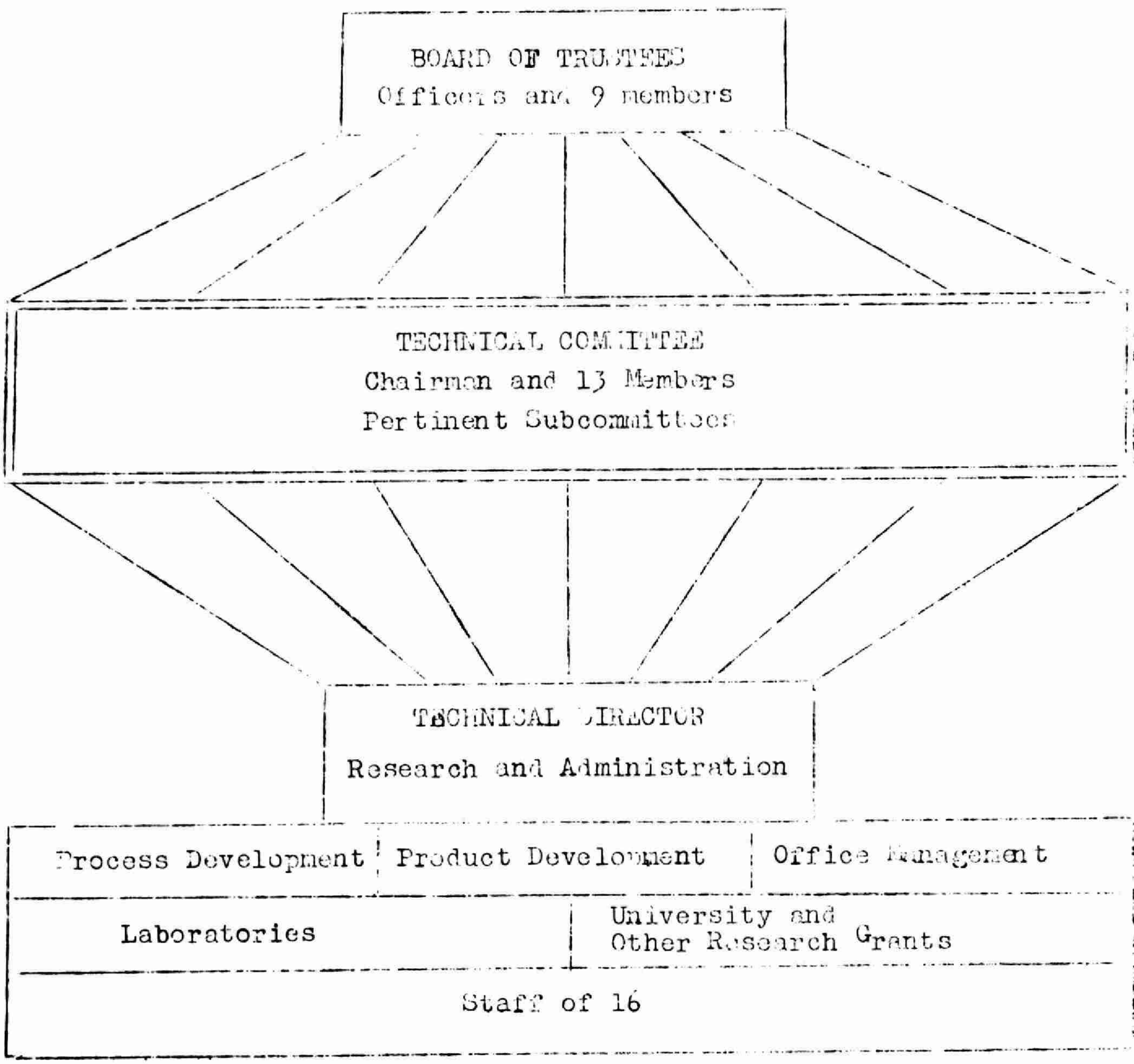
2. A COMMON INTEREST IN FINDING USES FOR THAT POTENTIALLY VALUABLE HALF OF THE PULPWOOD LOG BEING DISSOLVED AND DISCHARGED TO THE NEAREST WATER COURSE.

THE LEAGUE TECHNICAL STAFF HAS HAD AN INTERESTED AUDIENCE FOR EVERY REPORT ISSUED AND HAS BENEFITED FROM THE COMBINED EXPERIENCE, CRITICISM, AND SUGGESTIONS OF INDUSTRY REPRESENTATIVES. THE LEAGUE'S TECHNICAL COMMITTEE, WITH MEMBERSHIP DRAWN FROM THE RESEARCH STAFF OF EACH MEMBER MILL, MEETS QUARTERLY FOR INTENSIVE REVIEW OF PROGRESS AND FOR PLANNING OF TECHNICAL PROGRAM AND POLICY. SIXTY-FOUR SUCH MEETINGS, EACH AVERAGING ONE AND A HALF DAYS, HAVE BEEN HELD IN THE PAST SIXTEEN YEARS. LEAGUE TRUSTEES, WHO ARE RESPONSIBLE EXECUTIVES IN EACH MEMBER CORPORATION, MEET SEMI-ANNUALLY. THESE REGULARLY SCHEDULED MEETINGS ARE OF GREAT HELP IN PROVIDING THE CHANNELS FOR CLOSE COMMUNICATION BETWEEN MEMBER MILLS AND LEAGUE RESEARCH STAFF WHICH ARE VITAL TO THE CONTINUED SUCCESS OF GROUP EFFORT.

THE ORGANIZATIONAL CHART (FIG.1) OUTLINES THE COMMUNICATIONS FUNCTION AND INTERMEDIATE RELATIONSHIP OF THE LEAGUE'S TECHNICAL COMMITTEE BETWEEN THE RESEARCH STAFF AND THOSE ADMINISTRATIVE OFFICERS OF MEMBER MILLS SERVING ON THE LEAGUE BOARD OF TRUSTEES. FEW ARE THE BUSY EXECUTIVES WHO CAN TAKE TIME TO READ VOLUMINOUS TECHNICAL REPORTS ON ALL ASPECTS OF A SPECIALIZED WASTE RESEARCH PROBLEM. INSTEAD, EACH MILL HAS A TECHNICAL REPRESENTATIVE AVAILABLE FROM ITS OWN STAFF WHO CAN PROVIDE INFORMATION ON ANY QUESTION OF LEAGUE RESEARCH RESULTS THAT MAY ARISE DURING THE COURSE OF MILL ORGANIZATION'S REGULAR BUSINESS DAY CONTACTS WITH THE WASTE PROBLEM. THE SAME DIRECT LINE OF COMMUNICATION KEEPS THE LEAGUE STAFF UP TO DATE AND FULLY AWARE OF NEW ADMINISTRATIVE OR TECHNICAL PROBLEMS AND NEEDS OF EACH MEMBER MILL.

Figure 1

ORGANIZATION OF THE S.P.M. RESEARCH LEAGUE



The Staff of the Research League

Closely integrated research on industrial wastes can benefit greatly from well coordinated activities of a research and development staff working directly for the organization. The farming out of research grants to universities, large research institutes, and other research centers has a definite place in any large technical program, and this is discussed in greater detail elsewhere. However, our experience indicates that research conducted by the group's own team of specialists contributes greatly to the over-all effectiveness of the program. The S.P.M. Research League has supported its own staff from the beginning and presently maintains a group of 15 to 17 individuals in its own laboratories, pilot plants, and offices under a technical director. This group includes five project leaders at the Ph.D. and professional engineer level. Technical fields covered by these men and by others having specialties at the graduate level within the staff include physical, carbohydrate, analytical, and sanitary chemistry, biochemical engineering, chemical engineering and biochemistry. Special efforts are made to maintain conditions favorable for the staff to work as a closely integrated team. The team spirit contributes much toward adapting the research effort to changes in pace and in direction of individual projects which are characteristic of association research and which are apt to be much more difficult to accomodate in larger departmentalized research organizations.

Group research organizations operating their own staff laboratories have many other advantages in being able to service emergency requests of member mills where practical problems of waste utilization or disposal suddenly arise or where the member mill has an outside request for special material it may wish to provide to prospective market outlets. The research tem keeps itself informed and also helps to inform member organizations of new scientific developments. Technical journals are now too numberous to permit any one individual to maintain himself fully current, but a group with various specialized interests distributed among several individuals tends to read widely and together they keep other members of the team informed in many fields. Attendance at meetings of professional societies by staff members is encouraged whenever the technical program promises to be of value. The accumulated knowledge of a research team over a period of years becomes an invaluable asset to group research effort and to the entire membership supporting such research.

Facilities of the Research League

Library: A primary requisite of any research program is the availability of adequate library facilities. In the case of the Research League, Office and laboratory

SPACE ARE SITUATED AT THE INSTITUTE OF PAPER CHEMISTRY IN APPLETON, WISCONSIN, AND THE STAFF THUS HAS THE ADVANTAGE OF USING ONE OF THE FINEST AND MOST COMPLETE TECHNICAL LIBRARIES IN THE PULP AND PAPER FIELD. THE FIRST PROJECT AUTHORIZED AT THE BEGINNING OF THE LEAGUE PROGRAM PROVIDED FOR A LITERATURE SEARCH BY THE LATE DR. CLARENCE WEST WHO COMPILED THE BIBLIOGRAPHY OF SPENT SULPHITE LIQUOR. THE FIRST VOLUME OF THAT BIBLIOGRAPHY COVERED THE LITERATURE OF 1940 WITH EXCELLENT ABSTRACTS OF SEVERAL THOUSAND ARTICLES AND PATENTS. ANNUAL SUPPLEMENTS SINCE THEN HAVE BEEN COMPOSITED AT 5-YEAR INTERVALS. UNTIL RECENTLY THIS BIBLIOGRAPHY WAS MAINTAINED FOR THE LEAGUE MEMBERSHIP ONLY, BUT THE DEMAND HAS REACHED THE POINT WHERE A MICROCARD EDITION HAS BEEN PREPARED FOR GENERAL DISTRIBUTION AT NOMINAL COST. IN ADDITION TO THE GENERAL LIBRARY AT THE INSTITUTE OF PAPER CHEMISTRY, THE LEAGUE ALSO MAINTAINS ITS OWN HIGHLY SPECIALIZED LIBRARY OF SELECTED TEXTS AND JOURNALS FREQUENTLY USED BY THE STAFF. STAFF MEMBERS CONTRIBUTE TO THE MAINTENANCE AND GROWTH OF A CAREFULLY CROSS-INDEXED REPRINT COLLECTION NOW NUMBERING MORE THAN 5,000 ITEMS. TECHNICAL MEN FROM THE MEMBER MILLS FIND THIS LIBRARY OF SPECIAL UTILITY WHEN INITIATING LITERATURE REVIEWS FOR COMPANY PROJECTS AND WHEN WRITING PAPERS FOR TECHNICAL MEETINGS AND PUBLICATIONS.

LABORATORIES: INITIALLY, THE INSTITUTE OF PAPER CHEMISTRY PROVIDED LABORATORY SPACE AND EQUIPMENT FOR SETTING UP THE LEAGUE PROGRAM. BUT WITH THE GROWTH OF THE STAFF AND PROGRAM IT SOON BECAME DESIRABLE TO ACQUIRE SPECIAL TOOLS AND EQUIPMENT PARTICULARLY ADAPTED TO THE LEAGUE REQUIREMENTS. THE LEAGUE NOW OWNS ALL OF ITS OWN LABORATORY EQUIPMENT FOR WHICH THE INVESTMENT EXCEEDS $1,000,000. THIS IS EXCLUSIVE OF AN EVEN LARGER AMOUNT INVESTED IN THE PILOT PLANTS. THIS EQUIPMENT HAS BEEN ACQUIRED OVER A PERIOD OF SOME 16 YEARS AND EVERY EFFORT IS MADE TO SEE THAT MAJOR ITEMS WHICH CAN ONLY BE PURCHASED AT RELATIVELY HIGH COST ARE OF SUCH TYPE AS TO BE ADAPTABLE FOR USE BY THE GROUP AS A WHOLE. INCLUDED IN THIS CATEGORY ARE SUCH ITEMS AS THE RECORDING SPECTROPHOTOMETER, MOLECULAR STILL, AND COLUMN CHROMATOGRAPHIC EQUIPMENT WITH FRACTIONATION COLLECTORS. HOWEVER, CAPITAL CHARGES FOR SPECIALIZED LABORATORY EQUIPMENT COULD EASILY GET OUT OF HAND WERE IT NOT FOR A LONG CONTINUED POLICY OF ALSO UTILIZING THE MORE HIGHLY SPECIALIZED TYPES OF EXPENSIVE EQUIPMENT AT UNIVERSITIES AND OTHER ORGANIZATIONS WHEREVER AVAILABILITY PERMITS. AS AN EXAMPLE OF SUCH COOPERATION, THE LEAGUE RECENTLY WAS ABLE TO COOPERATE WITH ONE OF THE LARGER MANUFACTURERS OF ELECTRONIC EQUIPMENT FOR A SERIES OF IRRADIATION EXPERIMENTS AND ASSAYS. ADEQUATE TESTING AND EVALUATION OF THE IDEA WERE MADE POSSIBLE AND THE PROJECT WAS COMPLETED IN A REASONABLE PERIOD OF TIME WITHOUT NECESSITY FOR PURCHASE OF EQUIPMENT.

Pilot Plants: The League has exceptional pilot plant facilities for an organization of its size due to the fact that five separate processes have by this time been carried through the pilot stage of evaluation in seven separate pilot plant units. Four of those pilot plants were constructed to scale sufficiently large to handle the spent liquor from one or more tons of daily pulp production, and the others are large enough to fully deserve the designation of pilot plants. Of equal or more importance to day by day research activity are the many setups made in the pilots on an intermediate scale between laboratory and pilot using a valuable collection of unit process equipment common to chemical engineering practice. Standard small-scale equipment of accepted commercial design and manufacture are available for work on unit operations in the fields of absorption and stripping, contrifugation of several types, distillation, drying, evaporation, liquid extraction, filtration, mixing, ion exchange and fermentation. Most of this equipment is of long-lived 316 stainless steel construction and together with necessary supporting equipment such as tanks, pumps, valves, gauges, controlling instruments, and piping account for an additional capital investment of some $175,000.

Possession of this pilot plant equipment with its own small control laboratory is largely responsible for much of the quick service which can be characteristic of small, integrated research organizations of this kind. The pilot plants are staffed to permit around-the-clock operation of continuously operated experiments wherever required in the development of continuous processes on a laboratory or pilot scale. Any research administrator who has experienced the red tape incident to setting up small or large experiments for quick evaluation of an idea in large departmentalized organizations or alternatively, the difficulties of gathering needed equipment in very small organizations with limited facilities can readily appreciate the advantages accruing from availability of pilot facilities on this scale.

