SAMPLE - DO NOT REMOVE

12th

ONTARIO INDUSTRIAL WASTE CONFERENCE

Proceedings

JUNE 1965

SPONSORED BY

THE WATER AND POLLUTION ADVISORY COMMITTEE

TO THE

ONTARIO WATER RESOURCES COMMISSION

12th

ONTARIO

INDUSTRIAL WASTE

CONFERENCE

JUNE 13 - 16, 1965

BIGWIN INN

LAKE OF BAYS

ONTARIO

CONTENTS

PREFACE

D. S. Caverly,
General Manager,
Ontario Water Resources Commission,
Toronto.

Conference Chairman

The 12th Ontario Industrial Waste Conference, held at Bigwin Inn, Lake of Bays, Ontario, the scene of last year's conference, was a notable success both from the viewpoint of the attendance and also the variety and quality of papers presented.

The appreciation of the Water and Pollution Advisory Committee is extended to those who prepared and presented papers and to those who participated in the discussions.

All of the papers presented at the meeting together with the Banquet Address by Mr. G. E. Gathercole, of the Hydro-Electric Power Commission of Ontario, are recorded in the Proceedings. It is anticipated that these will be received with a great deal of interest by those involved in solving the complex problems created by industrial wastes.

The Ontario Water Resources Commission is anxious to promote full co-operation among all concerned to achieve the highest degree of purity in the rivers, streams and lakes of Ontario. Further information may be obtained from the Ontario Water Resources Commission, 801 Bay Street, Toronto 5, Ontario.

SESSION ONE

K. M. Mayall

Department of Energy & Resources
Management

Session Chairman

"TREATMENT OF MEAT PACKING PLANT WASTES IN ANAEROBIC AND AEROBIC LAGOONS"

by

DON R. STANLEY

INTRODUCTION

Waste from most industries located within developed urban areas is discharged to community sewer systems and is treated along with domestic sewage. As the need develops for higher degrees of treatment municipalities have to find means to finance the capital and operating costs of the treatment facilities required. Many communities have instituted sewer service charges designed to assess the cost of the facilities against the users of the systems on an equitable basis. Where industrial waste is a problem the sewer service by-law may put certain restrictions on the quality of the effluent allowed to be discharged to the system and in some cases may provide for surcharges based on the concentration of such characteristics as B.O.D., Suspended Solids, grease and Chlorine Demand, depending on how these affect the cost of treatment.

In a case where there is a highly concentrated waste and a surcharge based on quality, the industry has to analyze the problem to determine whether it is more economical to pay a high surcharge to the community for treating its waste rather than to construct its own pre-treatment facilities in order to reduce the surcharge. In some cases it may even be advantageous for the industry to construct treatment and disposal facilities to the extent necessary for direct discharge into a receiving stream.

The purpose of this paper is to examine a particular situation in the City of Edmonton where the location of three meat packing plants and their cost of waste treatment indicated a unique condition where the construction of separate treatment and disposal facilities was cheaper than discharging into the City's sewerage system.

GENERAL BACKGROUND

Prior to 1957 sewage from the City of Edmonton's sewerage system was discharged into the North Saskatchewan River with little, if any, effective treatment. Although sewage treatment plants were operated in the City prior to 1957 their effectiveness was not significant in controlling pollution in the North Saskatchewan River and as the City grew the situation became acute.

In 1950 the Provincial Health Department inaugurated a stream sanitation project, the prime purpose of which was to examine the major streams in Alberta and determine what, if anything, should be done about improving their sanitary conditions. Examinations of the North Saskatchewan River indicated serious pollution in the winter with available oxygen being used up by the bio-chemical oxygen demand of sewage from the City of Edmonton. In 1957 the City completed construction of an activated sludge plant to treat the major part of its sewage before discharge into the river.

In the operation of the main Edmonton treatment plant one of the major problems has been the handling of meat packing house wastes which were discharged to the City sewers. The plant was apparently designed with an initial capacity sufficient for a population of 350,000 people but about five years ago when the population had reached about 275,000 the plant was in danger of being overloaded. The major cause of this overloading apparently was the high concentration of waste discharged to the sewers by the four major packing plants in the City. Three of these plants are located in North Edmonton close to the north-east corner of the City. To recover the costs of treating highly concentrated wastes the City passed a by-law instituting a surcharge for treatment based on the quality of the waste. This charge made it economical for the packing plants to pre-treat their waste before discharging into the City sewers.

The by-law included surcharges based on the concentration of grease, B.O.D., and Suspended Solids and at present is calculated according to the following formula.

$$N = 1 + \frac{B.O.D. - 700}{2100} + \frac{S.S. - 400}{1200} + \frac{Grease - 200}{600}$$

Where
B.O.D. = Biochemical Oxygen Demand in ppm.
S.S. = Suspended Solids in ppm.
Grease = Grease in ppm.
N x 6¢ = Total charged per 100 cu. ft. of waste.

As can be seen from the above formula a surcharge is applied for B.O.D. concentrations above 700 ppm, suspended solids concentrations above 400 ppm, and a grease concentration above 200 ppm. To encourage more pretreatment of industrial waste the City has considered changing the formula to provide for surcharge for concentrations of B.O.D. above 350 ppm, suspended solids 350 ppm, and grease 100 ppm, but the formula has not as yet been changed to include these more stringent requirements.

The writer was contacted by one of the packing plants to give advice on the design of treatment facilities. In the initial discussions it appeared that there was merit in examining the problem from the point of view of the three packing plants rather than of one alone. There was no doubt that it would have been feasible to collect the waste from the three plants and construct one waste treatment facility which would have resulted in substantial saving in both the capital and operating costs to the three plants. However, in discussing this approach with officials of the plants the opinion was expressed that the administrative problem involved in the firms dealing with one another would not justify the savings that may be effected. The alternative appeared to be the operation of such a waste treatment plant by a private company on a contract basis with each packing plant.

Further investigation was carried out for a utility company and the possibility of utilizing a sewage lagoon (stabilization pond) method of treatment consisting of anaerobic followed by aerobic or storage lagoons was studied. It was anticipated that such facilities would handle any quality of waste without pre-treatment. At the time it was not known that this method had been used in any place for the treatment of meat packing plant wastes but on further study it was found that the Swift Company had two such installations, one near Moultrie, Georgia, and the other in Iowa.

Preliminary plans and estimates of cost of construction and operation of the proposed system to handle waste from the three meat packing plants were made and these indicated that the proposed project had sufficient merit to justify a more thorough examination. At the time the City of Edmonton was not interested in participating in the financing of such facilities and indicated that the project should be handled on a private enterprise basis. The City indicated that it would be pleased if the packing plants arranged for treatment of their own wastes by an alternative method to that of discharging into City sewers.

The subsequent study of the problem included the following:-

1. Technical feasibility of the use of anaerobic and aerobic lagoons for the treatment of meat packing plant wastes in the Edmonton area, and
2. Preliminary plans and estimates of cost of the proposed method of treatment and disposal.
3. Analysis of the economic feasibility of providing waste treatment service to the three meat packing plants in question by a utility company.

TECHNICAL FEASIBILITY OF TREATMENT METHOD

Sanitary sewage which requires a high degree of treatment is conventionally treated either by activated sludge plants or trickling filter plants. Another method of treatment which has now been widely accepted utilizes lagoons or stabilization ponds. These ponds embody primary and secondary treatment and sludge digestion in an open pond or ponds. The term "lagoons" was first used to describe this type of treatment but recently, the term "stabilization pond" has become more general.

In North America lagoons have generally been designed large enough to ensure aerobic conditions. In Australia (1) experiments were carried out with lagoons subjected to such high loadings that all oxygen was used up and these were called anaerobic lagoons. In Alberta during the past ten years anaerobic lagoons have been used extensively for the treatment of municipal sewage and are usually followed by aerobic or storage ponds. In New Zealand (2) anaerobic lagoons have been used for the treatment of packing house wastes and more recently this method has been used in the United States (3). Also, such ponds have been used for the treatment of many other industrial wastes.

In considering the feasibility of utilizing anaerobic lagoons followed by aerobic or storage ponds for the treatment of waste from packing houses in Edmonton, it was important to consider two major problems, namely, whether the scheme could provide treatment which the Provincial Board of Health considered adequate to protect the North Saskatchewan River from pollution, and secondly, whether such facilities would operate without creating a nuisance in the area.

Pollution of the North Saskatchewan River:- One of the main problems with pollution of the North Saskatchewan River is that of the high organic load being discharged into the river by the City of Edmonton. Before the construction of the new sewage treatment plant in Edmonton, this load was sufficient to use all the oxygen during the winter months when ice cover did not allow re-aeration. In the summer the condition was not as bad because of the higher flows and re-aeration. In the present operation of the Edmonton treatment plant the Provincial Health Department requires primary treatment during the summer but complete treatment in the winter.

When all of the packing plants were discharging waste into the City sewerage system, approximately 35% of the B.O.D. load on the City's plant was being contributed by the three packing plants in north-east Edmonton but this was included in only 10 - 15% of the flow. A simple solution to the problem would have been to store the waste of the three packing houses during the winter and discharge it during high water in the spring and summer. The problem, however, was to find a site sufficiently remote from habitation to allow the use of such facilities without creating an odour nuisance in the surrounding area.

There had been no experience, to the writer's knowledge, with this type of approach but there had been experience with anaerobic followed by aerobic lagoons, and in the limited number of installations there had been little, if any, reported problems with odour. Therefore, it was decided to pursue studies further to determine whether the experience under other climatic conditions could be applied to the situation in Edmonton.

The Problem of Odour:- Early in the investigations it became clear that the efficiency of treatment was not an important factor, providing there was sufficient storage following the anaerobic ponds. There was no doubt that the degree of treatment could not, under any circumstances, be worse than the primary treatment that was required by the Health Department for summer operations. Therefore, it was only necessary to provide enough storage so that discharge could be restricted to certain periods in the summer. Also there was every indication that treatment efficiency with anaerobic followed by aerobic ponds would be high in the summer. The problem then was simply to determine whether or not facilities could be operated without creating an odour nuisance.

The proper approach to this problem would have been to construct a pilot plant and operate it over a period of at least two winters. However, there were no funds available for such an approach and an assessment was made on the basis of the following investigations:-

1. Review of local experience with anaerobic and aerobic lagoons.
2. Examination of literature to determine if there was any recorded experience that could be applied to the proposed scheme.
3. Discussions with persons having technical experience in the sewage and industrial waste treatment field to find out if there was any experience with treatment of packing plant wastes under similar conditions utilizing similar methods, and also to obtain their opinions on whether such experience could be applied to the problem in Edmonton.

4. The examination of installations for the treatment of waste which could be of help in determining whether the proposed method of treatment could be used to solve the problem in Edmonton.

The writer first considered the use of anaerobic and aerobic lagoons for packing house wastes as an adaption from the experience with anaerobic lagoons used for municipal sewage in Australia and on the basis of two instances where such ponds had been used in Alberta. Since that time, however, much more experience has been gained in Alberta with the use of anaerobic lagoons for the treatment of municipal waste. Also, a new process had been developed called the "anaerobic contact process" for the treatment of packing house wastes. This process involves anaerobic treatment in a tank at a temperature of about 90°F. It was felt that a lower temperature but a longer retention time in a lagoon might possibly accomplish the same result.

Examination of available literature brought attention to a reference to experience in New Zealand, and correspondence was carried out with Mr. Ronald Hicks of the Auckland Metropolitan Drainage Board. Mr. Hicks outlined his experience and opinions on the use of anaerobic followed by aerobic lagoons for the treatment of packing house wastes and in his opinion such facilities could provide an efficient degree of treatment without odour nuisance. Mr. Hicks, however, mentioned temperatures of 70 to 80° in the anaerobic lagoons. In New Zealand, of course, maintaining such a temperature is not as difficult a problem as it would be in Alberta. Therefore, to adapt the experience in New Zealand to Alberta, the problem of maintaining such a temperature in the winter, or the effect of allowing the temperature to go below 70 degrees had to be assessed.

The writer also found out that the Swift Company in the United States had built two installations utilizing anaerobic and aerobic lagoons for the treatment of waste from two of their packing plants. These were located at Perry, Iowa and at Moultrie, Georgia (3). Unfortunately, at the time this was investigated the packing plant at Perry had been shut down and therefore the lagoon was not in operation. The experience with the operation at both of these indicated no appreciable odour nuisance, and the degree of treatment was high. The waste was pre-treated by the removal of paunch manure, grease and considerable settleable solids. Also, the temperature in the anaerobic lagoon at Moultrie was approximately 85°F most of the time. For the plant at Perry, Iowa the temperature was maintained at 70° or above by injecting heat.

The problem was also discussed with Professor George Shroepfer of the University of Minnesota. Visits were made to a sewage treatment plant in South St. Paul, Minnesota, which treats approximately 10 million gallons of waste a day, 90% of which is flow from packing houses. The significant experience at this plant is that sludge from the primary and secondary settling tanks is discharged to open lagoons where it is digested without any control and without nuisance. This was a direct indication that odour nuisance would not be a problem with the anaerobic type of treatment process when temperatures were low. Also, paunch manure is removed in a high rate settling tank prior to the regular treatment and then disposed of in an area close to the plant where it does not cause odour nuisance.

One of the important considerations in determining the overall economics of the proposed method of treatment is the degree to which the packing plants would be required to pre-treat their waste before discharge to a system utilizing the anaerobic and aerobic lagoons. If the lagoon system could handle paunch manure and any other waste then the overall economics would be considerably improved. However, the consideration again was whether or not the discharge of such excess waste would adversely affect the treatment process primarily with respect to increasing the probability of an odour nuisance. This matter was considered but no final conclusion drawn, although there are indications that it may be more economical to treat in the lagoons any waste which the packing plants wish to discharge, rather than to require certain pre-treatment facilities.

<u>Conclusion Re Feasibility</u>:- On the basis of the investigations outlined above, the following conclusions were drawn:-

1. That packing house waste from which grease and paunch manure has been essentially removed can be treated to a high degree utilizing anaerobic followed by aerobic lagoons. On the other hand, it may be that paunch manure and grease can be

left in the waste without adversely affecting the degree of treatment or causing any nuisance. It was concluded that the proposed facilities could be installed without pre-sedimentation to remove paunch manure and grease and that if the operation were unsatisfactory, pre-sedimentation facilities could be added. However, during the course of the study the packing plants installed their own facilities for removing grease and paunch manure and it was felt that the lagoons could be operated at the outset treating this pre-treated waste. The pre-treatment facilities could then be by-passed to see if this would result in an adverse effect on the lagoon operation.

2. That the treatment process can be carried out without creating an odour nuisance provided the location of the ponds is at least one half a mile from the nearest residence.

3. That the degree of treatment and absence of odour nuisance can be assured if a temperature of 70° is maintained in the anaerobic lagoons, but there is no indication that there will be odour nuisance if the temperature is allowed to drop. If the anaerobic lagoon is started and operated properly, it is probable that during the winter lower temperatures will not result in the creation of an odour nuisance, although the degree of treatment may be reduced.

4. There is no direct experience to indicate whether or not the aerobic or storage pond may cause an odour nuisance in the spring after it has had ice cover over the winter. However, experience with many other lagoons in Western Canada would indicate that this would not be any greater problem than other situations where aerobic lagoons are frozen in the winter and the same requirements as to location could apply.

DESCRIPTION OF FACILITIES

The proposed facilities included the following: a collection system to collect waste from the three packing plants, an outfall line to transport the waste to the disposal area; a syphon to cross the river, and anaerobic and aerobic or storage lagoons in the disposal area. It was also considered that if treatment facilities did not operate effectively it may have been necessary to construct a high rate sedimentation tank ahead of the anaerobic lagoons to remove paunch manure and grease if this was not removed satisfactorily by pre-treatment facilities in the packing plants.

After plans did not materialize for a private company to operate waste treatment facilities as a service to the packing plants the City of Edmonton undertook the project on a municipal basis.

Figure 1 shows the location of the facilities which were constructed by the City in 1964. The two alternate disposal areas shown were considered but the ponds were constructed on the most remote site to reduce the probability of odour nuisance.

The lagoon facilities are considerably more extensive than had been anticipated by the writer in his first investigations. Also, their location is further away, resulting in extra cost for outfall line although this provided an extra safety measure to reduce the possible odour nuisance. By lowering the outfall sewer it was possible to pick up domestic sewage from a part of the City which required additional service, and domestic waste from about 10,000 persons is now being treated in the lagoons along with packing plant waste. Figure No. II shows the layout of the anaerobic lagoons and the location of the aerobic or storage ponds constructed by the City.

In the preliminary design for the anaerobic lagoons provision was made for two lagoons with seven days storage in each on the basis of the initial flows but reducing to about four days due to flow increase in about six years. On the same basis the aerobic or storage lagoons would have provided seven months storage. The ponds built by the City as shown in Figure II included three anaerobic cells, each with a capacity of four day detention at three million gallons a day which is approximately the average daily flow at present.

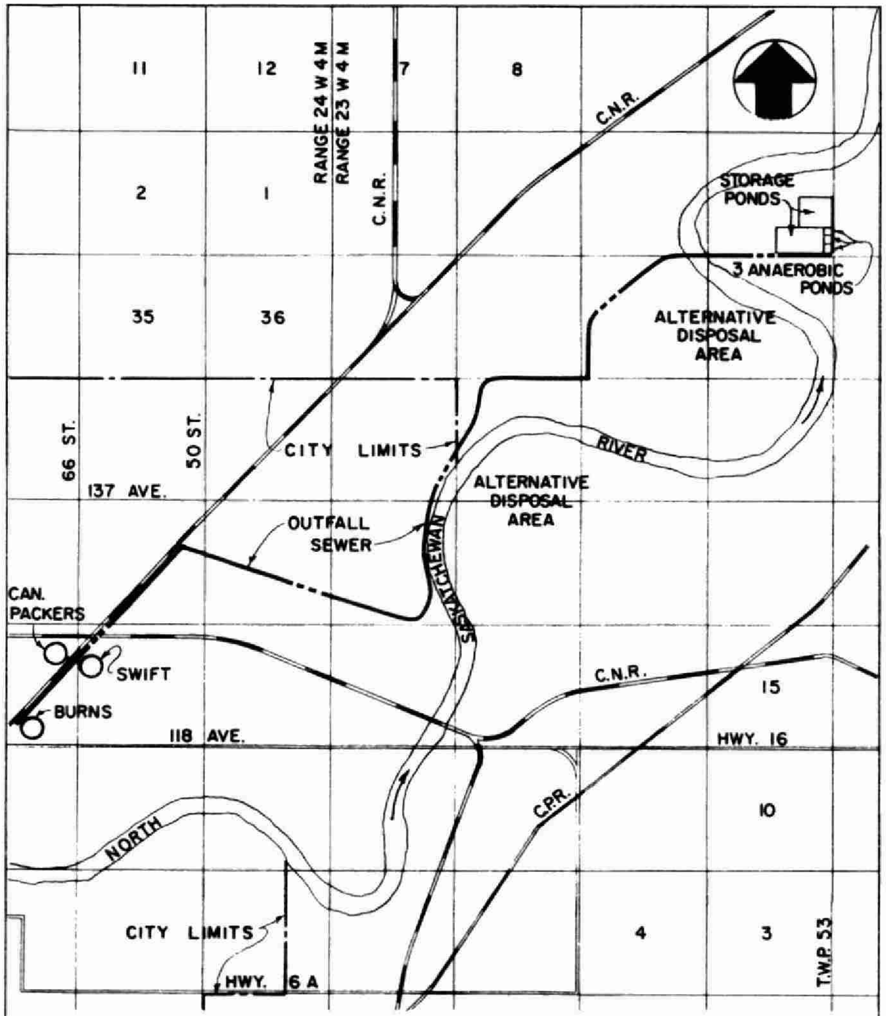


FIGURE I

CITY OF EDMONTON

PACKING PLANT WASTE TREATMENT
LOCATION PLAN

SCALE 1" = 1 MILE
JUNE 9, 1965

STANLEY, GRIMBLE, ROBLIN LTD.

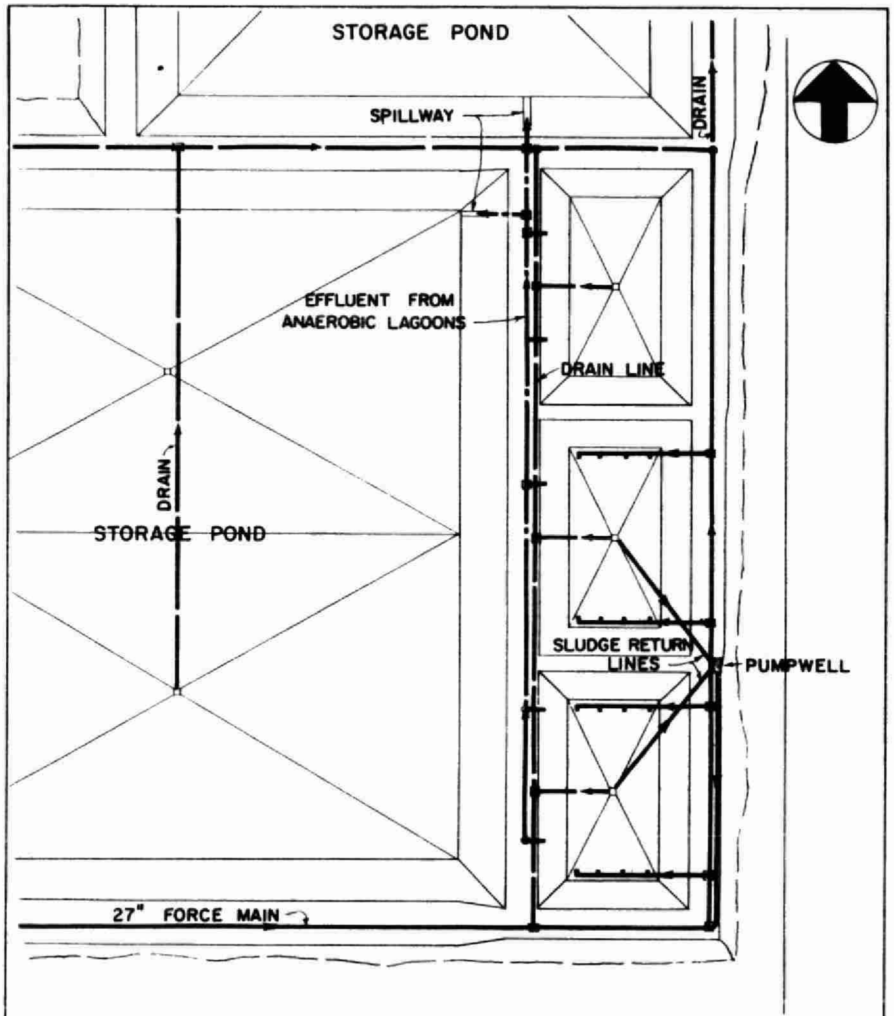


FIGURE II

CITY OF EDMONTON

PACKING PLANT WASTE TREATMENT
POND LAYOUT

SCALE 1" = 200'
JUNE 9, 1965

STANLEY, GRIMBLE, ROBLIN LTD.

In moderate climates where most of the experience with this type of facility for treating packing plant wastes had been gained both anaerobic and aerobic ponds can be operated with reasonable efficiency the year around. However, from experience with many other lagoons it was apparent that aerobic ponds could not be operated efficiently in the winter, and therefore, as a treatment unit, this part of the combination would have to be discounted and could be depended on only as a storage pond to retain waste during periods when it was not possible to discharge to the river.

Under other circumstances where it would not be permissible to discharge high B.O.D. wastes into the river at any time the problem could be solved by providing sufficient storage to retain waste until the summer when it could be treated efficiently in an aerobic pond. This could be accomplished with about seven or eight months storage. However, in the present situation this was not necessary and the main problem to consider was that of the operation of the anaerobic lagoons which it was felt could be kept relatively warm at all times due to the high temperatures in the waste coming from the packing plants. The main considerations of design then centered on the anaerobic lagoons. The important factors considered were retention period, shape, temperature and recirculation.

<u>Retention Period</u>:- The initial preliminary design provided for a retention period of seven days at the flow that existed at the time of the study which was five years ago. It was anticipated at the time that within a few years the flow would increase and reduce the retention period to four or five days. Information from various sources indicated that retention period in anaerobic lagoons is a critical factor and that either too short or too long a retention period would cause difficulty with odour nuisance. However, there hasn't been sufficient research or reliable experience to give anything other than a general indication of the effect of retention period. The optimum retention period depends on many factors, two important ones of which, no doubt, would be quality of waste and temperature. Hicks (2) suggests two days at 70° - 80°F. Sollo (3) used four days and reported reduced efficiency when the temperature dropped below 75°F but did not report any odour nuisance.

Temperature:- Another factor that is important is the temperature. This, of course, is a factor related to retention period and it would not be unreasonable to expect that the higher the temperature the shorter can be the retention period. Again, there is not sufficient evidence available to quantify this factor. On the other hand, experience to date indicates that with temperatures of 70° or above and retention periods of two to four days, anaerobic lagoons can effectively treat packing plant waste without creating an odour nuisance. This does not mean that there would not still be effective treatment at temperatures lower than 70°. In considering the design and the operating costs, estimates were made of the cost of heating one anaerobic lagoon and this was approximately $12,000.00 per year. This was based on a heat loss of 5 B.T.U. per square foot per hour per degree fahrenheit difference in temperature. It was expected that no heating would be required but this factor was included in the economic analysis to determine whether or not under the worst conditions the method of treatment could still be economically feasible. More research is needed on the effect of temperature before reliable conclusions can be drawn. Sollo (3) reported adding heat to anaerobic ponds to maintain temperatures above 70°F.

Shape:- The anaerobic lagoon designed by Swift & Company for waste treatment at Moultrie, Georgia (3) is rectangular in shape, 14 feet water depth with 3:1 side slopes and provides approximately four days detention. The writer has no reason to disagree with this type of design but feels that in any cold climate like Alberta the design should incorporate the maximum volume for the least surface area and, of course, having side slopes as steep as feasible consistent with the proper economy.

Recirculation:- The Swift plant in Georgia is operated with recirculation at a rate of approximately 50% of the average daily flow but there is capacity for higher circulation rates. The inlet to the recirculation pumphouse is in the bottom of the tank and thus draws sludge which is pumped to the influent of the tank with the incoming waste. This arrangement provides intimate mixing of activated anaerobic sludge with incoming waste. The operating results from the anaerobic ponds are excellent.

As shown in Figure II the anaerobic ponds constructed by the City of Edmonton are rectangular in shape and provide for recirculation of the sludge from the bottom of the ponds and for entrance of the waste including recirculated sludge at either end. Another method of providing recirculation is to circulate within the lagoon itself utilizing one anaerobic lagoon as a contact lagoon with gentle stirring at all times and with the second lagoon operated in series as a settling lagoon from which some sludge can be pumped, if necessary, back into the first pond.

Hicks (2) suggests gentle stirring by air bubbling in the first pond and then removal of sludge in a sedimentation tank with sludge being returned and mixed with incoming waste.

ECONOMIC FEASIBILITY OF PROJECT

An economic analysis of the proposed project was made to determine whether it was feasible for a utility company to construct and operate the facilities and provide waste treatment service on a contract basis to the three packing plants concerned. When this arrangement fell through, however, the City of Edmonton decided to go ahead with the project and it was considerably expanded to provide other features.

OPERATING EXPERIENCE

The City of Edmonton started operation of the facilities in the winter of 1964-65. It was unfortunate that it was not possible to start in the summer of 1964 when the temperature was much higher. Normally it is best to start-up in the spring, if possible, so that a few months of operation can be obtained while the air temperature is high and there is the best opportunity to get the anaerobic lagoons into proper operation. Also, at start-up it may be advisable to provide seed sludge from a digester of an operating plant.

Certain problems have arisen with respect to the operation of the lagoons. The main one of these is the production of considerable hydrogen sulphide. Despite this, however, the location of the lagoon is sufficiently remote so that, although there is noticeable odour close to them the odour does not travel far enough to cause a great nuisance. Under certain weather conditions, however, it may be noticeable at a distance of a mile or so. Nevertheless it is felt that with experience in operation it will be possible to control this odour. The City has tried utilizing enzymes for odour control and reports indicate that this is helpful. The cost of feeding enzymes is approximately $40.00 to $50.00 per day which amounts to about 1¢ per 1,000 gallons. Considering the overall economy of the project, 1¢ per 1,000 gallons for odour control is a good investment if it is possible to control it in this way.

To date there is very limited information on the operation of the lagoons but indications are that they are providing a reasonable degree of treatment. On tests run during the first part of May, 1965, indications are that the anaerobic lagoons are removing approximately 75% of the suspended solids, over 70% of the B.O.D. and 79% of the grease. Experience reported by Sollo (3) for the Swift Company plant in Moultrie, Georgia, indicated B.O.D. removal in the anaerobic lagoons as high as over 90%. It was found, however, that when the temperature in the pond dropped below 75°F there was a considerable reduction in operating efficiency, although again, no problem with odour.

CONCLUSIONS

As a result of the studies carried out the following conclusions were drawn:-

1. That the method of treatment using anaerobic followed by aerobic or storage ponds would provide the degree of treatment necessary for the protection of the North Saskatchewan River and could be operated without creating an odour nuisance providing their location was sufficiently remote.

2. That the proposed anaerobic and aerobic lagoons, if properly operated may be able to treat packing house wastes from which paunch manure and grease had not been removed without causing an odour nuisance at the proposed disposal site.

3. That the inclusion of a high rate settling tank for removal of paunch manure and grease would give more assurance that satisfactory operation without odour nuisance could be achieved.

4. That the cost of treatment of meat packing house waste by this method is much less than the alternative of treatment in the City's activated sludge plant.

5. That it is economically feasible to add heat to anaerobic lagoons if this is found necessary in order to obtain a certain efficiency.

1. Parker C.D. Jones, H.L. and Taylor W.S. Sewage and Industrial Wastes 22, 760-75, 1950.

2. Ronald Hicks, Auckland, New Zealand, Metropolitan Drainage Board - by private communication.

3. Sollo, F.W. "Pond Treatment of Meat Packing Plant Wastes," Proceedings of the Fifteenth Industrial Waste Conference, Purdue University, 1960, p. 386.

"AERATED LAGOONS FOR THE TREATMENT OF CANNERY WASTES"

by

K. H. SHIKAZE

INTRODUCTION

The treatment of cannery wastes at any time is never a very simple task and a great many approaches have been used for their treatment. Among these are spray irrigation, combined treatment with sanitary sewage at the municipal disposal plant, lagooning, chemical precipitation, anaerobic processes, aerobic processes and various other methods (1, 2, 3, 4, 5, 6). In fact, the amount of work carried out on these various methods is well illustrated in a recent book on industrial waste treatment by Nemerow (7) which cites some 192 references on cannery wastes and their treatment.

One of the earliest and simplest means whereby cannery wastes have been disposed has been by the use of some type of impounding lagoon. In its simplest form, the lagoon merely consists of a diked-off area of land in which the wastes are retained for a period of time before release. These impoundment structures have been referred to by many names - chiefly, oxidation ponds, sewage lagoons or waste stabilization ponds, the latter term being generally used by the OWRC. The ponds may utilize anaerobic or aerobic processes, or both combined, for the stabilization of wastes. Both aerobic and anaerobic ponds have been used in cannery waste treatment. However, in most cases, the use of the aerobic type is dictated because of the odour problem associated with anaerobic treatment.

The treatment of cannery wastes which are high in volume and strength would require considerable land area if conventional waste stabilization pond design criteria were followed. Even in the most rationally designed ponds, odours will occur because of the extreme variations in cannery wastes. In many lagoons, sodium nitrate is added to supply oxygen to meet partially the demands of the waste. However, the use of sodium nitrate results in increased operating costs. Another means whereby objectionable odours can be controlled and aerobic conditions maintained is by some means of supplementary aeration within the lagoon. Eckenfelder and O'Connor (8) in their work showed that an aerated lagoon using diffused air would satisfactorily treat cannery wastes from the production of fruit and baby products.

The application of an aerated lagoon system for the treatment of cannery waste at Chatham, Ontario, showed considerable promise. However, the limited information available on the use of this process, particularly for wastes from peas and tomatoes, led to the decision to carry out pilot plant studies so that some basis for design could be set up for a full-scale treatment works. Therefore, the primary aim of the study was to determine the BOD loadings which could apply to a rationally designed aerated lagoon without production of obnoxious odours.

THE AERATED LAGOON

The aerated lagoon is a refinement of the waste stabilization pond and differs only by the presence of a device whereby oxygen is introduced into the process. Therefore, in order to understand the functions within the aerated lagoon, it is necessary first to describe the stabilization of wastes in the conventional waste stabilization pond.

The successful operation of the waste stabilization pond is achieved under aerobic conditions produced by the interrelated activities of bacteria, algae protozoa and higher animals. The relationship is shown in the following cycle.

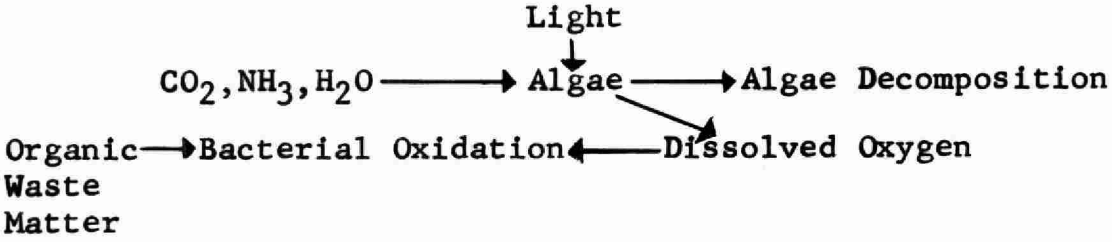


Figure 1 - Lagoon Biological Cycle

In the plant-animal cycle of nature in the waste stabilization pond, the algae play a very significant role. In the presence of sunlight, the algae utilize carbon dioxide, water, nitrates and other elements to produce new protoplasm with oxygen as the by-product. This oxygen then becomes available to the bacteria and other microbes which utilize it to stabilize the organic material in the wastes by metabolic processes. Bacterial decomposition of the organic matter results in the production of carbon dioxide, nitrates, water and other trace elements which the algae utilize and thereby complete the cycle.

In the waste stabilization pond, the algae under normal conditions do not supply enough oxygen to maintain a residual oxygen concentration. The other main source of oxygen results from uptake at the liquid surface from the atmosphere. Also, depth becomes a limiting factor in the efficiency of the photosynthetic process because light will not penetrate too deeply in algae-laden waters. In general, the optimum depth for waste stabilization ponds ranges from 3 to 5 feet.

Therefore, by increasing the depth, providing a means of introducing oxygen into the process, and inducing simultaneous mixing, it should be possible to increase the waste loadings to much higher values. By introducing an aeration device, the waste stabilization pond becomes an aerated lagoon capable of handling much higher loadings.

The aerated lagoon is an intermediate process, since it can be considered as either a highly loaded waste stabilization pond or very lightly loaded activated sludge plant. Most of the studies on aerated lagoons have been based on retention times which ranged from one to ten days; the process under such conditions becomes somewhat similar to complete mixing and total oxidation.

LAYOUT OF LAGOONS

The pilot studies at Chatham centered around the design of four ponds - two utilizing diffused air, one utilizing mechanical aeration and the other a conventional waste stabilization pond. An overall schematic layout is shown in Figure 2.

Lagoon #1, Diffused Aeration

As shown in figure 3, lagoon #1 was designed to have a surface 152 feet long and 72 feet wide when filled to its eight-foot deep capacity. Side slope was 2 to 1.

Aeration was provided by using perforated lead-keeled plastic tubing which was laid out in U-shaped loops along the bottom width of the lagoon. Each end of the loop was connected to a 4-inch air header which extended the length of the lagoon. Unperforated tubing was used to connect the loops to the air header along the slope.

Spacing of the tubing was as follows, beginning from the influent end:

12 laterals at 2 feet centre to centre
4 " " 10 " " " "
2 " " 20 " " " "

Lagoon #2, Diffused Aeration

This lagoon had an identical surface area as lagoon #1 (Figure 4). However, an unaerated 12-ft. deep basin on part of the lagoon bottom was provided for concentrating settleable solids. This deep section began 31 feet from the inlet end of the lagoon. Aeration tubing was suspended at the eight-foot-deep level over this deeper section and laid on the bottom over the remainder of the lagoon.

Aeration tubing spacing beginning at the inlet end was as follows:

24 laterals at 2 feet centre to centre
8 " " 4 " " " "
4 " " 10 " " " "

Lagoon #3, Mechanically Aerated

This lagoon shown in Figure 5 measured 32 feet square at the 8-foot operating depth. Relatively steep sides (slope of 1 to 1) were constructed for this lagoon by sandbagging the slopes. Polyethylene sheeting around the perimeter at the surface was used to prevent erosion due to wave action.

A 3-foot diameter Simcar surface aerator powered by a 3 HP motor provided the aeration. Rotational speed throughout the study was maintained at 75 rpm. Previous testing of this unit at the OWRC Laboratories gave an aeration capacity of four pounds of oxygen per hour (tapwater test media).