Another function of the pilot plant is concerned with the preparation of sample material to be sent out for evaluation of various spent sulphite liquor products produced in the program of utilization research. Several hundred such samples may be sent out each year to outside organizations interested in their evaluation and possible use. The distribution and evaluation of such samples constitute the first step toward eventual market evaluations. Of course, many of the samples sent out draw a blank, but those which do find interest more than justify the effort. This is a legitimate group research function that bridges the gap between fundamental and applied research. In our experience it has proved an important activity of the League through helping greatly to find applications for the basic work which brings new ideas.

Even though the importance of conducting fundamental research is fully recognized by the staff -- still it remains a difficult item to finance. Persons responsible for underwriting the expense of basic research cannot be blamed for finding fundamental research reports dull, uninteresting and hard to relate to the results they are looking for. The pilot plant preparation of market evaluation samples does much to keep interest alive and the over-all research program functioning smoothly.

Specialized Facilities Available Through Cooperation With Member Mills

Another advantage accruing from group research derives from interest of member mills in furthering the over-all research program by using any specialized facilities or manpower that may be available at the member mill and which would help develop answers to a group problem. A field problem may require men and material beyond the immediate capacity of the League staff and the lack may be provided from facilities of one of the member organizations. Practical mill-scale tests on burning concentrated liquor were carried out at several member mills in their boiler plants using concentrated liquor produced in the League pilot plant. A highly technical problem in heat transfer may be developed in cooperation with engineering specialists from a member mill. Such activities conducted cooperatively between League and member mill are carried out and reported to the membership as a whole. The advantages from such cooperation are obvious and have resulted in the acquisition of data more rapidly and at much lower cost than would otherwise be possible.

The facilities that can be made available for group research can best be summarized as an exceptional advantage seldom attainable under any other system of conducting industrial waste research. The group research staff can initiate a project and carry it through test tube, flask, and small laboratory unit stages on into pilot plant and even into semi-commercial tests with a minimum of cost, red tape, and delay.

Research Grants to Outside Agencies

Although it is desirable to emphasize the value of staff-conducted work as essential to an effective group research program, such emphasis is not meant to minimize the importance of research grants to universities, institutes and other outside organizations having specialized knowledge and equipment available. The Sulphite Pulp Manufacturers' Research League has consistently supported a program of research grants and has allotted funds each year to the extent of from 20% to 40% of the over-all annual budget.

The largest single grant has been to organic chemistry group of The Institute of Paper Chemistry for sponsorship of a continuing program of fundamental and applied lignin research. The cost of this project together with related Institute projects has totaled $400,000 at an average level of $25,000 annually. Specialized work in other fields has been supported by grants to the Universities of Wisconsin, Minnesota, New Hampshire, Wyoming, and Iowa and Michigan State Colleges.

The results obtained from cooperative research by outside institutions has been well worth the investment and such work will be continued. However, such work requires careful coordination and with concurrent staff research if its full value is to be realized in a reasonable period of over-all research effort.

The Nature and Scope of the League Research Program

Originally the member mills conceived of this industrial waste research program as a quick means of finding disposal methods for the spent liquor and the group was at first named the Sulphite Pulp Manufacturers' Committee on Waste Disposal. Utilization of spent sulphite liquor was conceived as a long-term research effort, but it soon became apparent that the practical problems inherent in the disposal of huge tonnages of organic matter called for at least some recovery of by-product values to balance the handling and processing charges. The League which was incorporated in 1946 under its present name is still searching for economical methods of disposal but devotes a large proportion of its effort toward utilization.

In Figure II we have listed the major projects currently under active research by the League and its cooperators. Of these projects, that for process and product development on torula yeast production and of lignin research are outstanding for length and scope of efforts. Both projects have been in progress more than 14 years. The torula yeast process has been carried through test tube, flask, and small laboratory fermentor stages; on to pilot plant and semi-commercial with design, construction, and experimental operation of the Rhinelander yeast plant. The League research in this field still continues with product development to upgrade the yeast and to extend the market in the belief that other mills will eventually be able to join the two now producing yeast in full commercial plants.

Figure 2

MAJOR PROJECTS FOR LEAGUE RESEARCH

a Whole Liquor	b Carbohydrate Fraction	c Lignin Fraction
Evaporation	Torula Yeast	Physical Chemistry
Burning	Process Development	Polymerization
Briquetting	Product Development	Surface Active Studies
Roadbinder	Sugar Derivatives	Fractionation
Soil Stabilization	Furfural	Chemical Derivatives
Soil Filtration	Others	Vanillatos
Stream Studies		Others

d
Literature Survey

16 Years Compilation

It is improbable that many research projects can be followed through in this way by a single research group. However, the opportunity presented had an unexpectedly valuable by-product in that it was a stimulant par excellence to the morale of the research group.

In this paper we can only generalize on the nature and scope of the individual research program conducted by the staff on each project. In recent years we have changed our outlook on the over-all research program from the strictly disposal and utilization standpoints toward a division into applied research on each major project using ideas that are in advanced stages of development and again to fundamental research in which a search for new ideas and new methods is made. Figure III outlines the scope of the research program according to this division of staff effort. Fundamental research has been given increasing emphasis in the search in the fundamental of carbohydrate, lignin and physical chemistry have proved especially important. But, here again, we recognize that basic or fundamental types of research must be accompanied by a good balance of closely associated applied effort.

Spent sulphite liquor is a mixture of many organic and inorganic compounds derived directly or as indirect reaction products from the solution of the noncellulosic components of wood in the bisulphite cooking acid. These compounds fall into several generic classes the most important of which are the lignosulfonates, the sugars and their hydrolytic breakdown products, various terpene and resin extractives, and the residual inorganics and salts derived from the cooking chemicals. The complexity of this mixture of organics and inorganics is reflected in the many potentially useful properties such as dispersion, adhesion, flocculation, and foaming, which have been recognized to be present in spent sulphite liquor. The research and development program of the League was first directed toward finding means for disposing of or utilizing the complex mixture contained inthe whole liquor just as it comes from the pulp mill. Gradually a major interest in the research program has evolved into a search for practical methods of islating fractions or individual compounds from the mixture which could give cheap new sources of basic chemicals for industry. Fundamental and applied research in laboratory and pilot plant is required to carry out this program. Much has been accomplished in this direction in and out of the League laboratories, but the future research program of the League is expected to be increasingly concerned with fractionation and development of new products therefrom.

Figure 3

SCOPE OF THE RESEARCH PROGRAM

FUNDAMENTAL STUDIES	APPLIED RESEARCH AND DEVELOPMENT
Carbohydrate Chemistry	Sugars and Derivatives
Lignin Chemistry	Lignosulphonates and Derivatives
Physical Chemistry	Surface Active Fractions
Soil Studies	Polymers
Stream Studies	Soil Stabilizers
Chemical Engineering	Ponding and Soil Filters
	Stream Loadings
	Unit Process Studies

Results of League Research in Terms of Commercial Use

Many individuals concerned with establishment and financing of research on industrial wastes have been interested in observing the amount of time required and the extent to which commercial application has been possible from group sponsored research. Any such observations must of course be conditioned by the scale of the research program, but the Sulphite Pulp Manufacturers' Research League program has an interesting record which has been tabulated in Figure IV.

The progression from laboratory through pilot to commercial required about five years for the yeast process and other processes have a similar record. The roadbinder and evaporation program started with pilot or semi-commercial applications based on experience from outside the League, but both processes have gone back to the laboratory for further development of principles. The yeast and evaporation studies may now be considered to be in advanced stages of process development, but research on product development and the up-grading to better markets is developing in laboratory and pilot stages for both processes. Much fundamental research may be required to form a firm foundation for product development and this is considered as within the province of group sponsored research. Final market

DEVELOPMENT IS TAKEN OVER BY THE INDIVIDUAL MILLS AS SOON AS COMPETITIVE INTEREST DEVELOPS IN AN IDEA.

CONCLUSION

THE LARGE BASIC INDUSTRIES OF OUR EARLIER UNITED STATES AND CANADIAN ECONOMIES BENEFITED GREATLY FROM THE USE OF RAW MATERIALS OF MINE AND FOREST WHICH WERE PLENTIFUL, CHEAP AND OFTEN CONSIDERED NEARLY INEXHAUSTIBLE. UNDER SUCH CONDITIONS MANUFACTURING OPERATIONS HAD LITTLE NEED OR INCENTIVE FOR RECOVERY OF PROCESS RESIDUES AND DISPOSAL WAS PRACTICED BY THE CHEAPEST MEANS AVAILABLE. IT WAS A WAY OF BUSINESS COMMON TO THE TIMES. THOSE TIMES AND CRITERIA ARE FAST DISAPPEARING.

STAGES OF LEAGUE RESEARCH AND COMMERCIAL APPLICATION

Figure 4

	DISPOSAL	UTILIZATION
1939 - 1944 (LAB)	TRICKLING FILTERS	LIGNIN RESEARCH
	ACTIVATED SLUDGE	METHANE FERMENTATION
	RIVER REAERATION	YEAST STUDIES
1944 - 1949 (PILOT)	DUST LAYING	EVAPORATION
	SOIL DISPOSAL	BRIQUETTING
	BURNING	ADHESIVES
		CHEMICAL RECOVERY
		YEAST
		VANILLATES
1949 - 1954 COMMERCIAL	PONDING AND SOIL FILTRATION	EVAPORATION
	STREAM STUDIES	YEAST
	BURNING	MARKETING OF CONCENTRATE
		FRACTIONATION STUDIES
		FUNDAMENTAL RESEARCH

TODAY WE FIND OUR INDUSTRIAL ECONOMY BECOMing INCREASINGLY CONSCIOUS OF NEED FOR RECOVERY OF ALL POSSIBLE VALUES FROM THE RAW MATERIALS WE USE. THE RECOVERY OF BY-PRODUCT VALUES IS BECOMING GOOD BUSINESS AND EVEN VITAL TO THE EXISTENCE OF COMPETITIVE UNITS WITHIN AN INDUSTRY. THE VERY EXISTANCE OF ENTIRE INDUSTRIES CAN DEPEND ON WHETHER OR NOT GREATER VALUES CAN BE FOUND AND RECOVERED BY PRACTICAL MEANS.

THE CRITICAL NATURE OF STREAM AND AIR POLLUTION PROBLEMS CONTRIBUTES GREATLY TO NECESSITY FOR AN EXPANDING RESEARCH EFFORT ON INDUSTRIAL WASTES.

THERE ARE NUMEROUS WAYS IN WHICH SUCH RESEARCH IS BEING ORGANIZED AND THE COST UNDERWRITTEN. GROUP RESEARCH AS DESCRIBED IN THIS PAPER HAS ALREADY PROVED OF VALUE ON INDUSTRIAL WASTE PROBLEMS.

IT CAN BE CONCLUDED THAT INDIVIDUAL COMPETITIVE UNITS WITHIN AN INDUSTRY CAN WORK TOGETHER SUCCESSFULLY AND EFFICIENTLY ON BOTH FUNDAMENTAL AND APPLIED RESEARCH FOR PROBLEMS COMMON TO THE ENTIRE INDUSTRY. COOPERATIVE GROUP RESEARCH PROBABLY CAN BE CONSIDERED AS ONE OF THE LOWEST COST METHODS FOR EFFECTIVE LONG RANGE ATTACK ON INDUSTRIAL WASTE PROBLEMS.

FROM WASTE AND NUISANCE TO USE AND PROFIT

* By *

J. RICHTER SALVESEN

Director of Central Research
Marathon Corporation

ROTHSCHILD, WISCONSIN.

The tree is a thing of beauty to the artist and a source of lyrics to the poet. But the engineer and the chemist see in the forest an ever growing source of raw material for cellulose -- nature's building material.

Wood is the most important renewable raw material in the world. It serves industry in two important ways: as a construction material, and as a raw material for the manufacture of paper.

Life most of nature's resources, wood must be subjected to processing steps to suit it to the ultimate use. Changing its physical size and shape generally renders it satisfactory for use in construction; however, its use in papermaking requires that it be broken down chemically into its components. Wood is a complex structure of cellulose fibers bound together by lignin and hemicelluloses.

About eighty years ago two chemical processes were developed for obtaining the cellulose fibers desired for papermaking by dissolving out the noncellulosic wood components. In principle, these two processes still represent the methods by which most pulp mills convert wood chips into cellulose fibers.

One process (sulfate) makes use of an alkaline liquor as a digesting medium which, after dissolving the non-cellulosic materials, is drained from the cellulose fibers. The high cost of these alkaline cooking chemicals made it necessary to recover them for reuse. This is technically a relatively simple process, accomplished by evaporating the cooking liquor, burning out the dissolved organic matter, and reconverting the ash for recycling as cooking chemicals. To-day this recovery process is developed to a high degree of efficiency, returning not only the cooking chemicals but steam and energy to more than pay for the recovery process, and leaving a minimum of effluent to the mill sewers.

The other major pulping process (sulfite) uses a solution of calcium bisulfite and SO_2 as a cooking liquor. Although the low cost of these cooking chemicals has made it economically permissible to discard the spent pulping liquor, this practice represents an enormous waste of a potentially valuable organic material. In the United States three million tons of wood components have gone to waste each year in the form of discarded spent sulfite liquor.

The sulfite liquor, as it drains from the cooked cellulose fibers, is acidic from SO_2 and organic acids and has from 10 to 12 per cent solids. Even with to-day's highly developed analytical methods it is possible to define and analyze only a part of the organic components. Roughly about 2/3 of the solids consist of calcium lignosulfonate and 1/3 of sugars -- mainly a mixture of pentoses and hexoses. The organic components are sterile and non-toxic. However, when discharged into waterways, the liquor causes depletion of the dissolved oxygen -- partly by the direct reaction with the SO_2 but mainly by the biochemical oxygen demand produced by the stimulating effect which the organic components (primarily the sugars) exert on the biological processes in the dilution water. Such oxygen demand may, under unfavorable conditions as regards dilution, temperature, and natural re-aeration, reduce the dissolved oxygen in the receiving waterways below the level necessary for normal aquatic life. This is the potential stream-polluting effect from spent sulfite liquor.

Efforts towards pollution abatement, and utilization of the spent sulfite liquor commenced shortly after the sulfite pulping process came into use. The thousands of publications and patents dealing with this problem illustrate clearly its complexity. The fact that even to-day only a small percentage of the spent liquor for sulfite pulping throughout the world is utilized means that a generally acceptable processing method for this by-product has still not been found.