Lagoon #4, Waste Stabilization Pond

As illustrated in Figure 6, the waste stabilization pond was relatively small with a 112 by 32 feet surface area (0.06 acre) and a 5-foot operating depth.

Waste feed for this lagoon consisted of a portion of the effluent from lagoon #3.

Figures 7 to 14 illustrate the construction features and operation of the pilot lagoons.

CANNERY WASTE FEED

Cannery waste feed for the lagoons was transported via 4-inch PVC forcemain from a cannery sewer manhole 800 feet from the lagoon area. The sewer at the manhole was partially blocked to create a small sump for a float-controlled pump intake. The cannery wastes were screened prior to discharge to the sewer.

Gate valves at the weir boxes located at the head of the three lagoon systems controlled waste volumes. V-notch weirs metered the volume of feed to the lagoons. By-passed wastes joined a ditch about the lagoon embankment perimeter.

AIR SUPPLY

Air was supplied by a positive displacement blower with a capacity of 35 cfm at 1120 rpm and 7 psi.

Air from the blower was metered using a bank of six natural gas meters. Three meters in parallel determined the air feed to each aerated lagoon.

CANNERY WASTES

Pea Pack Wastes

Processing of peas began in the latter part of June and the operation was carried out in two ten-hour shifts with a four hour clean-up occurring daily in the early morning. Because 1963 was a very dry season, the harvesting of the pea crop continued on a very irregular basis and consequently resulted in intermittent waste flows to the lagoons. It was therefore, very difficult to maintain a consistent loading to the lagoons.

A summary of the pea pack wastes is given in the following table.

Table 1

Pea Pack Wastes

	COD	BOD	Susp. Solids	pH	DO
Median	742	444	222	7.25	1.3
Maximum	4010	2620	1435	9.8	7.1
Minimum	124	74	7	5.3	0.5

Note: all results except pH in ppm
composite results (12 midnight to 12 noon)

Before the study began it was anticipated that the pea pack wastes would have an average BOD of 1000 ppm. This figure was exceeded only during the first few days of processing and the overall average over the season was considerably lower.

It should be noted that this cannery freezes its entire pack and this may have had some effect on the waste strength.

Tomato Pack Wastes

Processing of tomatoes began in the latter part of August and continued until mid-October. Canned products consisted of juice during September and soups over the remainder of the processing season. Processing hours were similar to those for pea pack operations.

Table 2 gives a summary of the tomato pack wastes.

Table 2

Tomato Pack Wastes

	COD	BOD	Susp. Solids	pH	DO
Median	551	468	256	8.1	7.2
Maximum	1670	1700	3044	12.2	10.0
Minimum	171	63	17	6.9	1.2

Note: all results except pH in ppm
composite samples (12 midnight to 12 noon)

One feature of the tomato wastes was the presence of discarded seeds. Seeds accumulated in the weir boxes and these boxes required a daily clean-out. In addition, seeds had a tendency to collect in sludge banks below the weir discharges into the lagoons.

PERFORMANCE OF LAGOONS

The results of the pilot studies were difficult to interpret for two main reasons.

Firstly, the periods of waste flow were short and very irregular. Variables such as sunshine and wind may effect lagoon performance and these require a much longer time period for evaluation as treatment parameters. The short operational periods also fails to reveal the effects of sludge deposition and accumulation.

Secondly, the unreliability of the air distribution system to lagoons #1 and #2 through the plastic hose aeration system created major problems for this study. In addition to requiring considerable maintenance and investigative attention, lack of a steady air feed upset the scheduling and evaluation of maximum waste loading capacities for these ponds. The back pressures developed by clogged air tubing also resulted in a number of equipment break-downs and consequent interruptions in air supply.

Diffused Aeration Lagoons

Because of the wide variations in waste flow and strength, the averaged results of operation over the specific processing periods give the best indication of the treatment capabilities of the lagoon.

The following table gives the averaged results for lagoons #1 and #2 during the pea pack.

Table 3

Pea Pack Results

	Lagoon #1	Lagoon #2
BOD loading lb/acre/day	130	130
BOD effluent ppm	37	35
BOD removal %	85	88
Suspended Solids effluent ppm	91	88
Dissolved Oxygen - day ppm	3.3	4.2
- night ppm	2.6	3.5
pH	7.7	7.6
Temperature °C	24	24

The BOD loading is based on the design surface area of the lagoon. The actual loadings would be somewhat higher (approximately 15%) because lagoon levels were not at maximum during the pea pack.

It can be seen that the average loadings were more than six times that for the design of conventional waste stabilization ponds in Ontario.

With the loading variations experienced, it was possible to determine the effect of shock loadings on the lagoon. For example, a high loading of 560 lb/acre/day had the effect of reducing the dissolved oxygen content from 3.2 to 0.6 ppm in lagoon #1. The effect on lagoon #2 was not as marked as the dissolved oxygen dropped from 6.6 to 4.3 ppm with a similar extreme loadings. It must be remembered, however, that lagoon #2 was receiving twice as much air as lagoon #1. Frequent maintenance was required on the blower and air tubing. Consequently, no correlation could be made on the relationship between the amount of oxygen supplied and BOD removed.

Air was supplied during the interim between the pea and tomato pack and the conditions within the two diffused air lagoons were not unlike that of the conventional waste stabilization pond.

The tomato pack began in late August and until the latter half of September and the average loadings to the lagoons approximated those during the pea pack. Operating problems with the equipment were the primary reasons for not increasing the loadings. Lagoon performance during this period was very good with dissolved oxygen values averaging around 5 ppm for most of the time.

Beginning on September 23rd, the loadings were increased appreciably in an attempt to determine the maximum capacity of the lagoons. In lagoon #1, from September 23 to 29, the loadings averaged 268 lb BOD/acre/day with a range 104 to 648 lb BOD/acre/day. Effluent BOD remained in the range from 10 to 31 ppm. The dissolved oxygen values dropped gradually from 8 ppm to 1.0 ppm during this period. In the same period for lagoon #2, the loading averaged 342 lb BOD/acre/day with a range of 136 to 800 lb BOD/acre/day. Effluent BOD values ranged from 20 to 32 ppm while dissolved oxygen values fell gradually from 6.8 to as low as 0.4 ppm. There were no signs of odours developing in either of these lagoons during this period.

During the next period extending from September 29 to October 5 loadings were further increased averaging 856 to 877 lb BOD/acre/day in lagoons #1 and #2, respectively. Effluent BOD values in both lagoons rose to greater than 75 ppm and dissolved oxygen values remained below one ppm. By October 5th, slight odours were detected from both lagoons. Loadings averaging over 1000 lb BOD/acre/day continued until October 8th in lagoon #1 and October 9th in lagoon #2. In the meantime, odours increased while dissolved oxygen dropped to zero. Waste feeding was then stopped to determine the recuperative powers of the lagoons. A minimal amount of air was still being fed to the lagoons.

Dissolved oxygen values rose to 4.9 and 6.7 ppm in lagoons #1 and #2, respectively, by October 13th, thus indicating a recovery time of about five days. Also, there were no longer any odours emanating from the lagoons.

Feed to both lagoons did not, however, commence until October 15th because of problems associated with the waste feed pump.

For the next four days ending on October 18th, widely varying loadings to the lagoons were experienced. The loadings averaged 1038 lb BOD/acre/day in lagoon #1 and 871 lb BOD/acre/day in lagoon #2. These high average loadings again resulted in odours from the lagoons. Effluent BOD values rose to 135 ppm in both lagoons and dissolved oxygen values dropped to zero again. October 18th also marked the end of the tomato processing season.

Once again it took approximately five days for the lagoons to recover as dissolved oxygen values of 1.5 and 2.4 ppm were found in lagoons #1 and #2, respectively on October 23rd. Dissolved oxygen values gradually increased and a deep green colour developed in both lagoons. The air supply was shut off on October 25th and both lagoons took on the appearance of a conventional waste stabilization pond with the exception that no feed was introduced.

Lagoon #3, Mechanically Aerated Lagoon

The behaviour of lagoon #3 in the studies was not unlike an activated sludge plant operating at very low suspended solids concentrations.

The following table gives the averaged results of operation during the pea pack.

Table 5

Lagoon #3, Pea Pack Results

BOD loading lb/day	65.6
BOD effluent ppm	202
BOD removal %	48.4
Suspended solids effluent ppm	344
Dissolved Oxygen ppm	3.2
pH	7.7
Temperature °C	22.5
Retention days	1.93

Table 4

Operating Results

Lagoons #1 and #2 During Heavy Loading

Date	Lagoon #1				Lagoon #2			
1963	BOD Loading lb/acre/day	DO ppm night	DO ppm day	Effl. BOD ppm	BOD Loading lb/acre/day	DO ppm night	DO ppm day	Effl. BOD ppm
Sept. 23	120	8.1	8.1	10	176	6.7	6.8	20
24	204	8.3	8.2	25	264	4.4	4.3	--
25	104	8.3	7.7	18	136	2.9	2.1	--
26	304	7.1	6.1	16	404	1.6	1.7	21
27	288	3.8	4.7	18	364	1.5	2.9	24
28	648	1.8	7.2	29	800	1.2	1.0	23
29	204	1.3	1.0	31	252	0.4	0.9	29
30	956	2.1	2.3	26	1188	1.3	1.7	32
Oct. 1	568	1.8	2.0	--	704	0.9	0.9	--
2	548	0.6	0.9	33	676	0.8	0.5	37
3	1712	0.3	0.6	38	1600	0.7	0.5	54
4	648	0.3	1.1	68	520	0.4	0.5	58
5	712	0.2	0.7	80 +	572	0.2	0.3	78
6	---	0	0.3	--	---	---	0.5	--
* 7	864	0	0.3	70	1032	0.1	0.2	72
* 8	1520	0.3	0	76 +	1800	0	0	74 +
* 9	---	0	0	78 +	2200	0	0	78 +
*10	---	0.5	0.5	79 +	---	0.3	0	79 +
*11	---	0.4	0.5	78 +	---	0.4	0.6	78 +
*12	---	0.5	0.6	28	---	0.5	1.5	78 +
13	---	---	4.9	--	---	---	6.7	--
14	---	---	5.8	--	---	---	6.2	--
15	780	5.7	5.5	84	776	5.3	4.8	74
16	2560	0.2	0.3	150	2160	0.2	0.5	156
17	172	0.3	0.7	107	84	0.2	1.2	80
*18	600	0.1	0	142	464	0.2	0	118
*19	---	---	0	132	---	---	0.1	136
*20	---	---	0.1	134	---	---	0	126
*21	---	---	0.3	96	---	---	0.3	86
*22	---	---	0.5	100	---	---	0.6	72
23	---	---	1.5	84	---	---	2.4	58
24	---	---	2.6	78	---	---	3.6	66

* odours noted from lagoons.

There were never any odours emanating from this lagoon during any part of the study and dissolved oxygen values fell below one ppm only occasionally.

Foaming, coincident with clean-up operations in the cannery, was experienced on numerous occasions. However, the foam did not cause any serious problems other than depositing an undesirable scum around the circumference of the lagoon.

It was not possible to build-up a solids concentration higher than that found in the effluent samples because no settled solids were recycled. The solids exhibited very poor settling properties and a microscopic examination showed the cause to be the presence of filamentous bacteria.

During the first half of the tomato pack, until September 21st, the average daily BOD load was 40.2 lbs/day, about 30 per cent lower than during the pea pack. This resulted in subsequently better effluent BOD and suspended solids values of 114 ppm and 196 ppm, respectively. Also, the average dissolved oxygen value was considerably higher at 6.9 ppm.

As in the diffused air lagoons, the loadings were markedly increased beginning on September 23rd. As a result, the average daily BOD load increased by over 400 per cent to 170 lb/day. This increased loading did not, however, have as marked an influence on the effluent BOD and suspended solids which rose to 150 ppm and 230 ppm, respectively. Average dissolved oxygen values fell slightly to 6.3 ppm during this latter part of the season.

However, it should be noted that the above are averaged values for the period September 23rd to October 18th and at the end of this period the BOD of the effluent was 250 ppm, somewhat higher than the average. Suspended solids and dissolved oxygen values at the end of the tomato pack were close to the averaged values for the last part of the season.

The aerator remained operating for ten days after the conclusion of the tomato pack. During this period, the BOD in the lagoon dropped from 250 ppm to 88 ppm. Suspended solids and dissolved oxygens were not appreciably changed during this period.

Lagoon #4, Waste Stabilization Pond

Of all the results, the data obtained from lagoon #4 were considered the least reliable. However, it did serve a purpose because this lagoon was greatly overloaded at the start of the pea pack. Daily loadings in excess of 500 lb BOD/acre/day were imposed upon this lagoon. These extreme loadings resulted from a failure in the system to return wastes to the sewer. These very high loadings which lasted for six days rendered the lagoon anaerobic and resulted in odours. After feeding was stopped, it took fifteen days for the lagoon to recover and maintain aerobic conditions. This was in comparison to only five days for the diffused air lagoons.

Because feed was not applied for fifteen days during the pea pack an accurate assessment of loadings could not be made. However, during the tomato pack an average BOD loading of 72 lbs/acre/day was experienced without any odour problems developing. Therefore, the design criteria of 20 lb BOD/acre/day for waste stabilization ponds does not appear to apply for seasonal operation. Considerably higher loadings can be accommodated if the lagoon operation is limited to the summer season when the environmental factors are at their optimum.

SUMMARY

From the operational data of lagoons #1, #2 and #4, the aerated lagoons showed at least a 5 to 10-fold superiority over the conventional stabilization pond in terms of BOD loading capacities per acre. Yet, this increased capability did not appear to be a direct function of the air supplied, although the additional aeration did result in higher dissolved oxygen levels. Therefore, it must be assumed that increased circulation within the lagoon provided by the aeration device was a major factor in improving the loading capacity of the lagoons. The resultant mixing provided greater diffusion rates of food, oxygen and nutrients into the bacterial cells. Mixing would also result in a much greater photosynthetic activity because more algae cells would be exposed to the sunlight. Indeed, intermittent light radiation has been found to produce more efficient algae activity (9, 10) than steady illumination.

A comparison of aeration devices was possible in this study. The mechanical aerator was highly regarded in its trouble-free operation. Foaming occurred periodically but did not create any problems. The sludge produced during the operation of this lagoon had very poor settling characteristics due primarily to the presence of a growth of filamentous bacteria which had developed.

The performance of the aeration tubing was very disappointing as considerable problems were experienced in the clogging of the air release slits. These slits were constantly plugging and caused excessive back-pressure loads on the blower unit.

Generally, a portable compressor was used to clear the air tubing laterals individually. Clogging was due to slime growths and scale formation in the vicinity of the pores of the tubing. Needless to say, the clogging problems seriously upset the operating schedule throughout the study.

CONCLUSIONS

1. The diffused aeration lagoons (#1 and #2) operated aerobically and without odours at overall loadings up to 500 lb BOD/acre/day. However, averaged longterm loadings of 350 lb BOD/acre/day appear at this time to be more realistic.

2. For this short study, the presence of an anaerobic section did not have any value in improving treatment as lagoons #1 and #2 gave similar treatment.

3. The required air supply was not conclusively determined during the study, but, it did not appear to be a limiting criterion in lagoon design as BOD removals were not dependent upon the volume of air supplied.

4. Continual turnover of the lagoon contents, particularly in the vertical direction, appeared to be the important factor in improving performance capacities of aerated lagoons.

5. The problem of clogging of the diffused air tubing used in these studies must be satisfactorily overcome before this method can be practical for general use.

6. Aerated lagoons are relatively stable toward shock loads. Based on a design loading of 350 lb BOD/acre/day, shock loadings of up to 1000 lb BOD/acre/day for a single day would appear to be within the lagoon's capabilities.

7. The study showed recuperative powers from anaerobic conditions of the diffused air lagoons to be three times faster than the conventional waste stabilization pond.

8. The mechanically aerated lagoon gave trouble-free operation with adequate dissolved oxygen present throughout the study.

9. Operating data for the conventional waste stabilization pond showed that loadings up to 75 lb BOD/acre/day can be applied during the summer season.

REFERENCES

1. Sanborn, N.H., "Treatment of Cannery Wastes", Sewage Works Eng., 20, 199 (1949).

2. Southgate, B.A., "Treatment and Disposal of Industrial Wastes", Her Majesty's Stationery Office, London, (1950).

3. Clinton, M.O., "Seymour Solves Unusually Difficult Waste Treatment Problem", Water and Sewage Works, 102, 11, 438, (1955).

4. Eckenfelder, W.W., "Pilot Plant Investigations of Biological Sludge Treatment of Cannery and Related Wastes", Proc. 7th Purdue Industrial Waste Conference, 181 (1952).

5. Templeton, C.W., "Cannery Waste Disposal and Treatment", Sew. and Ind. Wastes, 23, 12, 1540 (1951).

6. DuByne, F.T., "Development of a Spray Irrigation Disposal Program for Food Processing Plants", A case history, Campbell Soup Co., (June, 1962).

7. Nemerow, N.L., "Theory and Practices of Industrial Waste Treatment", Addison-Wesley Publishing Co., Reading, Mass., (1963).

8. Eckenfelder, W.W. and O'Connor, D.J., "Treatment of Cannery Wastes in an Aerated Lagoon", A report conducted by Civil Engineering Department, Manhattan College, N.Y., (Nov. 1958).

9. Arnon, D.I., "Conversion of Light into Chemical Energy in Photosynthesis", Scientific American, Vol. 184, (July 1959).

10. Arnon, D.I., "The Role of Light in Photosynthesis", Scientific American, Vol. 203, 5, (Nov. 1960).

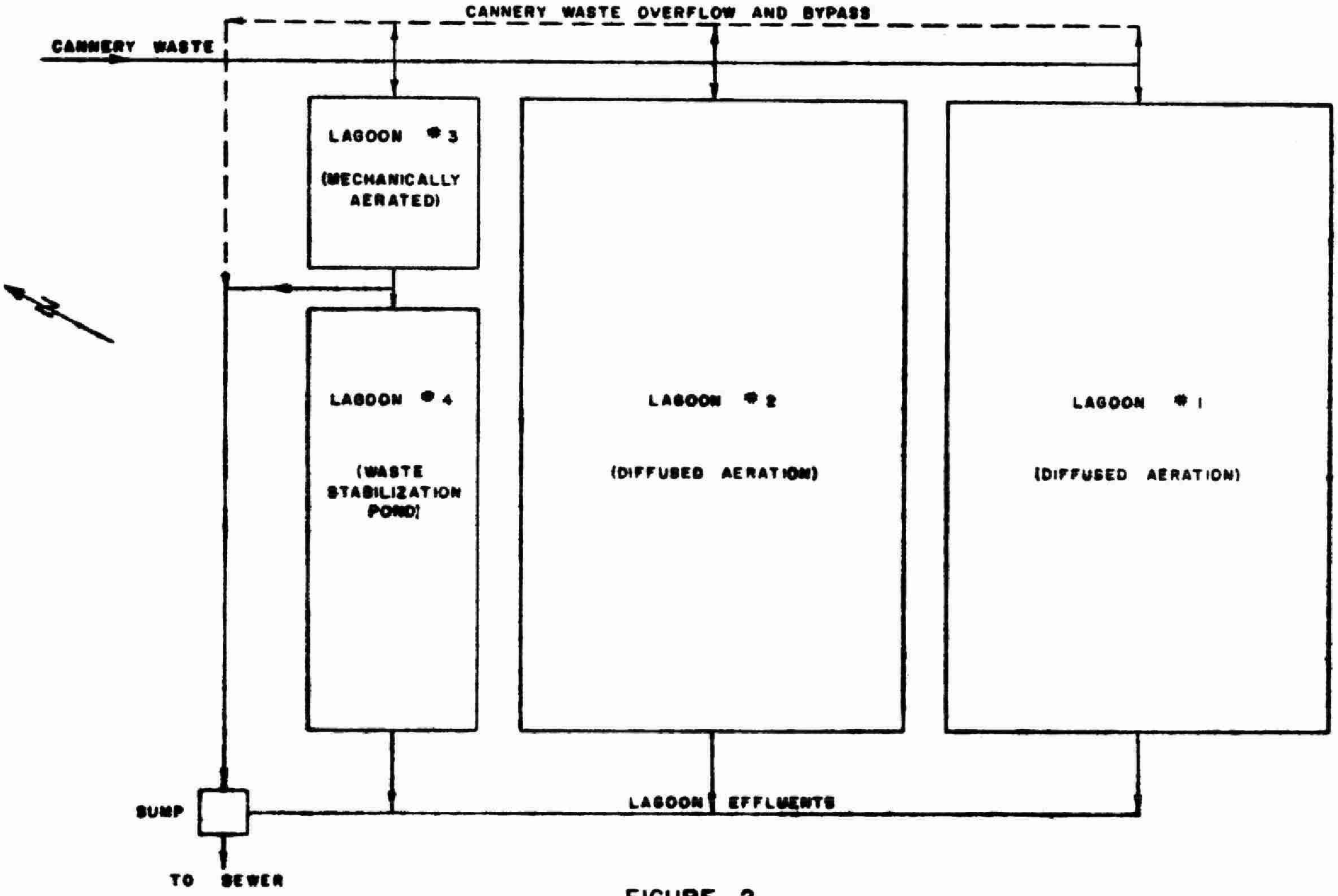


FIGURE 2

SCHEMATIC DIAGRAM OF PILOT STUDY LAGOONS - CHATHAM

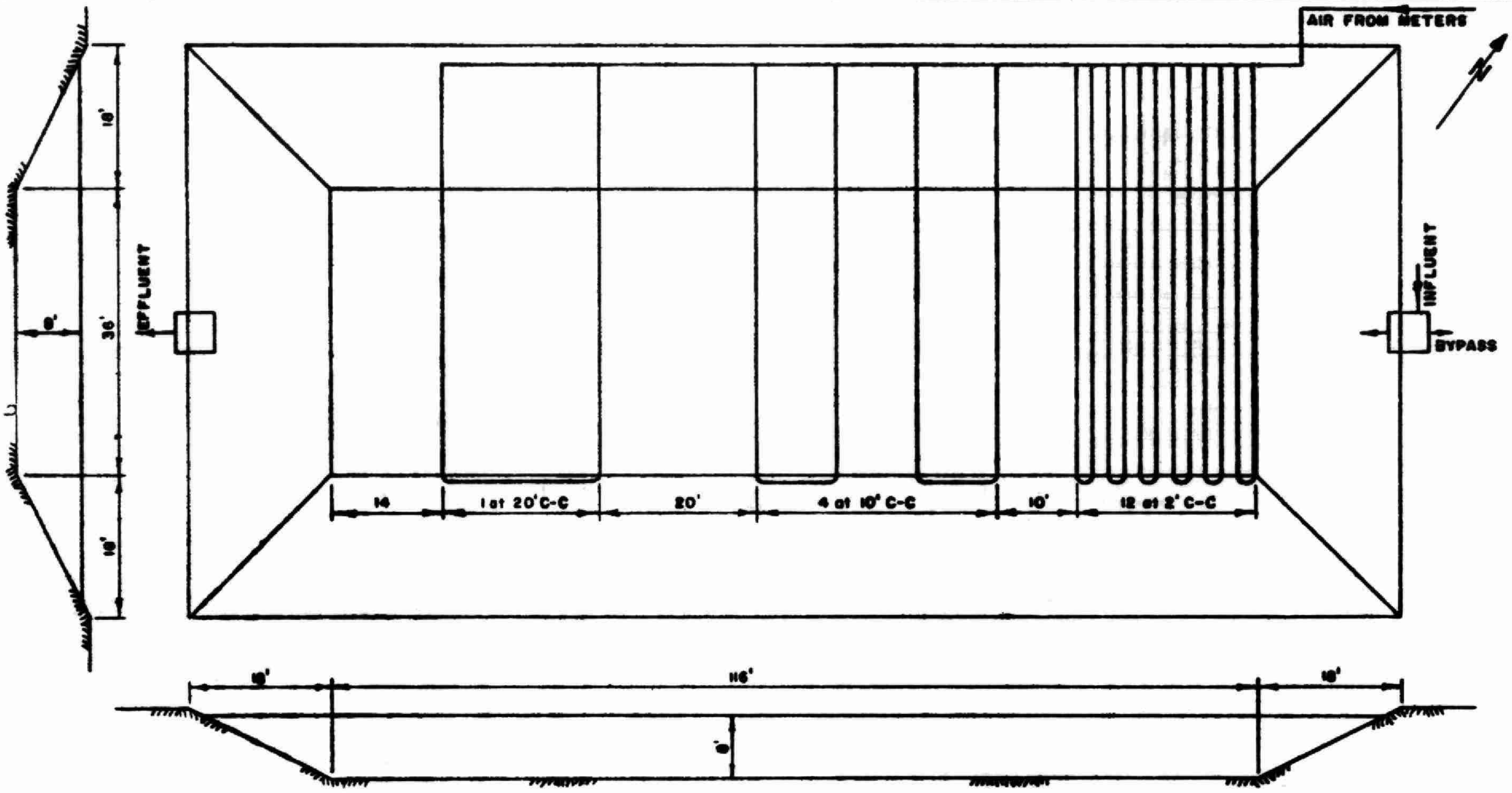


FIGURE 3

LAGOON #1 (DIFFUSED AERATION)

CONSTANT 8 FT. DEPTH

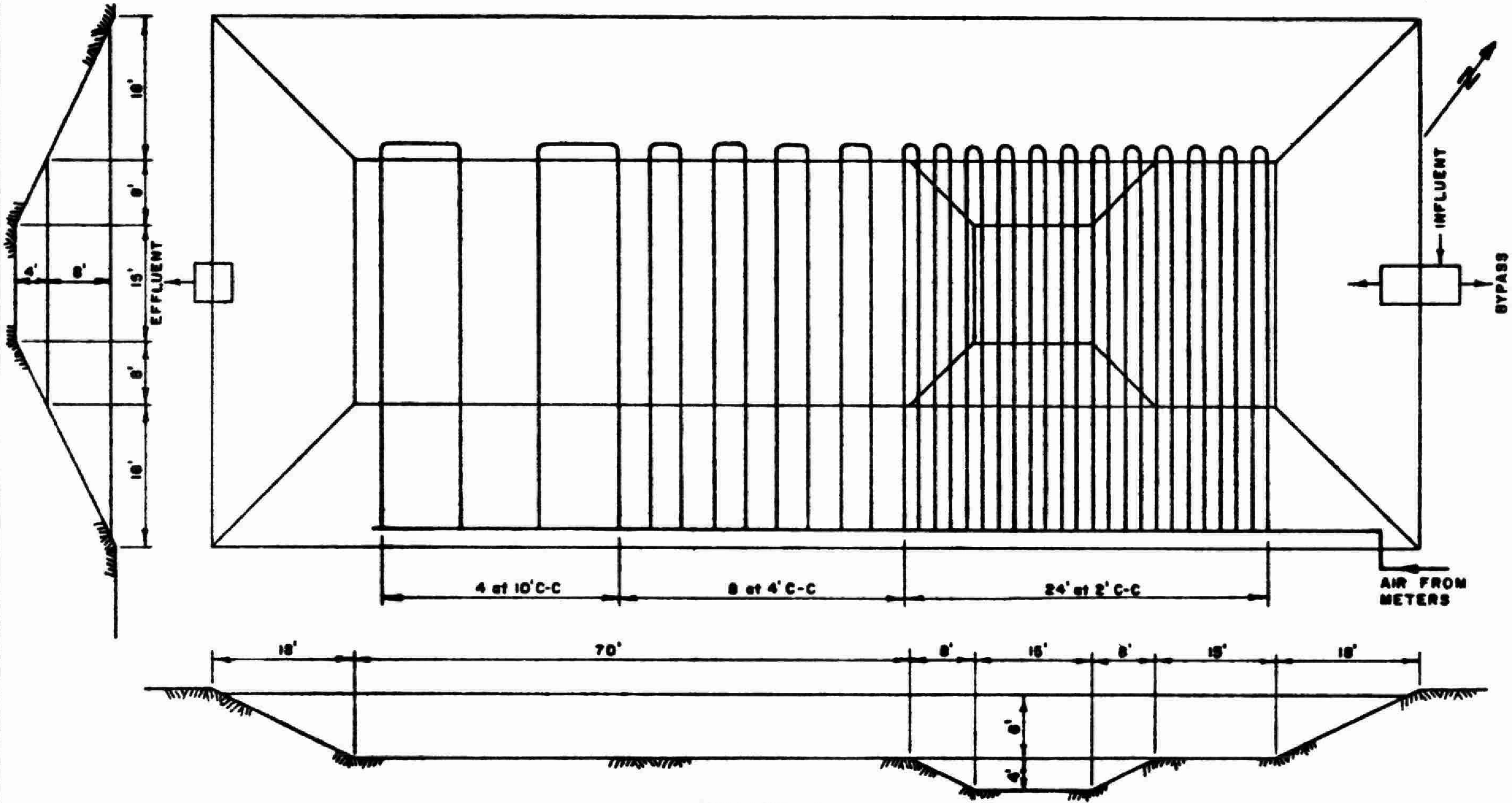
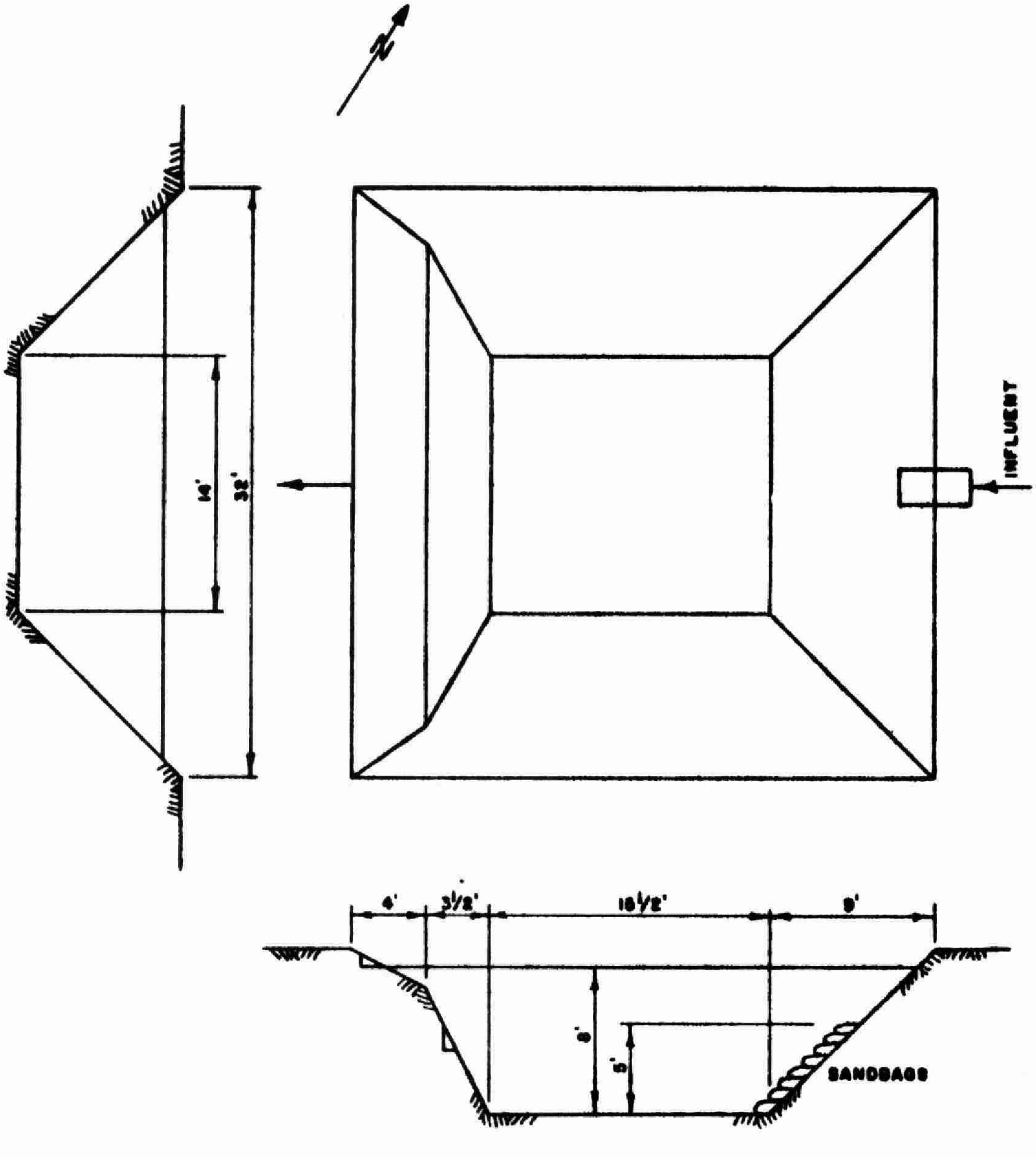


FIGURE 4

LAGOON *2 (DIFFUSED AERATION)

BI - LEVEL: 8' & 12' DEEP



NOTE

4' WIDE POLYETHYLENE FILM
AROUND PERIMETER OF LAGOON
AT SURFACE TO PREVENT EROSION.

FIGURE 5

LAGOON #3 (MECHANICALLY AERATED

SURFACE AERATOR 3' DIA. – 3 H.P.

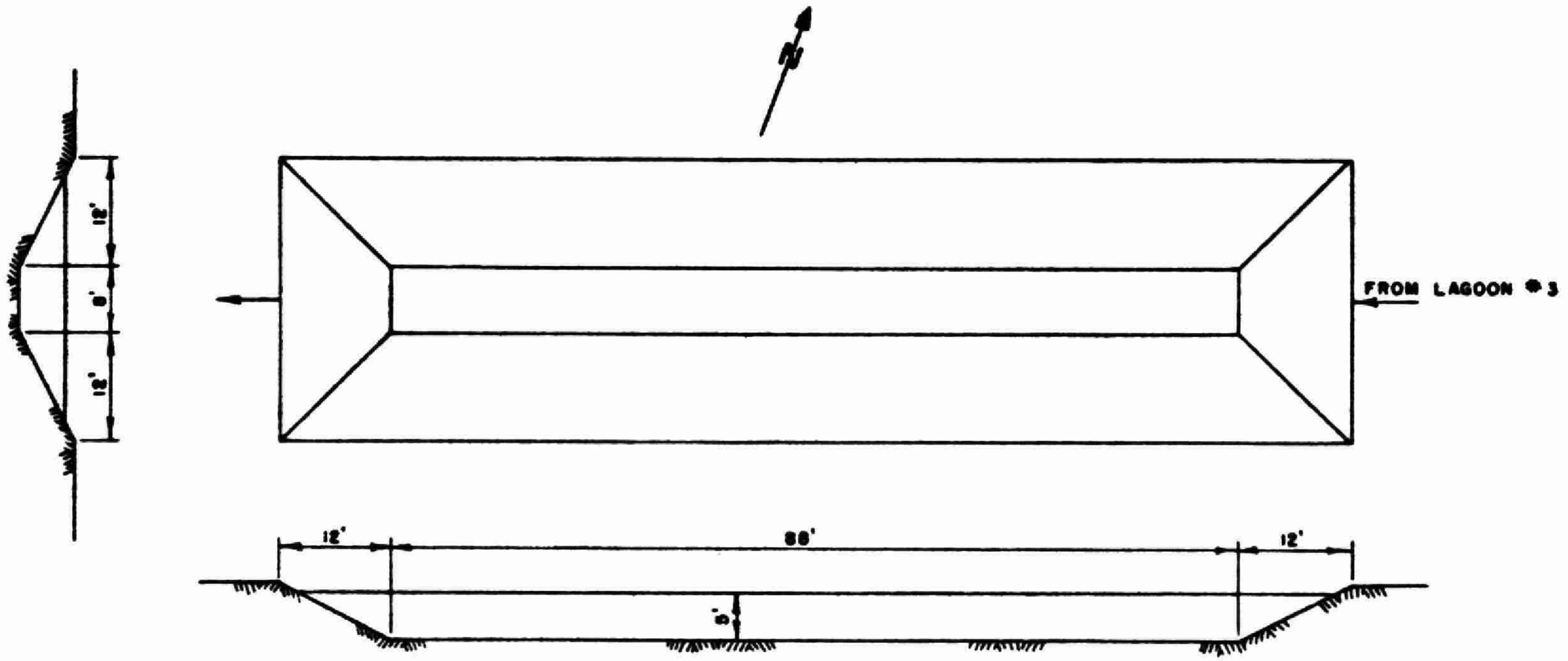


FIGURE 6

LAGOON #4 WASTE STABILIZATION POND

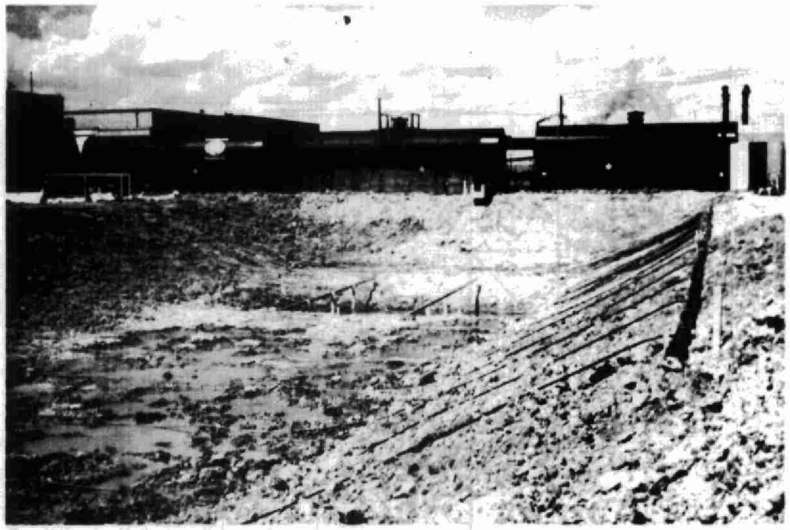


Figure 7

Exposed view of lagoon #2 from the effluent end. Support rods for aeration tubing over the 12-foot deep section are visible in the centre.