Straight evaporation with subsequent combustion of the concentrate -- as in the alkaline pulping process -- might seem a suitable solution. But several obstacles presented themselves. First, the acidity of the liquor required processing equipment fabricated from stainless steel, not industrially available until the early 30's. Second, calcium salts in the liquor produced scaling of the heating surfaces, thereby reducing heat transfer and causing plugging of tubes and openings. It was not until in the early 40's that engineering design and evaporation techniques offered adequate solutions to the scaling problems. Even with these developments, removal of 8-10 pounds of water per pound solids presents an unattractive heat balance unless the regular fuel cost is high.

With proper pretreatment of the spent liquor it is possible to produce ethyl alcohol from the hexose sugars. Again the scaling tendency and the low sugar concentration are formidable obstacles to efficient operation. But under special economic conditions production of alcohol from spent sulfite liquor is commercially attractive. In Sweden the economy is favorable for such production and the sulfite pulp mills there are presently producing a total of 20 million gallons per year 95 per cent ethanol from the spent liquor. One mill in Canada and one in the United States started producing ethanol by fermentation of their spent liquor during the Second World War-stimulated by the then existing conditions -- and are still operating such process. A second Canadian mill is now also producing ethanol from their spent liquor. By consuming the hexose sugars, the alcohol fermentation process reduces the biochemical oxygen demand of the spent liquor by some 30 per cent.

Within the last 15 years a method has been developed for utilizing all the carbohydrates in spent sulfite liquor by biochemical conversion into yeast, which can be separated by centrifuging and drying to be marketed as a powdery protein and vitamin-rich product suitable as animal feed component.

IN GERMANY IN THE LATE 30'S IT WAS DISCOVERED THAT A SPECIAL TYPE OF YEAST -- TORULA UTILIS -- WILL METABOLIZE AND MULTIPLY NOT ONLY ON HEXOSE SUGARS, BUT ALSO ON PENTOSES AND SOME OTHER ALIPHATIC ORGANIC COMPOUNDS. THE WISCONSIN SULPHITE PULP MANUFACTURERS'RESEARCH LEAGUE, INC., HAS CARRIED OUT EXTENSIVE RESEARCH BASED ON THIS DISCOVERY, TO ESTABLISH PRACTICAL AND EFFECTIVE MEANS OF PROPOGATING SUCH YEAST ON SPENT SULFITE LIQUOR AND RECOVERING IT IN MARKETABLE QUALITY. AFTER SUCCESSFULLY APPLYING THE RESEARCH FINDINGS IN PILOT PLANT OPERATION, THE PROCESS IS NOW OPERATED ON A COMMERCIAL SCALE BY TWO WISCONSIN SULFITE MILLS. THESE PLANTS HAVE A COMBINED CAPACITY OF 7,000 TONS DRY YEAST PER YEAR AND THE PROCESS AFFORDS ABOUT 60 PER CENT REDUCTION OF THE BIOCHEMICAL OXYGEN DEMAND OF THE LIQUOR PROCESSED. IT REMAINS FOR THE IMMEDIATE FUTURE TO ESTABLISH WHAT THE MARKET CAPACITY IS FOR THIS YEAST PRODUCT AT THE SELLING PRICE REQUIRED BY THE PROCESSING COSTS. SUCH MARKET ANALYSIS AND THE EXPERIENCE FROM THE TWO PRESENT PLANTS WILL DECIDE IF OTHER SULFITE MILLS CAN ADOPT THE METHOD FOR UTILIZATION AND POLLUTION REDUCTION OF THEIR OWN SPENT SULFITE LIQUOR.

MARATHON CORPORATION HAS, SINCE 1909, OPERATED A SULFITE MILL IN ROTHSCHILD, WISCONSIN THIS MILL PRESENTLY PRODUCES ABOUT 50,000 TONS CELLULOSE FIBERS PER YEAR. EVEN IN THE EARLY YEARS OF THIS PLANT'S OPERATIONS, MARATHON'S MANAGEMENT WAS SERIOUSLY CONCERNED ABOUT THE DISCHARGE OF SPENT SULFITE LIQUOR INTO THE WISCONSIN RIVER AND THE CONSEQUENT POLLUTION AND ANNUAL WASTE OF APPROXIMATELY 50,000 TONS OF ORGANIC SOLIDS.

IN 1927 MARATHON DECIDED TO ATTACK THE SPENT SULFITE LIQUOR PROBLEM. THIS WAS BASED ON AN ENTIRELY DIFFERENT APPROACH -- THE PRECIPITATION OF SPENT LIQUOR COMPONENTS AS SEPARATE, DISTINCT FRACTIONS BY CONTROLLED ADDITION OF LIME SLURRY. FIRST A THOROUGH STUDY IN BEAKER SCALE WAS CARRIED OUT TO LEARN THE MOST FAVORABLE CONDITIONS. THIS PROVED SO ENCOURAGING THAT THE NEXT STEP -- TO PILOT PLANT OPERATION -- APPEARED WARRANTED. STILL IN SMALL SCALE, BUT WITH LARGE SCALE EQUIPMENT SUCH AS FEEDERS, PUMPS, SETTLING TANKS AND FILTERS, THE LIQUOR FRACTIONATION WAS CARRIED OUT AS A CONTINUOUS PROCESS TO LEARN THE LARGE PLANT PROBLEMS AND TO FIND PRACTICAL SOLUTIONS TO TECHNICAL DIFFICULTIES. THE PILOT PLANT ALSO PRODUCED AMPLE QUANTITIES OF THE LIQUOR FRACTIONS FOR STUDIES OF THEIR UTILITY.

THE MAIN PROCESS EMERGING FROM THESE STUDIES HAD AS ITS FIRST STEP THE PRODUCTION OF A PRECIPITATE OF CALCIUM SULFITE BY ADDING LIME SLURRY TO THE SPENT SULFITE LIQUOR TO A CERTAIN STRICTLY CONTROLLED PH LEVEL. THE PRECIPITATE IS CONVEYED TO THE PULP MILL ACID PLANT WHERE IT IS USED IN THE CALCIUM BISULFITE-SO_2 COOKING LIQUOR MAKE-UP SYSTEM. THUS THE SO_2 IN THE SPENT LIQUOR IS KEPT FROM CONTAMINATING THE RIVER, BY BEING RETURNED TO THE PULPING PROCESS.

IN THE SECOND STEP THE CLEAR OVERFLOW AND FILTRATE FROM THE FIRST STEP ARE TREATED WITH FURTHER AMOUNTS OF LIME SLURRY UNDER STRICTLY CONTROLLED CONDITIONS, TO PRODUCE A YELLOW FLOCCULATED PRECIPITATE CONSISTING MAINLY OF BASIC CALCIUM LIGNOSULFONATE. THIS PRECIPITATE IS CONTINUOUSLY SEPARATED AS A FILTER CAKE ON A ROTARY VACUUM FILTER. THE FILTRATE IS FINALLY STRIPPED OF ALL PRECIPITATABLE ORGANIC MATTER BY ONE MORE ADDITION OF LIME SLURRY, AND IS THEN DISCHARGED INTO THE RIVER. ANALYSES HAVE CONSISTENTLY SHOWN THAT THIS PROCESS AFFORDS A 60-65 PER CENT REDUCTION IN BIOCHEMICAL OXYGEN DEMAND AS COMPARED WITH THE UNTREATED LIQUOR. PRESENTLY ABOUT 85 PER CENT OF THE SPENT SULFITE LIQUOR SOLIDS PASSES INTO THE PRECIPITATION PROCESS AND THE REST IS SO DILUTED WITH PULP WASH WATER THAT IT IS IMPRACTICAL TO PROCESS. THIS MEANS THEN THAT THE PROCESS PROVIDES 50-55 PER CENT OVERALL REDUCTION IN POLLUTION FROM SPENT SULFITE LIQUOR AT ROTHSCHILD.

Basic calcium lignosulfonate, the material resulting as a filter cake after the second precipitation step, is the main product of the process. As it represents around 50 per cent of the spent sulfite liquor solids, about 1000 pounds is obtained from the spent sulfite liquor equivalent of one ton of pulp produced. Obviously the all-important question for the practical usefulness of the process was: "How can these large quantities of this hitherto unknown lignin product be utilized?" Early in the development it was expected that this organic material could be used advantageously as fuel to replace some of the mill's coal requirement. However, large scale tests under actual boiler firing conditions proved this product to be technically and economically unsuitable as fuel.

This situation called for a broad and intensive research attack to develop new uses and profitable markets for the precipitated lignosulfonates -- actually a new organic raw material. Such typical "application research" consisted partially in establishing the properties of the product and practical modifications of it, partially in studying their applications to established industrial products and processes.

The first product offered to industry was a tanning agent. The first tank car shipment of "Maratan" was made in 1932 from the pilot plant production. There followed other products adapted for various industrial uses by modifying the structure of the lignosulfonates under varying conditions of temperature, pH, pressure, degree of sulfonation, and oxidation.

A process was developed for the alkaline hydrolysis of lignosulfonate, wherein vanillin was obtained as a cleavage product of the lignin, and the resulting effluent became a source of partially desulfonated lignosulfonates. These desulfonated lignosulfonates exhibited surface activity of such a degree as to indicate their potential value as dispersing agents. After extensive laboratory and pilot studies, processes for the manufacture of lignosulfonate products and vanillin showed such promising commercial possibilities that in 1935 a full scale plant was erected to treat the effluent from the Rothschild pulp mill. This assured a supply of lignin adequate to feed a commercial plant for making vanillin. This latter plant was constructed in 1937 under an arrangement whereby Marathon supplied the process and the lignin, with the manufacture and sale of the vanillin to be carried out by the Salvo Chemical Corporation, now a subsidiary of the Sterling Drug Company. Today the Rothschild plant has a vanillin production which supplies nearly 2/3 of the United States market for this flavoring agent.

The commercial success of Marathon's chemical venture has depended upon the ability of the company's research personnel to develop an ever-increasing number of new products to fulfill specific needs of the chemical process industries. Another important factor was the determination of its technical sales department to ferret out new markets and to demonstrate the true utility of the lignosulfonate products to those chemical process industries requiring dispersing agents and emulsion stabilizers in their products and processes.

Success did not come overnight. The structure of Marathon's purified lignosulfonates is such that they perform unusually well as dispersing agents, preventing flocculation of insoluble solids or the coalescence of immiscible liquid globules in water, but it was not until after World War II that surface active agents such as these found sizeable markets. By the time Marathon's Chemical Division showed its first profits -- in 1945 -- the company had spent several millions of dollars for research and manufactur-

ING INSTALLATIONS. TODAY'S CHEMICAL PLANT HAS THE CAPACITY TO PRODUCE A SEVENTY-FIVE MILLION POUNDS OF LIGNIN MATERIALS PER YEAR.

CHEMICAL RESEARCH IS CONDUCTED BY THE CENTRAL RESEARCH DEPARTMENT, WHOSE MEMBERS FORM PART OF MARATHON'S STAFF OF 250 ENGINEERS, SCIENTISTS, AND TECHNICIANS. THIS DEPARTMENT IS HOUSED IN A MODERN, STREAMLINED LABORATORY BUILDING HAVING EXCELLENT PILOT PLANT FACILITIES, AS WELL AS ANALYTICAL, ORGANIC, PHYSICAL, AND BACTERIOLOGICAL LABORATORIES FOR THE STUDY OF SPENT SULFITE LIQUOR AND ITS DERIVATIVES.

OUR LIGNOSULFONATES HAVE FINALLY GAINED ACCEPTANCE IN A WIDE RANGE OF INDUSTRIAL APPLICATIONS, WHERE THEIR SURFACE ACTIVITY IS OF PARTICULAR VALUE. THEIR USE IS BY NO MEANS LIMITED TO INDUSTRY IN THE UNITED STATES. THEY MAY BE FOUND IN SUCH WIDELY DIVERSE APPLICATIONS AS OIL WELL DRILLING MUDS IN VENEZUELA, PESTICIDES IN FORMOSA, ORE FLOTATION IN SOUTH AFRICA, INSECTICIDES IN ICELAND AND IRELAND, OIL WELL CEMENTING IN GERMANY, AND BOILER WATER TREATMENT IN MEXICO.

THE COMPANY'S CHEMICAL DIVISION HAS COME A LONG WAY TOWARDS OBTAINING THE TWO GOALS ORIGINALLY SET. STREAM POLLUTION AT THE ROTHSCHILD PLANT HAS BEEN CONSIDERABLY REDUCED AND PROFITABLE COMMERCIAL USES FOR DERIVATIVES OF SPENT SULFITE LIQUOR HAVE BEEN ESTABLISHED. THERE ARE SEVERAL OTHER COMMERCIALLY PROMISING APPLICATIONS FOR SULFITE LIQUOR DERIVATIVES CURRENTLY BEING EXPLORED, WHICH, IF SUCCESSFUL, WILL REPRESENT FURTHER PROGRESS TOWARDS COMPLETE ACHIEVEMENT OF OUR OBJECTIVES.

PIONEERING VENTURES WILL, IF SUCCESSFUL, ALWAYS FOSTER INCREASING COMPETITION. KEENER BIDDING FOR MARKETS WITH BETTER AND LOWER PRICED PRODUCTS IS PARTICULARLY CHARACTERISTIC FOR THE CHEMICAL INDUSTRIES TODAY. THEREFORE, THE COMMERCIAL ADVANTAGES FROM RESEARCH CAN ONLY BE PROTECTED WITH MORE RESEARCH. IN LINE WITH THIS IS MARATHON'S POLICY TO RETURN FOR RESEARCH AND DEVELOPMENT A SUBSTANTIAL PART OF THE PROFIT FROM THE WASTE UTILIZATION DEVELOPMENTS.

THIS DISCUSSION OF APPROACHES TO SPENT SULFITE LIQUOR UTILIZATION IS UNREALISTIC UNLESS IT CONVEYS THE UNDERSTANDING THAT THE COSTS OF SUCH VENTURES ARE GREAT AND THE TIME REQUIRED TO REACH SATISFACTORY SOLUTIONS ARE VERY CONSIDERABLE. WE KNOW OF NO MIRACLES, NO SHORT-CUTS TO SUBSTITUTE FOR THE EXPENSIVE AND HARD JOB OF TURNING "WASTE AND NUISANCE INTO USE AND PROFIT."

*
***
*****
****
*****
***
*

LEGAL AND MUNICIPAL ASPECTS OF WATER POLLUTION

* BY *

MERTON SEYMOUR, Q.C.

SOLICITOR

ST. CATHARINES, ONTARIO

GENERAL REMARKS

THE REQUEST FOR THIS PAPER APPEARS TO HAVE BEEN INSPIRED BY A QUESTION, AT THE POLLUTION CONTROL BOARD MEETING HELD IN THE CITY OF ST. CATHARINES ON JANUARY 25TH, 1955, ADDRESSED BY A MEMBER TO THE CHAIRMAN, DR. A. E. BERRY, WHICH WAS AS FOLLOWS:-

"MR. CHAIRMAN, THESE WILL NOT BE WORDS OF WISDOM, BUT COMING FROM A FARMER, ARE THERE NOT CERTAIN LAWS THAT GOVERN WHAT THEY (MEANING A FACTORY) MAY RUN IN STREAMS OR RIVERS? I DON'T KNOW WHETHER THAT IS TOUCHY OR NOT, BUT WHY I ASK THAT IS, I HAVE A DAUGHTER WHO LIVES IN TENNESSEE. SHE SENDS ME THE OUTDOORS BULLETIN FROM THE NASHVILLE PAPER. ONE FACTORY STARTED UP, I COULD GET THE NAME - IT IS EITHER RAYON OR CHEMICAL - AND WHAT THEY RAN THROUGH THEIR SEWERS IMMEDIATELY KILLED THE FISH. THE AUTHORITIES NOTIFIED THEM AND IN TWELVE MONTHS FROM THAT DAY THEY HAD NOT ONLY DONE AWAY WITH THAT AND CLEARED UP THE PROBLEM, BUT THEY HAD RESTOCKED THAT STREAM. NOW WAS THAT ON THEIR OWN GOODWILL OR WAS THERE A LAW? CAN WE DO IT HERE? DO WE HAVE SUCH A LAW HERE? I WOULD JUST LIKE TO KNOW."

DR. BERRY, IN REPLY, MENTIONED THAT THERE WAS PLENTY OF LEGISLATION IN THE PROVINCE DEALING WITH THE DISPOSAL OF SEWAGE AND INDUSTRIAL WASTES. I WOULD LIKE TO ENLARGE ON DR. BERRY'S COMMENTS, AND GIVE YOU A RESUME OF THE LAW, IN ONTARIO, BOTH COMMON LAW AND LEGISLATIVE, OR STATUTORY LAW, WHICH APPLIES TO THE PROBLEM OF WATER POLLUTION.

BUT WHAT IS LAW; HOW DID IT DERIVE; WHAT ARE ITS SANCTIONS; HOW IS IT CHANGED.

MAN HAS BEEN DESCRIBED AS A SOCIAL ANIMAL, BUT IN THE BEGINNINGS OF HUMAN LIFE HE WAS NO MORE SOCIAL THAN SOCIABLE AND IN THE BEGINNING HE WAS ANYTHING BUT SOCIABLE. HE LIVED BY HIMSELF AND FOR HIMSELF, GOVERNED, OR PERHAPS DRIVEN, BY THE TWO INSTINCTS OF SELF-PRESERVATION AND SELF-PROPOGATION. NATURE AND MAN WERE HIS NATURAL ENEMIES FROM WHOM HE WRESTED A PRECARIOUS LIVING.

THERE WAS NO SUCH THING AS LAW AS WE KNOW IT TODAY, THAT IS LAW GOVERNING THE RELATIONSHIP OF MAN AND MAN, ALTHOUGH, OF COURSE, THERE WERE THE NATURAL LAWS. MAN KNEW NO SUCH THING AS, FOR INSTANCE, LEGAL OWNERSHIP OF ANY KIND OF PROPERTY, LAND OR THINGS, AND POSSESSION OF A THING, LAND BEING UNIMPORTANT, WAS THEN TRULY "NINE POINTS OF THE LAW", THE ONLY LAW THEN RECOGNIZED AS BETWEEN MAN AND MAN NAMELY; THAT OF MIGHT. HE KNEW NO OTHER LAWS OR CUSTOMS OR CONVENTIONS FOR THE

VERY GOOD REASON THAT THERE WERE NON. WHAT HE WANTED, INCLUDING A MATE, HE TOOK - IF HE WERE STRONG ENOUGH. FROM THE INDIVIDUAL HE PROGRESSED TO THE FIRST SOCIAL UNIT, THE FAMILY. IN THE COURSE OF CENTURIES AS MAN PROPAGATED THE FAMILY EXPANDED INTO THE TRIBE. IT WAS INEVITABLE, HOWEVER, THAT CERTAIN RULES OF CONDUCT BEGAN TO BE ENFORCED BY TRIBAL HEADS IN ORDER TO PRESERVE THE STRENGTH AND RESOURCES OF THE TRIBE FOR THE PURPOSES OF DEFENCE AND OFFENCE AGAINST OTHER TRIBES. IT WOULD NEVER HAVE DONE TO HAVE HAD THE STRONGEST WARRIORS KILLED OFF BY TRIBAL FIGHTS OVER POSSESSION OF THINGS, WIVES OR OTHER CHATTELS. THE LAW OF THE TRIBE WAS THE WORD OF THE CHIEF. AS THESE NOMADIC BANDS INCREASED IN SIZE AND STRENGTH AND KNOWLEDGE, GRADUALLY SETTLED DOWN IN DEFINITE AREAS, CUSTOMS AND CONVENTIONS, THAT IS TO SAY, OF RULES OF CONDUCT, GREW IN NUMBER. NEW RULES WERE SLOWLY DEVELOPED TO MEET NEW CONDITIONS.

TRIBES DEVELOPED AND BECAME RACES AND RACES BECAME NATIONALITIES, EACH WITH ITS OWN SET OF CUSTOMS AND CONVENTIONS, BOTH SIMILAR AND DISSIMILAR, SUITED TO THE PECULIARITIES OF LIFE AS AFFECTED BY GEOGRAPHICAL AND ATMOSPHERIC CONDITIONS, RACIAL CHARACTERISTICS AND SO FORTH. THEN, (I AM TAKING YOU SWIFTLY OVER THE CENTURIES) WRITING WAS DEVELOPED AND BROUGHT A TREMENDOUS CHANGE. THE EXISTING RULES OF CONDUCT, OR CUSTOMS AND CONVENTIONS, NOW KNOWN TO US GENERALLY BY THE TERM "THE COMMON LAW", THAT IS THE LAW COMMON TO EVERYONE, GRADUALLY BEGAN TO BE CODIFIED AND FIXED IN WRITTEN STATUTES. AS THE CENTURIES PROGRESSED MORE AND MORE OF THESE UN-WRITTEN LAWS, THESE COMMON LAWS, BECAME STATUTE LAW, SUCH AS THE CRIMINAL CODE AND THE SALE OF GOODS ACT, TO NAME TWO FAMILIAR ONES. THEN, OF COURSE, COURTS BEGAN TO BE SET UP TO DEAL WITH DISPUTES AND INTERPRET THE COMMON LAW AND STATUTE LAW, AND THUS CAME INTO EXISTENCE ANOTHER BODY OF LAW, THE LEGAL PRECEDENTS OF JUDICIAL DECISIONS. AND SO TODAY WE HAVE THREE KINDS OF LAW, SO TO SPEAK, THE COMMON LAW, STATUTE LAW AND JUDICIAL PRECEDENTS.

THE COMMON LAW IS STILL A LIVING FORCE AND IS CONSTANTLY BEING CALLED UPON, MORE GENERALLY PERHAPS IN MERCANTILE MATTERS, WHERE THE TRADE OR LOCAL CUSTOMS, IN THEMSELVES MINOR COMMON LAWS, ARE USED TO INTERPRET AND DEFINE MERCANTILE CONTRACTS, BUT WE FIND THAT THE COMMON LAW IS CONSTANTLY BEING CALLED INTO CONSIDERATION OF THE COURTS.

PRIMARILY COMMON LAW, THEREFORE, IS THE DIST-INCTION BETWEEN UNWRITTEN AND WRITTEN LAW. IT RECEIVES ITS SANCTION AND BINDING POWERS NOT FROM ACTS OF PARLIAMENT BUT FROM LONG AND IMMEMORIAL USAGE AND UNIVERSAL RECEPTION AND ACCEPTANCE BY THE PEOPLE. THE AUTHENT-ICITY OF THESE CUSTOMS, RULES AND MAXIMS RESTS ENTIRELY UPON THAT RECEPTION AND USAGE AS ESTABLISHED AND AS DECLARED AND PROTECTED BY THE COURTS, THAT IS BY A JUDGE OR A JUDGE AND A JURY WHO ARE THE DEPOSITARIES, SO TO SPEAK, AND THE INTERPRETERS OF OUR COMMON LAW. BUT COMMON LAW DEALS WITH THE RIGHTS AND OBLIGATIONS OF HUMAN BEINGS REGULATING THEIR CONDUCT ONE WITH ANOTHER, AND, WITH THE ESTABLISHMENT OF GOVERNMENT WITH ITS FUNCTION OF LAW-MAKING, AS DISTINCT FROM THE NATURAL GROWTH OR EVOLUTION OF CUSTOMS, IT WAS INEVITABLE THAT MUCH NEW LAW WOULD BE INITIATED TO TAKE CARE OF NEW EVILS OR CONDITIONS ARISING, OR TO CREATE NEW CONDITIONS AND, SOMETIMES, NEW EVILS. IT WAS ALSO INEVITABLE THAT IN THE COURSE OF TIME NEW POWERS, NEW AUTHORITIES NEW FORMS OF HUMAN ACTIVITY, CREATED PURELY BY THIS LAW-MAKING MACHINERY, WOULD BE EVOLVED.

STATUTE LAW NEEDS NO EXPLANATION. IT IS THE LAW, BOTH CRIMINAL AND CIVIL, WHICH HAS BEEN ENACTED BY PARLIAMENT BEING EITHER A CODIFICATION, THAT IS A PUTTING IN WRITING, OR EXISTING COMMON LAW, THAT IS TO SAY OF EXISTING CUSTOMS, RULES OR MAXIMS, OR THE ENACTMENT OF entirely new law. It may be useful here to point out that as the Common Law depends for its strength and force upon universal acceptance by the people so, in the long run, do statutes. Any statute that people generally will not accept, or stand for, so to speak, will ultimately be repealed or at least modified. An example is that sheep stealing, in England, once was punished by hanging. A more recent and local illustration is Prohibition which was enacted in 1917 did not receive universal sanction by the people and was repealed in 1929.

It might be well to commence with a definition of pollution as established by the Common Law, and to mention the rigours of the Common Law in its application as illustrated by some established cases. In other words, what are the rights of individuals at common law when water is polluted?

Pollution, as noted in the English text by Salmond on The Law of Tort "includes any alteration of the natural quality of water whereby it is rendered less fit for any purpose for which in its natural state it is capable of being used." Every owner of land on the banks of a natural stream is entitled to a continued flow of that stream in its natural condition, both as to quantity and quality. He is called a riparian owner and he is the owner or occupier of riparian land which is the land abutting, or is washed by, the water of the stream. The ownership of the land forming the bed, or solu, of the stream is immaterial with respect to riparian rights. The ownership of the bed may give additional rights. If the stream is polluted, the riparian owner has suffered an actionable wrong, even without proof of actual damage that can be measured in terms of money.

Pollution has disturbed the manufacturers of Scotch Whiskey in Scotland. The case of Bankier Distillery Company vs. John Young & Company, reported in 1893, Appeal Cases at page 691, concerned a colliery pumping water from its establishment into the Doups Burn which was the only natural outlet for carrying off the water. The burn in question naturally contained soft water which was apparently eminently suitable for the distillation of whiskey. The colliery discharged water upstream which polluted the natural water to such an extent as to render it unfit for use in the distillation of whiskey. Clearly, the situation was one of national, if not international, importance. At the trial, the colliery was required to pay damages and an injunction was granted restraining it from pouring the polluted water into the burn. The colliery apparently felt coal was of equal importance to whiskey and appealed to the House of Lords. Lord Watson stated that the facts of the case "give rise to a question of general importance". The question for appeal was whether an upper stream proprietor may deprive water of certain qualities, provided he restore it fit for ordinary primary use. Lord Watson stated, "I am not satisfied that in returning the water in a state fit for primary use he has any right to alter its natural character, and so make it unfit for uses to which it had been put, or might be put, by a riparian proprietor below". Also Lord Watson stated, the distillery owner "is under no obligation to receive foreign water brought to the surface of his neighbour's property by artificial means, and I can see no distinction, in principle, between water raised from a mine below the level of the surface of either property, which is the case here, and water artificially conveyed from a distant streat."-

Their Lordships concurred with the view of the Lower Court without any suggestion that whiskey, as a consumer product,

SHOULD BE GIVEN A PREFERENCE OVER COAL. THIS CASE SERVES TO ILLUSTRATE THAT A RIPARIAN OWNER HAS A VERY DECIDED REMEDY IN COURT AND THAT THE COURTS WILL ASSIST HIM IMMEASURABLY BY EXERCISING THEIR JUDICIAL DISCRETION IN FAVOUR OF AN INJUNCTION.