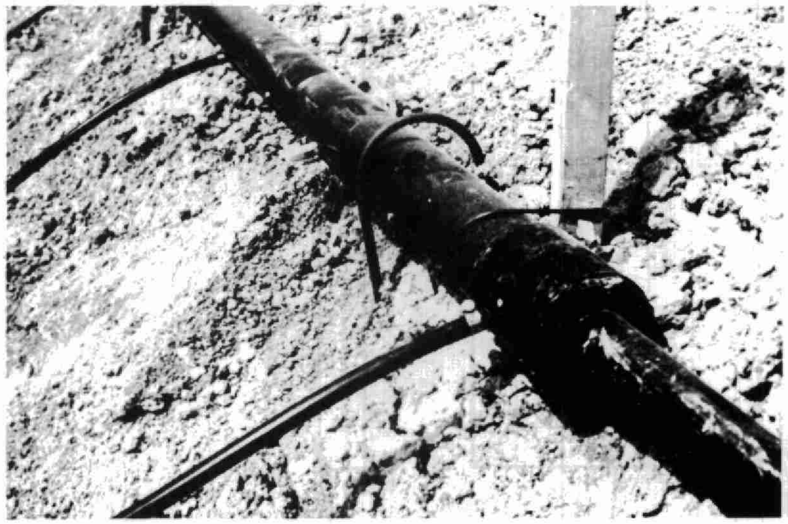


Figure 8

Close-up of air supply connections showing compressor line and lateral junctions with the air header.

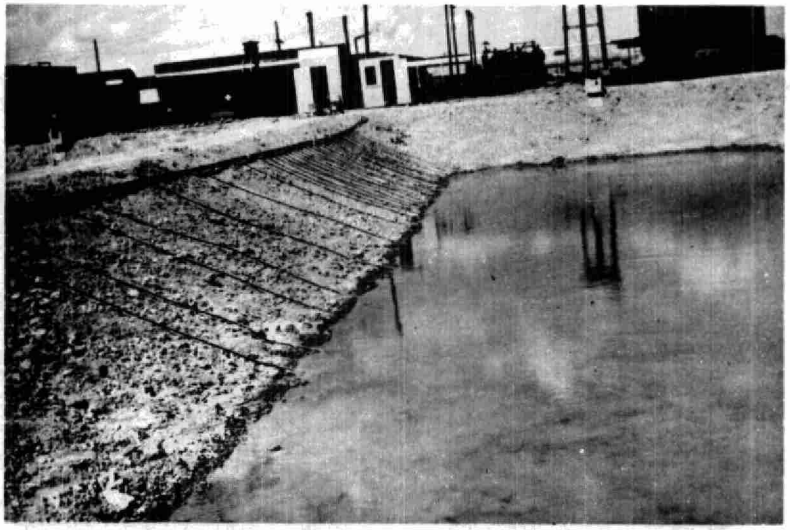


Figure 9

View towards influent end of lagoon #1 prior to waste introduction. One foot of municipal water is present.

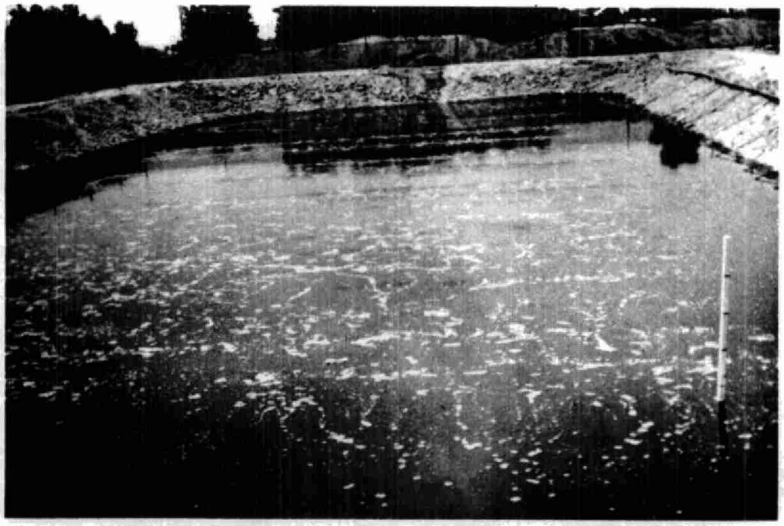


Figure 10

Aeration patterns on lagoon #1 during initial pea pack operations. View toward effluent end; water depth 4½ feet.

Figure 11

Aeration patterns on lagoon #2 during initial pea pack operations. View shows the more concentrated aeration at the influent end.

Figure 12

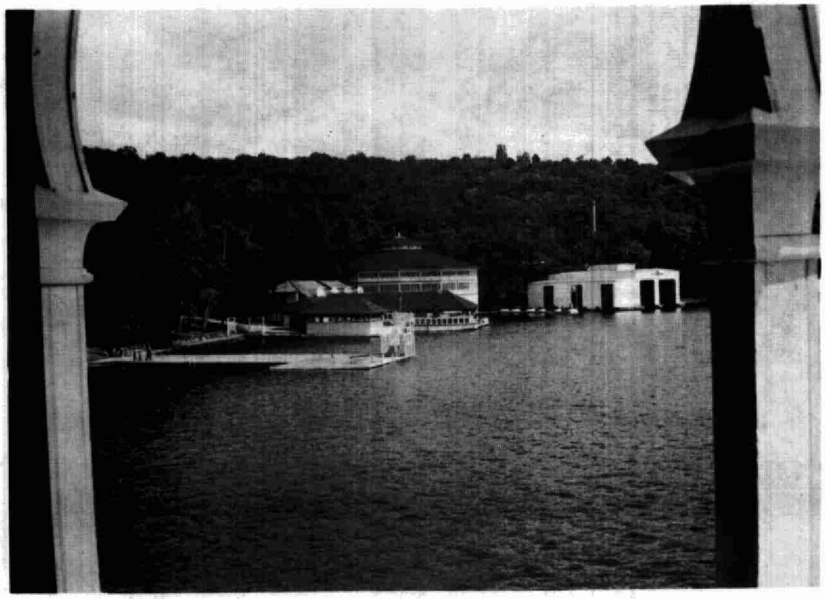
Pre-operational view of lagoon #3 showing aerator mounting assembly. Overflow trough is visible at right.

Figure 13

Operation of Lagoon #3 during pea pack.

Figure 14

Operation of lagoon #3 during tomato pack.



BIGWIN INN
LOCATION OF THE CONFERENCE

SESSION TWO

H. R. Holland
Imperial Oil Enterprises Limited

Session Chairman

"STUDIES ON THE RESPONSE OF ACTIVATED SLUDGE TO SHOCK-LOADINGS"

by

A. F. GAUDY, JR.

A.F. **GAUDY, JR.**, and P. **KRISHNAN**

SUMMARY

The response of heterogeneous populations to shock-loading was studied under a variety of operational conditions using synthetic wastes consisting of glycerol, glucose, and a mixture of glucose and glycerol. In all experiments the cells were acclimated to glycerol. The addition of glucose as a shock-loading at various times during the aeration period caused an immediate cessation of glycerol metabolism, and glycerol was not again actively metabolized until all glucose had been assimilated. Experiments conducted at various initial sludge concentrations showed that this effect was not dependent upon biological solids level. Glycerol metabolism was also blocked when glucose was applied as a shock-loading to a system operating under severe nitrogen deficiency, further reinforcing the conclusion that there is a blockage mechanism for catabolic pathways which operates to suppress enzyme function rather than enzyme synthesis. It was also found that considerable amounts of metabolic intermediates or end products were released during glucose metabolism regardless of the presence or absence of glycerol. In systems containing a source of nitrogen, these products were metabolized after dissimilation of glucose. In resting cell suspensions the metabolic intermediates were not subsequently removed, indicating that their metabolism depended upon the synthesis of new enzymes. Using old cell sludge, concurrent rather than sequential removal of glycerol and glucose was observed.

The results using two component (C_6-C_3) carbon sources were in general the same as for C_6-C_6 synthetic wastes. The results provide further evidence for the generality of sequential substrate removal and suggest that the metabolite suppressing catabolism of glycerol lies below the triose level.

INTRODUCTION

Variations in the chemical and physical environment imposed upon biological waste treatment processes may be broadly classified as shock-loads, and the response to such changes is an important area for research into the bioengineering aspects of the activated sludge process. While the term "shock-loading" is usually considered as denoting an increase in BOD loading or perhaps the introduction of a toxicant, equally severe shock effects can be brought about by a change in the chemical structure of the organic substrate to be removed in the treatment process. This type of environmental change has been termed a "qualitative" shock-loading, since it does not necessarily involve a change in the total amount of organic substrate (1). Depending upon the nature of the structural change, this type of shock-loading has been found to cause serious upsets to activated sludge systems (1). Further study, using heterogeneous populations acclimated to a specific compound in a synthetic waste (sorbitol), showed that when the cells were placed in a two-component medium, consisting of sorbitol and glucose, sorbitol was not metabolized until the glucose had been totally utilized (2). The sequential removal of substrate in response to the qualitative shock-load has serious ramifications to biological treatment processes, and has given rise to continued study in the authors' laboratory (3) (4) (5) (6) (7) (8).

The sorbitol-glucose synthetic waste provided a convenient model system for study, and in the majority of the work reported to date it has been used. Employing this system it was found that the physiological conditioning of the sludge affected the manifestation of sequential substrate removal (3). Using young cells acclimated to sorbitol, sequential removal was observed, while older sludges yielded concurrent removal of glucose and sorbitol (see Materials and Methods for detailed description of age designation). With cells acclimated to glucose, sequential substrate removal was observed regardless of cell age (3). The results using sorbitol-acclimated sludges indicated that the blockage of sorbitol metabolism was not uniquely caused by repression of enzyme synthesis. Further study using both heterogeneous populations and a pure culture of Escherichia coli, in which the blockage was shown to occur in non-proliferating as well as growth systems, led to the conclusion that sequential substrate removal could be caused by a suppression or blockage of the functioning of existing enzyme(s) in the system (4) (5). Further study showed that the blockage took place immediately. When glucose solution was injected into a young cell system actively metabolizing either mannitol or sorbitol (severe shock-loading conditions) complete cessation of their utilization ensued and it was not resumed until all the glucose had been utilized (6). Continued study has also shown that even a gradual change in inflowing substrate composition can cause severe disruption of the steady state efficiency in completely mixed continuous flow activated sludge systems as well as in batch systems (8). The study of substrate interactions in multicomponent media has been extended to a variety of compounds using young cells, and the blockage effect has been shown to occur for shock compounds other than glucose (7).

Various methods of administering the shock-loading have been studied; however, most of this work, in which a wide variety of operational parameters was employed, was conducted using the sorbitol-glucose synthetic waste. It was desirable to study the effect of some of these variables using a different model system. A glycerol-glucose medium was selected, since methods were available for chemical differentiation of glucose and glycerol and because most of the previous studies employed combinations of six-carbon compounds. Therefore the change from a C_6-C_6 to a C_3-C_6 system represented a considerable difference in the chemical composition of the synthetic waste under study which, in addition to allowing further investigation of the generality of the sequential removal effect, might also provide further insight into its causative mechanism.

MATERIALS AND METHODS

Batch activated sludge systems (1.5-liters of aeration liquor) were developed on glycerol (1000 mg/l) using initial seeding material obtained from the primary clarifier effluent of the municipal treatment plant at Stillwater, Oklahoma. The inorganic composition of the synthetic waste was identical to that employed in previous studies (3) (6) (8). Daily, 500 ml of the mixed liquor were wasted, and the remaining portion was allowed to settle for one hour prior to discarding 500 ml of supernatant. Synthetic waste was added to the 1.5 l mark to yield a concentration of 1000 mg/l glycerol. Diffused air was supplied through carburundum stones at an air flow rate of 4000 ml/min, and the temperature was maintained at 25° ± 1°C. At various times cells were harvested from the 500 ml portion of waste mixed liquor, and used for subsequent shock-loading experiments. Cell suspensions obtained directly from the batch activated sludge unit were designated as "old" cells (3). These were highly flocculent cells typical of activated sludge. "Young" cell suspensions were developed by placing a small inoculum of "old" cells from the batch activated sludge unit in fresh glycerol synthetic waste, in accordance with the previously reported procedure for obtaining young cells (3) (4). On four successive days a small inoculum of cells was transferred to fresh medium, and on the fourth day the cells were harvested after sixteen hours of aeration. The stage of growth at which young cells were harvested is shown in Figure 1.

For all shock-loading experiments cells were harvested by centrifugation and washed twice in 0.05 M potassium phosphate buffer, pH 7.0. These glycerol-acclimated cells were then shock-loaded by placing them in a glycerol-glucose medium containing the same inorganic salts concentration used above, and aerated under identical conditions. The only change was the presence of glucose in the medium. Immediately after bringing cells and substrate into contact, samples were withdrawn for measurement of initial biological solids by the membrane filter technique (6) (Millipore Filter Corp., HA, 0.45 μ). The filtrate was analyzed for glucose (anthrone), glycerol (periodate reaction), and COD (6). Frequent samples were taken during the succeeding 6-8 hour aeration period to assess solids production and removal of substrates.

For some experiments more severe shock-loading conditions were established by first feeding only glycerol, the compound to which the cells were acclimated, and administering glucose as a slug dose while the glycerol was being actively metabolized.

RESULTS

Young Cells

Figure 2 shows the course of substrate removal in the glycerol-glucose medium, and in the control systems. From an examination of the controls it can be seen that glucose was utilized more readily than glycerol, even though the cells were thoroughly acclimated to glycerol. Glucose and glycerol concentrations, as measured by the anthrone and periodate methods, respectively, were converted to equivalent COD values in order to facilitate comparison with the total chemical oxygen demand of the glucose-glycerol system as measured by the standard COD test. The total COD analysis was also made for both control units, but the results are not shown in this figure.

The results clearly indicate that glucose was removed at essentially the same rate in both the control and the two-carbon source system. Glycerol metabolism was blocked until the glucose had been metabolized. The total COD curve shows only a slight indication that substrate removal was diphasic.

Experiments were run at various initial solids concentrations to determine if glucose was less effective in blocking glycerol metabolism at increasing population levels. Portions of a single sludge were used in order to be certain that any differences in the results could not be attributed to variation in the biochemical behavior of the sludge. The results of one such experiment using young cells under growth conditions are shown in Figure 3. At the highest initial biological solids concentration there is an indication that a small amount of glycerol was metabolized while some of the glucose remained in the medium. However, suppressive effects of glucose on glycerol removal were manifested at all four levels of biological solids concentration. At all solids concentrations, glucose was removed much more rapidly than was glycerol, and glycerol was removed very slowly or not at all until after the rate of glucose metabolism had decreased. Thus it is apparent that even at higher solids levels, rapid metabolism of glucose prevents or severely inhibits glycerol metabolism.

Experiments using young cells were also conducted under nonproliferating conditions. In these experiments the only change in the synthetic waste was the absence of an exogenous source of nitrogen. A typical experiment is shown in Figure 4. Glucose removal proceeded at nearly the same rate in the control and in the combined substrate system, and there was essentially no removal of glycerol during the 11½ hour experimental period. It is seen by a comparison of the total COD removal curve and the anthrone COD curve for the two-component system that glucose was removed in approximately ten hours, but the COD which would be attributable to glucose was not. The COD was reduced approximately 200 mg/1, whereas the glucose COD (anthrone) was reduced by approximately 500 mg/1, indicating that approximately 300 mg/1 of non-anthrone reactive material was released by the cells during glucose removal and was not subsequently metabolized. These released constituents are attributable to either metabolic intermediates or end products produced and elaborated by the cells during glucose removal.

There was a question as to whether the release of such intermediates in the two-component system was due to the presence of glycerol, or if the result was due solely to mechanisms involved in glucose metabolism. The metabolism of glucose by glycerol-acclimated cells under proliferating and nonproliferating conditions is shown in Figure 5, where the COD and glucose removal curves are compared. These data are plotted from the control systems for experiments shown in Figure 2 (proliferating) and Figure 4 (nonproliferating). The curves labeled "intermediates" were obtained by subtracting the glucose values (calculated as COD) from the total COD values. It is seen that constituents are released by the cells during metabolism of glucose even in the absence of glycerol. These constituents were subsequently used when a nitrogen source was present, but were not used in the nonproliferating system.

Old Cell Sludge

Previous work has shown very different behavior for young and old cells in two-component systems consisting of glucose and sorbitol. The older cells exhibited concurrent rather than sequential removal of the carbon sources. Since this finding has important possible applications in exerting engineering controls over the biochemical response, it was desirable to determine if the same effect of sludge age would be manifested using the glucose-glycerol synthetic waste. Results using old cells are given in Figure 6. It is seen that glucose and glycerol were removed concurrently, thus indicating that the effect may be of general significance. Comparison of the control systems for glucose and glycerol shows that in contrast to young glycerol-acclimated cells, the older sludge metabolized glycerol more rapidly than glucose when each was used as a sole source of carbon.

Severe Shock-loading Conditions

Previous investigation under severe shock-loading conditions using young cells acclimated to either sorbitol or mannitol, wherein the cells were subjected to a slug dose of glucose injected into the aerating liquor during active metabolism of either of the six-carbon alcohols, had shown that metabolism of the alcohols was immediately blocked by the shock load. Similar experiments were conducted using glycerol-acclimated cells. The results of one such study are shown in Figure 7, where it may be observed that glycerol was being actively metabolized prior to introducing the shock-load and that its removal from the system was blocked immediately after injecting the slug dose. This blockage persisted until nearly all of the glucose had been metabolized. The diphasic substrate removal was also reflected in the total COD curve. The course of glycerol removal in the control unit, which did not receive a slug dose of glucose, is also shown.

DISCUSSION

The results clearly indicate that the type of metabolic control mechanism which was shown to operate in causing sequential substrate removal in other systems reported from this laboratory was also operative in the glycerol-glucose system herein reported. The results substantiate the authors' conclusion that a previously unstudied type of metabolic control mechanism, which acts in catabolic pathways in a manner analogous to feedback inhibition in anabolic pathways, exists in many bacteria. Since it causes sequential substrate removal in populations which already possess the enzymes required for metabolism of the blocked compound, the mechanism must function at the enzyme rather than at the gene level. This, however, does not indicate that metabolic controls operative at the genetic level (e.g., enzyme repression) are less important in waste water treatment considerations, since these do control acclimation to new substrates in the waste water; however, it is emphasized that suppression at the level of enzyme function can result in a more immediate blockage and thus more severe disruption of treatment efficiency in response to shock-loading. The rapidity of the response was clearly shown in Figure 7. The fact that the blockage of glycerol metabolism involves enzyme function rather than enzyme synthesis is borne out by the results shown in Figure 4 where nonproliferating cell suspensions previously acclimated to glycerol were prevented from metabolizing this substrate by the presence of glucose. These cells did possess a capability for removing glycerol under nonproliferating conditions, as seen by the glycerol COD (periodate) curve for the control system. However, it should be noted that under nonproliferating conditions glycerol was removed much slower than was glucose when either compound was used as the sole source of carbon.

The initial steps in glycerol metabolism may be mediated via two different reaction sequences. Glycerol may be acted upon by a glycerol kinase yielding α-glycerolphosphate and thence by a dehydrogenase, not linked to DPN, resulting in the production of dihydroxyacetone phosphate which is an intermediate in carbohydrate metabolism. Alternatively, glycerol may be converted to dihydroxyacetone by a DPN-linked dehydrogenase and thence via a kinase to dihydroxyacetone phosphate (9). Assuming that both pathways may be available for use by the cells, there would be four possible sites of inhibition of enzyme function. Blockage of any one in a particular reaction sequence by an intermediate produced during glucose metabolism could prevent glycerol utilization. Also, it is not known whether an additional enzymatically-controlled active transport mechanism to bring glycerol into the cell is needed by any of the organisms present in the heterogeneous population. However, since the enzymes required for glycerol metabolism were obviously already present in the system, it is apparent that one or all of the reaction sequences described above was prevented from catalyzing the reactions necessary to bring glycerol into the pathway of carbohydrate degradation.

The finding of sequential substrate removal in the glucose-glycerol system is of particular significance in understanding the mechanism of the inhibition. Glucose and sorbitol, used in much of the previous work, are both six-carbon compounds and can be interconverted by the action of a single enzyme, sorbitol dehydrogenase. Therefore, it might be argued that the suppression of sorbitol metabolism by glucose was due simply to end-product inhibitation of an initial reaction converting sorbitol to glucose. Also, in view of their structural similarity, competition for a common permease might have explained the interference with sorbitol metabolism when glucose was added. However, neither of these mechanisms could be applicable in the glucose-glycerol system where the two substrates are very dissimilar in structure and are interconvertible only through a series of reactions. The inhibition of glycerol metabolism observed in this system is perhaps more formally analogous to the feedback inhibition observed in biosynthetic pathways. It is emphasized that, whatever its mechanism, the occurrence of sequential removal of substrates in heterogeneous populations has significant bearing upon the understanding of biological treatment of waste waters. However, the elucidation of the mechanism of inhibition involved may be of importance in prediction of the frequency of its occurrence and the types of substrate systems likely to be involved.

Of particular interest is the release of intermediates during the metabolism of glucose as a sole carbon source by the glycerol-acclimated cells under either growing or nonproliferating conditions. In Figure 5 it is seen that considerable amounts of metabolic intermediates or end-products were released under growing conditions, as evidenced by the difference between the plotted glucose COD (anthrone) and the total COD values. Approximately 250 mg/l of such products (50% of the initial concentration of carbon source) were present in the system at the time of glucose removal (approximately four hours). They were subsequently metabolized by the cells without any apparent induction period. In other work undertaken in the authors' laboratory, similar accumulations of intermediates in the medium have been noted during the metabolism of glucose under growing conditions by cells acclimated to glucose. These were later utilized by the cells. However, as seen in Figure 5, using glycerol-acclimated cells under nonproliferating conditions, the intermediates which were released were not readily metabolized by the cells. The results for the non-proliferating system shown in this figure were obtained using a portion of the same cell suspension used for the experiment in the glucose-glycerol system shown in Figure 4. It is therefore clear that the presence of glycerol had no effect on the release of the intermediates. It can be surmised from the results for nonproliferating cells shown in Figure 5 that a source of extracellular nitrogen is required for the synthesis of enzyme(s) needed for metabolism of the components produced during the oxidative metabolism of glucose by glycerol-acclimated cells.

In conclusion, it has been shown that, under operating conditions leading to the promulgation of young cells, carbon sources are in many cases removed sequentially by heterogeneous populations, and that even during the removal of a sole carbon source intermediates are released which are metabolized only after the original substrate has been removed. In some cases these intermediates apparently cannot be removed without the production of additional enzyme systems. In other work in the authors' laboratory using glucose-acclimated cells and glucose as the sole source of carbon, it has been found that the released intermediates were primarily volatile acids and that in some cases an acclimation period was required before these intermediates could be metabolized (10). It has not yet been determined whether the same type of intermediates was released by glycerol-acclimated cells. The generality of volatile acid production and release during rapid removal of substrates awaits further investigation. A result of primary interest in the present investigation is that under conditions of nitrogen deficiency the compounds produced during the metabolism of an initial substrate may not be removed at all or only very slowly. This finding sheds light not only on the response to shock-loading, but on the overall understanding of the kinetics and mechanism of activated sludge processes under non-shock-loading conditions. Furthermore, it seems apparent that at least a portion of the so-called "refractory" compounds which remain in effluents from biological treatment plants may be compounds not originally present in the waste, but compounds produced by the cells from a portion of the original carbon source.

ACKNOWLEDGEMENT

This work was supported by a research grant (WP00075) from the Water Supply and Pollution Control Division, U.S.P.H.S.

REFERENCES

1. Gaudy, A.F. Jr., and R.S. Engelbrecht, J. Water Poll. Cont. Fed., 33, 800 (1961).
2. Gaudy, A.F. Jr., Appl. Microbiol., 10, 264 (1962).
3. Gaudy, A.F. Jr., K. Komolrit, and M.N. Bhatla, J. Water Poll. Cont. Fed., 35, 903 (1963).
4. Gaudy, A.F. Jr., E.T. Gaudy, and K. Komolrit, Appl. Microbiol., 11, 157 (1963).
5. Gaudy, A.F. Jr., K. Komolrit, E.T. Gaudy, and M.N. Bhatla, Bacteriol. Prod. p. xvii (1963).
6. Gaudy, A.F. Jr., K. Komolrit, and E.T. Gaudy, Appl. Microbiol., 12, 280 (1964).
7. Komolrit, K., and A.F. Guady, Jr., Proc. 19th Purdue Ind. Waste Conf., Lafayette, Ind., May 1964 (in press).
8. Komolrit, K., and A.F. Gaudy, Jr., Paper presented at 37th Ann. Conf. Water Poll. Cont. Fed., Bal Harbour, Fla., September (1964).
9. Koch, J.P., S. Hayashi, and E.C.C. Lin, J. Biol. Chem., 239, 3106 (1964).
10. Bhatla, M.N., and A.F. Gaudy, Jr. (in preparation).

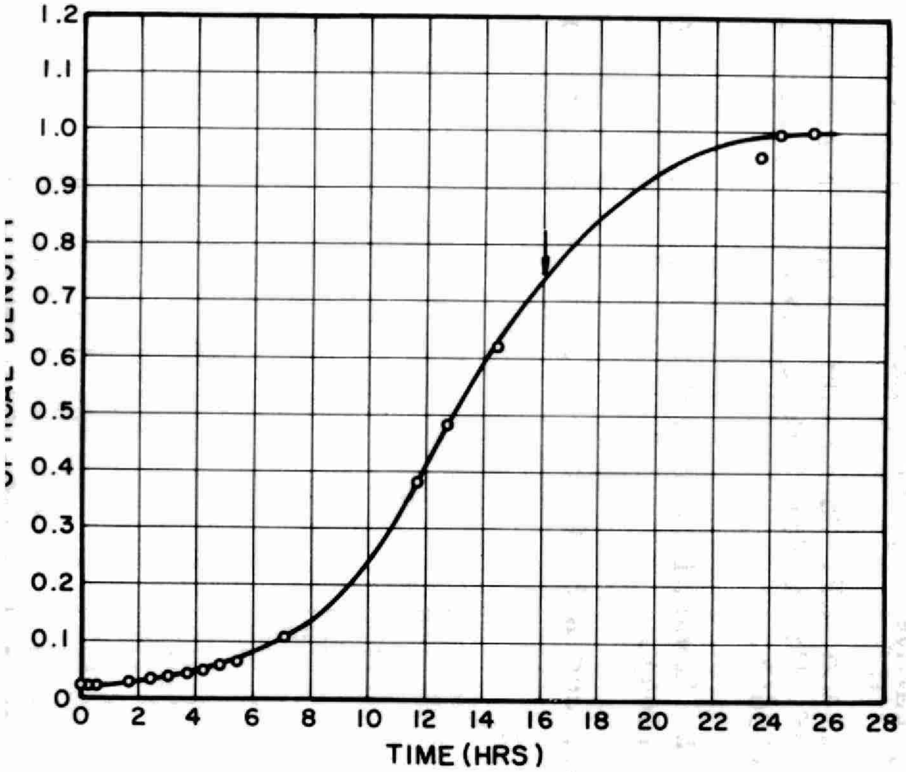


FIG. 1 - GROWTH CURVE SHOWING TIME OF HARVESTING YOUNG CELLS FOR EXPERIMETATION.

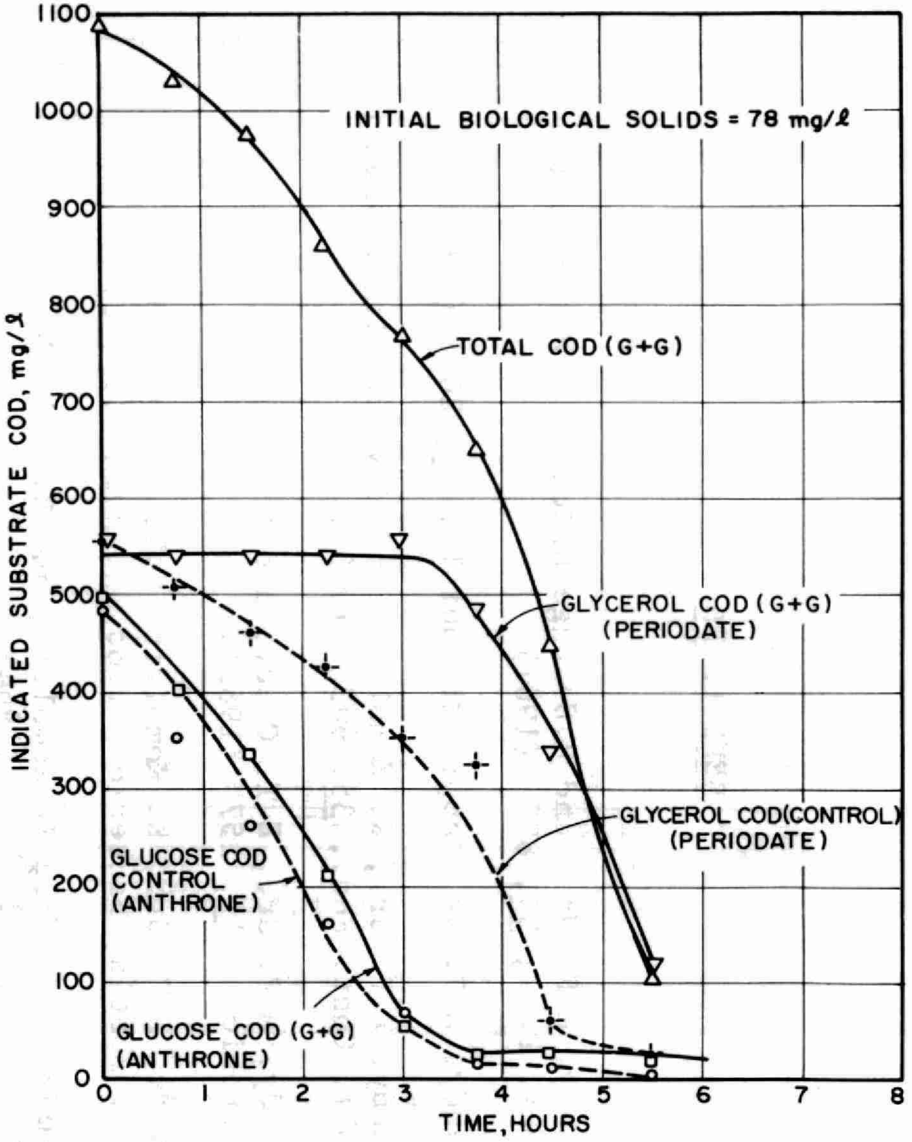


FIG. 2-SUBSTRATE REMOVAL UNDER GROWTH CONDITIONS IN A GLUCOSE-GLYCEROL MEDIUM BY YOUNG CELLS ACCLIMATED TO GLYCEROL.

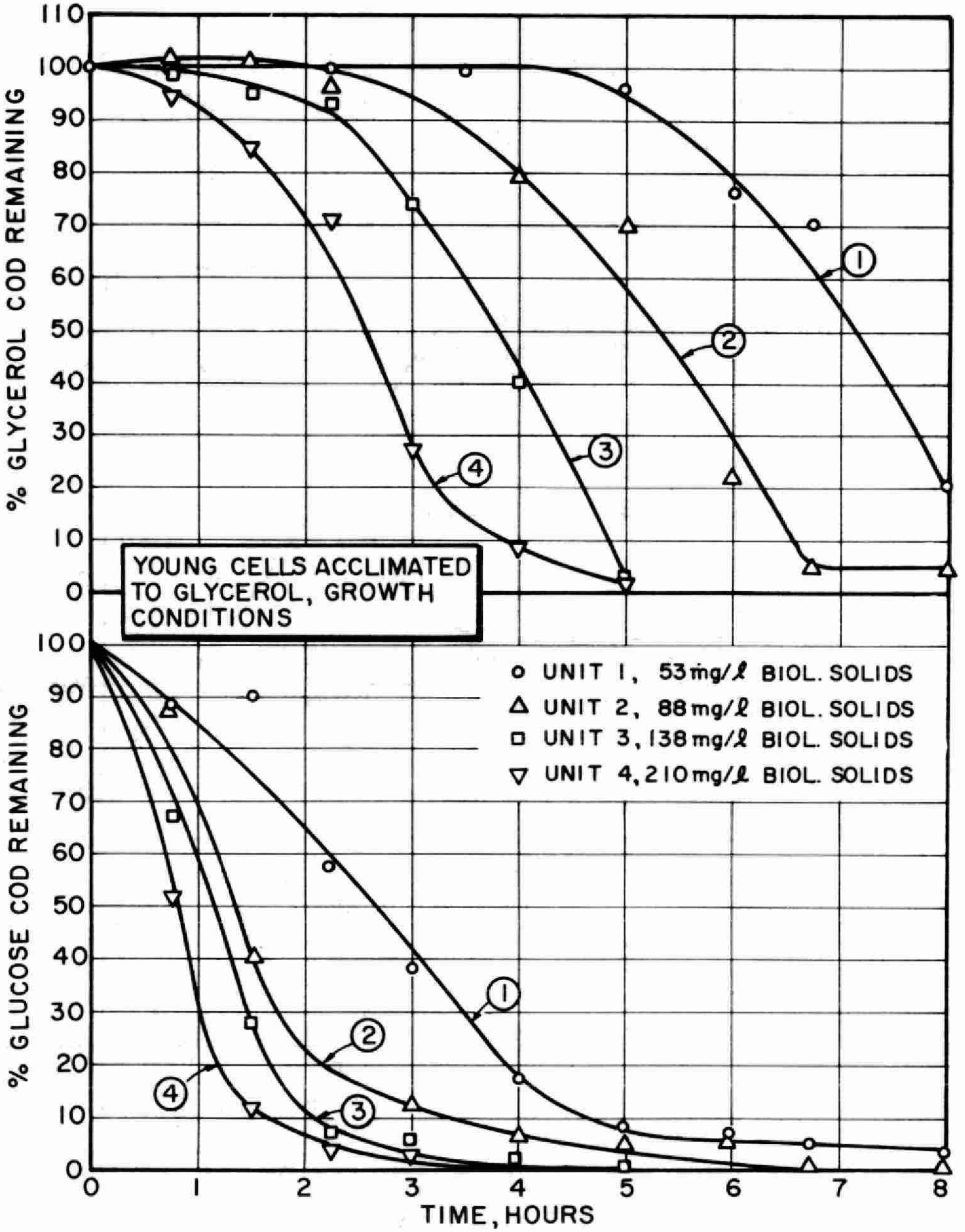


FIG. 3 - SUBSTRATE REMOVAL IN GLUCOSE-GLYCEROL MEDIUM FOR VARIOUS CONCENTRATIONS OF INITIAL BIOLOGICAL SOLIDS.