POLLUTION BY SEWAGE WAS DEALT WITH BY THE COURTS AS EARLY AS 1849; IN THE CASE OF WOOD AND ANOTHER VS. WAUD AND OTHERS, REPORTED IN 1848 3 EXCHEQUER COURT REPORTS AT PAGE 798, THE PLAINTIFFS WERE THE OWNERS OF CERTAIN MILLS IN YORKSHIRE, ENGLAND, AND BY REASON THEREOF, THE CASE NOTED, "OUGHT TO ENJOY THE ADVANTAGE OF A WATER COURSE CALLED THE BOWLING BECK, WHICH OUGHT TO HAVE RUN AND FLOWED IN GREABUNDANCE AND PURITY AND WITHOUT THE DISTURBANCE, POLLUTION AND HEATING THEREINAFTER MENTIONED, TO THE SAID MILLS". THE DEFENDANTS WRONGFULLY DISCHARGED THE FOLLOWING INTO THE WATER:- "QUANTITIES OF FOUL, NOXIOUS, IMPURE AND OFFENSIVE MATERIALS, TO WIT, LESS OF SOAP AND THE WASHINGS, FILTH AND REFUSE OF WOOL, TO WIT WOOL WHICH THE DEFENDANTS HAD WASHED NEAR AND ABOVE THE SAID MILLS, AND OTHER DIRT, FILTH AND IMPURITY, AND ALSO DISCHARGED AND POURED INTO AND MIXED WITH THE WATER OF THE SAID WATERCOURSE, QUANTITIES OF HOT WATER, BY MEANS WHEREOF THE WATER OF THE SAID WATERCOURSE WAS RENDERED FOUL, DIRTY, HEATED, SPOILED AND UNFIT TO BE USED FOR WORKING THE SAID MILLS". THE PLAINTIFFS PLEADING CONTINUED ON AT GREAT LENGTH AND FROM THIS EXAMPLE, YOU WILL SEE THAT A RIPARIAN OWNER CAN EXPRESS HIMSELF VERY FORCEFULLY. THE FACTS OF THE CASE SUGGEST THAT HE HAD BEEN SADLY ABUSED AND, AS WAS STATED, "GREATLY DAMNIFIED". THE JUDGMENT OF THE COURT WAS DELIVERED BY CHIEF BARON POLLOCK ONE OF THE GREATEST JURISTS OF THE DAY. THE JURY FOUND AS A FACT THAT THE POLLUTION OF A NATURAL STREAM DID NO ACTUAL DAMAGE TO THE PLAINTIFFS, BECAUSE IT WAS ALREADY POLLUTED BY ACTS OF SIMILAR MILL OWNERS ABOVE THE DEFENDANTS' MILLS. HIS LORDSHIP THOUGHT, HOWEVER, THAT THE PLAINTIFFS HAD RECEIVED DAMAGE IN POINT OF LAW. THERE WOULD APPEAR TO BE NO RIGHT OF REASONABLE POLLUTION, AS IF THE OTHER SOURCES OF POLLUTION SHOULD BE DISCONTINUED THE PLAINTIFFS WHO WOULD OTHERWISE HAVE HAD, IN THAT CASE, PURE WATER, WOULD BE COMPELLED TO SUBMIT TO THE POLLUTION OF THE DEFENDANT. THIS, INDEED, IS VERY STRICT RULE OF LAW WHICH HAS RECENTLY BEEN SUPPORTED IN CANADA.

THE RIGHTS OF A RIPARIAN OWNER INSOFAR AS CANADIAN LAW GOES, HAVE BEEN BROUGHT TO THE FORE IN THE WELL KNOWN AND IMPORTANT CASE OF MCKIE ET AL VS. THE KALAMAZOON VEGETABLE PARCHMENT COMPANY LIMITED, REPORTED IN 1948 ONTARIO REPORTS AT PAGE 398. HERE THE COMMON LAW WAS APPLIED BUT ITS RIGOURS AS FAR AS THIS CASE IS CONCERNED, AS WE SHALL SEE LATER, WERE SUBSEQUENTLY MITIGATED BY AN ACT OF THE LEGISLATIVE ASSEMBLY OF ONTARIO. THE FACTS MAY BE BRIEFLY STATED AS FOLLOWS: THE PLAINTIFFS WERE RIPARIAN OWNERS ON THE SPANISH RIVER, ALL OPERATING TOURIST CAMPS OF VARYING ACCOMMODATION. K.V.P.COMPANY OPERATED ITS PLANT FOR THE PURPOSE OF MANUFACTURING KRAFT PAPER BY THE SULPHATE PROCESS AND DISCHARGED INTO THE RIVER LARGE QUANTITIES OF FOREIGN MATTER UP STREAM FROM THE PROPERTY OF THE PLAINTIFFS. THE PLAINTIFFS CLAIMED DAMAGES AND ASKED FOR AN INJUNCTION ON THE FOLLOWING GROUNDS:-

1. THEIR COMFORT AND THE ENJOYMENT OF THEIR LAND IS INTERFERED WITH BY REASON OF FOUL ODORS GIVEN OFF FROM THE WATER.

2. THE WATER HAS BEEN RENDERED UNFIT FOR HUMAN CONSUMPTION EITHER IN ITS RAW STATE OR AFTER IT HAS BEEN BOILED.

3. THE ICE TAKEN FROM THE RIVER FOR DOMESTIC USE IS UNFIT FOR THE PURPOSES FOR WHICH IT IS USED.

4. The water is repulsive to farm animals and milking cows will not drink it in sufficient quantities to maintain normal milk supply.

5. The water is unfit to bathe in.

6. Wild rice, which has formerly grown in abundance in the waters of the river, forming a feeding ground for wild ducks, has been destroyed.

After considering the evidence, given at great length by factual and expert witnesses, Chief Justice McRuer, found that the waters of the Spanish River below the defendant's plant had been polluted in such a manner as to change the character and substantially affect the use to which the plaintiffs were entitled to put them and to interfere with the enjoyment of the plaintiffs as occupiers of riparian lands. Pollution of the water was found to have affected the fishing and there was some evidence that the rice beds had disappeared. Chief Justice McRuer stated that the origin of the Common Law goes back to and beyond the Roman Law, and we reviewed the authorities which emphasize the strictness of the Common Law. The absolute right of the riparian owner is noted by the Chief Justice in a quotation from the case of Pennington vs. Brinsop Coal Company, reported in 1877 5 Chancery Division at page 769, where Mr. Justice Fry stated "that the case of a stream affords a very clear illustration of the difference between injury and damage; for the pollution of a clear stream is to a riparian proprietor below both injury and damage, whilst the pollution of a stream already made foul and useless by other pollutions is an injury without damage, which would however, at once become both injury and damage on the cessation of the other pollutions". Chief Justice McRuer then stated that it is not a defence to this action to show that the waters of the river were in some measure polluted by the municipality of Espanola, higher upstream, or others responsible for the presence of colon bacilli therein.

Perhaps the case is of greater significance where it deals with the question of remedies. Evidence was adduced as to the importance of the business in the community and that it was carried on in proper manner. Chief Justice McRuer was of the opinion that neither of these elements should be considered in a case of this character, nor are the economic necessities of the defendant relevant to be considered. Indeed Chief Justice McRuer felt that if he were to consider such an argument he would in effect be giving the defendant a veritable power of expropriation of the Common Law rights of riparian owners, and without compensation. The Court exercised its discretion in favour of an injunction restraining the defendant from depositing foreign substance in the Spanish River, but its operation was stayed for six months "in order to give the defendant an opportunity to provide other means of disposal of its noxious fluid".

On appeal to the Supreme Court of Canada, reported in 1949, Supreme Court Reports, page 698, on the issue as to whether an injunction should be granted, Mr. Justice Kerwin, now Chief Justice, in delivering judgment again referred to the rigours of the Common Law stating that the rights of riparian owners have always been zealously guarded by the Court. The law clearly indicated that an injunction was the proper remedy and Mr. Justice Kerwin was of the opinion that the Court's discretion should not be exercised against "a current of authority which is of many years standing". His Lordship concluded by stating the injunction should be stayed for a period of six months.

You will note that the Courts felt bound to the stringencies of the Common Law to the extent of ignoring the exigencies of the

DEFENDANT COMPANY AND THE COMMUNITY WHICH DERIVED ITS LIVING THEREBY.

THE SAME QUESTION AROSE IN THE WHISKEY DISTILLERY CASE MENTIONED ABOVE WHERE COUNSEL INVITED THE COURT TO APPLY AN AMERICAN CASE, PENNSYLVANIA COAL COMPANY VS. SANDERSON, REPORTED IN 56, AMERICAN REPORTS AT PAGE 89 AND DECIDED IN 1866. THERE LORD SHAND NOTED THAT THE ENORMOUS VALUE OF THE MINING INDUSTRY IN THE DISTRICT OF PENNSYLVANIA MIGHT HAVE GIVEN SOME REASON TO APPEAL TO THE LEGISLATURE TO PASS A SPECIAL ACT TO RESTRAIN ANY PROCEEDING BY INJUNCTION, BUT FELT THE CASE HAD NO APPLICATION TO THE PRESENT ONE AS THE DECISION WAS BASED ON SPECIAL CIRCUMSTANCES, AS TO THE GREAT RELATIVE VALUE OF COAL MINING TO THE COMMUNITY. HE ALSO FELT THAT, IN ANY VIEW, SUCH A CASE MADE LAW RATHER THAN INTERPRETED IT SO AS TO GIVE EFFECT TO THE WELL RECOGNIZED PRINCIPLES OF COMMON INTERESTS OF UPPER AND LOWER PROPRIETORS IN THE RUNNING WATER OF A STREAM. THE CASE DOES, HOWEVER, RECOGNIZE THAT A DIFFICULT AND PERPLEXING SITUATION COULD WELL EXIST WHERE IT BECOMES MORE A MATTER OF A BALANCE OF INTERESTS THAN A MATTER OF LAW. THAT THIS CAN BE SO IS ILLUSTRATED BY THE END RESULT OF THE K.V.P. COMPANY CASE WHERE A SPECIAL ACT OF THE LEGISLATURE WAS ENACTED THAT HAD THE EFFECT OF NULLIFYING THE JUDGMENTS OF THE COURTS. AS SOME OF YOU MAY RECALL, THE INJUNCTION OF THE K.V.P. CASE WOULD HAVE HAD THE RESULT OF PUTTING THE COMPANY OUT OF ACTION AND OF THREATENING THE COMMUNITY WITH ECONOMIC DISASTER.

THE RELEVANT STATUTE IS FOUND IN THE ONTARIO STATUES, 1950, CHAPTER 33 AND IS ENTITLED "AN ACT RESPECTING THE K.V.P. COMPANY LIMITED". THE ACT WAS ASSENTED TO ON APRIL 31ST, 1950, AND IT NOTES INPART IN SECTION 1(1) THAT "WHETHER OR NOT ITS OPERATION IS NOW STAYED EVERY INJUNCTION HERETOFOR GRANTED AGAINST THE K.V.P.COMPANY LIMITED, HEREIN CALLED "THE COMPANY" RESTRAINING THE COMPANY FROM POLLUTING THE WATERS OF THE SPANISH RIVER IS DISSOLVED".

IT IS ALSO NOTED IN THE STATUE THAT ALL RIGHTS TO DAMAGES ARE PRESERVED AND THAT THE ACT SHALL NOT PREJUDICE THE RIGHT OF ANY PERSON TO BRING ANY ACTION , THAT IS FOR DAMAGES OR INJUNCTION OR BOTH, AGAINST THE COMPANY ARISING FROM THE POLLUTION FROM THE WATERS OF THE SPANISH RIVER. THE ACT PROVIDES THAT IN LIEU OF BRINGING AN ACTION, ANY PERSON SUFFERING DAMAGE MAY REQUIRE THE COMPANY TO SUBMIT THE MATTER FOR ARBITRATION.

YOU WILL SEE THE ACT SPECIFICALLY DEALS WITH THE K.V.P.COMPANY AND THE SPANISH RIVER AND DOES NOT PURPORT TO LAY DOWN ANY BROADER PRINCIPLE. IT DOES, HOWEVER, SET DOWN A VERY IMPORTANT PRECEDENT WHICH RECOGNIZES THAT THE COMMON LAW HAS GOT ITSELF INTO A VERY TIGHT CORNER, AND THAT IN THIS PARTICULAR FIELD, IS SEEMINGLY INCAPABLE, MAY BE PROPERLY SO, OF ADAPTING ITSELF TO PRESENT DAY SITUATIONS.

PRIOR TO THE ENACTMENT OF THE K.V.P.COMPANY ACT, BUT WHILE THE CASE WAS STILL ON APPEAL, THE LEGISLATURE REFEALED SECTION 30 OF THE LAKES AND RIVERS IMPROVEMENT ACT AND SUBSTITUTED THE FOLLOWING SECTION:-

30.-(1) IN THIS SECTION "MILL" MEANS A PLANT OR WORKS IN WHICH LOGS OR WOOD-BOLTS ARE PROCESSED AND INCLUDES A SAW MILL, A PULP MILL, AND A PULP AND PAPER MILL.

(2) WHERE IN AN ACTION OR PROCEEDING A PERSON CLAIMS, AND BUT FOR THIS SECTION WOULD BE ENTITLED TO, AND INJUNCTION AGAINST THE OWNER OR OCCUPIER OF A MILL FOR AN INJURY OR DAM AGE, DIRECT OR CONSEQUENTIAL, SUSTAINED BY SUCH PERSON, OR FOR ANY INTERFERENCE DIRECTLY OR INDIRECTLY WITH ANY RIGHTS OF SUCH PERSON

AS RIPARIAN PROPRIETOR OR OTHERWISE, BY REASON OR IN CONSEQUENCE OF THE THROWING, DEPOSITING OR DISCHARGING, OR PERMITTING THE THROWING, DEPOSITING OR DISCHARGING OF ANY REFUSE, SAWDUST, CHEMICAL, SUBSTANCE OR MATTER FROM THE MILL OR FROM IT AND OTHER MILLS INTO ANY LAKE OR RIVER; OR BY REASON OR IN CONSEQUENCE OF ANY ODOUR ARISING FROM ANY SUCH REFUSE, SAWDUST, CHEMICAL, SUBSTANCE OR MATTER SO THROWN, DEPOSITED OR DISCHARGED OR SO PERMITTED TO BE THROWN, DEPOSITED OR DISCHARGED, THE COURT OR JUDGE MAY,-

(A) REFUSE TO GRANT AN INJUNCTION IF IT IS PROVED THAT HAVING REGARD TO ALL THE CIRCUMSTANCES AND TAKING INTO CONSIDERATION THE IMPORTANCE OF THE OPERATION OF THE MILL TO THE LOCALITY IN WHICH IT OPERATES AND THE BENEFIT AND ADVANTAGE, DIRECT AND CONSEQUENTIAL, WHICH THE OPERATION OF THE MILL CONFERS ON THAT LOCALITY AND ON THE INHABITANTS OF THE LOCALITY, AND WEIGHING THE SAME AGAINST THE PRIVATE INJURY, DAMGE OR INTERFERENCE COMPLAINED OF, IT IS ON THE WHOLE PROPER AND EXPEDIENT NOT TO GRANT THE INJUNCTION; OR

(B) GRANT AN INJUNCTION TO TAKE EFFECT AFTER SUCH LAPSE OF TIME OR UPON SUCH TERMS AND CONDITIONS OR SUBJECT TO SUCH LIMITATIONS OR RESTRICTIONS AS MAY BE DEEMED PROPER; OR

(C) IN LIEU OF GRANTING AN INJUNCTION, DIRECT THAT THE OWNER OR OCCUPANT OF THE MILL TAKE SUCH MEASURES OR PERFORM SUCH ACTS TO PREVENT, AVOID, LESSEN OR DIMINISH THE INJURY, DAMAGE OR INTERFERENCE COMPLAINED OF AS MAY BE DEEMED PROPER.

(3) NOTHING IN SUBSECTION 2 SHALL AFFECT ANY RIGHT OF THE PERSON CLAIMING THE INJUNCTION TO DAMAGES AGAINST THE OWNER OR OCCUPIER OF THE MILL FOR ANY SUCH INJURY, DAMAGE OR INTERFERENCE.