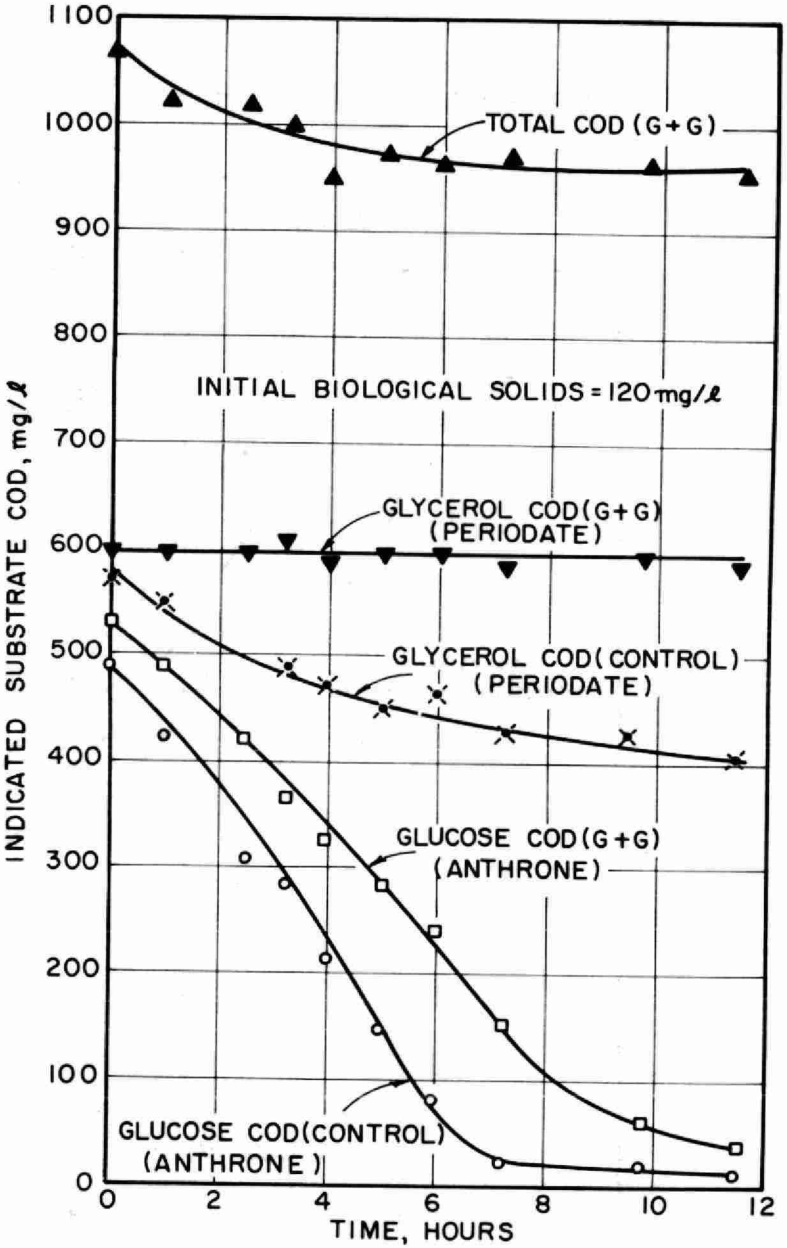


FIG. 4 - SUBSTRATE REMOVAL UNDER NON-PROLIFERATING CONDITIONS IN A GLUCOSE-GLYCEROL MEDIUM BY YOUNG CELLS ACCLIMATED TO GLYCEROL.

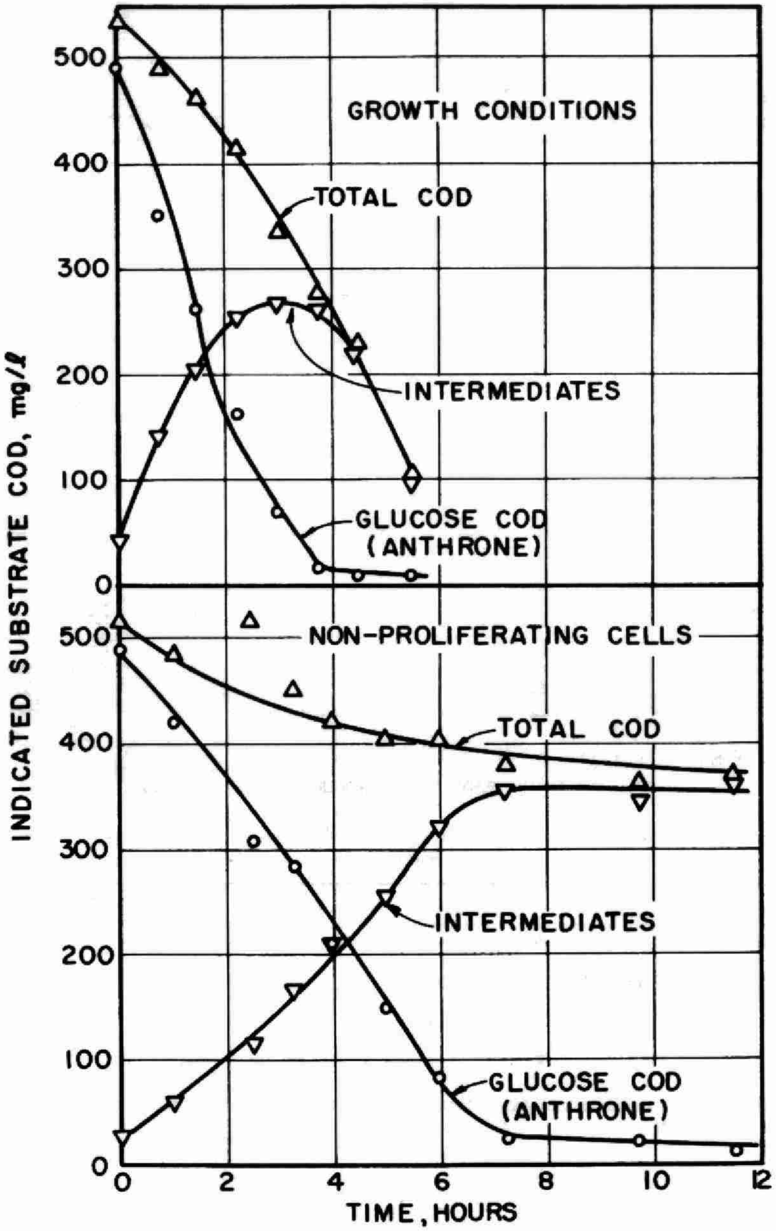


FIG. 5 - RELEASE OF INTERMEDIATES DURING METABOLISM OF GLUCOSE UNDER GROWING AND NON-PROLIFERATING CONDITIONS BY YOUNG CELLS ACCLIMATED TO GLYCEROL

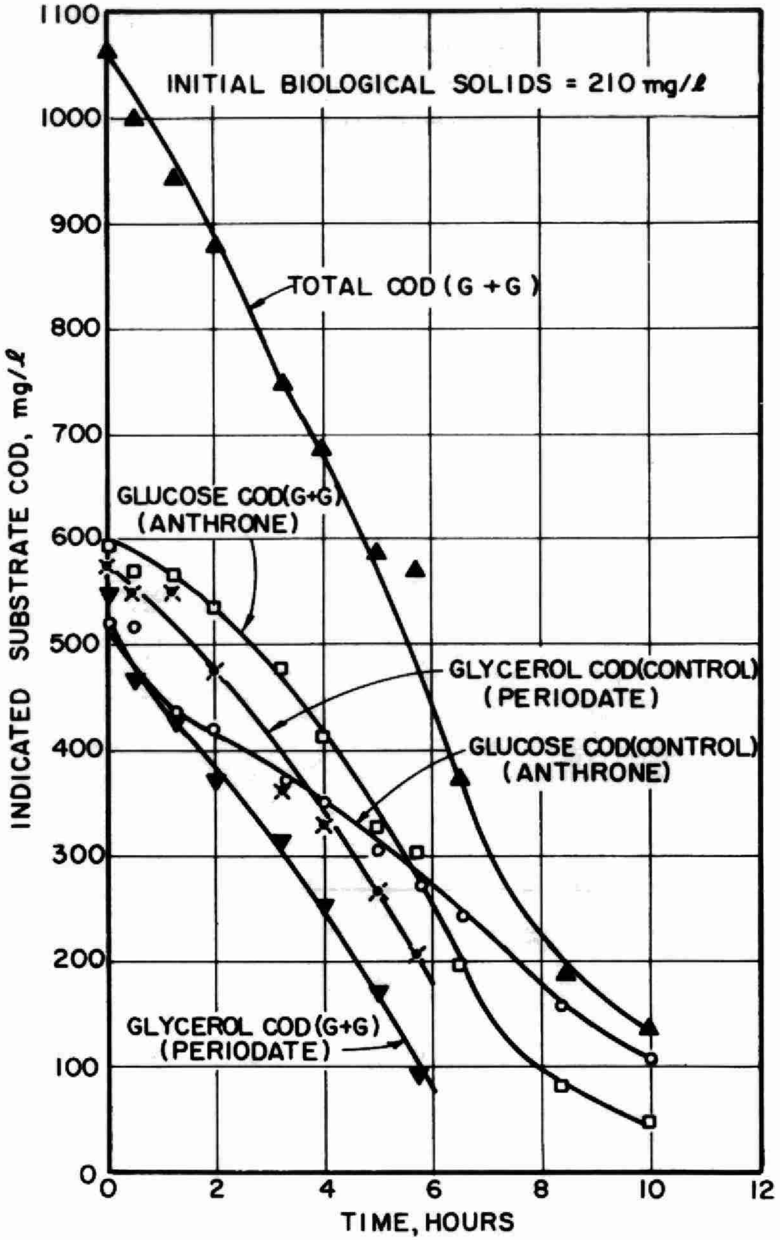


FIG. 6 - SUBSTRATE REMOVAL UNDER GROWTH CONDITIONS IN A GLUCOSE-GLYCEROL MEDIUM BY OLD CELLS ACCLIMATED TO GLYCEROL.

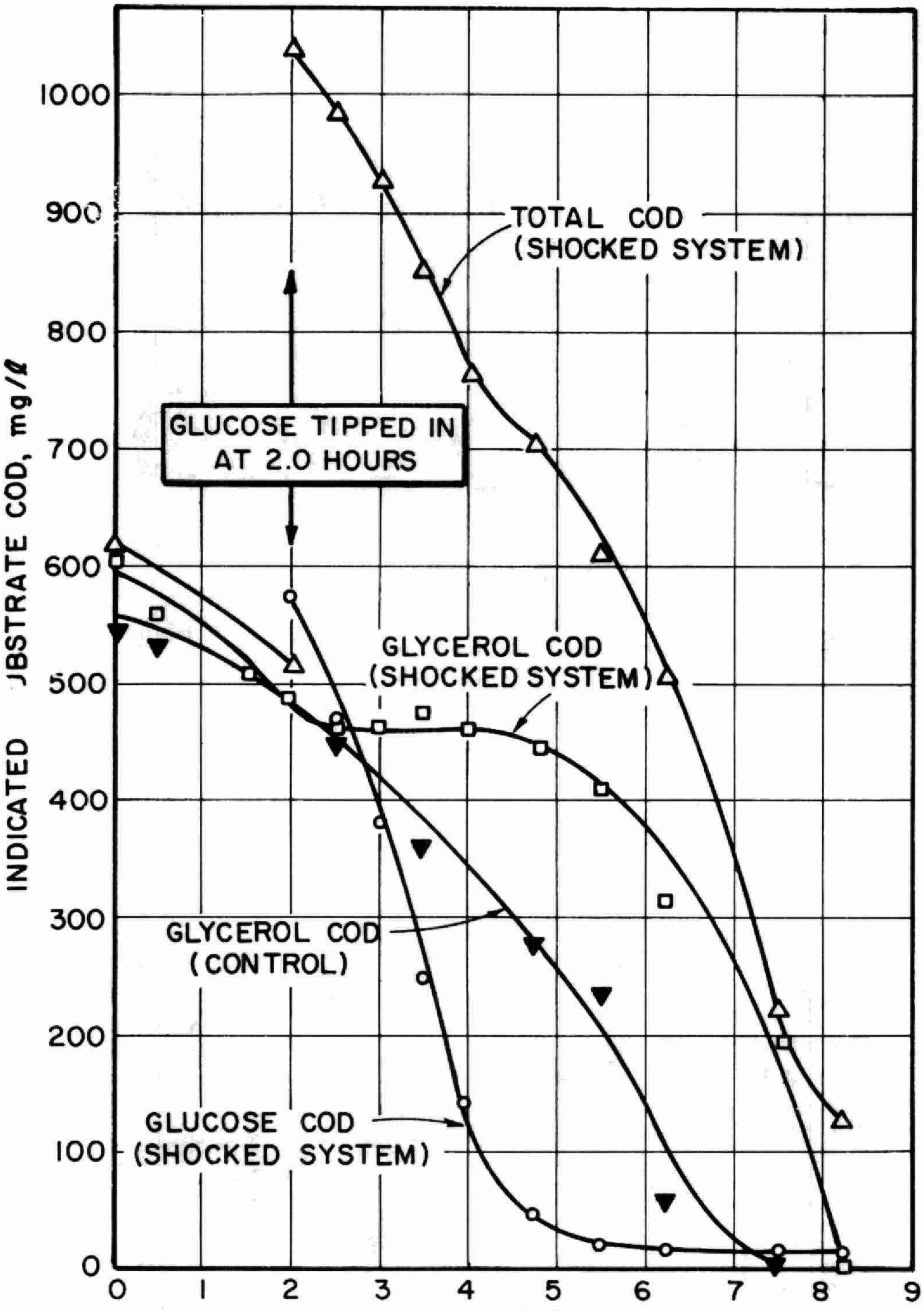
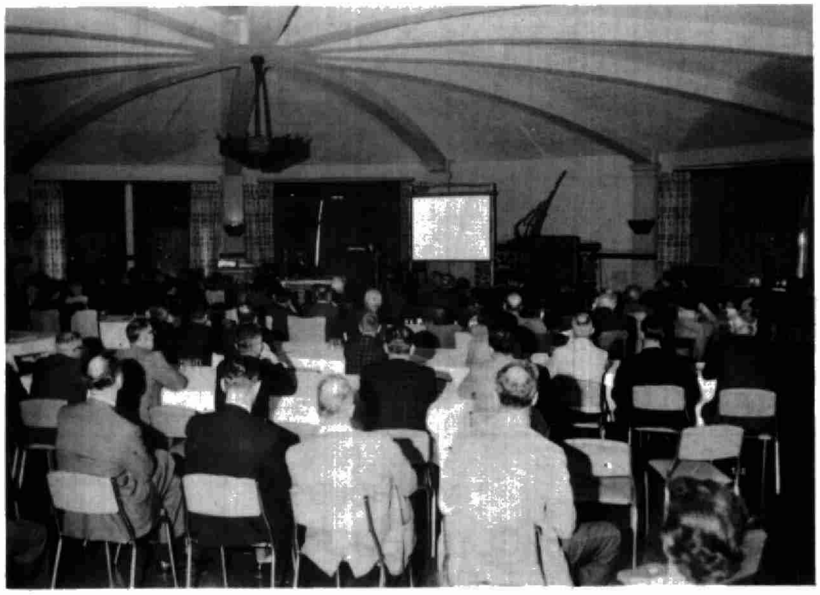


FIG. 7 - RESPONSE OF GLYCEROL ACCLIMATED SLUDGE TO A SLUG DOSE OF GLUCOSE. EXPERIMENT CARRIED OUT UNDER GROWTH CONDITIONS, INITIAL BIOLOGICAL SOLIDS CONCENTRATION WAS 100 mg/ℓ AND AT THE TIME OF ADMINISTERING THE SHOCK WAS 150 mg/ℓ.



TECHNICAL SESSIONS

"TREATMENT OF INDUSTRIAL WASTES BY MEANS OF THE OXIDATION DITCH"

by

F. **GUILLAUME**

INTRODUCTION

The oxidation ditch process is a modification of the conventional activated sludge process. Therefore we will be concerned only with those industrial wastes which are amenable to biological oxidation, e.g. wastes from the food process industries, oil refineries, tanneries, and pulp and paper industries. It is perhaps obvious that industrial wastes with main pollutants such as suspended solids, toxic chemicals and acidic or alkaline pH should be treated by physical or chemical methods, rather than by a biological process.

Practical experience of the Ontario Water Resources Commission with the oxidation ditch has been limited to several inspection trips of installations outside of Ontario, all except one, treating domestic wastewater. The process does appear very suitable for the treatment of small wasteflows, i.e. up to 500,000 gpd, although an upper limit of size has not been established.

Much work has been done in the Netherlands and Germany on the treatment of industrial wastes in an oxidation ditch plant. Similar work, on a smaller scale, is in progress in the United States. Correspondence with Dr. Pasveer in Holland and Dr. Viehl in Germany provided much of the material needed for this paper.

A discussion of the principles of operation of the oxidation ditch will be followed by a brief summary of an extended inspection tour of oxidation ditch plants. Four examples will illustrate the application of the oxidation ditch process to the treatment of wastewaters from a dairy, a soft-drink bottling plant, two coke ovens and a slaughterhouse.

PRINCIPLES OF OPERATION

The oxidation ditch is basically an extended aeration modification of the conventional activated sludge process, characterized by design retention times greater than 24 hrs. and low BOD-solids loadings.

The oxidation ditch was originally developed in the Netherlands by Dr. Pasveer from 1954 to 1957 (1). The main purpose was to find a method of waste treatment economically feasible for small communities and at the same time capable of adequate BOD removal efficiencies.

Preliminary investigations had shown that aeration of the raw sewage for a period of three days without retention of the suspended solids could reduce the BOD by 70 percent. A simple earthen ditch in the shape of a racetrack with a trapezoidal cross section was used as aeration tank (Slide 1). An aeration rotor provided circulation and aeration (Slides 2 & 3). This type of treatment is, in effect, the same as that provided by an aerated lagoon.

To improve the treatment efficiency the solids were retained by operating the rotor and the raw sewage pump intermittently. This allowed the solids to settle when the rotor was not operating. After a one-hour sedimentation period, the raw sewage pump was started. The supernatant liquid was displaced over the effluent weir by the incoming raw sewage. A specially designed swivel siphon permitted rapid discharge of the required amount of treated effluent. Retention of the solids allowed the accumulation of an activated sludge. The degree of BOD reduction was generally greater than 90 percent, sometimes even greater than 95 percent.

Several drawbacks of intermittent operation were recognized, such as: accumulation of raw sewage in the wet-well and the sewer system for periods up to 4 hrs., and the possibility of shortcircuiting in the ditch during the pump cycle when raw sewage displaces the treated liquid over the outlet weir.

A number of different designs were tried out to permit continuous separation of suspended solids. Most installations in Canada and the United States have been equipped with a final clarifier and sludge return system, resulting in satisfactory operation.

Experience with package-plant-size extended aeration systems has shown that so-called inert suspended solids in the treated effluent do represent a significant part of the BOD of the effluent. These suspended solids are discharged from the system, maintaining a natural solids balance. The activated sludge is allowed to build up until this equilibrium is reached.

Improved BOD and suspended solids removals will be achieved when excess sludge is wasted from the system, thereby keeping the mixed liquor suspended solids (MLSS) concentration below its equilibrium level. Oxidation ditch plants usually operate on this principle, making 95 percent BOD removals possible. The activated sludge is sufficiently stabilized that it can be wasted on sludge drying beds without causing nuisance conditions.

From the various experiments with the oxidation ditch suitable design criteria were developed. (It is noted that this work was carried out using domestic sewage only).

BOD-loading should not exceed 13.0 lb/1,000 cu.ft/day. For domestic sewage this would correspond to a retention period of approximately 24 hrs. Industrial wastes will generally have higher BOD values, resulting in longer retention periods. When the MLSS concentration is kept at 4,000 mg/1, the BOD-solids loading should not be greater than 4.5 lb. BOD/100 lb. MLSS/day.

Rotor length is calculated in two ways:

1) From the required oxygenation capacity (OC) of the system, which is taken as 2 lb. 0_2/lb. BOD applied. Curves are available showing the variation of OC per ft. of rotor with immersion and rotor speed, on the basis of aeration tests in tapwater at standard conditions. The OC generally increases with increasing rotor speed and immersion. An OC/load ratio = 2 allows for aeration of wastewater in the presence of a residual dissolved oxygen (DO).

2) The aeration rotor is the sole means of circulating the mixed liquor. Therefore ditch volume per foot of rotor should not exceed 13,300 gal. (Imperial Gallons) in a concrete lined ditch. The longer rotor length is used.

The clarifier should provide 3-hr. retention at design flow. The sludge return system should be capable of a 100 percent return rate, to handle the higher MLSS concentrations encountered in oxidation ditch operation.

Although the above design criteria were developed for the treatment of domestic sewage, it has been found in practice that they hold equally well for the treatment of industrial wastes (2). As an extended aeration system, the oxidation ditch provides a low-intensity rate of oxygen transfer. However, strong industrial wastes, e.g. dairy wastes, can be successfully treated as long as the developed design criteria are applied.

Strictly speaking, the oxidation ditch is an aeration system suitable for the activated sludge process. Any loading can be applied to the system provided that the oxygenation capacity is adequate to the BOD-load. However, with BOD-loadings higher than 13.0 lb/1,000 cu.ft./day and 4.5 lb/100 lb. MLSS/day, the excess sludge cannot be disposed of anymore on drying beds; sludge digestion facilities must be installed.

There is one important point of difference between the oxidation ditch and what is known as a total oxidation, extended aeration plant. Usually these extended aeration plants are equipped with a so-called completely mixed aeration tank in which the aeration device disperses the incoming sewage uniformly throughout the mixed liquor, and where a uniform DO level is maintained. However, in an oxidation ditch the aeration rotor propels the mixed liquor around the ditch. It is estimated that from 4 to 6 minutes are required for one complete passage around the circuit. Raw sewage is not dispersed quickly throughout the entire mixed liquor. This is maybe also a reason for the observed resilience to shock-loads. Dissolved oxygen is introduced only at the rotor. Therefore, the biological activity of the mixed liquor will cause a regular cycling of the residual DO from a maximum value at the rotor to a minimum value immediately upstream of the rotor. The minimum DO may drop as low as zero mg/1.

This condition of a continuously varying DO has apparently no harmful affects on the activated sludge process in the ditch. As a matter of fact, recent experiments in the Netherlands have indicated that the oxidation ditch is capable of denitrification as a result of the varying DO. Thus an effluent may be discharged which is low in BOD, SS, NH_3 and NO_3. This is a decided advantage when the receiving stream is very small, i.e. virtually no dilution is available for the treated effluent.

INSPECTION TOUR

To date the practical experience of the OWRC with oxidation ditches has been limited to inspection of several installations outside of Ontario. All plants except one received domestic sewage. About one year ago, an extended inspection tour was conducted through Western Canada and the State of Oregon. In March of this year an oxidation ditch plant was visited in Minnesota to observe the operation under winter conditions similar to Ontario's climate (Slides 4 - 6).

We were able to conclude from our observations (3) that the oxidation ditch will provide BOD reductions of the same order of magnitude as the conventional activated sludge process; as long as the plant is adequately designed and properly operated. DO surveys in a number of plants demonstrated the presence of the cycling DO concentrations from 1.5 to zero mg/l. Where detailed operating data had been kept, the plants carried MLSS in the range of 6,000 to 7,000 mg/l, with infrequent sludge wasting, and effluent BOD's ranging from 10 to 20 mg/l. These effluent BOD's were observed when the plants received the approximate design load.

Most of the plants were operating continuously, equipped with a clarifier and a sludge return system. Also, most ditches were lined with concrete, e.g. gunite or shotcrete. It should be realized that the inspected plants were more elaborate and relatively more expensive than most of the oxidation ditches built in the Netherlands. There, several modifications were made to achieve continuous sludge separation, without resorting to a secondary clarifier. Smaller plants with a maximum design population of 1,000 give a quite satisfactory BOD removal with intermittent operation.

Although a separate clarifier will increase the capital cost as well as the operating cost of a plant, reliable continuous operation will result even under winter conditions if the plant is equipped with a clarifier.

The purpose of the inspection tour through Western Canada and the State of Oregon was to determine whether the oxidation ditch would be acceptable as a method of wastewater treatment for small municipalities in Ontario, competitive with conventional lagoons and aerated lagoons. Quality of the treated effluent from an oxidation ditch will be equal to or better than that possible with either type of lagoon. Where land costs are high, the oxidation ditch will also be preferred because of the much reduced land requirements, compared to a conventional lagoon.

TREATMENT OF INDUSTRIAL WASTES

At this point we come to the discussion of some specific examples where an oxidation ditch has been used for the treatment of different industrial wastes. A considerable number of laboratory and pilot-scale tests have been run by the Netherlands Research Institute for Public Health Engineering (2) on a wide variety of wastes, ranging from dairy, cannery and potato wastes to refinery and tannery wastes. In all cases satisfactory treatment was obtainable with the oxidation ditch. Much work has been done in Germany also on the treatment of industrial wastes, e.g. on wastewater from a soft drink industry, poultry plant, slaughterhouse, textile mill and a sugar factory (4). Relatively speaking, only a few oxidation ditch plants are in operation in North America for the treatment of industrial wastes.

To illustrate the application of the oxidation ditch process to industrial wastewater treatment, certain specific installations will be described, for which detailed information has been obtained. The discussion will be limited in most cases to a description of the plant layout and of the treatment process. Cost data have been omitted because of the inaccuracy resulting from varying foreign exchange rates and relative inflation.

The first example deals with the treatment of dairy wastes (5). A new dairy was proposed for a small town, population 1,800 in Germany, located on a river with an average low flow of 2 cfs. The approximate waste load could be predicted on the basis of the designed production facilities: The design milk delivery is approximately 10,000 gal/day. Daily production - 4,000 lb. butter and 1,300 lb. cheese; butter milk, skim milk and whey are returned.

When the cooling water is excluded from the waste stream, a daily waste flow of 15,400 gal. is expected with a BOD load of 463 lbs. corresponding to an average strength of 3,000 mg/1.

The waste treatment plant is designed to treat the dairy waste as well as a part of the domestic waste of the town. According to European practice the waste flow of a contributory population of 800 is estimated at 17,650 gal/day and a BOD load of 88.2 lb/day. Thus the waste treatment plant is designed for a total waste flow of 33,000 gal/day and a BOD load of 551 lb/day, or an average BOD of 670 mg/1.

Constructed in 1958, the treatment plant consists of a pumping station, oxidation ditch, clarifier and sludge drying beds. The ditch has a volume of 210,000 gal., providing an average retention time of 6-1/2 days. The clarifier has a capacity of 8,820 gal. The sludge drying beds have a total area of 2,480 sq. ft.

Three 27-1/2 in. diameter cage rotors are installed with a total length of 24.6 ft., designed to rotate at 75 rpm. The effluent weir of the clarifier controls the immersion of the rotors. Frost protection, including electric heat is provided.

The local regulatory agency made several surveys to determine the performance of the waste treatment plant. In February 1959, the milk delivered was 8,400 gal/day;

> daily production - 3,080 lb. butter and 330 lb. cheese, daily waste flow - 22,000 gal. with a BOD load of 308 lb., corresponding to 1,400 mg/1. The clarified effluent showed a BOD of 17 mg/1, equivalent to an overall BOD removal of almost 99 percent.

In May 1959, approximately 10,000 gal/day of milk were delivered;

> daily production - 3,300 lb. butter and 840 lb. cheese, daily waste flow - 33,000 gal. with a BOD load of 353 lb., corresponding to 1,070 mg/1. The clarified effluent showed a BOD of 10 mg/1, again a reduction of 99 percent.

During this initial period the measured waste flow originated in the dairy; no domestic connections had been made as yet. Although excellent BOD removals were reported, a serious problem was experienced with poorly settling sludge. Three weeks after start-up the mixed liquor contained about 1,500 mg/l suspended solids, with a sludge volume index (SVI) of 600. The mixed liquor could be build up to a maximum of only 2,000 mg/l suspended solids, with a half hour volume of settleable solids of 95 percent corresponding to an SVI of 475. In spite of a 6-hr. retention time in the clarifier, sludge was lost frequently over the effluent weir. The surface loading was 615 gal/sq. ft/day for a maximum hourly flow rate of 4,400 gal. The surface loading calculated on the basis of an average daily design flow of 33,000 gal. is 192 gal/sq. ft/day. It is expected that the settling characteristics of the sludge will improve, when domestic wastewater becomes a significant part of the total waste flow.

Using the data from the May, 1959, survey the actual loadings can be calculated, assuming a MLSS concentration of 2,000 mg/l. For an average daily flow of 33,000 gal. the oxidation ditch provides a retention time of more than 6 days. The BOD loading amounts to 10.5 lb/1,000 cu. ft/day. The BOD solids loading is equivalent to 8.4 lb/100 lb. MLSS/day. These are average figures. The instantaneous loadings may be considerably higher depending on the irregularity of waste discharge.

The installed rotor length will supply 2 lb. O_2/lb. BOD applied at a design loading of 551 lb. BOD/day. The required OC is 1.86 lb/hr/ft. of rotor, which can be obtained at 75 rpm and an immersion of 6 in.

In a smaller installation for the treatment of dairy wastes (6), also in Germany, similar problems were encountered with respect to a poorly settling sludge. However, as a result of intermittent operation of the oxidation ditch, and the associated sludge separation in the ditch, the MLSS could be increased to 6,000 mg/l.

Operating problems may arise because of extreme fluctuations in the quantity and strength of the wastewater throughout an operating day. Generally the daily volume of waste is discharged over an 8 or 10 hour period. Economic considerations may limit the installed rotor length so that the OC would be adequate if the BOD load was distributed uniformly over a 24-hour day. For this reason, as well as in the case of accidental losses of whey, etc., an equalizing tank will be an asset for the reliable operation of the treatment plant.

The second example, of interest in the present discussion, is an oxidation ditch for the treatment of wastes from a soft drink industry, also in Germany (7). This treatment system was put into operation less than two years ago. Its design and operation illustrate an interesting development which has occurred in Germany. This development might be considered a step backwards from the original design criteria for the oxidation ditch. Higher BOD loadings and reduced retention times yield still satisfactory BOD removals, but a not fully stabilized sludge. This requires cold digestion for disposal of the excess sludge rather than simple disposal on drying beds.

The industry produces a lemon drink (something like 7-Up), and soda water. Three bottle wash and filling machines produce an average total of 140,000 bottles, and a maximum of 225,000 bottles daily. About 85 percent are used bottles which still contain leftovers of the previous contents.

A caustic soda solution with detergents added is used as wash liquid. Once a week it is replaced. Because of its quality, pH = 11.0 and BOD - 2,500 mg/1, the wash liquid, about 6,600 gal., is stored in a 17,600 gal. storage tank, from which it is pumped to the treatment plant at a constant rate throughout the entire work week. Another source of process waste is the accidental breakage of bottles when carbon dioxide is added. Sanitary wastes from 160 employees and the wastewater from two restaurants are also part of the total waste flow.

The industry operates 5 days per week, 9-1/2 hrs. per day. The waste flow occurs during these periods. The strength (BOD) fluctuates rather widely between 160 and 3,100 mg/1, with an average value of about 640 mg/1. The average pH is 8.5. The volume of wastewater is estimated at 419 gal. per 1,000 bottles washed and filled. For a maximum production of 225,000 bottles a daily volume of 93,700 gal. wastewater is discharged and for an average of 140,000 bottles, 58,700 gal/day.

A preliminary investigation had shown adequate BOD reduction with a 12-hr. aeration period. In view of favourable experience with the oxidation ditch as well as with the heavier loaded oxidation ditch, it was decided to construct an oxidation ditch with at least 12-hr. retention.

The waste treatment plant consists of the following units: an oxidation ditch of 55,100 gal., a clarifier of 22,000 gal. capacity, a sludge holding tank 17,640 gal. (2,820 cu. ft.), the already mentioned wash liquid storage tank, and two sludge pumps. The raw waste is screened only before it enters the ditch. Two cage rotors, each 8.2 ft. long, provide aeration and circulation of the mixed liquor. Again, oxygen is supplied at the rate of 2 lb/lb BOD applied, requiring an OC of 2.7 lb/hr/ft. of rotor. During the night and on the weekends, one rotor is turned off. The oxygen supply can be further controlled by varying the immersion of the rotors.

Within a year after start-up of the treatment plant, the performance of the plant was determined by means of several grab samples as well as a sampling program at half-hour intervals throughout an operating day. The grab samples had already indicated BOD and SS removal efficiencies of the order of 98 percent. This was confirmed by the composite sampling program. During the sampling period the flow fluctuated between 4,400 and 10,000 gal/hr., averaging 8,000 gal/hr., giving a total volume of 80,000 gal. for the 10-hr. period. The production on that day amounted to 189,362 bottles.

The BOD of the wastewater varied widely, between 160 and 3,100 mg/l, with an average of 640 mg/l. The clarified effluent showed BOD's ranging from 6 to 10 mg/l, yielding a removal efficiency in excess of 98 percent. Under continuous operation a MLSS concentration of 6,000 mg/l could be maintained. An SVI of 100 was observed. In spite of an ash content of 37 percent, the sludge was not stabilized. Deterioration occurred in the sludge holding tank, to the extent that it could be called a cold digester. This is definitely a disadvantage of the high BOD loading.

If the wasteflow is assumed to be uniformly distributed over a 24-hr. day, the BOD loading is estimated at 58 lb/1,000 cu. ft/day, and the BOD/solids loading at 15 lb/100 lb. MLSS/day. The installed rotors are capable of a maximum rate of oxygen transfer of 80 mg/l/hr. This would qualify the treatment process as a high-rate activated sludge process, even beyond the conventional process. Dissolved oxygen surveys showed a steadily decreasing DO content in the mixed liquor from a high of 3.9 mg/l in the morning, to a minimum of 0.8 mg/l in the afternoon. The observed variation is related to the variation in waste loading from virtually nil during the night to maximum in the daytime. An equalization tank might be used to advantage in such a situation.

When the original design criteria are applied to the observed BOD loading of 512 lb/day, the ditch capacity will have to be increased to 246,000 gal., in order to reduce the loading to 13 lbs. BOD/1,000 cu. ft/day. When the MLSS concentration is maintained at 4,000 mg/l, the BOD solids loading becomes 5.2 lb/100 lb. MLSS/day. Additional rotor length is not required. However, both rotors must operate continuously to prevent settling out of solids.

The third example shows a waste treatment plant for coke oven wastes and is of interest because of its sheer size (2). Originally the oxidation ditch was developed for the purpose of providing economical waste treatment facilities for small communities, e.g. up to 5,000 population. The present example will illustrate that size is not a limiting factor in oxidation ditch operation.

The Netherlands State Mines conducted extensive studies on the biological treatment of coke oven wastes (8). The performance of an oxidation ditch was compared with that of a diffused air activated sludge plant, both on a pilot scale, in order to determine the most suitable method of waste treatment.

The average composition of the wastes from two large coke ovens may be given as:

		Weekdays	Weekend
BOD	mg/l	150	1,000
COD	mg/l	300	1,500
Phenols	mg/l	20	300
SCN	mg/l	30	30
HCN	mg/l	2	2
Waste flow from one plant	mgd	0.74	1.06
BOD loading	lb/day	1,110	10,600

These data show rather clearly that the weekend BOD loading is almost ten times as great as the average weekday value. On the weekend a carbon washer is not in use, where during the week cooling water with a high phenol content is treated at a flow rate of 0.32 mgd. For any waste treatment system this situation amounts to a severe shockload at a regular weekly intervals.

Pilot plant facilities consisted of:

an oxidation ditch plant - with a 99,000 gal. capacity ditch and an 11,000 gal. capacity clarifier. The ditch was about 25 ft. wide, and was equipped with a 16.4 ft. long, angle-iron rotor, 19.7 in. diameter. The rotor speed could be varied from 90 to 170 rpm.

an activated sludge plant - with a 7,700 gal. capacity aeration tank and also an 11,000 gal. capacity clarifier. Air was supplied through diffuser tubes. The air rate could be varied from 2.6 to 9.6 cu. ft/gal. of waste, over the range of waste flows tested.

Both plants received the effluent from a common primary settling tank. The oxidation ditch was operated at retention times of two and three days, compared to retention times of three and five hours in the activated sludge plant. Besides retention time, BOD loading was the main variable. A more detailed description of the experimental work is available in the literature.

Satisfactory results were achieved with both treatment plants using the normal weekday loadings. However, the weekend shockloads seriously upset the activated sludge plant, whereas the oxidation ditch maintained good removal efficiency even when fed with artificial shockloads of acids and HCN. Concentrations of HCN as high as 35 mg/l were reduced to 2 and 1 mg/l in the oxidation ditch. These toxic shockloads had killed the organisms in the activated sludge plant. On the basis of the pilot plant test results it was decided to construct an oxidation ditch with a clarifier for the treatment of the combined wastes.

The oxidation ditch is designed for a waste flow of 2.12 mgd, with a loading equivalent to a population of 100,000. Actually the process wastes are discharged into a so-called micro-river, and the whole flow (2.12 mgd) flows into the oxidation ditch. The treated effluent is returned to the dry stream bed. The ditch has a capacity of 6.61 mil. gal. Four rows of cage rotors, each 82 ft. long, are required for the design loading. During construction it was found that the wastes from a new chemical plant would be discharged into the oxidation ditch. The volume of this waste was rather small, but the organic loading was equivalent to a population of 150,000. Therefore another 6 rows of cage rotors were installed, also 82 ft. long each (Slide 7). The surface area of the ditch is almost 5 acres. The ditch is operated at a liquid depth of 5 ft.

The clarifier provides approximately 4 hr. retention. Settled sludge can be returned at 100 percent. The surface loading of the clarifier at design flow is 300 gal/sq.ft/day. After 5 months operation on the initial load of 100,000 population equivalents, the clarified effluent showed a BOD of 3 mg/1. No other analyses are available. Phosphate must be added as nutrient for the activated sludge.

Since it would not be economically feasible to line such a huge ditch with concrete, the side walls were covered with waste rock from the mines, to minimize erosion. The bottom of the ditch was also protected with rock for a distance of 33 feet downstream of each row of rotors. Considerable seepage did occur at first, but rather soon the soil pores clogged, and the seepage stopped. Based on the very limited operating data, it would appear that the oxidation ditch is the solution of this waste treatment problem.

The last example is an installation in the United States, which might be of greater interest than the foregoing examples, simply because the plant is located in North America rather than in Europe. An experimental oxidation ditch plant treats packing house wastes from the Maurer-Neuer plant in Arkansas City, Kansas. The oxidation ditch has a capacity of 37,500 gal. giving an average retention time of about 32 hr., and an average loading of 29.8 lb. BOD/1,000 cu. ft/day, on the basis of operating results accumulated in the fall of 1963. The ditch is equipped with two 4-ft. long cage rotors (27-1/2 in. diameter). An average BOD removal of 94 percent was observed, reducing the BOD of the raw waste from 645 to 38 mg/1 in the treated effluent. Further data were not available.

SUMMARY AND CONCLUSIONS

1. The oxidation ditch process produces an effluent equivalent to that from the conventional activated sludge process, over a wide range of loadings and for a variety of industrial wastes. Well stabilized excess sludge can be disposed of on drying beds, if the BOD loading does not exceed 13 lb/1,000 cu. ft/day. Since sludge production varies for different types of industrial wastes, pilot plant studies will show whether higher BOD loadings can be applied, without having to resort to digestion for disposal of excess sludge.

2. BOD loading is the essential design parameter, rather than retention time, for the treatment of industrial wastes. Sufficient rotor length must be installed to provide 2 lb. O_2 per lb. BOD applied.

   Liquid depth in the ditch may vary from 3 to 5 ft. Greater depths might complicate the construction of the side walls. Ditch lining is mainly required for control of erosion. The soil must be suitable to permit construction of an unlined ditch, for proper control of the liquid level (rotor immersion) and protection of the groundwater. Rotors must be protected against frost in the Ontario climate, because minimum temperatures of the mixed liquor may be as low as 32°F.

3. Correct design of the clarifier is essential to the satisfactory operation of an activated sludge plant, especially of an oxidation ditch with the very high MLSS content, and a 100 percent sludge return rate. The retention time should be at least 3 hr. The surface loading must not be greater than 600 gpd/sq. ft. The examples have illustrated the effects of irregular waste discharge during an operating day. Perhaps still longer retention times and lower surface loadings should be considered. In the case of a poorly settling sludge the intermittent oxidation ditch has an advantage over a continuous ditch with a clarifier.

4. The oxidation ditch process has shown a good resistance to shockloads, but equalizing tanks are desirable to prevent daily cycles of overloading and starvation.

5. A cost study will determine the economic advantages of the oxidation ditch over other methods of biological waste treatment.

6. As a unit process the continuous oxidation ditch is an aeration tank. Its oxygenation capacity depends on rotor length, speed and immersion. The original design produces low intensity aeration suitable for the low loadings associated with the extended aeration process. The intensity of aeration can be increased by adding more rotor length per unit ditch volume.

ACKNOWLEDGMENTS

The author wishes to express his thanks to Dr. A. Pasveer of the Research Institute for Public Health Engineering, Delft, The Netherlands, and to Dr. K. Viehl of the Office of Water Examination, Hildesheim, Germany, for their generous providing of much information, essential for this paper.

The assistance of Messrs. S.A. McWilliams and A.R. Wallace of Pumps and Softeners Ltd., Toronto, and London, Ontario, is also appreciated.

REFERENCES

(1) "Eenvoudige afvalwater zuivering", (Simplified Method of Sewage Purification), Dr. Ir. A. Pasveer, Report No. 26, Research Institute for Public Health Engineering, T.N.O., The Netherlands.

(2) Private correspondence, dated January 13 and April 23, 1965, from Dr. Ir. A. Pasveer, Chemist Bacteriologist, Water Soil and Air Division, Research Institute for Public Health Engineering, T.N.O., The Netherlands.

(3) "Evaluation of the Oxidation Ditch as a Means of Wastewater Treatment in Ontario", F. Guillaume, Research Publication No. 6, July 1964, The Ontario Water Resources Commission.

(4) Private correspondence, dated March 2, 1965, from Dr. Karl Viehl, Director of the Office of Water Examination of Lower Saxony, Hildesheim, Germany.

(5) "Die Reinigung von Molkereiabwaessern in einem Oxydations - graben", (The Treatment of Dairy Wastes in an Oxidation Ditch), A. Goetz, Berichte der Abwassertechnischen Vereinigung, Heft 11, 1960, s. 254.

(6) "Molkereiabwaesser und ihre Reinigung", (Dairy Wastes and their Treatment), F.v. Ammon, Berichte der Abwasser-technischen Vereinigung, Heft 11, 1960, s. 236.

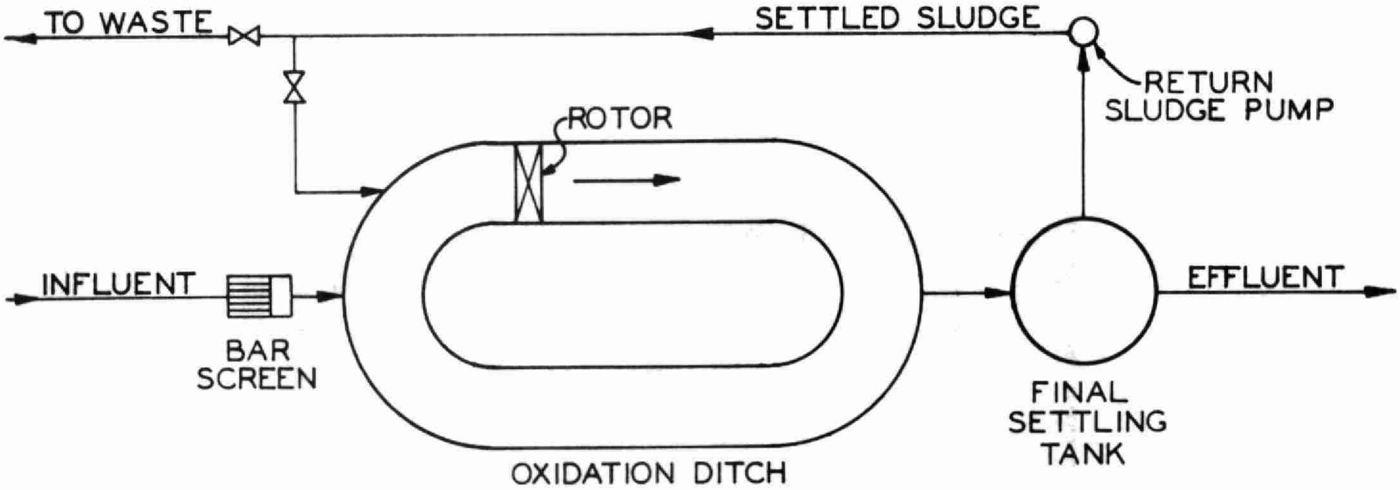
(7) "Ein Belebungsgraben fuer das Abwasser eines Betriebes der Getraenke - Industrie", (An Oxidation Ditch for the Wastewater from a Soft-Drink Industry), K. Viehl, Gas und Wasserfach, <u>106</u>, 2, 37 (January 15, 1965).

(8) "Étude à l'échelle semi-industrielle de l'épuration biologique de l'eau résiduaire de la cokerie Maurits", (Pilot plant study of the biological purification of wastewater from the Maurits coke oven), D. Adema and R. Tietma, Techniques et Sciences Municipales, February 1962, p. 77.

SLIDE 1

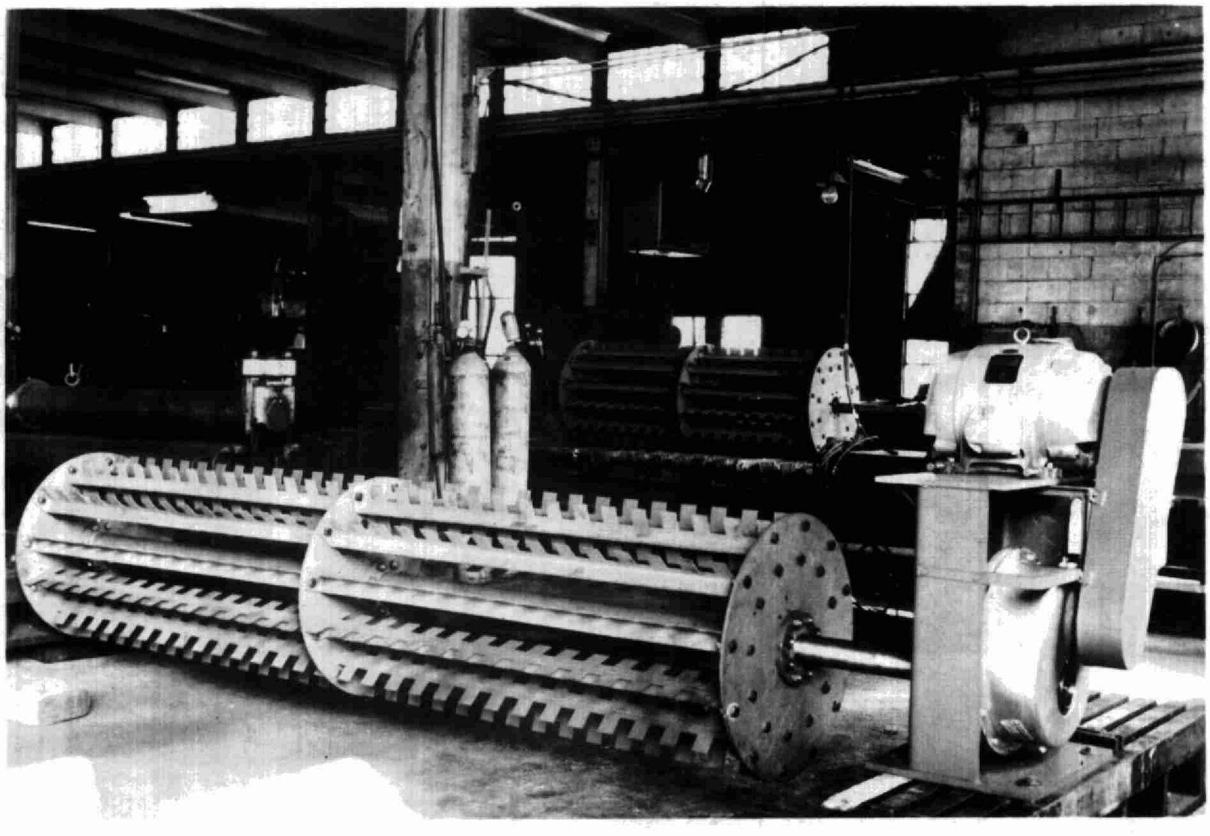
SLIDE 4

Slides 1 - 6 illustrate the layout and operation of the oxidation ditch process.



OXIDATION DITCH PLANT LINE DIAGRAM

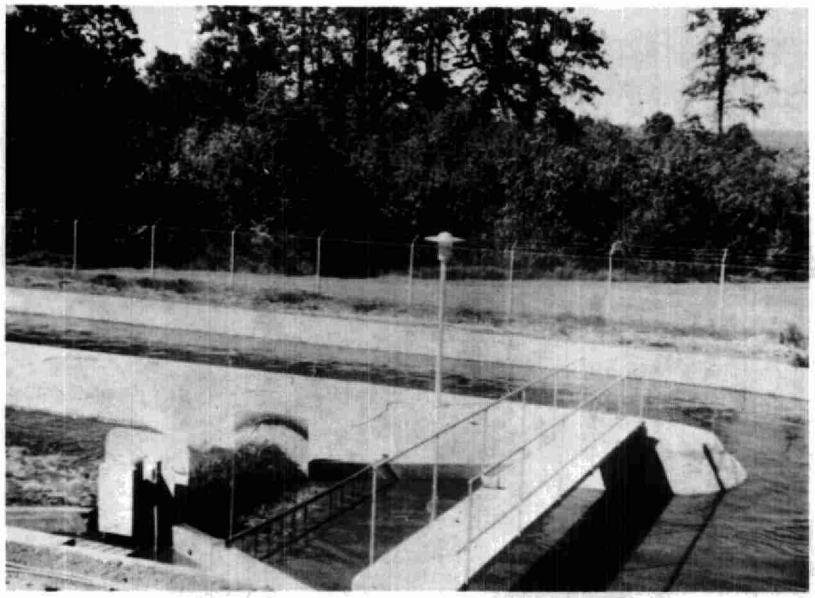
Slide 2



1 - 10'-0" CAGE ROTOR
1 - 6'-0" CAGE ROTOR

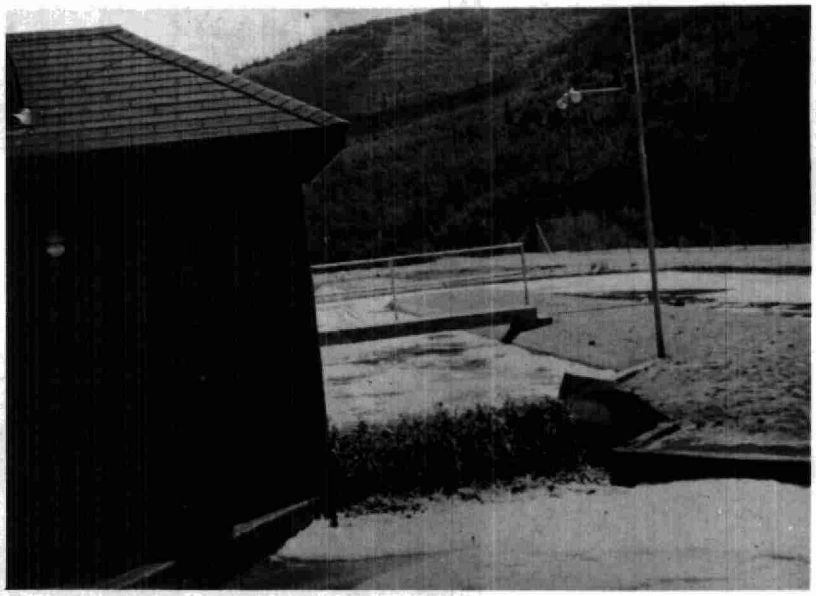
$27\frac{1}{2}$" CAGE DESIGN
GEAR REDUCER
10 HP DRIVE MOTOR

Slide 3



SLIDE 5

SLIDE 6



SLIDE 7

BANQUET NIGHT

"SAFEGUARDING THE QUALITY OF BOUNDARY WATERS"

by

M. W. THOMPSON

> "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other."

This statement is quoted from Article IV of the Boundary Waters Treaty of 1909. Since these boundary waters form the southern border of Ontario, and since many of the industries represented here to-day use these same waters to dispose of their waste products, and since the general public is becoming increasingly aware of the dangers of water pollution, it is appropriate to discuss at this Industrial Waste Conference how the Governments of Canada and the United States fulfil their Treaty obligations to safeguard the quality of boundary waters.

In order to appreciate the application and implementation of Article IV of the Boundary Waters Treaty, it is necessary to describe briefly pertinent portions of the Treaty itself, the nature of the International Joint Commission's activities with special reference to water pollution and especially how the Commission discharges the functions entrusted to it by the Boundary Waters Treaty.

At the turn of the century it was apparent to statesmen in Canada and the United States that there was a need for improving the procedures for settling problems regarding the use of waters flowing along and across the boundary between our two countries. Their efforts culminated in the signing of the Boundary Waters Treaty on January 11, 1909.

The preamble declares the purposes of the Treaty:

(1) "to prevent disputes regarding the use of boundary waters",

(2) "to settle all questions which (were then) pending between the United States and Canada involving the rights, obligations or interests of either in relation to the other or to the inhabitants of the other along their common frontier"; and

(3) "to make provision for the adjustment and settlement of all such questions as may hereafter arise."

The pending questions referred to involved the division of water between the two countries at Niagara Falls for power generation and in the St. Mary River and Milk River on the Prairies for irrigation.

In addition to furnishing a solution to these two disputes the Boundary Waters Treaty provided the United States and Canada not only with a firm set of principles to deal with their international water problems but also the machinery to implement them. Other countries now faced with similar international water problems are envious of this mutual agreement which has stood the test of more than half a century.

The Treaty defines "boundary waters" as waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary passes, including all bays, arms and inlets thereof. Under this definition, Lake Huron and Georgian Bay are boundary waters. Lake Michigan, on the other hand, is not. Neither are rivers such as the Columbia and the Red which flow across the boundary.

The navigation of all navigable boundary waters shall forever continue free and open for the purposes of commerce to the ships of both countries. This right of navigation was specifically extended to the waters of Lake Michigan.

The Boundary Waters Treaty reserves the sovereign right of the upstream state to use or divert the waters of transboundary streams while in its territory. Interests that may be injured in the other country are protected.

Each country shall have equal and similar rights in the use of boundary waters. The Treaty forbids the construction of any works below the Boundary that raise the natural elevation of the waters on the other side without prior approval. It specifies the order of precedence in the use of boundary waters: domestic and sanitary purposes first, navigation second, and power and irrigation last. It also provides that boundary waters shall not be polluted.

The Treaty provided for the establishment of the International Joint Commission with jurisdiction to approve certain types of uses and diversions of water, and to investigate and report on any questions or matters of difference referred to it by the two governments. The Treaty clothed the Commission with quasi-judicial, investigative and administrative powers to implement the Treaty.

The International Joint Commission is a permanent international tribunal. It is unique in that it is composed of three citizens from each of the two countries affected by its findings and decisions. The Commissioners act as a single body in their joint deliverations, not as separate national delegations under instruction from their respective governments. Each Commissioner on his appointment must make a solemn declaration in writing that he will faithfully and impartially perform the duties imposed upon him by the Treaty.

The Commission's functions fall into two general categories:

(1) approving or rejecting applications for approval of works, and

(2) at the request of one or both governments, investigating and making reports with recommendations on specific problems along the common frontier.

The first category covers applications which may be made by individuals, public or private agencies or the governments themselves for works in either country, designed to utilize, obstruct or divert boundary waters whenever such works would affect the natural level or flow of waters on either side of the boundary. An example is the St. Lawrence Power Project with its powerhouse and control dams at Cornwall, Iroquois and Long Sault.

The procedure requires submission of an application to the Commission by either government or by individuals or agencies through their own government. This is to ensure that the application conforms with any domestic requirements of the government having jurisdiction. In the case of works situated in both countries, the usual practice is for identical applications to be forwarded by each government.

Upon receipt of an application the Commission notifies all concerned, arranges for Public Hearings and provides an opportunity for all interests to file formal statements. After the Public Hearing and consideration of all of the representations, the Commission issues an Order of Approval for those applications found to be acceptable. The Order contains conditions to ensure compliance with the principles of the Treaty and protection or indemnity of all interests affected by the project.

The second category covers investigations and studies specific problems referred to the Commission by one or both governments. Examples are the current references concerning the levels of the Great Lakes and the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River.

Since its first meeting 53 years ago, the Commission has dealt with 51 applications and 31 references covering regulation of lakes and rivers with respect to levels and flows, tidal power, the use of water for municipal consumption, irrigation, navigation and hydro electric power, air pollution and water pollution. The geographic distribution extends from Passamaquoddy Bay, to the St. Croix and St. John Rivers in the Maritimes, to the Richelieu, Great Lakes and Lake of the Woods Basins, and to the transboundary streams of the Prairies and Rocky Mountains, a distance of 3000 miles.

The Commission has not the staff with which to undertake the variety of investigations required under the references from the governments. Consequently the governments, upon request, make available the services of engineers and other specially qualified personnel of the governmental agencies, and information and technical data that have been or may be acquired by such agencies. In some cases Provincial and State Governments provide experts from their technical agencies. If necessary the Commission retains private consultants. The Commission then establishes an International Board of Advisers to organize and carry out the technical studies and field work required.

Similarly, when the Commission issues an Order of Approval, it usually appoints an International Board of Control to ensure that the applicant complies with all the terms of the Order. Each of these Boards reports formally to the Commission at regular intervals. They also keep the Commission currently informed of all matters related to the Order.

The Engineering Boards and Boards of Control, like the Commission, operate as a single body seeking a common solution in the joint interest of both countries.

The water pollution problems are an increasingly important part of the Commission's work. The current water pollution references cover the connecting channels of the Great Lakes, the St. Croix River, the Rainy River, the Red River, the International Section of the St. Lawrence River, Lake Ontario and Lake Erie. The investigative and advisory boards appointed by the Commission are composed of federal, provincial and state officials who not only bring with them their own special knowledge and experience but also their staff to do the field surveys, laboratory analysis, office studies and surveillance. There is the closest co-operation between the International Joint Commission and the Ontario Water Resources Commission.

Dr. A.E. Berry, A.V. Delaporte and G.M. Galimbert from the Ontario Water Resources Commission and the late G.H. Ferguson and the late J.R. Menzies from the Federal Department of Health and Welfare have served as members on several of the Commission's Advisory Boards on water pollution. Mr. D.S. Caverly, F.A. Voege of the OWRC and W.R. Edmonds, R.E. Tait and W.K. Sharpe of the Department of National Health and Welfare are now members.

In the limited time available let us briefly examine the three current water pollution references that concern the Province of Ontario.

In 1946 the Commission received identical references from the two governments requesting it to determine whether the waters of the St. Mary's River, St. Clair River, Lake St. Clair, Detroit River and Niagara River were being polluted on either side of the boundary to the injury of health and property on the other side; if so, in what areas and from what sources; and to recommend remedial measures to correct the situation. The Commission established a board of technical advisers composed of federal, provincial and state officials. After an exhaustive investigation the board submitted its report to the Commission in 1950.

Following Public Hearings in the areas affected, the Commission submitted its report to the governments. The Commission found that all of these rivers were indeed being polluted by industries and municipalities on each side of the boundary to the injury of health and property on the other. It recommended specific "Objectives for Boundary Waters Quality Control", to be adopted by the two governments as the criteria to be met in maintaining these boundary waters in a satisfactory condition. Incidentally, the State of Missouri has since adopted these same Objectives for us on the Mississippi River. The Commission also recommended that it be authorized to establish and maintain continuing supervision over boundary waters pollution through boards established for that purpose, and to recommend to the authorities in each country appropriate action in cases where the Objectives are not being met.

The two governments approved all of the Commission's recommendations. A new Advisory Board with membership similar to the investigation stage was established by the Commission to follow up the specific pollution problems delineated in the investigation and to advise the Commission on all matters pertinent to the realization of the Objectives. The surveillance activities include continuous collection of basic water quality data, determination of improvements effected by municipal and industrial waste treatment, assembly of data on water uses, and informing the Commission of those industries and municipalities who are laggards in meeting the Objectives.

In addition to their own meetings the Advisory Board meets with the Commission at least twice a year to review progress being made, to indicate where needs exist for putting remedial measures in effect and to see that such findings are brought to the attention of the proper water pollution control agencies for appropriate action.

The results of these pollution abatement activities have been most encouraging. An international system for warning downstream water users following industrial waste spills has been established in the St. Clair and Detroit Rivers. Another example of the co-operative approach to the abatement of industrial pollution is the St. Clair Research Committee. A dozen industries in the Sarnia area pool their experience and research efforts to find practical solutions to air and water pollution problems in this highly industrialized and sensitive area. Industry has spent millions of dollars in an effort to solve its pollution problems. Several waste problems have been solved by profitable by-product recovery methods. Even the most reluctant municipalities have been moving to eliminate the discharge of raw sewage into the connecting channels. The Commission's activities were responsible, in part, for the enactment of legislation which created the Ontario Water Resources Commission. The pollution control authorities of Michigan, New York, Minnesota and Ontario have co-operated with the Commission in its investigative and surveillance activities. All concerned can be proud of the progress in pollution abatement - but there is still a long way to go to reach the goal contemplated by the Boundary Waters Treaty.

In 1959 the Governments of the United States and Canada asked the Commission to investigate and report on the pollution of Rainy River and Lake of the Woods. The Commission immediately appointed an Advisory Board to carry out the necessary technical investigations. The field studies included: analysis of water samples taken from Rainy River and its tributaries and portions of Rainy Lake and Lake of the Woods, float tests for determining the direction of currents, visual and microscopic investigation of water and benthalogical samples, and investigation of the sources of waste. Water samples were analyzed for coliform organisms, pH, temperature, dissolved oxygen, BOD, turbidity, total, suspended and volatile solids, lignin, COD, phenol, calcium, alkilinity, conductivity and hardness. Bottom samples were examined for bark, chips, fibres and types of soil.

The Board, during the course of the investigation, submitted nine semi-annual progress reports, a summary report for the Public Hearing, a special report accompanying the April 1963 progress report and a final report dated October 1964. The Board's findings cover such subjects as the multiple uses of Rainy River, transboundary movement of its waters, and the extent, source and effects of pollution. They recommended specific remedial measures. Wastes from the two pulp and paper plants and an adjacent municipality caused the pollution problems. The Commission has submitted its own report to the two governments who now have it under consideration.

Last October the Commission received a Reference from both governments, requesting it to investigate the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River. Investigation on this massive and complex assignment has started. An Advisory Board has been appointed. The Canadian Section is composed of officials from the Ontario Water Resources Commission and the Federal Departments of National Health and Welfare, Fisheries, and Mines and Technical Surveys. The United States Section is composed of representatives from the three States whose waters are covered by the Reference as well as from the United States Public Health Service. This reflects the multiplicity of interest in the problem.

In safeguarding the quality of boundary waters, the Commission recognizes that the maximum beneficial use of available water resources should be permitted, and unreasonable use of the water should be prevented. The disposal of waste into a river should be controlled so as to achieve the highest quality consistent with maximum benefit to all users. The discharge of suitably treated domestic and industrial wastes into a river is a reasonable use of these waters provided that such use does not create a hazard to public health or cause undue interference with the rights of others who use these waters for legitimate purposes. Furthermore, wastes discharged into boundary waters must be such as not to cause injury to health or property in the other country. Water quality objectives should not exclude all impurities from the water course, nor should they permit the maximum quantity of domestic and industrial waste that the stream can assimilate.

The Governments of Canada and the United States and the adjacent Provinces, States, municipalities and industries, all have the duty of protecting boundary waters from further degradation even though the problems multiply as the population and industrial development on the shores constantly increase. Man's needs for water to-morrow must not be forfeited by his present indifference to the enactment and enforcement of necessary legislation.

Each Federal Government has an obligation to the other under Article IV of the Boundary Waters Treaty. Where boundary waters are concerned the International Joint Commission endeavours to bridge the gap and co-ordinate the activities of the various enforcement agencies in both countries.

The primary responsibility in the field of pollution abatement, of course, rests with the Provinces and the States. Failure to enforce pollution laws has created a back-log of established polluters to the detriment of the overall interest in our water resources. The Commission's objectives for the various boundary waters should be adopted by the respective provinces and states as a minimal criteria for their own water quality standards. The recent directives issued by OWRC to municipalities and industries clarified their obligations under existing legislation. The objectives incorporated in the directives are in accord with the IJC Objectives.

After all, polluted waters are the open sewers that collect the wastes from the affluent society. The development of new products has created new and complex pollution problems. Should not an equal amount of time and money be devoted to the treatment of wastes created by the manufacture of these products? Surely industry is not so devoid of ideas and so bankrupt of skills that it cannot provide remedial measures to remove pollutants from their own effluents.

The interests of all water users, including municipalities and industries, are in jeopardy. Indifference to pollution abatement can no longer be tolerated. Industry and all levels of government must stop the rising tide of water pollution. "Boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other."

BANQUET NIGHT

SESSION THREE

J.G. Lockhart
New Brunswick Water Authority
Session Chairman

"USE OF ORGANIC POLYMERS IN THE TREATMENT OF INDUSTRIAL WASTES"

by
R. F. **DAY**

During the past several years industrial waste treatment has been expanding rapidly and the trend appears to be toward an even greater rate of increase in the foreseeable future.

With expansion of treatment operations, interest has developed in the methods of operating standard processes to obtain improved performance and often to allow processing of larger quantities of wastes through existing facilities.

One process usually basic to industrial waste treatment is solids-liquid separation. This process may take the form of stream clarification (settling of relatively low percent suspended solids), solids thickening (settling of higher percent suspended solids), and solids dewatering (filteration and centrifuging of underfeed suspended solids).

It is in this process of solids-liquid separation that the water-soluble polymeric coagulation chemicals are playing an increasingly important economic role.

At present, polymers have been used to achieve improved waste solids settling in the coal, steel, mining, glass, metal-plating, chemical, rubber, and oil industries. Their use has resulted in clear, better quality effluents sent to our rivers and streams. Interest in the eventual use of polymers in these areas was started, in some cases, as a result of the inability to accomplish effective settling and satisfactory solids removal, regardless of system size and hydrodynamics. In other cases, original equipment installations sized for a specific flow were not large enough to handle higher flow rates, or greater solids loading, as the processes of these industries expanded. Application of polymers in these cases has provided a satisfactory effluent water without increasing the size of the equipment. Greater re-use of water has resulted in many cases from the application of polymers, thus minimizing water consumption and the quantity of effluent discharged to our rivers and lakes.

Other areas of interest at the present time are low solids systems, and systems where solids are primarily in the colloidal state. Industrial systems in this category may be able to achieve a two-fold benefit of re-usable solids re-clamation and a clear plant effluent with improved flocculation afforded by a polymer. These chemicals have also proven themselves effective in achieving greater oil removal from systems where this is of primary concern.

Improved dewatering of industrial slurries is also being accomplished by the use of polymers.

Polymers are characterized by the ionization of their active groups - that is, how they ionize in water. Some ionize as cationic, some as anionic, and still others are relatively non-ionic. As well as their particular charge, the molecular weight and chain length variance also play a very important part in their effectiveness in a specific system. Because the molecular structure can be varied in so many ways, there are a large number of polymers that can be produced and each one will perform somewhat differently in a specific system.

Many theories have been presented on coagulation and the factors which influence coagulation and flocculation of colloidal systems with chemicals. A knowledge of the system and the factor or factors influencing the colloidal particles is essential in determining the type of treatment required. The following explanation is an attempt to outline one of the theories of coagulation which has extensive agreement in the water treatment industry.

The first phase of coagulation can be called neutralization. Figure 1 shows the electrical charge distribution of a colloid particle. The colloidal particles of suspended matter in water are characterized by a high surface-to-volume ratio and create turbidity, colour and some types of odours. Turbidity, the most common problem condition in water requiring coagulation and settling, is essentially a suspension of colloidal-size clay particles (usually Kaolin). A colloidal Kaolin clay particle is composed of platelets with fixed negative charges at their edges. Counter-balancing these negative charges are movable positive charges or "counter-ions" which exist in the water solution in the layer immediately surrounding the colloid particle. This charged system - the surface of the colloid and the neutralizing counter-ions - is called a "double-layer" or Helmholtz layer. If the negative charge is large, some counter-ions will be so strongly attracted that they will stick to the surface of the colloid as a firmly attached compact layer. This layer partially neutralizes the charge and electrostatic attraction of the colloid so that the remaining counter-ions can be further away and still be in the immediate vicinity of the colloid. These additional counter-ions form a so-called diffuse part of the double layer. The neutralizing counter-ions, therefore, are most concentrated near the colloid and gradually become negligible farther away. Similarly, negative ions of any salts present tend to be repelled from the immediate vicinity of the colloidal particles.

From this it can be understood that the colloidal particles of turbidity repel each other due to their like charges and would remain suspended indefinitely. The "zeta potential", therefore, is the potential at the surface separating the im-mobile part of the double layer from the diffuse part measured by electrophoretic means. As a result, zeta potential is related to the force and the distance over which the particles can repel each other and thus prevent flocculation.

The counter-ions are usually monovalent, and when exchanged for the bivalent or specially trivalent cations, the result is a shrinkage of the diffuse double layer surrounding each particle. This lessens the ionic charge on a particle due to the neutralizing effect of a fixed negative charge when in close proximity to positive counter-ions. Neutralization, therefore, is carried out until a zeta potential of 20 millivolts per centimeter, which is a critical level, or less, is obtained, and then the existing forces of attraction known as Van Der Wall's forces can exert their influence and cause agglomeration of the fine particles.

It is generally agreed in the water or waste treatment industry that coagulation with salts such as aluminum sulphate, or polymers, requires that the colloidal suspension be made unstable. When coagulation of a colloidal suspension occurs, the zeta potential is insufficient to maintain suspension stability. As the zeta potential decreases to near zero, or, in other words, as the isoelectric point is approached, coagulation may occur. It is also generally agreed that turbidity, organics, colloidal suspensions etc., are negatively charged colloidal particles, or, more accurately, colloids with negative zeta potential. When aluminum sulphate dissolves and the trivalent aluminum ions become available, or when cationic polymers dissolve and ionize as cationics, they neutralize the negative charge on the colloidal particle. Since this is the initial phase which takes place, possibly long before any visible floc is formed, the efficiency can be increased if the particles can be brought into intimate contact. This emphasizes the necessity of rapid mixing during initial floc formation.

In the conventional waste treatment plant of the precipitation type we know that suspended solids or floc are removed by letting them precipitate in the tank. The agglomerated particles of suspended solids, which form as a result of neutralization of the zeta potential or repelling charges, are still quite small and would require hours, if not days, to settle completely. Flocculation of the agglomerated particles involves a further increase in size of floc to hasten the settling rate and thus shorten the detention time required. Flocculation consists of mechanical gathering together of the agglomerated particles by the adsorption on the floc formed by coagulant chemicals, and also by molecular bridging of the individual molecules of the coagulant. The organic-polymeric materials are particularly effective in increasing floc size by "molecular bridging" and adsorption of the neutralized particles on a long molecular chain. Figure 2 shows molecular bridging, as we understand it, and shows the attachment of molecules of the polymer coagulant to each other. When this occurs between a suspended particle and an organic polymer of high molecular weight, i.e., a long molecule, a portion of the organic material is adsorbed on to one particle, while another portion of the polymer adsorbs on to a second particle and a third portion of the polymer adsorbs on to a third particle, and so on. The polymer picks up particles much like a fly ribbon picks up flies. Polymers that are effective are of the order of one million molecular weight.

If it is assumed that these polymers are not coiled, they will have lengths of around 100,000 angstrom units, or about 10 microns. Since stable colloids have a size of 0.2 micron or less, one can see that the length of such a polymer is around fifty times the diameter of a particle.

The result of flocculation is an increase in floc size. The value of increasing floc size can be very well illustrated by studying the next slide.

$$f = 4/3\pi \quad r^3(d - d^1)g,$$

where f is the force of gravity pulling floc to the thickener bottom

r is the radius of the particle

d is the density of the particle

d^1 is the density of the liquid

f is the gravitational constant

This equation is derived from the law of attraction of two bodies which states that the force of attraction is proportional to the mass ($r^3.d$) of the two bodies and the distance between them. The density of the liquid enters in because this is the buoyancy force exerted on the particle. It is readily seen from this equation the great effect the size of suspended particles has on the rate of settling. For example, if the radius of the suspended particle can be doubled, the mass of the particle, and consequently the force of gravity on a particle, will be increased by a factor of 8. It is to take advantage of this fact that we want to increase particle size and thereby increase rate of settling for waste treatment by precipitation.

To summarize, there are three factors that influence the stability of colloidal systems. To begin with, double-layer repulsion, the degree of which is determined by the magnitude of the zeta potential of the suspended colloids, is an important factor in colloid stability. The suspended particles, among which the mutual forces of attraction exist at all times, are stabilized by the higher double-layer repulsion force (zeta potential). The magnitude of this potential can be measured by any one of several methods, the most popular of which is microelectrophoresis, where mobility of the particles is measured in an electric field. Mobility, reported as M/sec/v/cm, is directly proportional to the zeta potential of the colloidal particles. High mobilities, both negative and positive, indicate a high stabilizing potential and vice versa. A system stabilized by high zeta potential can be destabilized by an agent that reduces this potential, as I mentioned before, to a range between a critical value and zero. The size and magnitude of this potential generally denotes the type of treatment necessary. Surface waters and most of the familiar aqueous colloidal systems have a negative potential and require a positive species to reduce it. Alum, iron salts, and other sources of cationic matter have been known for a long time. More recently, however, cationic polyelectrolytes have played a major role in such applications.

In practice, examination of the system under study using electrophoresis indicates the charge and the magnitude of the zeta potential and the effect of various chemicals on its reduction.

In general, reduction of the zeta potential to allow the attractive forces to take over does not necessarily result all the time in efficient treatment; other factors, such as floc size and sedimentation qualities, are as important and should be taken into consideration. The use of flocculants as aids to the chemicals effecting the primary coagulation step is common practice. Flocculants act by forming large, dense, and therefore fast-settling, floc via a bridge mechanism. High molecular weight polymers, both natural and synthetic, serve this purpose. Economy and compatibility with the system determine the most effective flocculant. In addition, mechanical factors (hydrodynamics of the system) should be considered in making the proper choice.

The second stabilizing factor which is often encountered is a short-range hydration repulsion. A system might contain enough electrolytes to effect the needed reduction in zeta potential and yet can be stable. The stabilizing factor in such a case is due to adsorbed solvent molecules on the particles to the extent of one or two monolayers. This tends to reduce the effective attractive forces among the particles and thereby prevent coagulation. A flocculant having active groups that can penetrate the hydration shell and adsorb on the surface, thereby bridging the particles, is generally an effective treatment. Many systems familiar to the audience fall into this category, such as steel mill waste water and industrial slurries. In these systems we have found long-chain synthetic polymers, both anionic and non-ionic, to be efficient.