(4) WHERE DAMAGE FROM THE SAME CAUSE CONTINUES THE PERSON ENTITLED TO THE DAMAGES MAY APPLY FROM TIME TO TIME IN THE SAME ACTION OR PROCEEDING FOR THE ASSESSMENT OF SUBSEQUENT DAMAGES OR FOR ANY OTHER RELIEF TO WHICH BY SUBSEQUENT EVENTS HE MAY FROM TIME TO TIME BECOME ENTITLED.

(5) THIS SECTION SHALL APPLY WHETHER THE INJURY, DAMAGE OR INTERFERENCE IS OR IS NOT A CONTINUING ONE, AND WHETHER THE PERSON CLAIMING THE INJUNCTION IN THE ACTION OR PROCEEDING IS A PLAINTIFF OR IS A DEFENDANT PROCEEDING BY WAY OF COUNTER-CLAIM.

(2) SECTION 30 THE THE LAKES AND RIVERS IMPROVEMENT ACT, AS RE-ENACTED BY SUBSECTION 1 OF THIS SECTION, SHALL APPLY TO EVERY ACTION OR PROCEEDING IN WHICH AN INJUNCTION IS CLAIMED IN RESPECT OF ANY OF THE MATTERS MENTIONED IN SUCH SECTION, INCLUDING EVERY PENDING ACTION AND PROCEEDING AND INCLUDING EVERY ACTION OR PROCEEDING IN WHICH AN INJUNCTION HAS BEEN GRANTED AND IN WHICH ANY APPEAL IS PENDING.

THIS SECTION APPLIES TO A MILL SUCH AS THE MILL OF THE K.V.P.COMPANY. THE DEFINITION OF A LAKE IN THE LAKES AND RIVERS IMPROVEMENT ACT INCLUDES A POND, AND THE DEFINITION OF A RIVER INCLUDES A CREEK AND A STREAM. IN EFFECT, THE SECTION GIVES THE COURT A WIDE DISCRETION AS TO THE GRANTING OF AN INJUNCTION WHERE IT MAY PROVE PREJUDICIAL TO THE COMMUNITY AS A WHOLE. YOU WILL NOTE, HOWEVER, THAT THE SECTION STATES THAT THE COURT OR

JUDGE MAY REFUSE TO GRANT AN INJUNCTION IF IT IS PROVED THAT ITS RESULT WOULD HAVE A HARMFUL EFFECT, AND ALSO THE COURT OR JUDGE MAY GRANT AN INJUNCTION TO TAKE EFFECT AFTER A STIPULATED TIME AND ON CERTAIN TERMS AND CONDITIONS. IT MIGHT ALSO BE ADDED THAT THIS SECTION HAS, TO A CONSIDERABLE EXTENT, CHANGED THE COURSE OF THE COMMON LAW INSOFAR AS THE REMEDIES OF A RIPARIAN OWNER AGAINST A PULP AND PAPER MILL ARE CONCERNED.

I NOW WISH TO MENTION SOME OF THE STATUTORY PROVISIONS DEALING WITH POLLUTION OF WATERCOURSES WITHIN A MUNICIPALITY.

1. PROVISIONS IN THE MUNICIPAL ACT:

A MUNICIPALITY MAY PASS A BY-LAW PURSUANT TO SECTION 388(1) 119(A) OF THE MUNICIPAL ACT "FOR PROHIBITING AND REGULATING THE DISCHARGE OF ANY GASEOUS, LIQUID OR SOLID MATTER INTO LAND DRAINAGE WORKS, PRIVATE BRANCH DRAINS AND CONNECTIONS TO ANY SEWER, SEWER SYSTEM OR SEWAGE WORKS FOR THE CARRYING AWAY OF DOMESTIC SEWAGE OR INDUSTRIAL WASTES OF BOTH, WHETHER CONNECTED TO A TREATMENT WORKS OR NOT". THIS SECTION WAS ENACTED IN 1953, AND, AS YOU SEE, COULD BE INVOKED TO RESTRAIN INDIVIDUALS OR INDUSTRY FROM OVERLOADING A SEWER IN THE MUNICIPALITY OR PROHIBITING ITS USE FOR CERTAIN PURPOSES.

THERE IS ALSO THE POWER TO PASS A BY-LAW TO PROHIBIT AND ABATE A PUBLIC NUISANCE, WHICH COULD INCLUDE POLLUTION, PURSUANT TO SECTION 388(1) 113, AND ALSO BY SECTION 388(1)8, TO MAKE REGULATIONS FOR SEWERAGE OR DRAINAGE THAT MAY BE DEEMED NECESSARY FOR SANITARY PURPOSES.

A MUNICIPALITY MAY PASS A BY-LAW FOR IMPOSING PENALTIES OF NOT MORE THAN $50.00 EXCLUSIVE OF COSTS UPON EVERY PERSON WHO CONTRAVENES ANY BY-LAW PASSED UNDER THE AUTHORITY OF THIS ACT. THERE IS, HOWEVER, NO DUTY UPON A MUNICIPALITY TO ENFORCE A BY-LAW WHICH IT HAS ENACTED IN THE EXERCISE OF A DISCRETIONARY POWER. THE COURTS HAVE HELD THAT A MUNICIPALITY IS FREE TO ENACT OR NOT TO ENACT, AND HAVING ENACTED, MAY REPEAL WITHOUT ANY RESPONSIBILITY WHICH CAN BE EXAMINED BY THE COURTS.

IN ADDITION TO THIS PENALTY, IS THE MORE SIGNIFICANT SANCTION SET FORTH IN SECTION 497 OF THE MUNICIPAL ACT, PROVIDING THAT ANY SUCH CONTRAVENTION MAY BE RESTRAINED BY ACTION AT THE INSTANCE OF THE CORPORATION OR A RATEPAYER. YOU WILL NOTE THIS POWER IS PERMISSIVE.

THE CASE OF THE CITY OF TORONTO VS RUDD & RUDD REPORTED IN 1952, ONTARIO REPORTS AT PAGE 84, CONCERNED THE OPERATION OF A PRIVATE HOSPITAL ON CASTLE FRANK ROAD IN ROSEDALE, TORONTO, CONTRARY TO A BY-LAW. THIS WAS NOT A POLLUTION CASE BUT IT NOTED THAT THE GRANTING OF AN INJUNCTION UNDER SECTION 497, IS DISCRETIONARY AND IS NOT GRANTED UNLESS A CLEAR CASE HAS BEEN MADE OUT TO THE COURT. CONSIDERABLE WEIGHT WAS GIVEN TO THE ARGUMENT THAT THE CITY WAS DILATORY IN PURSUING THE ACTION. THE COURT, HOWEVER, EXERCISED ITS DISCRETION IN FAVOUR OF THE INJUNCTION, BUT STAYED ITS OPERATION FOR EIGHTEEN MONTHS TO GIVE THE DEFENDANT AN OPPORTUNITY TO MAKE OTHER ARRANGEMENTS.

THUS, THE COURTS ARE VERY CHARY WHEN CONFRONTED BY A REQUEST FOR AN INJUNCTION AT THE SUIT OF A MUNICIPALITY. HOWEVER, THE REMEDY IS THERE AND, AS NOTED IN THE ABOVE CASE, HAS RECEIVED THE SUPPORT OF THE COURTS. PRESUMABLY, THEREFORE, A MUNICIPALITY COULD INVOKE THIS POWER, UNDER SECTION 497, TO RESTRAIN INDUSTRY DEPOSITING INDUSTRIAL WASTES WITHIN ITS SEWER SYSTEM.

II. PROVISIONS IN THE PUBLIC HEALTH ACT:

SECTION 102(1) OF THE PUBLIC HEALTH ACT, R.S.O. CHAPTER 306, DEALS WITH THE PUBLIC WATER SUPPLY AND GIVES THE DEPARTMENT OF HEALTH THE RIGHT TO SUPERVISE SPRINGS, WELLS, PONDS, LAKES, STREAMS OR RIVERS USED AS A SOURCE FOR PUBLIC WATER SUPPLY, AND ALSO GIVES THE DEPARTMENT THE RIGHT TO EXAMINE FROM TIME TO TIME AND INQUIRE WHAT, IF ANY, POLLUTION EXISTS AND THE CAUSES THEREOF.

SUBSECTION (2) GIVES THE DEPARTMENT A RIGHT OF INQUIRY INTO AND TO HEAR AND DETERMINE ANY COMPLAINT MADE BY OR ON BEHALF OF ANY RIPARIAN PROPRIETOR WHO COMPLAINS OF POLLUTED WATERS.

SUBSECTION (3) GIVES THE DEPARTMENT THE RIGHT TO MAKE A REPORT AS TO WHAT REMEDIAL MEASURES ARE REQUIRED IN RESPECT OF THE INVASION OF ANY RIGHTS SUCH AS THOSE OF A RIPARIAN OWNER.

SUBSECTION (4) PROVIDES THAT IF THE DEPARTMENT RECOMMENDS THE REMOVAL OF ANY POLLUTING MATERIAL ANY RIPARIAN PROPRIETOR MAY APPLY TO A SUPREME COURT OR A COUNTY COURT JUDGE FOR AN ORDER REQUIRING THE REMOVAL OR ABATEMENT OF THE INJURY IN TERMS OF THE REPORT AND TO RESTRAIN THE PROPRIETORS OF THE INDUSTRY FROM CARRYING ON THE SAME, OR THE OFFENDING PARTY OR PARTIES FROM CONTINUING THE ACTS COMPLAINED OF, UNTIL THE INVASION OF THE RIGHT HAS BEEN ABATED TO THE SATISFACTION OF THE DEPARTMENT. THIS DOES NOT NECESSARILY MEAN TO THE SATISFACTION OF THE RIPARIAN OWNER OR THE COURT, SHOULD HE SEEK REDRESS THERE.

THESE SECTIONS MAY BE INVOKED BY THE DEPARTMENT TO PROTECT THE HEALTH OF THE COMMUNITY AND FOR AGRICULTURAL, DOMESTIC OR INDUSTRIAL PURPOSES AND THEREBY ARE BROAD ENOUGH IN SCOPE TO INCLUDE CLAIMS ARISING OUT OF POLLUTION. THE PROVISION ALLOWING A SUPREME COURT OR COUNTY COURT JUDGE TO MAKE AN ORDER, IS PERMISSIVE, AND IS IN ADDITION TO, AND AN ALTERNATIVE RIGHT, TO THAT GIVEN BY THE COMMON LAW, AND SHOULD NOT BE DEEMED TO DEROGATE FROM THE COMMON LAW DOCTRINE OF AN INDIVIDUAL'S RIGHT TO BRING AN ACTION AS A RIPARIAN OWNER.

SECTION 103 OF THE PUBLIC HEALTH ACT PROHIBITS THE DEPOSITING OF FOREIGN MATTER IN WATERS AND BECAUSE OF ITS IMPORTANCE IN A CASE LATER TO BE DISCUSSED, I QUOTE IT VERBATIM.

> 103-(1) NO GARBAGE, EXCRETA, MANURE, VEGETABLE OR ANIMAL MATTER OR FILTH SHALL BE DISCHARGED INTO OR BE DEPOSITED IN ANY OF THE LAKES, RIVERS, STREAMS OR OTHER WATERS IN ONTARIO OR ON THE SHORES OR BANKS THEREOF, AND NO INDUSTRIAL OR OTHER WASTES DANGEROUS OR LIABLE TO BECOME DANGEROUS TO HEALTH OR TO BECOME A NUISANCE OR TO IMPAIR THE SAFETY, PALATABILITY OR POTABILITY OF THE WATER SUPPLY OF ANY MUNICIPALITY OR RIPARIAN OWNER, SHALL BE DISCHARGED INTO OR BE DEPOSITED IN ANY OF THE LAKES, RIVERS, STREAMS OR OTHER WATERS OF ONTARIO, OR ON THE SHORES OR BANKS THEREOF.
>
> (2) THE OWNERS AND OFFICERS OF BOATS AND OTHER VESSELS PLYING UPON ANY SUCH LAKE, RIVER, STREAM OR OTHER WATER SHALL SO DISPOSE OF THE GARBAGE, EXCRETA, MANURE, VEGETABLE OR ANIMAL MATTER OR FILTH UPON SUCH BOATS OR VESSELS AS NOT TO CREATE A NUISANCE OR ENTER OR POLLUTE SUCH LAKE, RIVER, STREAM OR OTHER WATER.

(3) Residents of a health resort or summer resort shall so dispose of garbage, excreta, manure, vegetable or animal matter or filth as not to create a nuisance or permit of its gaining entrance to or polluting any such lake, river, stream or other water.

(4) Any person who contravenes any of the provisions of this Section shall be guilty of an offence and liable to a penalty of not more than $100.00 R.S.O. 1937, c.299, s.93.

Section 105(1) deals withe the pollution of any source of public water supply for domestic use in the municipality and prohibits the depositing of sewage, commercial or factory refuse in such waters Such a prohibition even covers the surrounding area in case there is any seepage through the ground adjacent to any water source. A penalty is imposed of not less than $50.00 and not more than $100.00, together with a further penalty for each week's continuance of the offence.

I now wish to discuss the liability of a municipality. Suppose an industry in a municipality is discharging waste into a stream to the annoyance of a down-stream riparian owner. Can this riparian owner claim any damages from the municipality for allowing the industry to discharge its waste without due regard to the rights of others, and can the individual compel the municipality to restrain the industry from continuing to pollute the waters of a stream or river?

We have seen what common law rights the individual possesses, and how in the K.V.P. Company case he was able to curb the activities of the Company. It is conceivable that the efforts of a municipality to restrain the pollution of industrial waste on its own initiative could result in the same situation, that is a municipality causing an industry to cease activity, would have an injurious and harmful economic effect on the municipality, as well as the industry.

To date it would appear that some municipalities have been too busy worrying over the treatment and disposal of their domestic sewage, and they appear to feel that an industry within its confines, is a secondary consideration involving vast expense, which perhaps should be borne in part by Government. Some municipalities are allowing industry access to their sewers where they have sufficient sewer capacity, which may make the municipality liable as we will see later on.

There appears to be no principle of law making a municipality liable for pollution of streams or rivers within its confines caused by an industry that is not exclusively under its control and that is not discharging into the municipality's sewers. The problem of industrial waste is also a problem of the municipalities but the municipality's liability in law is an entirely different question. A municipality is liable to an individual if the municipality knowingly permits the entry of deleterious substances into its own sewers or drains, which substances result in a nuisance or in an unsanitary condition. Such liability is restricted to the sewers of the municipality, installed and maintained pursuant to permissive statutory authority and subject to the approval of the Department of Health as set out in Section 106 of The Public Health Act. Such municipal liability is based on the ground, express or implied, that the municipality in constructing the sewer has the independent right to determine the capacity, location and other engineering requirements of the particular sewer. It is also clearly established, as a matter of law, that a municipality is not bound to

PROVIDE DRAINAGE FOR PROPERTY WITHIN ITS LIMITS, BUT IF IT DOES SO AND NEGLIGENTLY CONSTRUCTS THE DRAINS OR SEWERS IT WILL BE HELD RESPONSIBLE FOR SUCH DAMAGES AS MAY ENSUE.

I PROPOSE TO MENTION ONLY ONE CASE WITH REGARD TO MUNICIPAL LIABILITY FOR THE DISCHARGE OF INDUSTRIAL EFFLUENT INTO THE MUNICIPALITY'S DRAINAGE SYSTEM. THE CASE OF GRAY VS. THE CORPORATION OF THE TOWN OF DUNDAS REPORTED IN 1886 11 ONTARIO REPORTS AT PAGE 317. HERE THE DEFENDANT MAINTAINED A DRAIN ON THE MAIN STREET FOR THE PURPOSE OF CARRYING OFF SURFACE WATER TO A CREEK. A FACTORY REQUESTED PERMISSION TO CONNECT WITH THE SEWER, WHICH PERMISSION WAS GRANTED. HOWEVER, COMPLAINTS AROSE ALLEGING THAT THE WATER WAS FOULED BY NAUSEOUS MATTER FROM THE FACTORY, WHEREUPON THE MUNICIPALITY WITHDREW ITS PERMISSION AND THE FACTORY THEN UTILIZED AN OLD CELLAR AS A RESERVOIR. THE WATER IN THE RESERVOIR WAS ALLEGED, HOWEVER, TO HAVE FILTERED THROUGH THE SOIL TO THE DRAIN. THE DRAIN, WITHOUT THE INFILTRATION INTO IT FROM THE RESERVOIR FROM WHICH IT WAS DISTANT AT LEAST 26 FEET, WOULD NOT HAVE CONVEYED ANYTHING INJURIOUS INTO THE CREEK. THE CASE WAS DISTINGUISHED FROM VAN EGMOND VS. TOWN OF SEAFORTH 1884 6 O.R., PAGE 599, WHERE THE DEFENDANT MUNICIPALITY CUT ITS DRAINS THROUGH SOIL CONTAINING INJURIOUS MATTER AND CARRIED IT TO A CREEK, THUS BEING THE DIRECT AND ACTIVE AGENT IN THE MISCHIEF. HERE THE MUNICIPALITY HAD NOT CONNECTED THE RESERVOIR AND THE DRAIN, AND WAS NOT, THEREFORE, IN A POSITION TO PHYSICALLY PREVENT THE DISCHARGE OF WASTE BY STOPPING UP THE CONNECTION. IT WAS HELD THAT THE MUNICIPALITY WAS NOT LIABLE FOR DAMAGE TO A RIPARIAN OWNER. THE COURT OF APPEAL FOR ONTARIO AFFIRMED THIS JUDGMENT AND IT WOULD STILL APPEAR TO BE GOOD LAW.

IT IS, HOWEVER, IMPORTANT TO NOTE THAT IF A MUNICIPALITY ALLOWS AN INDUSTRY TO DUMP POLLUTING MATERIAL INTO ITS MUNICIPAL SEWERS IT MAY BE HELD LIABLE TO DAMAGES AND AN INJUNCTION AND BE REQUIRED TO ABATE ANY NUISANCE CAUSED. THE PROBLEM BECOMES SOMEWHAT VEXING WHERE BOTH THE MUNICIPALITY AND THE INDUSTRY ARE DISCHARGING POLLUTING MATERIAL INTO A MUNICIPAL SEWER RESULTING IN A NUISANCE OR INJURY, OR BOTH, TO A DOWN-STREAM RIPARIAN OWNER. PRESUMABLY, THE MUNICIPALITY WOULD BE FOUND LIABLE AND BE REQUIRED TO ABATE THE NUISANCE IF THE MUNICIPALITY PERMITTED THE INDUSTRY SO TO DO. IF, HOWEVER, THE INDUSTRY WERE SO DISCHARGING POLLUTING MATERIAL WITHOUT THE PERMISSION OF THE MUNICIPALITY, OR IN CONTRAVENTION OF A PROHIBITORY BY-LAW, IT WOULD APPEAR THAT THE MUNICIPALITY, IF SUED, COULD JOIN THE INDUSTRY IN THE ACTION AND BOTH COULD BE HELD LIABLE AND BE REQUIRED TO ABATE THE NUISANCE.

WE MAY, THEREFORE, SAY:-

(1) THERE IS NO LIABILITY ON THE PART OF A MUNICIPALITY FOR THE DISCHARGE BY INDUSTRIES OF INDUSTRIAL WASTE INTO STREAMS, RIVERS AND WATERS WITHIN ITS CONFINES.

(2) THE MUNICIPALITY COULD BE LIABLE WHERE THE MUNICIPALITY, BY AGREEMENT, ALLOWS AN INDUSTRY TO EMPTY POLLUTING MATERIAL INTO ITS MUNICIPAL SEWERS AND THEREBY POLLUTES WHAT OTHERWISE WOULD NOT HAVE CAUSED ANY NUISANCE OR INJURY.

(3) WHERE THE MUNICIPALITY EMPTIES ITS SEWAGE INTO A SEWER AND AN INDUSTRY EMPTIES INTO IT ALSO, BUT WITHOUT PERMISSION, IT WOULD APPEAR THAT BOTH COULD BE HELD LIABLE AT THE SUIT OF A RIPARIAN OWNER WHO HAS A RIGHT OF ACTION.

(4) A MUNICIPALITY MAY BE LIABLE TO A DOWNSTREAM RIPARIAN OWNER NO MATTER WHAT TREATMENT IT GIVES ITS SEWAGE OR WHAT PRECAUTIONS IT TAKES IF IT STILL POLLUTES THE WATER.

AGAIN I WISH TO REFER YOU TO WHAT HAS BEEN SAID EARLIER IN THIS DISCUSSION ON THE COMMON LAW RIGHT OF THE RIPARIAN OWNER, AND SUGGEST THAT ANY REMEDY HERE, BY WAY OF INJUNCTION TO RESTRAIN BOTH THE MUNICIPALITY AND THE INDUSTRY COULD HAVE DRASTIC EFFECTS ON THE COMMUNITY. IT IS SUGGESTED THAT THE SITUATION SHOULD BE APPROACHED BY A FURTHER STUDY OF WASTE DISPOSAL EITHER BY THE MUNICIPALITY AND THE INDUSTRY TOGETHER OR WITH THE ASSISTANCE AND AID OF THE GOVERNMENT.

ANOTHER SOMEWHAT VEXING PROBLEM THAT OCCASIONALLY FACES A MUNICIPALITY IS WHERE IT EXERCISES ITS PERMISSIVE POWER IN THE CONSTRUCTION OF A SEWER AND SEWAGE DISPOSAL SYSTEM AND CONFORMS TO ALL THE REQUIREMENTS OF THE PUBLIC HEALTH ACT ONLY TO BE REWARDED BY A HIGHLY ANNOYED RIPARIAN OWNER COMMENCING AN ACTION AGAINST IT ALLEGING THAT THE SEWAGE DISPOSAL PLANT IS, IN EFFECT, NOT DOING WHAT IT IS SUPPOSED TO DO AND HE IS BOTHERED BY A FOUL, NOXIOUS STENCH IN HIS STREAM, CAN NO LONGER USE THE WATER, HIS UNDERGROUND WELL HAS BECOME POLLUTED, AND THE VALUE OF HIS PROPERTY LESSENED.

WHAT CAN A MUNICIPALITY DO? IT MUST DEPOSIT ITS SEWAGE, OR THE EFFLUENT OF ITS DISPOSAL PLANT SOMEWHERE AND IT RECEIVES THE SANCTION OF THE DEPARTMENT OF HEALTH TO DO IT IN A CERTAIN WAY. WHAT DEFENCE HAS IT, AND IF IT HAS NO DEFENCE, WHERE CAN IT TURN FOR HELP OR WHERE SHOULD IT BE ABLE TO TURN? A LONG DISCUSSION OF THE LAW SURROUNDING THIS PROBLEM WOULD CONSUME A CONSIDERABLE LENGTH OF TIME, AND I PROPOSE TO DEAL ONLY WITH A FEW SALIENT FEATURES ILLUSTRATED BY SOME CASES WHICH CONCERN THE LIABILITY OF MUNICIPALITIES.

SECTION 386(12) OF THE MUNICIPAL ACT GIVES THE MUNICIPALITY THE POWER TO PASS A BY-LAW; "FOR CONSTRUCTING, MAINTAINING, IMPROVING, REPAIRING, WIDENING, ALTERING, DIVERTING AND STOPPING UP DRAINS, SEWERS OR WATERCOURSES; FOR PROVIDING AN OUTLET FOR A SEWER; FOR ESTABLISHING WORKS OR BASINS FOR THE INTERCEPTION OR PURIFICATION OF SEWAGE; FOR MAKING ALL NECESSARY CONNECTIONS THEREWITH AND FOR ACQUIRING LAND IN OR ADJACENT TO THE MUNICIPALITY FOR ANY SUCH PURPOSES". ALSO A BY-LAW MAY BE PASSED AS SET OUT IN SECTION 388(1) (81A) OF THE MUNICIPAL ACT FOR ESTABLISHING, OPERATING AND MAINTAINING SEWAGE WORKS, INCLUDING SEWERS, PUMPING PLANTS, TREATMENT WORKS AND OTHER LIKE WORKS NECESSARY FOR A SEWER SYSTEM, AND FOR REGULATING THE OPERATIONS AND MAINTENANCE THEREOF. THESE TWO SUBSECTIONS APPEAR ALMOST A DUPLICATION BUT THE FIRST IS UNDER A SUB-HEADING OF "DRAINAGE AND FLOODS" WHEREAS THE SECOND IS UNDER A SUB-HEADING OF "HEALTH, SANITATION AND SAFETY". SUCH POWERS ARE PERMISSIVE, THAT IS TO SAY, ENABLING LEGISLATION, TO PERMIT THE MUNICIPALITY TO DO WHATEVER IS CONTEMPLATED IN A MANNER WHICH IT MAY DETERMINE, SUBJECT, OF COURSE, TO APPROVAL UNDER THE PUBLIC HEALTH ACT.

THESE ENABLING POWERS ARE TO BE CONTRASTED TO LEGISLATION COMPELLING A CERTAIN THING TO BE DONE WHERE THE LEGISLATURE THEN INDICATES HOW AND WHERE IT SHOULD BE DONE.

WILL SUCH ENABLING LEGISLATION PROVIDE A DEFENCE TO AN ACTION IN NUISANCE WHERE, FOR INSTANCE, A MUNICIPALITY HAS ERECTED A SEWAGE DISPOSAL PLANT, APPROVED BY THE DEPARTMENT OF HEALTH AND NOT NEGLIGENTLY OPERATED, THAT, TO THE ANNOYANCE OF THE NEIGHBOURHOOD, DOES NOT EFFECTIVELY COPE WITH THE SEWAGE.

THE CASE OF GUELPH WORSTED SPINNING COMPANY AND GUELPH CARPET MILLS COMPANY VS THE CITY OF GUELPH, REPORTED IN 30 ONTARIO LAW REPORTS AT PAGE 466, GIVES AN ILLUSTRATION OF HOW THIS MATTER MAY BE DEALT WITH, ALTHOUGH IT IS NOT A POLLUTION CASE.

THE ACTION AROSE OUT OF THE FLOODING OF THE WORKS OF THE PLAINTIFFS IN THE SPRING OF 1912, WHICH FLOODING WAS CAUSED BY THE ERECTION, BY THE DEFENDANTS, OF A BRIDGE ACROSS THE SPEED RIVER, WHICH BRIDGE PROVED INADEQUATE TO PERMIT THE PASSAGE OF THE WATER DURING SPRING FLOODS. THE VOLUME OF WATER IN THE YEAR 1913 EXCEEDED ALL OTHER RECORDED YEARS, EXCEPT THAT OF THE SPRING OF 1869. THE DEFENCE RESTED ON THE PRINCIPLE ESTABLISHED IN THE CASE OF THE CANADIAN PACIFIC RAILWAY CO., VS ROY, 1902 APPEAL CASES AT PAGE 220, WHICH NOTED IN PART THAT "THE LEGISLATURE IS SUPREME, AND IF IT HAS ENACTED THAT A THING IS LAWFUL, SUCH A THING CANNOT BE AT FAULT OR AN ACTIONABLE WRONG. THE THING TO BE DONE IS A PRIVILEGE AS WELL AS A RIGHT AND A DUTY".

MR. JUSTICE MIDDLETON IN THE GUELPH CASE, QUOTES THE JUDGMENT OF LORD WATSON IN THE CASE OF THE METROPOLITAN ASYLUM DISTRICT MANAGER VS HILL, REPORTED IN 1881, 6 APPEAL CASES, PAGE 193, AS FOLLOWS: "WHERE THE TERMS OF THE STATUTE ARE NOT IMPERATIVE BUT PERMISSIVE, WHEN IT IS LEFT TO THE DISCRETION OF THE PERSON EMPOWERED TO DETERMINE WHETHER THE GENERAL POWERS COMMITTED TO THEM SHALL BE PUT INTO EXECUTION OR NOT, I THINK THE FAIR INFERENCE IS THAT THE LEGISLATURE INTENDED THE DISCRETION TO BE EXERCISED IN STRICT CONFORMITY WITH PRIVATE RIGHTS, AND DID NOT CONFER LICENCE TO COMMIT NUISANCES IN ANY PLACE WHICH MIGHT BE SELECTED FOR THE PURPOSES", AND, AT PAGE 474, "IT HAS BEEN LAID DOWN THAT WHERE THE LEGISLATURE HAS CONFERRED AUTHORITY BY AN ACT WHICH IS PERMISSIVE IN ITS TERMS, THERE IS NO AUTHORITY TO IGNORE THE COMMON LAW RIGHT OF OTHERS".