The third stabilizing factor shown in this slide is the protective colloid phenomenon encountered in systems where surface-active molecules can preferentially adsorb on the particles, either creating steric hindrance to the necessary close approach for coagulation, or giving the surface a new property related to that of the adsorbed molecules, such as the case with gelatin on clay or silica. In both cases, the proper treatment involves a chemical that can penetrate this protective layer and reach the surface to effect flocculation via bridging.

The foregoing indicates that a colloidal system can be stabilized by one or more contributing factors. A knowledge of these factors can be very helpful in the choice of the most economical and effective treatment. Electrophoresis, when used properly, can give valuable information on the role of zeta potential in the system but our experience has shown that for most practical applications the use of jar tests with a multiple gang-stirrer, or graduated cylinder tests, must be used to design a coagulation program which will perform in the presence of all influencing factors, such as rate of agitation, retention time, order of addition of chemicals, and others.

Jar tests give a better indication of the efficiency of various coagulants and of polymers under the exact conditions of agitation and temperature.

Systems having moderate to high suspended solids, can best be evaluated using the cylinder test where the rate of settling, as governed by the efficiency of the flocculation, is the important factor.

The cationic polyelectrolytes usually provide the basis for coagulation programs designed to clarify waste streams containing a high percentage of colloidal sized turbidity. In the presence of agitation, their cationic sites serve to neutralize the negative surface charges present on the colloid to an extent that natural agglomeration or floc formation takes place. Through the physical mechanism of floc bridging, these cationic polymers subsequently continue to increase the size of the floc formed plus functioning also as coagulant aids.

Where systems have a high percentage of gross (large) solids, and particularly where a high degree of sparkling clarity is not required in the effluent, the effect of surface charges is greatly diminished. The very nature of the larger sized solids referred to here involves a much lower surface-to-volume ratio so that the effect of the surface charge is essentially counteracted by particle density at the very start of the solids-liquid separation process. In this type of system, the physical functions of molecular bridging and floc bridging are usually most effective for increasing the rate of solids separation by settling. A non-ionic polymer, with its very long chain length, is usually suited for this purpose. It provides the maximum possible increase in floc size and density, for rapid settling, solids thickening and prevention of floc carryover.

Where systems containing a preponderance of gross suspended solids are also alkaline in nature (above 7.5 pH) frequently the long chain anionic polymers perform most effectively. It is believed that they function essentially through molecular and floc bridging, similar to the non-ionics. However, in an alkaline media the anionic polymers hydrolize and the negative sites along the chain length cause it to uncoil by mutual repulsion of each other. Thus the anionic polymer is often uncoiled to a greater extent than a non-ionic polymer in an alkaline system, leading to still greater efficiency in the bridging mechanism. It has been shown by controlled hydrolysis experiments that anionic polyelectrolytes should have enough charge sites to extend the chains to permit inter-particle bridging without increasing the charge density enough to interfere with adsorption on the negative particles. This also explains why partial zeta potential neutralization by a metal coagulant increases anionic polyelectrolyte adsorption by reducing the repulsive force between the negative polymer and the negative particles.

The areas where polymers are presently used in industrial waste systems are divided into two main categories: the first being solids settling in the liquid phase; the second, dewatering of industrial thickener underflow.

We have covered quite thoroughly the theoretical aspects of solids settling for coagulation and have discussed, to a minor degree, dewatering of industrial thickener underflow. The mechanism of dewatering is accomplished in three stages as shown in Figure 3. The curve shows the three stages which are: free-settling or dewatering, hindered settling or dewatering, and compaction of the sludge or cake.

The figure shows that a plot of settling or filtration rates (volume/time) versus time generally results in a curve with three slopes. The first slope charaterizes a fast rate resulting in the free fall of floc particles with little or no interference from one another (free-settling or dewatering).

The second slope characterizes the rate resulting from particles interfering with one another in their movement causing lower but more uniform rate (hindrance settling or dewatering).

The third slope characterizes the rate resulting from compaction of the floc particles causing an even lower rate.

In both settling and dewatering the relative values of the three stages are important and reflect the efficiency of treatment. Uniformity of the floc and the floc size are major factors influencing the rates obtained. In filtration, a non-uniform floc distribution can result in premature compaction and inefficient dewatering.

The use of polymers in flue dust thickeners in the United States and, to a lesser extent, in Canada, is becoming more popular due to the more stringent requirements on solids carryover to lakes and streams. When many of the thickeners were first installed they were able to perform efficiently. With the advent of open hearth precipitators and basic oxygen furnaces, some of these systems had to be rebuilt to cope with the additional solids load. Many companies chose to improve the efficiency of these thickeners by the use of polymers. They found that a small amount of polymer would greatly increase solids settling. The value of the increased solids recovered may sometimes exceed the chemical cost. This is dependent on the value to the plant on the basis of subsequent process capabilities.

The dosage required and the type of polymer used depend upon several factors, namely the thickener size and rise rate, pH, temperature and quality of effluent desired. Jar test studies can be most useful to determine the approximate dosages for these systems. More efficient removal of solids or faster settling rates in low solids systems (less than 2000 parts per million) can be enhanced by these polymers. Settling basins in these systems can be various shapes and dimensions and have varying flow rates, and are typical of some of the conventional clarification plants in use today. As in thickeners, the flow rate, pH, temperature and quality of effluent desired can have a bearing on the type of polymer and dosage required.

In the United States, one of the major uses for polymers in waste treatment at the present time is in the coal industry. They are used primarily in essentially closed systems where coal tailings and clay have to be settled quickly and effectively to produce a re-usable water. The polymer best suited for this type of system can be determined by running slurry settling tests utilizing graduated cylinders.

In Canada, a major user of polymers for waste treatment is the iron mining industry which, similar to the coal industry in the United States, must settle the tailings sufficiently well to produce a water of adequate clarity in the overflow in order that the water may be re-used in the mill circuit.

Experience has shown that a combination of a coagulant such as aluminum sulphate and a polymer can give the most economical results and more uniform clarity than a coagulant alone can give. The use of a polymer alone sometimes can give perfectly satisfactory results at a low chemical cost and eliminate the need for a two-chemical feed system and the increase in corrosive tendencies of the reclaim water due to the addition of a coagulant such as alum or iron sulphate.

Where thickener underflow is to be dewatered by filtering, polymers may be a necessity. Inadequate moisture reduction and/or cake manageability are the reasons for considering a flocculant. The types of industrial waste slurries being dewatered with the addition of polymers are coal, blast furnace dust, flue dust, basic oxygen furnace dust and open hearth precipitator dust.

The following examples are typical of some of the results that are being obtained in various industries:

PLANT A - AUTOMOTIVE ASSEMBLY PLANT

Problem: Gross suspended solids carryover from clarifier waste is a highly concentrated mixture of -

1. Water and oil based paints
2. Reduced chromates
3. Metal phosphatizing waste
4. Sodium sulphate
5. Oil
6. Caustic

Corrective Program:
Addition of 12 ppm cationic polyelectrolyte to ferric chloride and caustic combination.

Results:

1. 50% reduction in ferric chloride and caustic dosages
2. Total solids decreased from 2000 ppm to 800 ppm
3. Turbidity reduced from 200 ppm to 40 ppm

PLANT B - INTEGRATED STEEL MILL

Problem: Suspended solids carryover from furnace flue dust washer solids thickener.

Corrective Program:
Addition of 2 ppm of a non-ionic polymer flocculant to clarifier feed slurry.

Results:

1. Over 50% reduction in sludge pump and filter operating time
2. Longer operating life for filter bags, pump impellers and strainers
3. Less labour to handle filter cake
4. More efficient sinter plant operation

Improved results have provided over $15,000 net savings per year.

PLANT C - GLASS MANUFACTURING PLANT

Problem: Over 50 tons per day of polishing sand and rouge solids carryover from clarifier.

Corrective Program:
Addition of 0.7 ppm of a non-ionic polymer flocculant to clarifier feed slurry.

Results:

1. Over 90% reduction in carryover of suspended solids from clarifier
2. Over 30% increase in filter cake yield

PLANT D - IRON ORE MINE TAILINGS THICKENING

Problem: Aluminum sulphate used at 90 ppm results in high steel losses, low pH of reclaim water and filter plugging.

Corrective Program:
Reduction of alum dosage to 20 ppm plus the addition of 1 ppm of a cationic polyelectrolyte.

Results:

1. Substantial increase in pH of reclaim water
2. Thickener overflow clarity improved giving required clarity under all conditions of tailings feed
3. Substantial decrease in frequency of filter cleaning

Improved results with the polymer addition have decreased chemical cost to less than 40% of original cost.

PLANT E - GLASS PLANT

Problem: Excessive oil content in effluent water from an oil flotation removal unit.

Corrective Program:

Addition of a specially selected, refined bentonitic type of montmorillonite clay and a cationic polymer. Clay addition varies between 5 and 10 ppm and the cationic polymer between 5 and 10 ppm.

Results:

Effluent water oil content reduced to 2 to 10 ppm

PLANT F - INTEGRATED STEEL MILL

Problem: To improve effectiveness of

a) Clarification of general mill wastes - to eliminate stream pollution from carryover of floc and uncoagulated solids.
b) Solids thickening of clarifier underflow - to minimize the recycle of solids carryover back into the system.
c) Dewatering of thickener underflow - to improve solids recovery in the filters and increase the solids fed to the sinter strand.

Corrective Program:

a) Clarification - addition of 0.4 ppm of polymer flocculant.
b) Solids thickening - intermittent low level dosage of 0.5 ppm or less of polymer flocculant.
c) Dewatering - addition of 1.0 pounds of polymer per ton of solids (dry weight basis) to the filters.

Results:

a) Clarification - effluent to the river consistently at or above the quality desired. This condition was rarely met prior to polymer usage.
b) Solids thickening - the recycle of solids has been reduced drastically.

c) Dewatering - feed of polymer to filters has consistently resulted in solids recovery over 95% with cake moisture averaging 50%. Prior to polymer usage solids recovery averaged 55 - 65%.

The above case histories are a few representative applications of polymers in industry. The best polymers to use and approximate dosages can be determined by inplant laboratory tests. The point of application of a flocculant aid will be dictated by the hydrodynamics of the individual system and can be best determined by a plant trial.

Our experience with the use of polymers in industrial waste treatment has shown that although some polymers require large amounts of agitation, other polymers require very slight mixing. The distribution of polymers into the industrial waste is extremely important as is the mixing and preparation of the polymer solution.

In summary, we want to emphasize that polymers are not always a cure-all. However, where they are applicable and economical, they should be considered for use because of the many advantages it is possible to obtain by their use. In most cases, laboratory tests or inplant bench evaluations can be utilized to determine the feasibility of using a polymer. If these laboratory or bench scale studies show a polymer to be effective, results in the plant equipment will usually correspond. The system hydrodynamics and economics of application will then determine, by actual plant test, whether a continuation of the polymer addition is warranted.

ELECTRICAL CHARGE DISTRIBUTION
OF A COLLOID PARTICLE

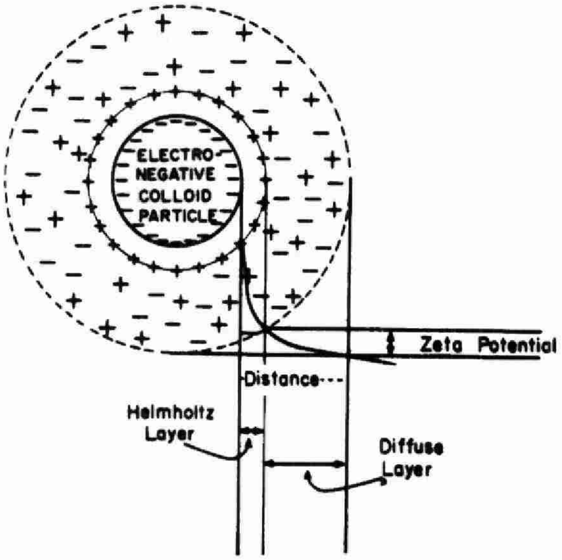


FIGURE 1

MOLECULAR BRIDGING:

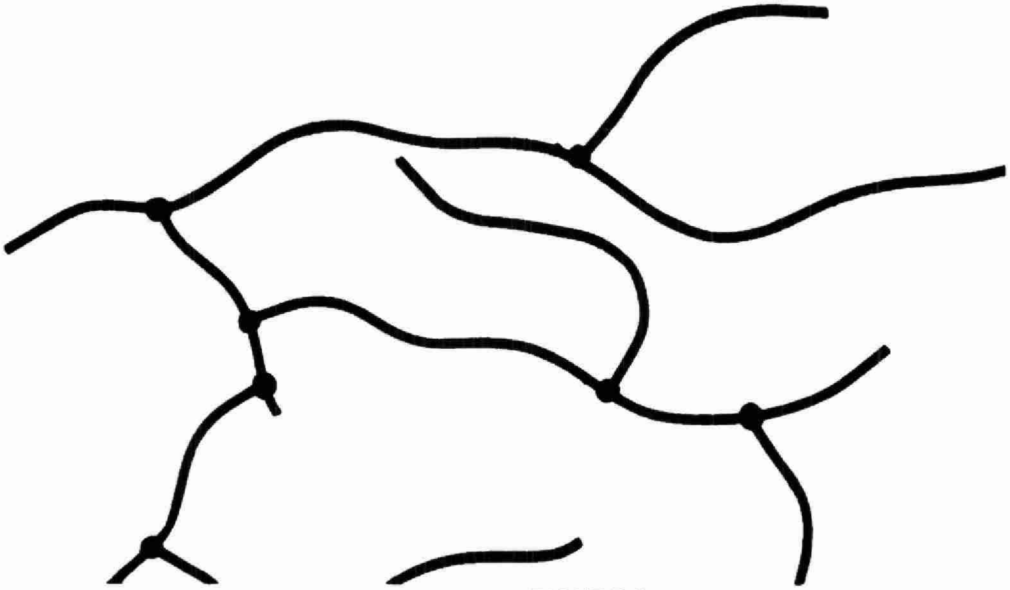


FIGURE 2

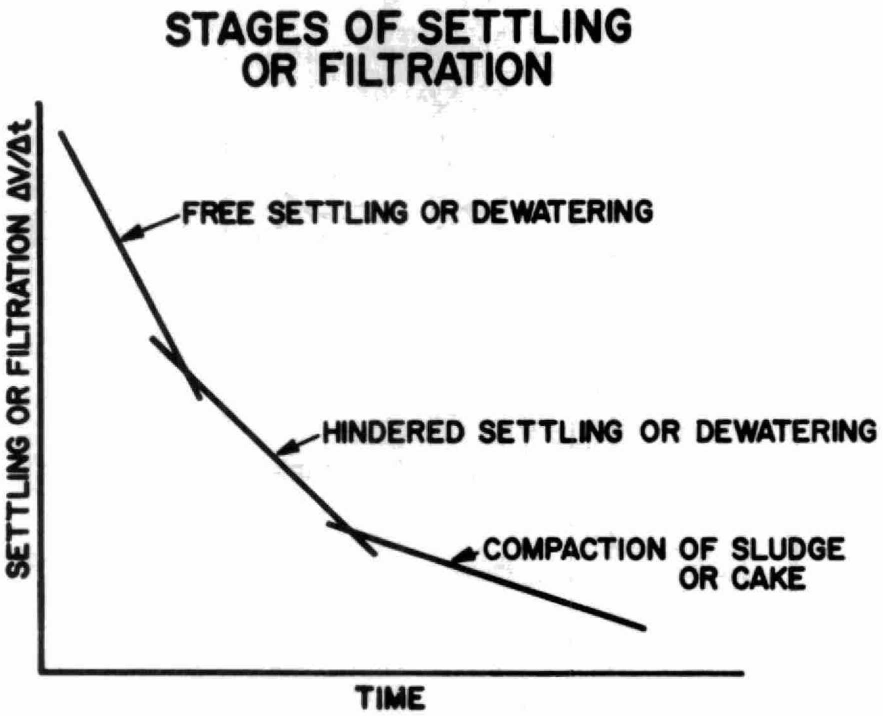

STAGES OF SETTLING OR FILTRATION
SETTLING OR FILTRATION ΔV/Δt
FREE SETTLING OR DEWATERING
HINDERED SETTLING OR DEWATERING
COMPACTION OF SLUDGE OR CAKE
TIME

FIGURE 3

W. R. GARVIE

"OBSERVATIONS ON AQUA AMMONIA NEUTRALIZATION OF ACID WASTE IN A BREWERY"

by

W.R. **GARVIE** and D.E. **WAITE**

INTRODUCTION

Recent literature concerned with the neutralization of acid waste indicates a lack of knowledge or limited practical experience in utilizing aqua ammonia. This paper is offered in the hope that our experience in this field may prove beneficial to other industries with similar problems.

A literature survey of methods for treating acid wastes would show that many chemicals have been used in a variety of processes. Limestone, caustic soda and soda ash have won the popularity contest to date but we think aqua ammonia has merit in many instances.

THEORY

Acidity, alkalinity and neutrality are a function of the hydrogen ion concentration. We can measure this by means of pH. A neutral solution is said to have a pH of 7, which tells us that the concentration of the hydrogen ion is 10^{-7} moles per litre. When an acid or an alkali or base are mixed a salt is formed. This salt can also impart a pH to a solution. If the acid is a strong acid such as HCl or H_2SO4 and the base is a weak base then the salt has an acidic pH and the resulting solution needs a little more (1 or 2%) of the base to bring it to exact neutrality. The converse is also true if the acid is weak and the base strong. Aqua ammonia is generally considered a weak base; however, it is one of the stronger weak bases. This means that when used to neutralize a strong acid at chemical equivalents where only salt and water exist the pH is slightly lower than 7. We have drawn several pH curves as examples of this.

There are quite a few commercially available alkaline materials which can be used to neutralize acid wastes. The next slide gives some of the pertinent facts about these alkalies. The chemicals are primarily listed according to their costs per neutralizing equivalent but some of the other points are of vital interest - for example, the solubilities of their salts when reacted with common acids. It is also important to note that some are sold as liquids.

BACKGROUND

The city water supply to The Carling Breweries Limited, Waterloo, originates from a number of deep wells which vary widely in total hardness. Incoming water was found to vary in total dissolved solids from 300 to 2400 ppm.

The next two slides will cover a typical water composition and show the main variables that occur. Only those components of interest to our problem are included.

Slide #3

This is a fairly typical analysis of Waterloo water which indicates that the sample was high in calcium, sulphate and bicarbonate. Total hardness level is also quite high.

Slide #4

The variation between wells in shown here. It is readily observed that calcium and magnesium increase greatly. With increasing total hardness the sulphate fraction increases while the bicarbonate remains relatively constant.

Although excellent for drinking purposes, this water proved unsuitable for the processing of uniform lager or ale products as a result of the following:

(a) High bicarbonate alkalinity
(b) Extreme fluctuations in total dissolved solids.

Also, in choosing an adequate water treatment system, the high volume of purified water, estimated at 25 to 30 million gallons per year, was a major factor.

ION EXCHANGE INSTALLATION

After some study an ion exchange system capable of producing 250 gpm of highly purified water was installed. It was designed to remove 50 grains $CaCO_3$ per gallon from 150,000 I.G. per day, under existing conditions.

The installation included two cation exchangers (IR120) operating on the hydrogen cycle with sulphuric acid as the regenerant. The anion resin (1R45) chosen was a weakly basic one, which would permit the bicarbonate hardness to be eliminated by a decarbonating tower, following the exchange process.

PROBLEM CREATED BY ACID REGENERATION OF CATION EXCHANGERS

Since the cation exchangers are regenerated with a 1% and 5% solution of 66°B sulphuric acid there is a large amount of free acid passing to waste which must be neutralized. This effluent will vary considerably as a result of the following factors:

(a) Variation in strength of acid throughout the regeneration cycle based on the rate of acid application and the volume of water flow at each stage of the cycle.

(b) Variation in total waste acid in effluent based on -

1. Degree of resin exhaustion
2. Regenerant rate
3. Efficiency of the resin's acid utilization

In practice, using a regenerant rate of 5.7 lbs. $66^{o}B$ H_2SO_4 per cubic foot of Amberlite 1R120 resin, we have found that efficiency has varied from 30% to almost 60% of acid utilization. If an average figure of 45% is used, this represents a total waste acid figure of 440 lbs. $66^{o}B$ H_2SO_4 to be neutralized per regeneration.

Slide #5 illustrates more clearly the variation in effluent strength during the regeneration. The variations in rate of acid addition and water flow rate are also shown. Such a waste requires a flexible system of control to adequately handle volume and strength changes.

An acid waste of this nature can cause rather serious problems with the city sewer system, not to mention the healthful operation of the activated sludge process at the local sewage plant. The members of O.W.R.C. will readily concur with this point, I am sure.

The problem is further magnified when one realizes the plant involved uses approximately 25% of the city water supply. Plant wastes are only slightly diluted by other wastes in travelling to the sewage plant, hence pH variations are greater than may occur in larger centres.

NEUTRALIZATION SYSTEM

The next slides picture the actual neutralization system. The facilities supplying aqua ammonia to the mixing pits are shown first.

Slide #6

Aqua ammonia is delivered as a $26^{o}B$ liquid (29.4% NH_3) by tank trucks carrying 40,000 lbs. or approximately 4400 I.G. Unloading is by pump through "Evertite" 2-inch fittings to a 6,000 I.G. tank of mild steel. This tank is vented to atmosphere through two 45-gallon steel drums, each of which is filled approximately 1/3 with water. Boiler tubing is used as a sight glass for inventory control, although a level gauge of the float and pulley type, such as the "Varec Level Gauge", has been recommended.

Aqua ammonia is supplied automatically to the neutralizing pits by means of three air-operated diaphragm valves.

Slide #7

The two mixing pits are shown in series with the flow. Both contain agitators and pH electrodes. The first pit receives most of the neutralizing solution, while the second provides the fine pH adjustment. In the diagram a baffle plate may be observed which acts as a weir forcing the flow over it and down under the cross wall to the second pit. Improved mixing results from the changes in directional flow and appears necessary as physical limitations in this area permitted only a small installation. Each pit holds only 185 I.G.

Aqua ammonia flow, based on the signal to the air-operated control valves, is supplied as seen in the slide. The pipes are drilled with small holes to provide maximum distribution and each outlet is located to attain maximum mixing. The first pit pH varies from 3 to 9+ pH. The second is controlled at 6 to 8 pH.

Slide #8

The automatic control system consists of a Bristol Dynamaster pH Model Controller-Recorder and a direct reading Beckman pH meter for each of the two pH electrodes. Each controller-recorder is fitted with set pointer, proportional band and reset adjustments. Registration of the chart is from - 1 to 9 pH. The signal from the pH electrodes in conjunction with the setting of the set pointer, proportional band and reset adjustments, determines the output air signal to the air-operated supply valves. The valves are adjusted to open under different controller output air pressures thus allowing aqua ammonia to be supplied preferentially to any of the three points.

It might be noted that the system described was originally used with 36% NaOH as the neutralizing agent but was readily converted to aqua ammonia.

COMPARISON OF AQUA AMMONIA vs. NaOH

(a) Neutralizing power or equivalent weights

40 lb. 100% NaOh = 35 lb. 100% NH_4OH

100 lb. 100% NaOH = 87.5 lb. 100% NH_4OH

(100 lb. 26°B NH_4OH= 60.7 lbs. 100% NH_4OH)

* $\therefore$ 100 lbs.100% NaOH =100 X $\frac{87.5}{60.7}$ = 144.5 lb. 26°B NH_4OH

(b) Cost of Materials - Waterloo

1. 100% NaOH (76% Na_2O) purchased as 50% liquid

	Per 100 Lbs.	
Cost Sarnia in tank trucks	\$ 3.10	
Freight @ 30¢/100 lbs.50% liquid	.60	
	\$ 3.70	*

2. 26°B Aqua Ammonia

Cost Toronto in tank trucks	\$ 1.60	
Freight 20-ton loads	.28	
	\$ 1.88	
Basis equivalent weights 1.445 X 1.88	\$ 2.72	*

3. Theoretical savings per 100 lbs. 100% NaOH previously used — \$ 0.98 *

Experimental lab analyses indicated that about 2% more aqua ammonia than theoretical would be required to neutralize this waste to pH 7.0.

(c) Savings per regeneration

Since 440 lbs. 66°B and H_2SO_4 must be neutralized per regeneration saving may be calculated as follows:

$$1 \text{ Lb. } 93\% \; H_2SO_4 = .93 \times \frac{35}{49} = .664 \text{ Lbs. } 100\% \; NH_4OH$$

$$= \frac{.664}{60.7} \times 100 \text{ or } 1.095 \text{ lbs. aqua ammonia for neutralization}$$

$$1 \text{ lb. } 93\% \; H_2SO_4 = .93 \times \frac{40}{49} \text{ or } .76 \text{ lbs. } 100\% \; NaOH$$

Therefore -

440 Lbs. 66°B H_2SO_4 requires per regeneration:

100% NaOH	Aqua Ammonia
440 X .76	440 X 1.095
334 X .0370	482 X .0188
* \$12.36	* \$9.06

*Theoretical saving with aqua ammonia \$3.30/regeneration
Theoretical saving with aqua ammonia \$3,500.00/year

A second major cost factor appeared when it was found that the efficiency of neutralization increased sharply as a result of the reduced viscosity of aqua ammonia. NaOH, as used previously, had been viscous and difficult to mix efficiently, with resultant lack of control and usage far in excess of theoretical requirements.

BENEFITS ACHIEVED WITH AQUA AMMONIA

(a) Reduced chemical costs based on equivalent weights

(b) Reduced chemical costs based on more efficient neutralization

(c) Improved automatic control giving a more uniform effluent to the sewer system

(d) Reduced suspended solids in effluent as a result of the increased solubility of ammonia salts

(e) Provision of a prime source of available nitrogen to the activated sludge process of the sewage plant

This latter point is worthy of further comment, in that a deficiency of available nitrogen seriously affects the activated sludge process. A ratio of BOD to N of 20 to 1 is considered normal(3). In certain circumstances the municipality must compensate at some expense by adding an available source of nitrogen to hold this ratio.

Thus we find this waste to be beneficial to sewage plant operation, keeping the O.W.R.C. happy, and providing ourselves with a point for discussion should increased surcharges be considered.

POSSIBLE PROBLEMS IN HANDLING AQUA AMMONIA

(a) Formation of ammonia fumes during neutralization.

The original neutralization in the laboratory indicated a faint odour of ammonia at pH3 which became more noticeable above pH 7.5.

Two trial neutralizations were conducted in the plant with success.

Operation of this system since October 1963 has shown that, providing the addition is made below the surface of the liquid, and a prolonged period at high pH is avoided, ammonia fumes do not pose a problem. When the pH was held at 9 for a prolonged period a trace of odour was noticeable. Above this point the odour became more pronounced. In operation it has not caused difficulties provided pH control is maintained.

(b) Corrosiveness

Copper, copper alloys, aluminum alloys and galvanized surfaces are affected.

(c) Explosive hazards

There is a danger of explosion if NH_3 mixes with air at 16 to 25% by volume of NH_3. Danger increases with contact with oil or other combustibles. Complete ventilation is necessary prior to welding. Mercury and ammonia can form a violently explosive compound.

(d) Proper personnel protective equipment is required as for handling corrosive chemicals or gases.

DESIGN

We propose now to dwell briefly on possible methods of neutralizing an acid effluent with aqua ammonia. These schemes will work with any alkaline solution. Economics, availability, and other factors have, as mentioned before, had a bearing on the choice of chemicals. Should aqua ammonia be used we can avail ourselves of at least one plus factor and this is that it mixes with the acid effluent very readily because it has a low viscosity and its S.G. is very nearly that of water. The choice of a process will depend largely on the type of effluent. Is it a constant flow? Has it a constant acidity? Has a great deal of water got to be handled with the acid? As you can see, there will be almost as many methods as problems. Briefly: when the volume is low, sporadic, with a wide fluctuation in acid concentration, the batch system looks attractive. This involves two tanks alternately receiving the waste and being neutralized manually. Equipment required here, besides the two tanks, need only be a roll of pH paper, a mixer in each tank, and a pipe line to feed the aqua ammonia from storage. When the volume of effluent is too great to consider the batch approach, a simple in-line neutralization can be carried out. If the effluent volume and acidity are fairly constant a manual control will suffice. Here again we need only a small tank with adequate agitation, a feed line for aqua ammonia, and a man with a roll of pH paper. Unfortunately, we are not likely to be so lucky. Effluents have a bad habit of being very inconsistent. In these cases we must rely on instumentation to ensure a good final effluent. In some cases one pH senser and controller will handle the job. It is important that most motor valves have a rangeability of 20-1. This is to say the limits of their controlled flow range from a maximum of 20 units to a minimum of 1 unit. When dealing with pH where a pH of 3 is 10 times as acidic as pH4, which is 10 times as acidic as pH5 and so on, it is difficult to do a good neutralizing job with one controller and valve. The final proposal, therefore, as shown in the sketch includes two controllers and valves in series, the first valve being several times larger than the second. This scheme allows for a small "touch-up" flow to adjust a crude neutralization carried out by the first valve. If we for a moment consider the cost of such a system a fair estimate would be about $2,000.00 per control unit installed.

CONCLUSION

This case history of a waste problem is typical of what industry must face when the local water supply is unsuitable. To achieve the necessary standard becomes expensive both in capital and operating costs. Add to this the cost of treating the wastes incurred and you find that water has become a very expensive utility. We heartily concur that water is one of our most precious commodities.

REFERENCES

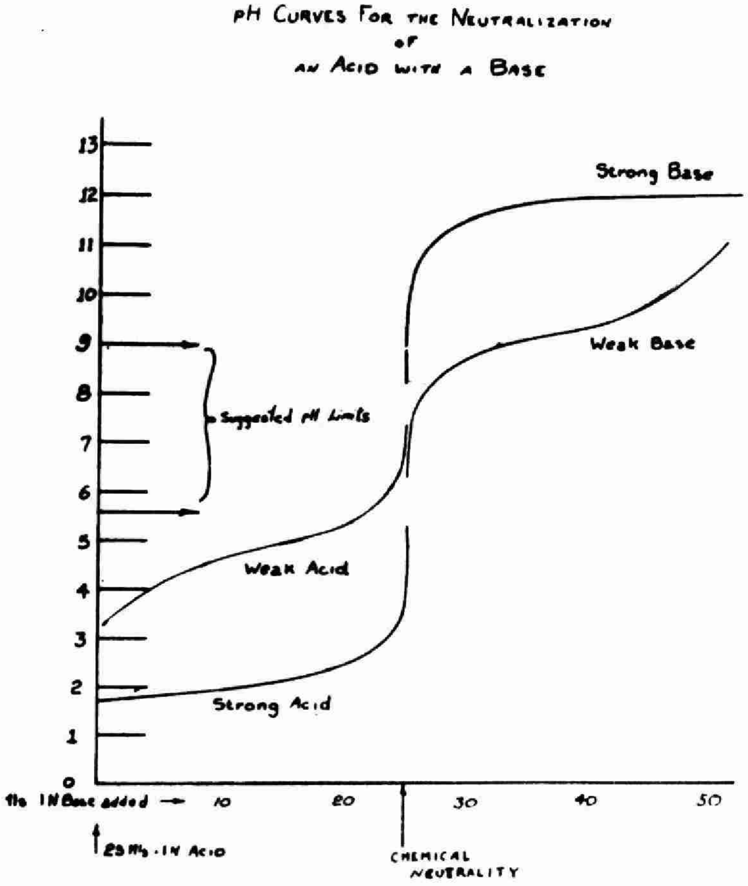
1. Introduction to Semi Micro Qualitative Chemical Analyses
Louis J. Curtman
The MacMillan Company

2. Fundamentals of Physical Chemistry

H.D. Rockford - Samuel B. Knight
John Wiley & Sons in New York

3. Biological Treatments of Sewage and Industrial Waste
Volume 1
Bacterial Nutrition & Synthesis - Clair and Sawyer
Edited by J. McCabe and W.W. Eckenfielder Jr.
Rienhold Publishing Corporation, New York, 1956

4. Calculations of Analytical Chemistry
Hamilton and Simpson
Fifth Edition
McGraw-Hill Book Company



Slide 1

ALKALINE CHEMICALS

Chemical Commercially Available as		Chemical Formula	Cost per Equivalent (Usual)	Lbs. to Neut. 100# H_2SO_4	Solubility of Salts gms/100 cc Water at 20°C	
Solid	Liquid				Chloride	Sulphate
Limestone		$CaCO_3$	Lowest	101	74	0.21
Quick Lime		CaO		57	74	0.21
Slaked Lime		$Ca(OH)_2$		75	74	0.21
	Ammonia	NH_3		34.3	37.2	75.4
	Aqua Ammonia	NH_4OH 26°Be.		117.5	37.2	75.4
Soda Ash		Na_2CO_3		109	36	19.5
	Caustic Soda	Na(OH) 50%		163	36	19.5
Caustic Soda Flake		Na(OH)		81.5	36	19.5
	Caustic Potash	K(OH)	Highest	111	34.7	10.9

Slide 2

TYPICAL ANALYSIS WATERLOO WATER

Total Solids 710 ppm

		PPM	PPM as Ca CO3
Cations	Ca	148	370 *
	Mg	9	37
	Na	15	33
	K	4	5
Total ionizable cations			445
Anions	SO4	172	179 *
	HCO3	285	234 *
	Cl	23	32
Total ionizable anions			445

Total hardness
Ca + Mg as Ca CO3 = 407 ppm
= 28.6 grains/IG

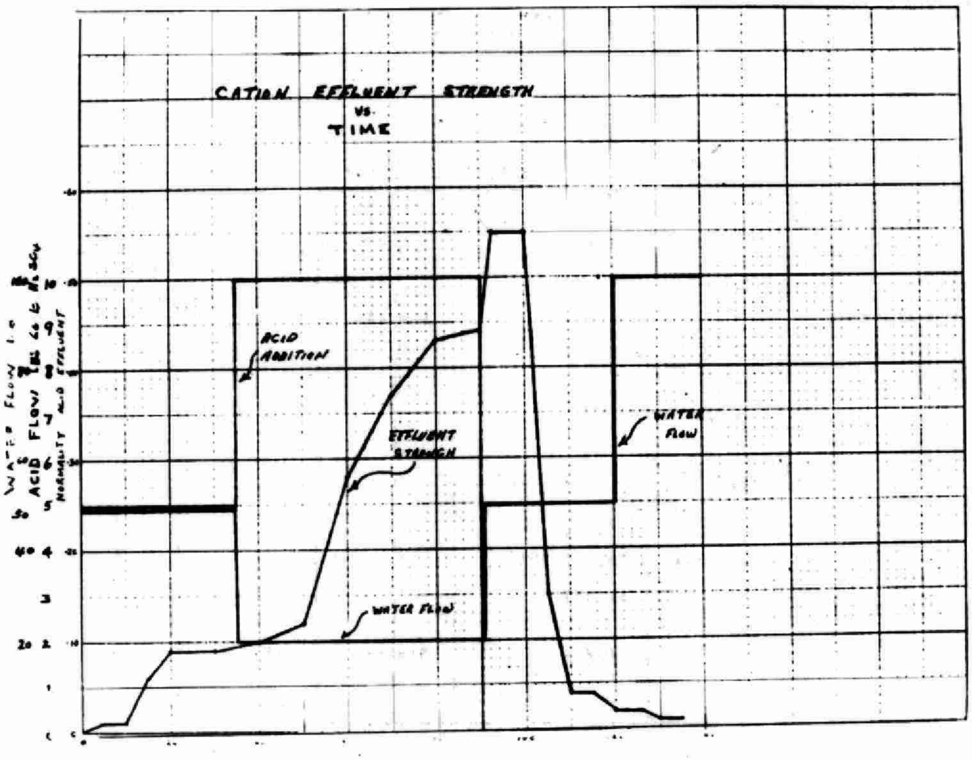
Slide 3

POSSIBLE VARIATION OF WELL SUPPLY

		WELL A	WELL B
Total ionizable solids ppm		412	2146
PPM as Ca CO_3	Ca	230	1335 *
	Mg	90	246 *
	Na	13	44
		333	1625
	HCO3	226	189
	SO4	102	1451 *
	Cl	14	6
		342	1646

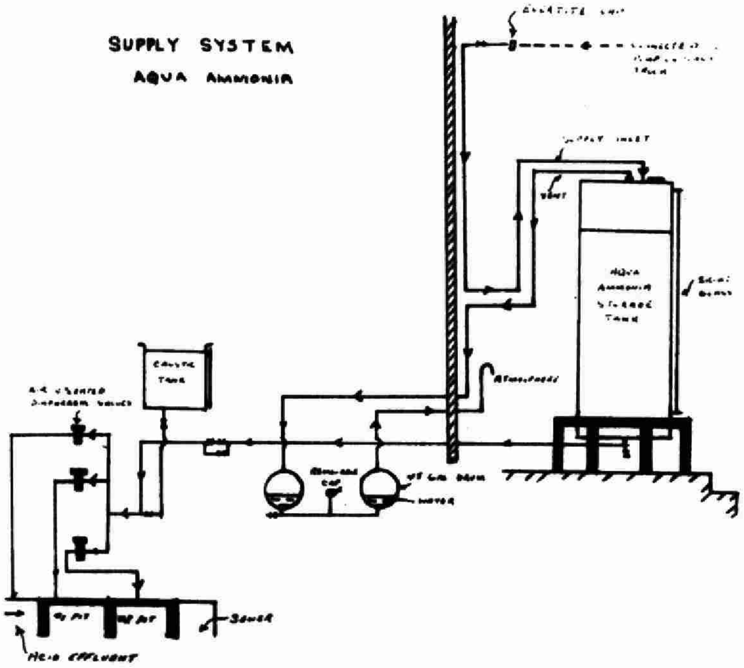
Note: Basis variation lies in increased Ca and Mg sulphate

Slide 4



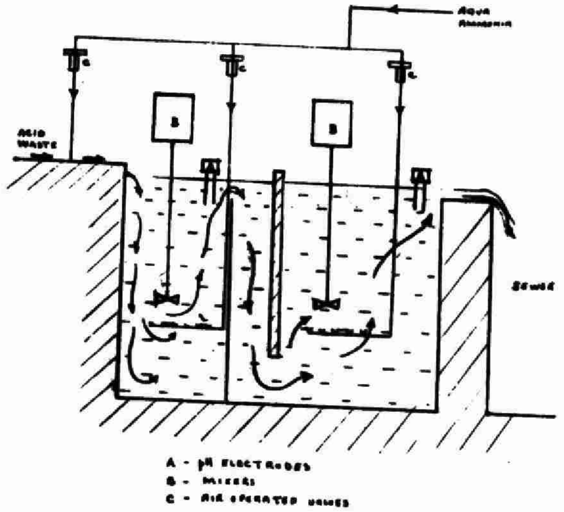
Slide 5

SUPPLY SYSTEM
AQUA AMMONIA

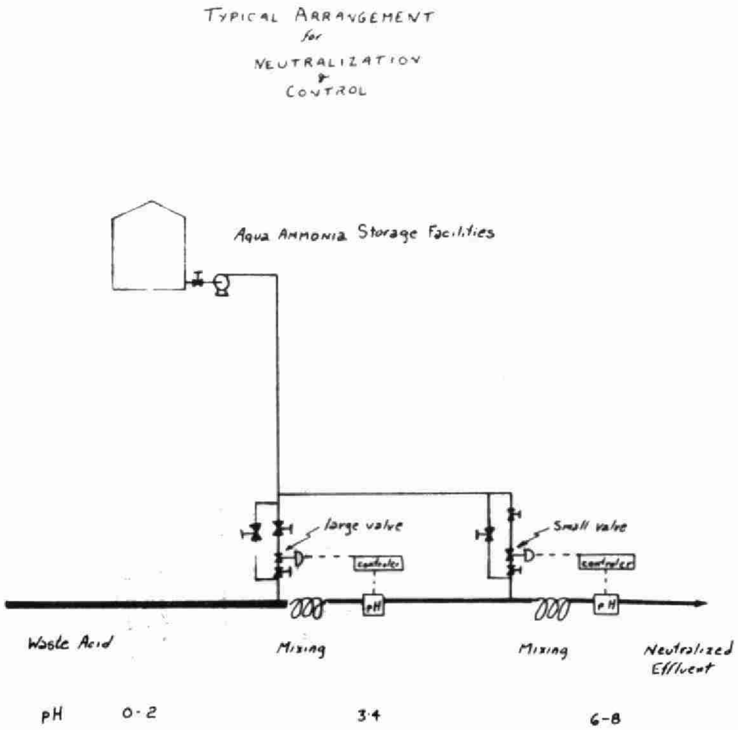


Slide 6

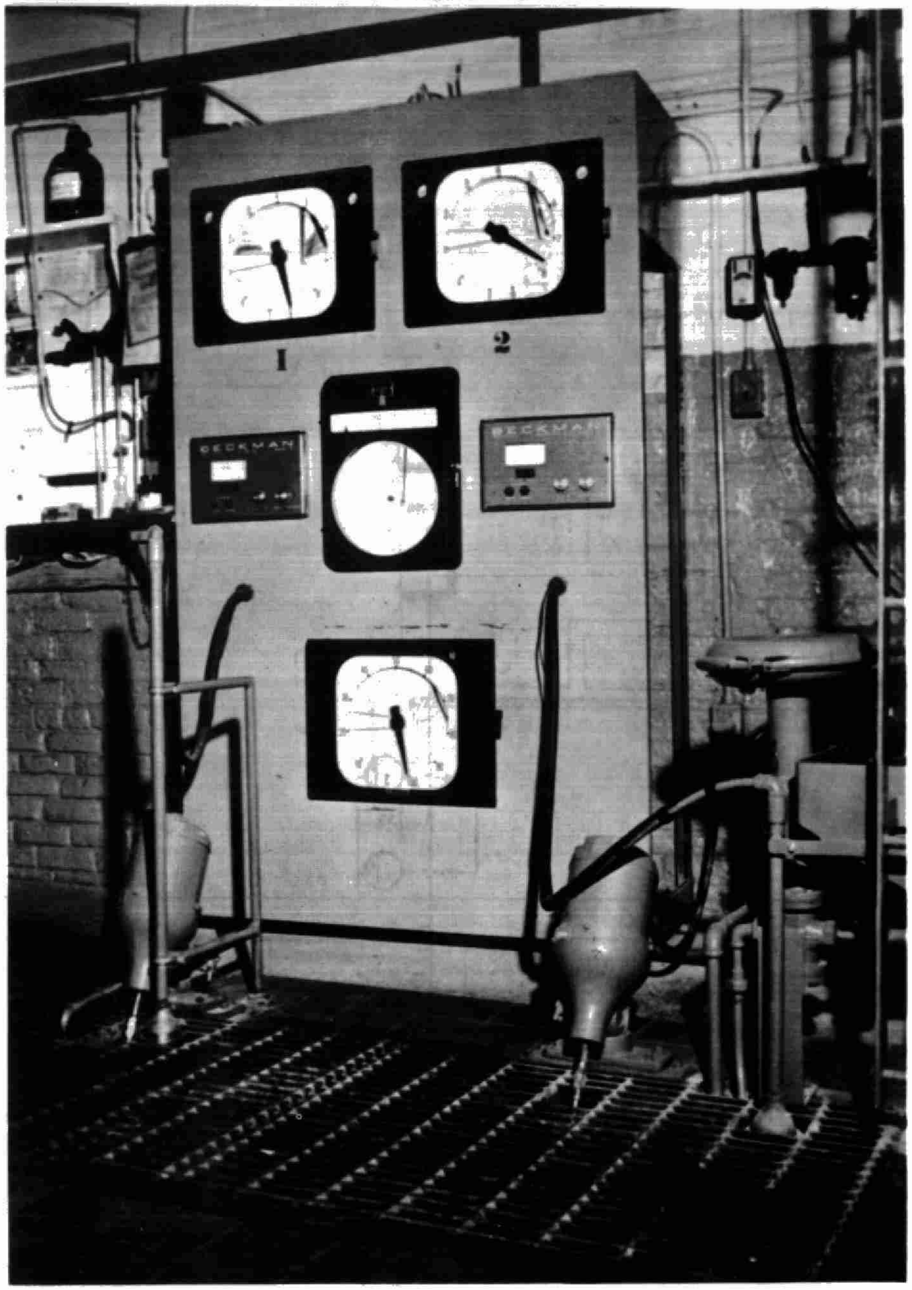
NEUTRALIZATION
PITS



Slide 7



Slide 9



Slide 8

A. E. KRAMER

"DESIGN AND OPERATION PROBLEMS OF A TREATMENT PLANT FOR METAL FINISHING WASTES"

by

A.E. **KRAMER** and H. **NIERSTRASZ**

INTRODUCTION

This paper is a description of the practical problems encountered in the design and operation of the Waste Treatment Plant at Northern Electric Company, Limited, Toronto Works, in Bramalea, Ontario.

(Figure #1)

The plant, located in Bramalea, Ontario, was built in 1962 to satisfy the increased demand for communication equipment, previously manufactured in the Montreal Works. It has a floor area of 480,000 sq. ft. The Metal Finishing Department occupies approximately 10,000 sq. ft. and the Waste Treatment 3,300 sq. ft. of this area. The plant employs 2,000 people of whom 34 are directly associated with metal finishing operations.

The products of this plant are telephone switching equipment for private branch (local and long distance) offices. The main load of the Metal Finishing Department consists of relay components and crossbar switch parts as well as a variety of findings. The finishes comply to rigid specifications and high quality standards. They are mainly applied for functional reasons such as corrosion resistance, solderability, and wear resistance.

(Figure #2)

Finishing processes in the plant include: Electroplating of zinc, copper, tin, nickel and chrome (Figure #3); also cleaning of copper, brass, aluminum, high and low carbon steel, and silicon steel. This is carried out in 1 zinc automatic, 1 nickel-chrome automatic, 1 semi-automatic barrel-line, 1 semi-automatic silicon cleaning line, 1 aluminum etch line. The nickel chrome automatic includes a rack stripping cycle. For deburring of small pieceparts a rotary barrel and a vibratory finishing machine is in use. Waste waters from the finishing processes are highly toxic and require chemical treatment before discharging into the sanitary sewage system. The design of a Waste Treatment Plant was, therefore, included in the planning of the Plating Shop.

DESIGN CONCEPT FOR THE WASTE TREATMENT PLANT

The first Northern Electric Plant which was equipped with Waste Treatment facilities was built in 1959, in London, Ontario. The advice of consultants was sought in developing the design. The Treatment Plant for the Toronto Works, however, was designed by our Plant Engineering Division.

The design procedure is described in the literature. The treatment methods have been well known for several years and are widely used. The task we were faced with was to evaluate and select the optimum combination of the available systems and equipment that provide the most reliable operation at minimum cost.

The starting point in the design process is obviously the regulations and/or By-laws in force at the plant location. Toronto Works was designed to conform to the Ontario Water Resources Commission water quality objectives for discharge to the sanitary sewer. During the design stage the advice and co-operation of the Ontario Water Resources Commission was invaluable.

The By-law prohibits the discharge of any waste into the sewage system "which might interfere with the operation of sewers or sewage plant." Knowledge of the type and operation of the sewage plant is, therefore, a necessary step in the design procedure.

The next problem is the determination of average and peak flow rates and also an appreciation of future requirements. To minimize capital and operating costs, close co-operation between the plating engineer and the plant engineer is essential. Substantial savings can be realized in the cost of rinse water and associated treatment costs by selecting multiple rinses in the Plating Shop instead of the conventional single rinses. Cascading of rinse water, the use of air agitation, solubridges, surface active agents, etc., are all contributing factors in the saving program. All these factors must be recognized in the initial planning stage because in general it is too costly to make the change later. It is most advisable, therefore, that the Plating Shop and the Waste Treatment Plant be designed simultaneously and preferably by the same personnel.

Every plant we visited either increased its capacity, or planned to do so, within the first five years of operation. There is a tendency to undersize the treatment plants and allow for the minimum requirements only. Plating shops generally expand soon after the initial installation, requiring additional treatment capacity. It is advisable to plan and allow for future expansion in the original layout, thus eliminating costly and time-consuming re-arrangement later when the addition becomes necessary.

RINSE WATER REQUIREMENTS

Good rinsing is required to prevent contamination of solutions used for cleaning or plating with chemicals from previous baths that may result in defective plating, staining, or corrosive action of the finished parts, greater losses of chemicals, etc. To guarantee a product with optimum qualities, rinsing must be adequate. The rinse water treatment cost is to a large extent proportional to the volume. Therefore, the minimum flow requirements should be determined very carefully. The literature provides several formulae that can be reduced mathematically to the following two equations:-

(Figure #4)

I The "minimum" formula: $Q = \frac{V}{t} \ln \left[1 + \frac{D}{V} \sqrt[n]{\frac{Co}{C_1}} \right]$

II The material balance or "average" formula:

$$Qa = \frac{D}{t} \sqrt[n]{\frac{Co}{Ca}}$$

wherein Q is the minimum continuous flow in U.S. G.P.M.
Qa is the average flow in U.S. G.P.M.
V is the volume of the tank in U.S. gallons.
t is the minimum cycle time in minutes.
D is the drag-over volume in U.S. gallons.
Co is the concentration of the preceding process solution in oz/U.S. gallon.
C_1 is the maximum allowable equilibrium concentration of the rinse water in oz/U.S. gallon.
Ca is the average concentration of the rinse water to be discharged to the Waste Treatment Plant in oz/U.S. gallon.
n is the number of rinses between two process tanks.

For multiple rinsing both formulae will give similar results. However, for single rinses the average formula could produce values which are too high to be practicable. This is especially the case in barrel plating with high drag-out rates.

The variables can be easily established from the design intent except for the drag-over D and the rinsing criterion Co/Cl. The literature gives some figures (Graham, A.K.: The Electroplating Engineering Handbook, page 709) that vary from .2 to 10 gallons per 1,000 sq. ft. and thus cannot be applied directly. The original paper by Hanson and Zabban (Plating, pages 909 to 918, 1959) is a little more specific but still leaves room for interpretation. Consequently, it is advisable to determine the drag-over D by direct measurements on existing or experimental equipment.

We determined the drag-over by dipping a loaded barrel into a solution and rinsing it in an air-agitated stagnant rinse. By chemical analysis the concentrations of the solution and that of the rinse water were determined.

Knowing the volume of the tank, the drag-over volume could be calculated. Acids were titrated with .1 N sodium hydroxide. Alkalis, that normally have only low concentration, were determined with the aid of cyanide as a tracer. Cyanide can be analysed by titration with silver nitrate or colorimetrically. We found that the drag-over D is 0.6 to 0.8 U.S. gallon for a 14" x 30" barrel loaded, with parts having 100 sq. ft. of surface area. For racks on automatics and still lines we obtained figures close to the 5 gallon/1000 sq. ft., as mentioned by Hanson and Zabban.

The determination of the rinsing criterion Co/Cl requires establishing of the maximum allowable equilibrium concentration Cl. The figures recommended by Hanson and Zabban were used for critical rinses, like those before plating solutions. Slightly modified limits were used allowing higher concentrations in certain pre-cleaning operations that have no direct bearing on the quality of the product. Subsequently the rinse water flow is calculated for each tank using formula #1 on single rinses. For simplicity, formula #2 may replace #1 for multiple rinses, without significant change in accuracy.

In practice we have to take into consideration the deviations from the theory. Instantaneous mixing does not occur. To improve this it is advantageous to plan for agitation. Also, it is not always practical to keep the barrels in the rinse water for the full cycle time. They will therefore leave the rinse tank while the concentration is still above equilibrium level. To alleviate this problem, higher flow rates and solubridge controls can be used. The prime purpose of solubridges is to supply water when most required and to shut off the supply when equilibrium is reached. This makes it possible to realize maximum water economy. In our case we designed the water supply system for twice the calculated flow and let the solubridges control the feed to maintain the predetermined concentration. The advantage here is that the high contamination peak in the first part of the cycle is washed away immediately and also the drop in concentration is much faster; therefore, the parts leaving the tank in only a fraction of the cycle time will carry a much lower concentration. Solubridge control with high flow rates results in an actual saving in the daily water consumption compared to a continuous flow system. It was recognized that multiple unit solubridges are not as effective as the individual type. They are active for every half minute and are out of operation for 5-1/2 minutes. This creates a chance of 1:12 that the water supply does not come on when required and does not shut off when equilibrium concentration is reached.

From the rinse water formulae it is obvious that two rinses require a lower flow than a single rinse, since the rinsing criterion is replaced by its square root, (i.e. 25 G.P.M. is replaced by 2 x 5 G.P.M. = 10 G.P.M.) By cascading the last rinse to the preceding one it is possible to cut this amount in half (10 G.P.M. to 5 G.P.M.). However, it should be borne in mind that only a dilute second rinse should be cascaded into a more concentrated first rinse. It has been proposed to cascade single rinses from one kind of solution to another, or use acid rinses for alkalis and vice versa. Generally speaking, this is not recommended since the high salt concentrations may retard proper rinsing and leave too high salt concentrations on the metals. Acid rinses contain metals that precipitate in alkali media and would require a continuous supply of sequestering agents to keep them in solution.

To ensure that proper rinsing is carried out several steps must be taken. Air agitation is used to speed up the solution process. Experiments indicate that, for the majority of the barrel work, a minimum of three minutes is required to mix 95% of the adhering solution. For rackwork this time is shorter and depends more on the grade of agitation and the kind of solution.

Secondly, the solubridges are set by the plating engineer. It is advisable to enclose and lock the controls to prevent unauthorized personnel tampering with them. The probes must be cleaned regularly to prevent off-standard readings resulting from calcium scale build-up. (The use of softenered or deionized water is advantageous here). Thirdly, orifices are installed in the pipe lines to maintain the calculated flow levels. This can not completely prevent abuse since by-passes are required for filling the rinse tanks but it minimizes the need for readjustment of valves to maintain the specified flow.

After the theoretical flow rates for each tank have been calculated the total required rinse water demand is computed and tabulated for the entire shop. (Figure #5). This volume would be required only if 100% rinsing efficiency would be achieved; therefore, a correction factor is used. The generally accepted value for this factor is two. The calculated flow rates for each tanks are again tabulated using the correction factor and values are rounded off to the nearest practical figure. (Figure #5)

These practical figures are normally determined by the size in which the flow control valves are available. The total flow rates so computed will be the maximum momentary peak demand on the supply system. The probability of all solubridge controls calling for water at the same time is remote. This introduces the utilization factor. The value of this factor depends entirely on local conditions such as cycle times, work loads on different lines, holding or equalizing tank capacities, etc.

We selected 0.75 based on data obtained from similar installations adjusted by judgment to suit our conditions, and tabulated the expected flow. (Figure #5)

The supply piping is sized for twice the theoretical water requirement (2Q) to meet the maximum demand. The discharge and treatment systems are designed to handle 75% of the possible peak load, (.75 x 2Q = 1.5Q) which is still twice the expected average flow (.75Q), considering the 0.75 utilization factor. The instantaneous peak flow is taken up by the holding tank in each line. The minimum recommended detention time in each holding tank is two to three times the longest rinsing cycle in the respective stream.

COMPOSITION OF PLATING WASTES

The waste waters can be segregated into the following classes:- acids, alkalis, chromates, and cyanides. Each group is further sub-divided into concentrated and dilute streams.

(Figure #6)

The local conditions will determine whether a separate drain line for each type of effluent or a combined system is more economical. Generally speaking, as the number of streams increases, the investment cost rises, and the operating cost decreases.

At this plant the concentrated alkali and the cyanide dumps are combined as well as the acids with the chromates. The same is done with the rinses. The dilute waste waters which do not contain cyanides could be reclaimed by demineralization. This depends on the cost of treating larger volumes of water versus cost of larger demineralizer units. It could be justified if the cost of the larger demineralizer unit is offset by either the reduction in the size of the treatment equipment due to decreased volume or savings in the rinse water costs.

WASTE TREATMENT PLANT DESIGN

The effluent from the processing tanks is drained by gravity into a separate holding tank for each type of waste. These tanks are located in a large, acid-resistant, brick-lined pit underneath the Plating Shop. Pumps situated in the same pit transfer the wastes to the treatment plant some 300 feet away. For both the concentrated and the dilute cyanide systems, black iron pipes, mild steel tanks, and all-iron pumps are used. The maintenance record of these systems is excellent. The acid-chromate stream was constructed by utilizing schedule 80 PVC and pyrex drain pipes, plastisol-coated mild steel tanks, and ceramic-lined pumps. The drain lines are located in trenches protected with acid-resistant bricks. It might be worth mentioning that the ceramic-lined pumps have been satisfactorily handling a mixture containing hydrofluoric acid for two years.

The pumps are operated by level controllers equipped with emergency high level contacts. All motors, controls, and alarms are centralized in one control panel. Flood-proof electric motors are used both in the holding pit and in the treatment plant.

The retention time in the holding tanks should be at least twice the longest rinse cycle to provide a more balanced load on the treatment plant. It is our experience that spillage of cyanides or chromates do occur during the treatment of plating solutions; therefore, the floor drains should be segregated to prevent heavy metal or nickel salts being mixed with cyanide-containing wastes. This facilitates the treatment of the floor drains by the available equipment.

(Figure #7)

The wastes are treated in a fully automatic continuous process. The cyanides are oxidized by chlorine, the chromates are reduced by sulphur dioxide, and the pH of the outgoing wastes is controlled by the addition of acid or alkali. All dumps are pumped into two holding tanks. The cyanide dumps are bled into the cyanide treatment tank and the acids are retained for pH adjustment in the chrome treatment system.

The cyanide rinses run into the cyanide treatment tank. This unit is equipped with two sets of probes, one for measuring the oxidation-reduction potential, the other for measuring the pH. As the best operating conditions we found a pH of 10.5 to 11 and an O.R.P. of 250 MV, which can be preset on the control panel. This is the treatment process:-

The cyanide recirculation pump draws liquid from the treatment tank, brings it first to the caustic feed in the suction line and then to the chlorine injector, and returns it to the tank. The pH probe senses that the pH is below 10.5 and opens a solenoid valve which controls a pneumatic valve to add a 50% caustic soda solution from the storage tank to the suction line of the pump. The O.R.P. probe measures a potential, and if less than 250 MV opens the chlorine injection system. Chlorine gas is added until the O.R.P. rises to 300 MV. This means that now free chlorine is present in the tank and all cyanides must be oxidized to the less toxic cyanates. The pH probe at the same time closes the valve when the pH reaches 10.5. The now treated rinses leave the treatment tank and run into the two-compartment final pH adjustment tank. The reaction time is still not known with sufficient accuracy. It is known that the first reaction:

$$NaCN + Cl_2 = CNCl + NaCl$$

is instantaneous, but the hydrolysis reaction

$$2NaOH + CNCl = NaCNO + NaCl + H_2O$$

seems to take appreciable time and depends on several conditions. Chamberlain, for instance, reports that if pure sodium cyanide is used the reaction may be completed within 10 minutes but he also recommends in practice to use at least one hour retention after mixing for the hydrolysis reaction to reach completion, knowing that heavy metals slow down the reaction considerably. Our equipment did not lend itself to establishing accurately where the limit is for our conditions. However, we were successful in destroying cyanides with less than 40 minutes retention time.

The floor drain from the nickel automatic was carefully separated from the cyanide stream to make sure that no nickel salt can enter the system to interfere with the treatment process.

Similar to the cyanide treatment is the reduction of chromates, from the hexavalent to the trivalent state. We found as best operating conditions a pH of 2 - 2.2 and an O.R.P. of 460 MV. A pH probe in the treatment tank actuates a solenoid valve which adds concentrated acid wastes or fresh sulphuric acid until the pH reaches 2. A recirculation pump transfers liquid to the sulphonator which is operated by the O.R.P. control unit. As soon as the preset operating conditions are reached, the acid and sulphur dioxide feed is cut off. The tank effluent runs also into the two-compartment final pH tank. The final pH tank receives the treated cyanide rinses with a pH of 10.5, the treated chrome rinse with a pH of 2 - 2.2. The O.W.R.C. pH requirements for the outgoing waste is pH 5.5 - 9.5. We try to maintain a pH of 8.5 to ensure precipitation of copper, when present. If the pH should drop below 6.5 due to a sudden surge in the acid rinse, then the probe will open a solenoid valve and add 50% caustic soda solution. Alternatively, if the pH rises above 8.5, sulphuric acid is added automatically. The effluent is then pumped to the sewer. If the copper content should exceed the allowable limit, the precipitated copper salts would have to be removed.

It was found that the sizing of the automatic control valves in the chemical lines is very critical. Oversizing could result in excessive treatment chemical usage and high operating costs. We have added a 40% capacity trim in these valves to prevent cycling. With these processes and facilities an effluent is produced which meets the O.W.R.C. requirements.

(Figure #8)

The automatic control system is checked twice a week , which includes the inspection and standardization of probes and controllers. Every four hours a sample is taken from the effluent and analysed for cyanides and hexavalent chromes. These routine tests are simple, fast, and can be carried out by the stationary engineer on duty. He has the training either to initiate a corrective action or recognize that special assistance is required.

Special consideration was given to reduce the safety hazards associated with this type of operation. Each holding or treatment tank, as well as all sumps, are equipped with local exhausts. Forced ventilation is also provided to ensure one complete air change every two minutes in the treatment area. The process chemical storage area has a ventilation rate of one air change per minute. This exhaust rate maintains a negative pressure relative to the manufacturing areas to prevent the escape of contaminated air into the plant.

It is well know that cyanides discharged into the sanitary sewer could endanger human life. Hexavalent chrome surges can seriously interfere with the operation of the municipal sewage plant. To prevent either of these conditions occurring and still maintain around-the-clock operation, the critical facilities are duplicated. Chlorinated lime and sodium bisulphite are kept on hand for manual feeding into the respective treatment tanks as an additional safeguard against discharging harmful wastes.

SOLID REMOVAL SYSTEMS

From preliminary investigations it became evident that the total suspended solids concentration of our waste waters might exceed the limits specified by the O.W.R.C. The normal operating level is around 100 - 200 p.p.m. The spent acids contain an appreciable amount of dissolved metals. If this acid is fed directly into the treatment stream at a high rate, the metal hydroxide formed could increase the solids concentration as high as 3,000 p.p.m. or more. A pressure filter unit was therefore purchased to ensure a clean effluent.

The most critical parameter in filtration is the selection of the filtration rate. The rates mentioned in the available literature appear to be optimistic for our application. During visits to similar installations in the United States we found that the rates actually used were considerably lower. The successful plants were operating between 0.04 and 0.08 G.P.M./sq. ft. of filter area. This rate depends on several factors, the most important being the iron hydroxide content and the neutralizing agent. Effluents containing less than 10% iron hydroxide appear to be relatively easy to filter while waste waters with more than 30% present almost insurmountable difficulties. Caustic soda is replacing lime as the neutralizing agent at several plants due to ease of handling. However, this change reduces the filterability of the resulting effluent and can necessitate the constant addition of filter aid or reduction of the filtration rate.

A constant filter aid feed means additional material handling, higher operating cost, and expense in housekeeping. To prevent plugging, a minimum ratio of filter aid to solid concentration should be maintained. It is economically prohibitive to add diatomacious earth to cope with extended peak conditions. The control of the metal hydroxide content should therefore be attempted. This control could be best achieved by manipulating the used acid feed into the stream. The timing and the rate of flow is equally important.

To reduce the process chemical cost, the acid dumps are bled into the chrome treatment tank automatically by the pH control system. Only if excessive acid is on hand is it discharged by manual control during light load periods. Utilizing this method, the process costs were reduced and as a by-product the total suspended solids level is kept within the allowable limits. Solids removal, it would appear, is no longer required at this plant.

It was found that pressure filtration is a very labour-consuming operation. All available labour-saving devices, such as hydraulics locking and opening, shaking, etc., are consequently worth investigating.

The filter cake has a tendency to slip particularly under these low flow rates. In effect, this means that the filter is used as a settling tank where the supernatant liquid is drawn off through the leaves. The leaf spacing can thereby be completely filled and extremely long cycles obtained. At one plant we have seen a filter in operation regularly for as long as 120 hours at a rate of .04 G.P.M./sq. ft. The resulting cake has a high moisture content. This should be considered when the sludge handling system is designed. Cycles this long, however, are exceptions rather than the rule. The average cycle time in the filtration of plating wastes varies between 4 to 16 hours. The filters could plug in less than an hour if the solid content of the waste waters is higher than 1,000 to 3,000 p.p.m. Therefore, multiple filter units or large holding tanks, or both, are required to maintain continuous service.

It was also found that stainless steel dutch weave leaves appear to perform better than either mild or stainless steel leaves covered with cloth, particularly where reclamation of the waste waters is considered. A cloth bag which is subject to tearing has a definite disadvantage over the dutch weave type.

Considering all these problems associated with pressure filtration, and also because the economics appear to favor gravity settling at our flow rate, we are presently investigating units of the latter type.

We have been informed that clarifiers for similar applications would produce an effluent of less than 50 p.p.m. suspended solids. This is well within the specified limits. The solids content of the sludge would be approximately 1 - 2%. To reduce transportation cost, additional thickening could bring it up to about 10%. This appears to be the concentrations of sludges obtained from filters operating without body feed.

Based on our experience gained in visiting plants equipped with filters and/or clarifiers, the following comparison can be made:-
Pressure filter systems require a highly qualified operator in attendance at all times and are subject to constant maintenance. The most common sources of trouble are the pumps, hydraulic systems, the filter bags and leaves. A filter is more sensitive to overloading or variations in the suspended solids concentration than a settling unit. The main advantage is clear effluent with properly maintained leaves. This is particularly important where re-use of the waste waters is considered. Filter units for lower flow rates generally require less floor space.

Clarifiers need little attention while operating and maintenance costs appear to be lower than for filters with comparable capacity. They can handle loads as high as 150% of the designed capacity and still produce an acceptable effluent.

Should a solids removal system be required in the future for our plant, a clarifier installation is foreseen.

INVESTMENT AND OPERATING COSTS

The cost of waste treatment seems to be rather high especially when compared with the plating costs. Our Plating Shop - which was called one of the most modern plating shops of Canada - cost about $400,000.00 installed. To treat its wastes, an additional $200,000.00 was invested. This excludes the possible future installation of a solid removal system. The Plating Shop requires an annual expenditure of about $25,000.00 for chemicals, while the treatment of the wastes requires around $20,000.00 for material only. The cost of chrome treatment is relatively minor since we utilize the ferrous iron and acid content of our waste acids. For cyanide treatment actually only the cost of chlorine should be considered since the sodium hydroxide is required anyhow to neutralize the normally acidic wastes. The chlorine represents only 5% of the total chemical cost.

It can be stated that the treatment of the waste acids are the cost-bearing items since they require neutralization and solids removal. For this reason pickling plants have gone to acid recovery by distillation or lime neutralization. For an integrated system it would mean that fresh acid and sulphur dioxide would have to be added to the chrome treatment, requiring additional sodium-hydroxide for neutralization, thus increasing the cost instead of reducing it.

From the above it is clear that even though for small plants it may be advantageous to use non-cyanide-cleaning and non-cyanide-plating solutions, in our case it would mean relatively little saving especially since pyrophosphate zinc and acid copper baths do not as yet produce the same quality plating. (In the past year great improvements have been made in this field and soon this statement may no longer be true). New cleaning solutions containing sequestering agents, like sodium gluconate, are replacing cyanide for many platers already.

The cost of solids removal is one of the most important factors in the treatment of wastes, since it is high in capital and annual expenses. A pressure filter costs roughly $20.00 per square foot of filtration area. This increases to $40.00 per square foot by the time it is installed. To provide capacity during change over either a large holding tank or an extra filter is required. This results in roughly $1,000.00/U.S. G.P.M. in capital investment.

Clarification is not very practical for low flow rates. The smallest workable clarifier system costs roughly $45,000.00 installed ($15,000.00 purchase price) and can handle 100 U.S. G.P.M. For a slightly higher cost (about $5,000.00 a larger unit can handle 200 U.S. G.P.M.

From the above it can be concluded that filtration is only economical in flow ranges up to approximately 40 U.S. G.P.M. Beyond that clarifiers are more advantageous. It should be noted also that planning for the future is very important not only from a practical point of view but mainly because increasing the capacity after a clarifier has been installed.is extremely expensive.

The running cost of filtration appears to be higher per gallon than clarification. Both filtration and clarification produce a "clear" effluent of about 25-40 p.p.m. and a metal hydroxide sludge that must be hauled away. Trucking costs increase with the volume in a straight line and depend strictly on local conditions. Reduction of the transportation cost can be achieved by concentration methods like centrifuging or vacuum filtration, but the volume must be sufficient to offset the extensive cost of investment and maintenance.

With filtration the maintenance cost may run high even if the best equipment has been selected. Labour cost, replacement of filter bags or leaves, and filter aid must be added to the cost of sludge removal. Unfortunately general figures cannot be given on running cost to suit all applications.

CONCLUSION

(1) Analysis and understanding of the design requirements, present and future, are necessary to ensure a properly sized plant. Provisions for future expansion will eliminate the need for costly modifications later.

(2) Experimental verification of process variables such as drag-out volumes, cycle times, allowable concentrations, etc., are highly desirable.

(3) The use of multiple and cascading rinses can substantially reduce the water requirements and the treatment plant investment.

(4) Conductivity bridge controllers and flow control orifices can successfully prevent water wastage.

(5) Softened or de-ionized water in certain rinse tanks will not only ensure better plating quality but will reduce maintenance costs on the controls.

(6) Sufficient holding capacity is required to accommodate hydraulic peaks.

(7) Gravity settling appears to compare favourably in both investment and operating costs with pressure filtration.

(8) It is advisable to have the Plating Shop and the Waste Treatment Plant designed simultaneously and preferably by the same personnel.

(9) Waste treatment, though it adds to the cost of electroplating, should not be considered only as a burden. A practical approach to this problem can result in the conservation of our natural resources at a reasonable cost.

APPENDIX

TESTING CYANIDE AND HEXAVALENT CHROME IN INDUSTRIAL WASTES

Several methods are available to test small quantities of cyanide or hexavalent chrome in industrial wastes. Practically all methods in use are colorimetric that can be used by visual comparison, with a comparator or with an electronic colorimeter. We use visual comparison with a comparator in the shop on a routine basis twice a shift. The electronic colorimeter in the laboratory is used only for control tests.

The "short method" for cyanide is based upon the conversion of cyanide into hydrogen-cyanide (prussic acid) and the reaction with the coloring compound. However, heavy metals and particularly nickel resist de-composition of their complex with cyanide. This is evident in the chlorination of cyanide which normally can be completed within 20 minutes but in the presence of nickel may take over one hour. Whenever heavy metals are present the "long method" may show positive while the "short" shop method indicates negative results. The "long method" consists of the distillation of hydrogencyanide (prussic acid) liberated by a strong acid and absorbed by sodium hydroxide thus converted into sodium cyanide. Subsequently the "short method" is used to evaluate the sample.

If heavy metals can be kept out, the "short method" is sifficiently accurate for routine shop analysis.

BIBLIOGRAPHY

1. Rinsing Theory and Practice

(1) Neil H. Hanson & Walter Zabban: Design & Operation Problems of a Continuous Automatic Plating Waste Treatment Plant : Plating (1959) P. 909 - 918.

(2) J.B. Mohler : Characteristics of Controlled Rinse Tanks : Plating (1956) P. 732 - 737.

(3) Joseph B. Kushner : Rinsing : Plating (1949) P. 798-866-915-918-1110-1130.

(4) Charles A. Walker & John A. Tallmadge : Chemical : Engineering Progress (1959) P. 73-79.

(5) H.L. Pinkerton : Rinsing : Plating (1952) P. 1016-1031.

(6) J.B. Mohler : Rinse Tank Control : Metal Finishing (1955) P. 66-68.

(7) John A. Tallmadge Jr. & Bryan A. Buffham : Rinsing Effectiveness in Metal Finishing : Water Pollution Federal Control Journal (1961) P. 817-828.

(8) Metal Finishing Guide Book Directory (1964) P. 409-415.

(9) Graham : Electroplating Engineering Handbook 2nd Edition (1962) P. 705-715.

2. Waste Treatment

(1) N.S. Chamberlain & H.B. Snyder, Jr. : Treatment of Cyanide and Chromium Wastes : Proceedings - Regional Conference on Industrial Health, Houston, Texas. Sept. 27-29, 1952.

(2) B.F. Dodge : America Electroplating Society Research Project No. 10 : Plating (1949)

(3) G.K. Erganian : Effect of Chrome Plating Wastes on the Warsaw, Indiana, Sewage Treatment Plant. : Purdue University Conference on Waste Treatment.

(4) C.R. Ekholm : Compact Waste Treatment System Give Flexonics Plenty of "Scrubbing" Action. : Plant Engineering Volume 15, No. 11,1961.

(5) R.W. Crain : A Realistic Approach to Waste Treatment. : O.W.R.C. Waste Treatment Conference, 1962.

(6) C.E. Shrayer : Systematic Waste Treatment Tames Seven Solutions. : Plant Engineering, August, 1964.

(7) J.F. Zievers & C.W. Riley : Handling Waste Sludges.

3. Chemical Analysis

(1) W.M. Aldridge : A New Method for the Estimation of Microquantities of Cyanide and Thio-cyanide. Analyst (1944) 69, P. 262; (1945) 70, P. 474.

(2) Butts, Gahler & Mellan : Colorimetric Determination of Acetates in Sewage and Industrial Wastes. : Sewage and Industrial Wastes (1950) 22 P. 1543.

(3) K.E. Longford : Analysis of Electroplating & Related Solutions (Draper, London) (1962) P. 319.

(4) Ohio River Valley Water Sanitation Commission : Procedures for Analysis Metal Finishing Wastes, (e.g. 54) P. 7, P. 28.