IN HIS REASONS FOR JUDGMENT, MR. JUSTICE MIDDLETON STATED: "THERE IS, IT SEEMS TO ME, LIABILITY QUITE APART FROM ANY FINDING OF WHAT I MAY CALL ACTUAL NEGLIGENCE, BECAUSE THE VERY THING DONE WAS NOT AUTHORIZED BY THE LEGISLATURE, BUT THE CONSTRUCTION AND MODE OF CONSTRUCTION WERE LEFT ENTIRELY TO THE MUNICIPALITY; SECONDLY, BECAUSE THE LEGISLATION WAS PERMISSIVE ONLY, AND THIRDLY, BECAUSE THE CONSTRUCTION OF THE BRIDGE ONLY WAS AUTHORIZED, AND NOT THE OBSTRUCTION OF THE FLOW OF THE RIVER".

LIABILITY WAS ESTABLISHED, THEREFORE, NOT FOR DAMAGE RESULTING FROM A SPECIFICALLY AUTHORIZED WORKS BUT FROM THE METHOD OF CARRYING IT OUT WHICH WAS IN THE DISCRETION OF THOSE DOING THE WORK.

THE MATTER OF HOW THE WORK IS DONE IS FURTHER DISCUSSED IN A RECENT CASE DEALING WITH THE DEFENCE OF STATUTORY AUTHORIZATION. THIS IS THE CASE OF J. P. PORTER COMPANY LTD. VS. BELL, REPORTED IN 1955. I. DOMINION LAW REPORTS AT PAGE 62. AT TRIAL, JUDGMENT WAS FOUND FOR THE PLAINTIFF FOR DAMAGES BY REASON OF BLASTING OPERATIONS CARRIED ON BY THE DEFENDANT AT THE SEAWARD DEFENCE PROJECT ON THE WEST SIDE OF HALIFAX HARBOUR. THE CASE WAS APPEALED TO THE NOVA SCOTIA SUPREME COURT. MR. JUSTICE MACDONALD IN DELIVERING JUDGMENT QUOTES VISCOUNT DUNEDEN IN THE CASE OF MANCHESTER VS FARNWORTH, REPORTED IN 1930, APPEAL CASES AT PAGE 171: "WHEN PARLIAMENT HAS AUTHORIZED A CERTAIN THING TO BE MADE OR DONE IN A CERTAIN PLACE, THERE CAN BE NO ACTION FOR NUISANCE CAUSED BY THE MAKING OR DOING OF THAT THING IF THE NUISANCE IS THE INEVITABLE RESULT OF THE MAKING OR DOING SO AUTHORIZED. THE ONUS OF PROVING THAT THE RESULT IS INEVITABLE IS ON THOSE WHO WISH TO ESCAPE LIABILITY FOR NUISANCE, BUT THE CRITERION OF INEVITABILITY IS NOT WHAT IS THEORETICALLY POSSIBLE BUT WHAT IS POSSIBLE ACCORDING TO THE STATE OF SCIENTIFIC KNOWLEDGE AT THE TIME, HAVING ALSO IN VIEW A CERTAIN COMMON SENSE APPRECIATION, WHICH CANNOT BE RIGIDLY DEFINED, OF PRACTICAL FEASIBILITY IN VIEW OF SITUATION AND OF EXPENSE

Mr. Justice Macdonald also notes that the protection of the statute extends not only to the doing of the thing specifically authorized but of all acts necessarily incidental thereto.

There arises out of this statutory authority a correlative duty which is to employ all proper means and to see that in the exercise of its power, it does no unnecessary harm to property of some third person; in other words, if it can be shown that the work has been done in a reasonable way and not negligently, there will be no liability.

Mr. Justice Macdonald at page 71, summarizes the authorities as follows: "Accordingly, when damage has resulted from the exercise of permissive powers, the onus is on the defendant to show that he acted reasonably in the sense that he employed all proper means and took all proper care to see that no unnecessary harm was occasioned; or that the manner of execution of his power was the only way in which it could be done; or that the damage was the 'inevitable result' of the thing authorized More shortly, the onus is on the defendant to show "that in practical feasibility the obligation could be performed in no other way save one which involves damage to others".

It was held in that case that the defendant failed to prove that the damage was the inevitable result of operations properly carried on in the execution of statutory authority. That is, it failed to prove that other methods could not have been used which would not have incurred damage.

To summarize, if the municipality relies on a statutory defence, such as the sanction given by The Municipal Act for the construction of work, the defendant municipality must establish that it has acted with due diligence and reasonableness in the sense of being cognizant of the many aspects of the work and its ramifications insofar as affecting the rights of individuals. Coupled with this proposition is the fact that where the Legislation is permissive in its terms, <u>there is no authority to ignore the common law rights of others</u>.

The above cases and the line of authority of English Law, have not had to consider the situation where, in addition to the permissive powers given by the Legislature, there is also the obligation to have the proposed work approved by some governmental authority, such as is the situation where a municipality constructs a sewage disposal plant. The Public Health Act requires by Section 106, in subsection 2, that "a construction of a sewage project by the council of the municipality or by any board of commission created or established by a municipal corporation pursuant to statutory authority, or by any company or person, shall not be commenced until the approval of the Department has been obtained". The Department of Health then inquires and reports upon the work to be undertaken, as to whether it is adequate for the requirements of the inhabitants affected and whether such works are likely to prove prejudicial to the health of the inhabitants and that the construction has been approved of in accordance with Section 101 of The Public Health Act. Can a municipality point to the approval of the Department of Health as additional sanction or authority for its undertaking?

Unfortunately for this discussion, the case that would be the most helpful and illuminating, insofar as this entire question of liability of a municipality is concerned, has not been decided.

THE CASE IS THAT OF ANNIE I. STEPHENS VS THE CORPORATION OF THE VILLAGE OF RICHMOND HILL, WHICH WAS HEARD BEFORE MR. JUSTICE STEWART IN TORONTO, EARLY LAST MONTH. THE PLAINTIFF OWNS PROPERTY THROUGH WHICH FLOWS A BRANCH OF THE DON RIVER, AND THE PLAINTIFF ALLEGED THAT SHE WAS AND IS, ENTITLED TO THE FLOW OF THE SAID STREAM IN AN THROUGH THE SAID LANDS. SINCE DECEMBER, 1952, THE DEFENDANT MUNICIPALITY HAS OPERATED A SEWAGE DISPOSAL PLANT FROM WHICH THE EFFLUENT IS TURNED INTO THE STREAM. SHE ALLEGED THAT THE WATER BECAME POLLUTED, SEEPAGE FROM THE STREAM PENETRATED THE WELLS ON HER LAND WHICH BECAME POLLUTED, AND THE ATMOSPHERE WAS POLLUTED BY A NAUSEATING STENCH. IN ADDITION, THE PLAINTIFF HAD ALSO MADE APPLICATION TO THE ONTARIO MUNICIPAL BOARD FOR APPROVAL OF A HOUSING SUBDIVISION ON HER LANDS, WHICH APPLICATION WAS REFUSED, ONE OF THE GROUNDS FOR REFUSAL BEING THAT THE CREEK RUNNING THROUGH THE LAND OF THE PROPOSED SUBDIVISION CARRIES OPEN EFFLUENT FROM THE DISPOSAL PLANT OF THE VILLAGE OF RICHMOND HILL. ONE OF THE CLAIMS OF THE PLAINTIFF IS FOR AN INJUNCTION RESTRAINING THE DEFENDANT, FROM CONSTRUCTING OR REPEATING ANY OF THE WRONGFUL ACTS COMPLAINED OF AND FROM POLLUTING THE SAID WATERS IN ANY MANNER SO AS TO INTERFERE WITH THE PLAINTIFF'S RIGHTS. THE DEFENCE OF THE CORPORATION ALLEGED THAT THE SEWERAGE SYSTEM WAS LAWFULLY CONSTRUCTED WITH THE APPROVAL OF THE DEPARTMENT OF PUBLIC HEALTH, PLEADED THE PROVISIONS OF THE PUBLIC HEALTH ACT, PARTICULARLY SECTION 106, AND ALLEGED THAT IT HAS A DUTY TO OPERATE THE SEWAGE PROJECT IN THE MANNER IN WHICH IT HAS BEEN OPERATED. THE DEFENDANT ALSO DENIED THAT THERE WAS ANY POLLUTION OF THE WATER. THE MAIN DEFENCE WAS THAT OF STATUTORY APPROVAL GIVING AN IMPLIED AUTHORITY TO POLLUTE THE STREAM. A GREAT MANY CASES WERE CITED SETTING OUT THE PRINCIPLES OF LAW, NOTED ABOVE, AND STRESSING THE FACT THAT THE UNDERTAKING WAS CONSTRUCTED WITH THE FULL APPROVAL OF THE DEPARTMENT OF HEALTH, AND ENTIRELY IN A REASONABLE EXERCISE OF ITS PERMISSIVE POWER TO CONSTRUCT A SEWAGE DISPOSAL PLANT AS ESTABLISED BY THE MUNICIPAL ACT. IN EFFECT THE MUNICIPALITY ARGUED THAT IT DID EVERYTHING IT COULD CONCEIVABLY HAVE DONE AND THAT IF, WHICH WAS NOT ADMITTED, ANY INJURY WAS CAUSED OR WILL BE CAUSED, SUCH INJURY COULD NOT HAVE BEEN AVOIDED BY THE EXERCISE OF REASONABLE CARE ON THE PART OF THE DEFENDANT.

THE DEFENDANT ALSO PLEADED THE PROVISIONS OF SUB-SECTION 15 OF SECTION 106 OF THE PUBLIC HEALTH ACT, WHICH PURPORTS TO GIVE THE ONTARIO MUNICIPAL BOARD, EXCLUSIVE JURISDICTION TO DETERMINE THE PLAINTIFF'S CLAIM, AND THAT AS A RESULT, THE ACTION WAS NOT PROPERLY CONSTITUTED AS BEING BROUGHT BEFORE THE COURT.

THE PLAINTIFF IN THE CASE RELIED MAINLY ON HER COMMON LAW RIGHT TO HAVE AND USE THE WATER FREE FROM POLLUTION. HER ANSWER TO THE DEFENCE OF STATUTORY AUTHORITY WAS A SIMPLE ONE. HOW COULD THERE POSSIBLY BE ANY IMPLIED AUTHORITY IN THE STATUTORY APPROVAL OF A SEWAGE PROJECT IN THE FACE OF THE EXPRESS PROHIBITION OF SECTION 103 OF THE PUBLIC HEALTH ACT WHICH I HAVE ALREADY QUOTED VERBATIM.

WE HAVE ALSO SEEN ABOVE, THAT STATUTORY AUTHORIZATION GIVEN BY THE MUNICIPAL ACT TO A MUNICIPALITY TO CONSTRUCT A SEWER AS DISTINCT FROM DEPARTMENTAL APPROVAL OBTAINED PURSUANT TO THE PUBLIC HEALTH ACT, IS A PERMISSIVE POWER AND, AS SUCH, THERE IS NO AUTHORITY TO IGNORE THE COMMON LAW RIGHTS OF OTHERS.

THE PLAINTIFF'S ANSWER TO THE DEFENCE THAT THE ONTARIO MUNICIPAL BOARD HAD EXCLUSIVE JURISDICTION TO DEAL WITH THE PROBLEM UNDER SUBSECTION 15 OF SECTION 106 OF THE PUBLIC HEALTH ACT, WAS SIMPLY THAT THIS SUBSECTION WAS ULTRA VIRES, THAT IS, BEYOND THE POWER OF THE PROVINCIAL LEGISLATURE TO ENACT. AUTHORITY FOR THIS IS FOUND IN THE CASE OF TORONTO CORPORATION VS YORK CORPORATION, APPEALED TO THE PRIVY COUNCIL 1938 A.C. AT PAGE 415, WHERE IT WAS HELD THAT THE ONTARIO MUNICIPAL BOARD IS PRIMARILY AN

ADMINISTRATIVE BODY AND IS NOT VALIDLY CONSTITUTED UNDER THE BRITISH NORTH AMERICA ACT TO RECEIVE JUDICIAL AUTHORITY. THE BOARD IS, THEREFORE, VALIDLY CONSTITUTED FOR PERFORMANCE OF ADMINISTRATIVE JURISDICTION, BUT ANY DELIBERATIONS INVOLVING JUDICIAL POWERS, IT WAS CLAIMED, WOULD BE INVALID. IT WAS STRONGLY ARGUED, ON BEHALF OF THE PLAINTIFF, IN THE STEPHENS AND RICHMOND HILL CASE THAT THE LIABILITY OF THE MUNICIPALITY WAS A MATTER OF LAW TO BE DETERMINED BY A COURT VALIDLY CONSTITUTED TO RECEIVE JUDICIAL AUTHORITY.

AS STATED ABOVE, THERE HAS BEEN NO DECISION HANDED DOWN IN THIS CASE AS YET. IT IS INTERESTING TO NOTE, HOWEVER, THAT MR. JUSTICE STEWART, INDICATED THAT THE COURT WAS DEALING WITH A PROBLEM OF LAW AND NOT A SOCIOLOGICAL PROBLEM OF WHERE A MUNICIPALITY CAN DISPOSE OF ITS SEWAGE. WE MAY ASSUME THEREFORE THAT IF THE PLAINTIFF PROVES HER COMMON LAW RIGHT TO THE UNINTERRUPTED FLOW OF WATER FREE FROM POLLUTION, AN INJUNCTION WILL BE GRANTED AGAINST THE VILLAGE OF RICHMOND HILL RESTRAINING IT FROM POLLUTING THE STREAM IN QUESTION. IT WOULD THEN REMAIN FOR THE MUNICIPALITY TO SO IMPROVE ITS OPERATIONS IN THE DISPOSAL PLANT THAT POLLUTION IS ELIMINATED. THIS, IT MAY NOT BE ABLE TO DO. AN APPEAL TO THE APPEAL COURTS MIGHT SERVE ONLY TO CONFIRM THE PLAINTIFF'S RIGHT TO AN INJUNCTION. ONE COULD NOT EVEN HAZARD A GUESS WHETHER A HIGHER COURT WOULD MENTION THE SOCIOLOGICAL ASPECTS OF WATER POLLUTION, CHIEF JUSTICE MCRUER REFUSED TO CONSIDER IT IN THE K.V.P. CASE, BUT ONE COULD STATE WITH REASONABLE CERTAINTY THAT THE COMMON LAW WOULD GOVERN THE COURT AND ANY CHANGE WOULD HAVE TO BE EFFECTED BY THE LEGISLATURE, WHICH MIGHT ENACT LEGISLATION SIMILAR IN SCOPE TO THE 1949 AMENDMENT TO THE LAKES AND RIVERS IMPROVEMENT ACT TO WHICH I HAVE EARLIER REFERRED.

*
***
*****
****
*****
***
*