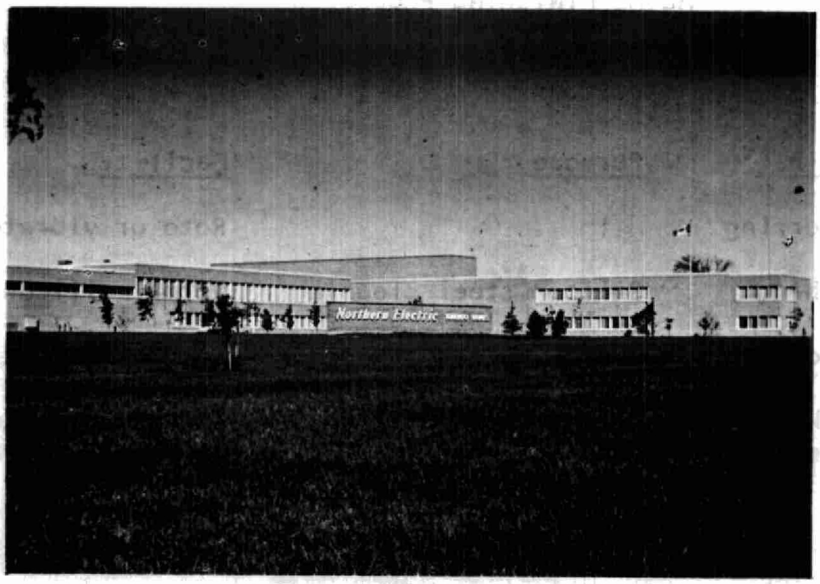


Figure 1

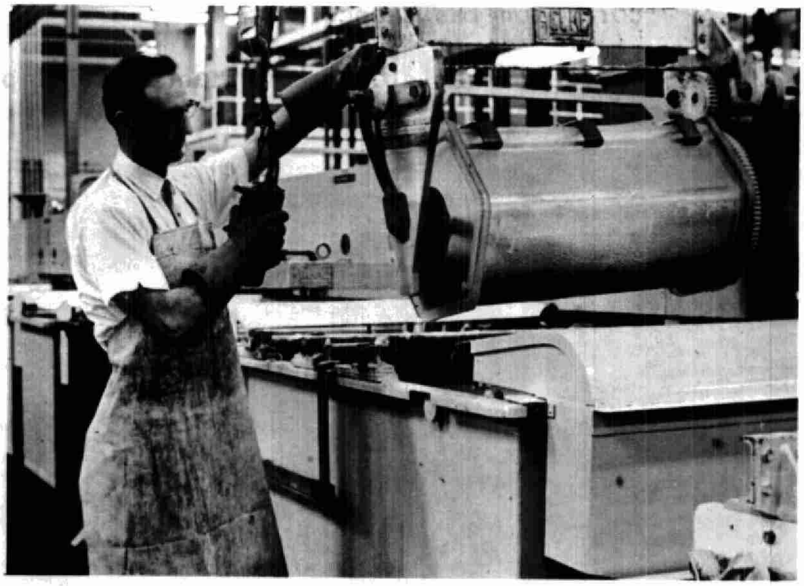


Figure 2

FIGURE 3

METAL FINISHING PROCESSES

Typical Product	Finish	Purpose	Facility
Relay Core:	(Deburring		Roto or vibratory finishing barrels
	(Etching	Silicon steel cleaning	Normal silicon steel cleaning line
	(Zinc	Corrosion resistance	Automatic zinc plating machine
	(Nickel-chrome	Corrosion & abrasion resistance	Automatic nickel-chrome plating machine with rack stripping facilities
Switch Frames:	Zinc	Corrosion resistance	Automatic Zinc Plating Machine
Findings:	Zinc	Corrosion resistance	Manual barrel plating line
Terminals:	(Copper	Underlayer for tin plating	Manual barrel plating line
	(Tin:	solderability and corrosion resistance	Manual barrel plating line
Mounting Plates:	Zinc	Corrosion resistance	Manual still plating line

FIGURE 4

REQUIRED RINSE WATER VOLUME CALCULATION

I The "minimum" formula: $Q = \frac{V}{t} \ln \left[1 = \frac{D}{V} \sqrt[n]{\frac{Co}{C_1}} \right]$

II The material balance or "average" formula:

$$Qa = \frac{D}{t} \sqrt[n]{\frac{Co}{Ca}}$$

wherein Q is the minimum continuous flow in U.S. G.P.M.
Qa is the average flow in U.S. G.P.M.
V is the volume of the tank in U.S. gallons
t is the minimum cycle time in minutes
D is the drag-over volume in U.S. gallons
Co is the concentration of the preceding process solution in oz/U.S. gallon
C_1 is the maximum allowable equilibrium concentration of the rinse water in oz/U.S. gallon
Ca is the average concentration of the rinse water to be discharged to the Waste Treatment Plant in oz/U.S. gallon
n is the number of rinses between two process tanks.

Rinse Water Requirements for Toronto Plating Shop

	Design Parameters									Supply			Waste	
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	tl	V	D	Co	CL	Qth	2Qth	Qx	Qy	CW	DI	SW	CN+ OH	Cr +H
B-2	15	180	.7	8	.1	3.5	7	7	5.25			7	5.25	
B-5	15	180	.7	48	.3	8	16	15	12	15				12
B-6B	10	50	.2	100	.15	6.5	13	15	9.75	15				9.75
B-8	15	180	.7	16	.1	6	12	10	9	10			9	
B-10	30	360	.3	26	.04	5.5	11	10	8.25	10			8.25	
B-12	30	180	.7	36	.04	9	18	20	13.5	20			13.5	
B-14	30	180	.7	20	.02	9.5	19	20	14.25	20			14.25	
B-16	30	180	.7	34	.1	5	10	10	7.5	10			7.5	
B-19	15	2x180	.7	5	.005	1.5	3	3	2.25			3		2.25
Sub-total						54.5	109	110	81.75	100		10	57.75	24.0
N-2	1.3	140	.02	8	.1	1	2	2	1.5			2	1.5	
N-4	1.3	140	.02	25	.04	10	20	20	15		20			15
N-6.7.8	1.3	3x140	.02	60	.002	1	2	2	1.5		2			1.5
N-11.12.14	1.3	2x140	.02	7	.002	1	2	2	1.5		2			1.5
N-18-19	1.3	2x140	.005	32	.1	.5	1	1.5	.75			1.5		.75
N-21	1.3	140	.005	64	.15	1	2	2	1.5			2		1.5
N-23	1.3	140	.005	6	.1	.5	1	1.5	.75			1.5		1
Sub-total						15	30	29	22.5		24	7	1.5	21.25
S-2	3	100	.25	8	.1	5.5	11	10	8.25			10	8.25	
S-4	3	100	.25	30	.3	7	14	15	10.5	15				10.5
S-6	3	100	.25	48	.3	12	24	25	18	25				18
S-8	3	100	.25	16	.1	12	24	25	18	25			18	
S-9	3	100	.25	.1	.005	1.7	3	3	2.55			3	2.55	
Sub-total						38	76	78	57.3	65		13	28.8	28.5
Z-2	.6	130	.03	8	.1	4	8	8	6			8	6	
Z-4.5	.6	2x130	.03	48	.1	1	2	2	1.5			2		1.5
Z-9.9	.6	2x130	.03	26	.004	4	8	8	6			8	6	
Z-11.12	.6	2x130	.03	3	.004	1.5	3	3	2.25			3		2.25
Sub-total						10.5	21	21	15.75			21	12	3.75
E-2	1	220	.03	8	.1	2.5	5	5	3.75			5	3.75	
E-4	1	220	.03	4	.1	1.2	2.4	2.5	1.8			2.5		1.8
E-7	1	220	.03	16	.3	1.6	3.2	3.5	2.4			3.5	2.4	
Sub-total						5.3	10.6	11	7.95			11	6.15	1.8
TOTAL						123.3	247	251	185.25	165	24	62	106.2	79.3

2Q = 246.6 Qy = 185.5 Qx = 251

Legend

Column # 0 Tank code according to -

B-2 = Alkali Cleaner Warm Rinse
B-5 = Hydrochloric Rinse
B-6B = Bright Dip Rinse
B-8 = Cyanide Rinse
B-10 = Zinc Cyanide Rinse
B-12 = Zinc Cyanide Rinse
B-14 = Copper Cyanide Rinse
B-16 = Tin Rinse
B-19 = Final Double Rinse
S-2 = Alkali Cleaner Warm Rinse
S-4 = Hydrofluoric Rinse
S-6 = Hydrochloric Rinse
S-8 = Cyanide Rinse
S-9 = Final Warm Rinse

N-2 = Alkali Cleaner Rinse
N-4 = Hydrochloric Acid Rinse
N-678 = Nickel Rinse
N-11.12.14 = Chrome Rinse
N-18.19 = Chrome Strip Rinse
N-21 = Nickel Strip Rinse
N-23 = Alkali Rinse
Z-2 = Alkali Cleaner Rinse
Z-4.5 = Hydrochloric Acid Rinse
Z-8.9 = Zinc Cyanide Rinse
Z-11.12 = Chromate Rinse
E-2 = Alkali Etch Rinse
E-4 = Nitric Acid Rinse
E-7 = Alkali Rinse

Column #1 t_1 = Cycle time in minutes. This is not dipping time t_d

e.g. td Barrel = 3 - 5 minutes

td Silicon = 0.5 - 1 minute

Column #2 V = Volume rinse tank in U.S. gallons

Column #3 D = Dragin/dragout volume in U.S. gallons

Column #4 Co = Concentration of previous tank

Column #5 New critical concentrations as accepted as our standards

Column #6 Flow calculated from #5

Column #7 Doubling of #6 for solubridges control as recommended by lit.

Column #8 Closest approach of #7 with orifices

Column #9 Qy = Average flow = 1-1/2 Qth

Column #10 City water supply

Column #11 Deionized water supply

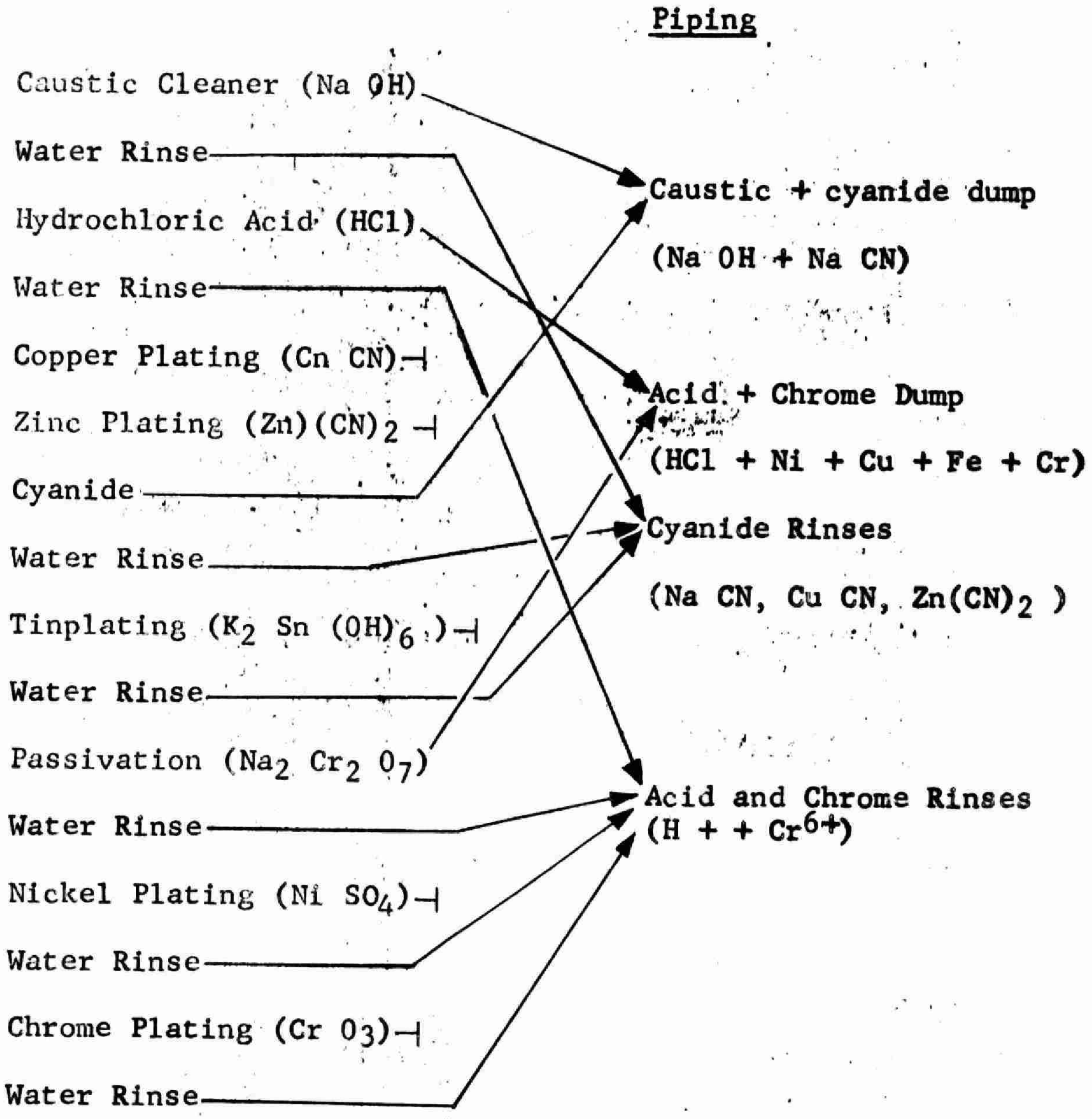
Column #12 Soft water supply

Column #13 Cyanide and alkali waste line

Column #14 Chrome and acid waste line.

FIGURE 6

SOURCES OF WASTES



EFFLUENT ANALYSIS

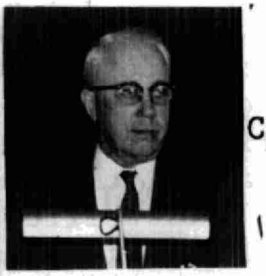
FIGURE 8

	Expected Range in Cyanide Rinses	Expected Range in Chrome Rinses	Expected Range from Rinses	Expected Range from Rinses & Dumps Together	O.W.R.C. Requirements for Sanitary Sewer (Proposed By-Law	Test Results of last Survey by O.W.R.C.
B.O.D.	-	-	-	-	-	2.8
Solids:						
Total -	50-100	200-500	100-400	150-1800	-	768
Suspended -	5-20	0.0	0-100	50-300	350	128
Dissolved -	45-80	200-500	100-300	100-1500	-	640
pH	9-10	2-3	7.0-9.0	7.0-9.0	5.5-9.5	8.1
CN as HCN	20-30	-	0.0	0.0	2.0	.5
Cr Total	-	5-10	0.4	0-10	-	.1
Hexavalent	-	5-10	0.0	0-1.0	3.0	0.0
Ni	-	1.0-2.0	0-1.0	0-1.0	-	0.0
Cu	.5-1.0	.5-1.0	0-1.0	0-1.0	1.0	.1
Zn	.5-2.0	0.0-.5	0-1.0	0-1.0	-	1.4
Sn	1.0-2.0	0.0-.5	0-1.0	0-1.0	-	1.0

ALL VALUES IN P.P.M.

HEAD TABLE

SESSION FOUR



Dr. A. E. Berry
Secretary-Treasurer
Canadian Institute on Pollution Control

Session Chairman

"MODERN CONCEPTS OF BOD-DO RELATIONSHIPS"

by

E. C. **TSIVOGLOU**

INTRODUCTION

The purpose of this report is to give a brief summary of some of the more recent work at the Robert A. Taft Sanitary Engineering Center on the factors involved in stream self-purification, with particular emphasis on the relationship of this work to the disposal of industrial effluents. It is not the purpose of this discussion to present the detailed mathematical models that have been developed, but rather only to describe the concepts that are currently under consideration and in use. The detailed mathematical descriptions of the complex BOD and oxygen sag processes that are referred to are contained, with examples, in a separate report that is in preparation.

The two primary processes involved in stream self-purification are deoxygenation (the exertion of the BOD) and the opposing process of reaeration, by which a stream takes up oxygen from the atmosphere. Recent work in the Technical Advisory and Investigations Section at SEC has been concerned particularly with the reaction kinetics of the BOD process, and with the development of tracer techniques that, it is hoped, will permit the independent determination of the reaeration capacity of a stream. However, before discussing these subjects in more detail certain basic points require emphasis.

Deoxygenation, expressed in terms of a BOD, is the process in which organic pollution subjected to bacterial attack is oxidized, with a resulting depletion of the available dissolved oxygen of the water. It is a biochemical reaction whose rate depends upon such factors as the degradability of the organic material, the quantity of organic material present (available food), temperature, the presence of a suitable and adequate bacterial population, and the availability of certain necessary nutrients. It should be emphasized that, properly performed, the BOD test is a very sensitive measure of the oxygen-depleting ability of the organic material present. As such, it is a very useful and important measure of effluent and river quality. However, it should also be clearly understood that the BOD test is quite specific, and in particular was never intended to be a universal measure of pollution. For example, it has no relation to the coliform content of water, nor does it provide adequate information regarding the chemical toxicity of pollutants. Thus, in order to fully characterize a pollution situation, a number of analytical determinations are necessary, of which the BOD is only one. However, it should be borne in mind that the BOD is a quite general test for the oxygen-depleting characteristics of organic material.

Reaeration, the absorption of atmospheric oxygen by a turbulent stream, is a purely physical process, in contrast to the biochemical nature of the BOD process. Reaeration takes place because of an oxygen partial pressure difference between the air and the water, and the rate at which reaeration takes place is proportional to the magnitude of the actual partial pressure difference. The rate at which the atmospheric oxygen is absorbed is also highly dependent on the degree of turbulent mixing that takes place in the water, as well as on temperature. Other conditions being equal, the degree of turbulent mixing, or the rate at which volume elements of water are exposed at the air-water interface, is a controlling factor in reaeration.

The natural self-purification process in a polluted stream is essentially the resultant of the two processes of deoxygenation and reaeration. Stream self-purification is therefore a time-temperature function, and because of the specific nature of industrial wastes and the specific hydraulic turbulence characteristics of various stream reaches, each stream has a different, or individual, self-purification capacity. The self-purification process, in idealized form, is expressed mathematically in the famous oxygen sag equation of Streeter and Phelps.[1]

Other factors that affect the course of stream self-purification are recognized. These include the activities of attached slimes on the stream bed, the effect of sludge deposition and oxygen demand, the effects of tributary runoff (bringing in additional pollution and dissolved oxygen), and the photosynthetic and respiratory effects of algae. These are viewed, however, as external, or side, effects to the main processes of deoxygenation, according to the BOD, and reaeration with atmospheric oxygen. This discussion will be confined to the two primary factors of deoxygenation and reaeration, and to the simplified and idealized, but elegant, form of the oxygen sag equation.

KINETICS OF DEOXYGENATION

There has been considerable discussion over the past several decades regarding the exact course of the BOD reaction. It has been shown[2, 3] that the traditional first order reaction kinetics so thoroughly demonstrated by Theriault[4] is not always an adequate representation of the course of the BOD reaction. Theriault's first order kinetics postulates essentially that the time rate of change of the concentration of available food (organic material) is proportional at any time to the concentration of food remaining. Most observed BOD rate curves are still quite adequately described by this first order reaction mathematics, so far as the carbonaceous phase, or first stage, of the process is concerned. However, an increasing number of BOD rate curves observed in recent times are more complex. They arise in part from the increasingly complex nature of the organic constituents of industrial effluents. Although such curves are not adequately described by the simple first order kinetics referred to above, they do not disprove or discredit the first order reaction kinetics of Theriault. They do indicate that a single first order reaction is not always an adequate description of the BOD process.

Recent work at the Technical Advisory and Investigations Section of SEC has indicated clearly that what is required to explain and describe the more recently observed complex BOD reactions is a relatively simple expansion and generalization of the first order kinetics of Theriault.

In brief, it is necessary only to recognize that in specific cases there may be simultaneous but independent first order reactions, and that in other cases the observed BOD rate curve may reflect sequential first order reactions due to the chain degradation of complex organic compounds.

Multicomponent BOD Reactions

An increasing number of BOD rate curves observed during studies of pollution situations in the United States clearly show the presence of simultaneous but independent first order reactions. These are referred to as multicomponent BOD rate curves. That is to say, the observed BOD rate curve is not adequately described by a single first order reaction but that it can be fully described by the assumption of two first order processes that take place simultaneously but independently. The first noted example of this has been detailed earlier in the literature.[2] In that case the two processes resulted from the addition of relatively large amounts of ammonia as a pollutant in the presence of other more usual organic materials. Additional examples, more recently observed, involved the presence of specific industrial effluents, such as wool scouring wastes, in the presence of more usual organic materials.

Thus far in our experience it has not been necessary to assume the presence of more than two first order components in any observed BOD rate curve in order to be able to fully describe the course of the observed reaction mathematically. However, there is every reason to expect that three or more components, each having a substantial demand, may occur.

The occurrence of multicomponent BOD reactions is determined by the application of a graphical procedure for analysis of the BOD reaction kinetics, as outlined in Reference 2. Having observed the presence of a multicomponent reaction, it is highly desirable to determine the reasons for it in the particular situation such as, for instance, the presence of a specific industrial waste in the presence of more ordinary organic pollution.

It should be noted, also, that the oxygen sag equation can be readily modified to include multiple first order BOD processes rather than a single deoxygenation reaction.

Sequential First Order BOD Reactions

It is well known that certain complex organic compounds are degraded by bacterial action in a sequence of steps rather than in a single process. In such cases the compound is degraded by bacterial action to an intermediate compound that is not fully oxidized but is still biodegradable. This intermediate compound is degraded, in turn, either to a stable (nondegradable) end product or to another intermediate. Eventually this sequence leads to a stable (fully oxidized) end product. The reaction is fully analogous to the radioactive chain decay process in which a parent element decays to a first daughter, which is also radioactive and which in turn decays to a second daughter, etc., until a nonradioactive end product is reached.

The essential point is that in either case the steps involved in reducing the material to stable form are sequential rather than simultaneous. Each step in the sequence is first order, but a later step in the degradation cannot take place until the preceding steps have occurred. Examples of compounds that break down sequentially would include benzene compounds such as detergents.

The mathematical models for chain degradation of complex organic compounds are identical with those for radioactive chain decay, except that the symbols refer to the concentration of the organic material rather than to a concentration of radioactive atoms. It should be emphasized that the several reaction velocity constants involved in the associated steps of the chain degradation process are not the same, except in rare cases. For instance, with complex organic materials that are known to be difficult to degrade, it is often the case that the first step takes place at a very low reaction rate, whereas, once the intermediate product has been formed, the second step in the degradation process may be quite rapid. In this case the observed oxygen demand curve would develop slowly, the slow reaction constant controlling. In the opposite case, that is, for a reaction in which the first step is rapid but the second step slow, the observed BOD rate curve develops fast initially but then continues at a slower pace for a relatively long time.

It should be noted that direct observation of the sequential BOD process is rare, even though its occurrence is obvious. The complex compounds that are degraded in this manner are not ordinarily present in river samples or most effluents in sufficient quantity to constitute a substantial portion of the total BOD. Thus direct observation of the sequential reaction will not usually be possible except in the laboratory with specific chemicals, although it appears likely that thorough investigation would disclose an occasional industrial effluent that reacts in this manner. In addition, the sequential reaction having a relatively rapid first step with a slower second step is not distinguishable mathematically from a reaction involving two simultaneous but independent first order processes. The necessary mathematical models that characterize the chain degradation BOD process are contained in the more detailed reference currently in preparation.

Logistic BOD Reactions

The "logistic" function developed many years ago[5] is widely known and used in other fields,[6] although it is not so familiar in sanitary engineering. It is a second order function that was initially developed as a best means of describing the sigmoid curves of human population growth with time. In later years the function was recognized as being applicable in a number of other fields. For example, it describes the "autocatalytic" reactions of chemistry. It is also referred to as a bimolecular reaction.

The logistic function has features that make it especially attractive as a means of describing certain BOD processes. In particular it can be used as a means of describing the lag period so often observed in BOD reactions, and it is especially effective as a description of the lagging portion of the nitrification stage of the BOD process.

Bearing in mind that the observable BOD results from the activity of a large bacterial population which obeys relatively simple rules regarding the available food supply, it is logical to expect that the logistic function might properly describe the lagging portion of the BOD process. The first order reaction is one in which the food supply is limiting and controls the course of the reaction - that is to say, the bacterial population involved is as large as the available food supply will support. Thus, as the food supply is consumed the bacterial population diminishes accordingly. In contrast, the nitrification phase of the BOD process is characterized by a period during which the necessary bacterial population is quite low relative to the amount of available food. This results in a lag period during which the bacterial populations multiply until they reach the limit that is associated with the available food supply. This phase of population development is apparently logistic in nature, and is quite adequately described by the logistic function.

Thus, using the necessary combination of first order and logistic functions it has proved possible to fully describe the course of the BOD reaction, including the nitrification stage, with a logical and familiar mathematical model. Although the carbonaceous BOD is usually primarily responsible for the magnitude of observed criticial stream D.O's, it is becoming more common, in these times of higher degrees of waste treatment, for nitrification oxygen demands to contribute significantly to the occurrence of low stream D.O. concentrations. Under these circumstances it is becoming more important to be able to predict the course of nitrification with adequate mathematical models, and it appears that the logistic function is highly useful for this purpose. The necessary equations, with examples, are given in the reference noted above which is in preparation.

SUMMARY

The foregoing is a brief description of the concepts of BOD reaction kinetics presently in use at the Technical Advisory and Investigations Section at the Robert A. Taft Sanitary Engineering Center. The full description of the mathematical models involved will be available shortly. The purpose of this discussion, however, has not been to present the detailed mathematical model, but rather has been to emphasize the need for adequate descriptions of BOD reaction kinetics in modern-day society. It is impossible to adequately know the oxygen-depleting capability of a particular industrial effluent on the basis of 5-day BOD determinations. The cost of treating industrial effluents, to say nothing of the costs of releasing unknown kinds and quantities of wastes to our water courses, requires adequate knowledge of the oxygen-depleting characteristics of industrial wastes. This knowledge can only be developed by the thorough analysis of the BOD reaction kinetics, as determined on the basis of observed BOD rate curves. Without this knowledge it is not possible to adequately design waste treatment plants and, in a substantial proportion of cases, waste treatment plants designed only on the basis of a 5-da7 BOD determination will prove inadequate to meet the desired D.O. objectives in receiving streams.

REAERATION OF STREAMS

Assuming that the deoxygenation of streams by flowing pollution loads is sufficiently well characterized mathematically, it remains to evaluate the opposing process, namely reaeration, in order to permit measurement and prediction of stream self-purification capacity. Unfortunately, the means for independent determination of the stream reaeration rate constant, K_2, still elude us, and hence estimation of stream self-purification capacity still involves a circular argument that prevents definite and firm results. A sharply increasing public demand for unpolluted streams at the same time that we have substantially greater pollution loads due to population and industrial growth indicates that the costs of waste treatment are bound to rise rapidly. In order to keep these costs as low as possible, consistent with specific stream D.O. objectives, it has become necessary to refine our estimates of stream self-purification capacity, and to substantially improve the necessary techniques and methods.

The traditional approach to estimating reaeration oxygen income and stream self-purification capacity has been to attempt to measure everything else and then calculate a reaeration rate constant by use of the oxygen sag equation or some other more sophisticated oxygen balance technique. This approach is taken because, to date, we have had no means of independently determining K_2. The difficulty is that D.O. concentrations in a stream are the net result of operation of a variety of causes, not all of which are measurable. Hence, the above computational procedure results simply in a calculated value of K_2 that incorporates sufficient error to compensate collectively for all of the actual errors of measurement or neglect that have been made. In some cases it is possible to thus calculate a K_2 which does not actually involve great error, but in others the resulting estimate of self-purification capacity contains substantial error. Subsequent computations of required degrees of waste treatment err accordingly, and the costs of such inaccuracy can be substantial. In essence, the necessary degree of waste treatment, and the associated costs, are highly sensitive to the magnitude of K_2, but we have no independent means of definitely knowing K_2.

Mathematical models derived from theoretical analyses of turbulent mixing do exist and permit independent calculation of K_2,[7,8,9] and such models are useful in giving us ranges of estimate. However, they are no more subject to independent verification than the value of K_2 itself, and hence there is no way to be sure which of the several models, if any, yields a correct or true value of K_2.

As a result of these considerations, research to develop an independent method for the field determination of reaeration rate constants has been begun by the Technical Advisory and Investigations Section at SEC. The initial results of this work are published elsewhere,[10] and need not be repeated here. The approach involves the use of a chemically inert radioactive tracer gas, krypton-85, as a means of defining the turbulence regime to the extent that the exchange capability for oxygen can be evaluated. The results so far are sufficiently promising to warrant attempts at field use of the tracer gas, and these studies are presently in progress.

In brief, other conditions of temperature, turbulence, etc., being equal, it is presumed that the ability of a gas to dissolve in water, or to diffuse out of water, is a fundamental property of the gas, related to its molecular properties. Thus the ability of krypton to diffuse should be related in a fairly simple manner to the ability of oxygen to diffuse. If the relative diffusivities of krypton and oxygen could be determined, then observed losses of dissolved krypton-85 from a turbulent water system would permit direct estimate of the ability of oxygen to be gained, under identical conditions. The relative gas exchange capabilities, or diffusivities, of krypton and oxygen have been determined experimentally, and it appears that the necessary basic relationship has been established.[10]

Field application of the krypton-85 tracer method involves the simultaneous use of two or three tracers. In principle only two are required, namely, the tracer gas and a second tracer to indicate the extent to which dispersion has taken place. Thus it is assumed that the concentration of dispersion tracer decreases from an upstream to a downstream sampling point only as the result of physical dispersion due to turbulent mixing. The concentration of gaseous tracer should decrease due to dispersion in the same way, but should decrease additionally because of losses of gas to the atmosphere. The percent loss of tracer gas to the atmosphere can be calculated directly from data on the amounts of tracers released together with observed concentrations at a downstream sampling point. The desired K_2 for oxygen is then obtained by use of the basic relative krypton:oxygen diffusivity and measured time of flow to the sampling point.

In practice, a third tracer appears desirable, namely a dye tracer such as pontacil pink. This tracer, used with a fluorometer at the sampling point, is convenient for time of flow determinations, for observation of the degree of longitudinal dispersion, and as a means of knowing when to sample for maximum concentration of the other tracers. If the dyes did not suffer losses to the stream bed the separate dispersion tracer would be unnecessary.

Initial field studies have indicated that the foregoing concepts and approaches are feasible, and necessary field methods have been developed. One difficulty remains - namely, the selection and testing of a specific tracer for dispersion that assuredly is not lost to the stream bed. In this connection also, it is understood that a new fluorescent dye that undergoes little or no such loss is now available. Thus it appears hopeful that field techniques can be perfected and tested during the coming year, and that they will lead to a practical technique for the field evaluation of the stream reaeration rate constant.

BIBLIOGRAPHY

1. Streeter, H.W., and Phelps, E.B. A Study of the Pollution and Natural Purification of the Ohio River. III. Factors Concerned in the Phenomena of Oxidation and Reaeration. Publ. Hlth. Bull. No. 146, U.S. Public Health Service, Wash., D.C. (1925).

2. Tsivoglou, E.C. Discussion - Application of Stream Data to Waste Treatment Design. Proceedings, Oxygen Relationships in Streams, U.S. Dept. Hlth., Educ., and Wlfre., Public Health Service, Robt. A. Taft San. Engrg. Ctr., Cincinnati, Ohio, p. 151-5. (1958).

3. Orford, H.E., and Ingram, W.T. Deoxygenation of Sewage. I. Critical Review of the Monomolecular Formula. Sewage and Indus. Wastes, 25, No. 4, 419-34. (April 1953).

4. Theriault, E.J. The Oxygen Demand of Polluted Waters. Publ. Hlth. Bull. No. 173, U.S. Public Health Service, Wash., D.C. (1927).

5. Ostwold, W. Jnl. Prakt. Chem., 136, 481. (1883).

6. Reed, L.J., and Berkson, J. Application of the Logistic Function to Experimental Data. Jnl. Phys. Chem., 33, 760-79. (1929).

7. Phelps, E.B. Stream Sanitation, John Wiley and Sons, New York, N.Y., 150-54. (1944).

8. O'Conner, D.J., and Dobbins, W.E. The Mechanism of Reaeration in Natural Streams. Jnl. San. Engrg. Div., Proc. Am. Soc. Civ. Engrs., 82, No. SA6. (Dec. 1956).

9. Krenkel, P.A., and Orlob, G.T. Turbulent Diffusion and the Reaeration Coefficient. Jnl. San. Engrg. Div., Proc. Am. Soc. Civ. Engrs., 88, No. SA2, 53-84. (March 1962).

10. Tsivoglou, E.C., O'Connell, R.L., Walter, C.M., Codsil, P.J., and Logsdon, G.S. Tracer Measurements of Atmospheric Reaeration. I. Laboratory Studies. Jnl. Water Pol. Control Federation. In press. (Oct. 1965).

Mr. D.S. Caverly
General Manager, Ontario Water Resources Commission

Dr. James A. Vance
Chairman, Ontario Water Resources Commission

AFTER DINNER SPEAKERS

J. E. HANWAY, JR.

"THE APPLICATION OF THE CONTAINER-COPELAND PROCESS TO STREAM POLLUTION PROBLEMS"

by

J.E. **HANWAY, JR.**, and G.G. **COPELAND**

ABSTRACT

The Container-Copeland Process was originally developed to mitigate stream pollution problems caused by waste pulping effluents from neutral sulfite semi-chemical pulping mills. In this application, in which the organic constituents extracted from wood during pulping are concentrated and burned in a fluidized-bed reactor, the process has been eminently successful.

Since its original development, the basic concept of the Container-Copeland Process has been applied to treatment of other types of pulping waste where it possesses the potential of not only preventing stream and air pollution from pulp mill effluents, but of also recovering chemicals from the waste effluents stream. In this manner, stream and air pollution problems are solved and at the same time an economic return may be realized from the treatment plant investment.

In addition to treatment of pulp and paper mill wastes, the basic concept of the Container-Copeland Process may also be applicable to treat other industrial and also municipal wastes. It would appear that many waste effluents commonly encountered in the chemical, steel, petroleum and food industries and which represent a formidable stream pollution problem could be feasibly and economically disposed of by the Container-Copeland Process. The field of municipal waste treatment, with its problems being accentuated by our population explosion, represents another promising application of the Container-Copeland Process.

The development of the Container-Copeland Process is described. The applications and successes in combating stream pollution for the paper and pulp industry are outlined, and the potential applications of the Container-Copeland Process in other industries to eliminate pollutional problems are presented.

INTRODUCTION

The term "population explosion", of vogue in the past several years, implies many things in our future. Problems of food supply, housing, transportation and education are with us now or loom precariously in the immediate future because of the ever-increasing number of human beings on the face of the earth. "Spin-off" problems from the increasing population are important, too, but many, perhaps, have been relegated to positions of less concern. These ancillary "spin-off" problems, nevertheless, are equally as serious as the more basic ones which have been researched, studied and discussed by philosopher and technician alike.

The one "spin-off" problem with which we are specifically concerned here - that of stream pollution - has, in relatively recent time, been recognized as one of the greatest challenges to our foresight, ingenuity and application in order to preserve our natural heritage for our generation and future generations, and perhaps even more fundamentally, to ensure the health and well-being of countless of our world's population.

As industry gears up repeatedly to meet the capital and consumer goods demand of an expanded population, industrial pollutants will increase in volume. At the same time, the expanded population imposes an increased amount of domestic wastes that must be assimilated by some method. Yet, the very fact that more people are and will be inhabiting the earth requires that our natural resources - and particularly our streams - be preserved in such conditions conducive to safe and maximum use from both a public health and recreational standpoint.

Several facts are self-evident. Our pollutional load is ever increasing. Our stream potential for assimilating pollutants is not constant, but is actually decreasing at an accelerated rate either because of regulation or because of greater public use of these streams for other purposes. The time is coming when our streams cannot be used to dispose of our waste materials - other methods must be found. If the use of water is involved in these other methods, it must be used in closed-cycle operation or else returned to the stream at a quality no lower than when taken from the stream. All of this implies, of course, that our waste products, both industrial and domestic, must be treated to eliminate permanently their noxious, toxic, or offensive characteristics which lead to pollution of our water supplies.

From an industrial standpoint, the real question which remains is whether industry as a whole can react quickly enough to discover the necessary technical approach to the solution of each of the myriad of waste disposal problems leading to stream pollution and to meet the pressing deadlines being set by new legislation and public demand.

It is toward the technical aspects of this problem which this presentation is directed, with the ultimate objective being two-fold:

1. to show that new and improved methods of present industrial technology is capable of solving many of our immediate and near-future waste disposal problems, and
2. to stimulate new thinking, new application, new technology and, not the least, renewed ingenuity leading to continued solution of our waste disposal problems in the future.

THE CONTAINER-COPELAND PROCESS

The Container-Copeland Process was originally developed to treat the waste pulping effluent from NSSC pulp mills. In that application, the process employed a fluidized-solids oxidation technique for the treatment of a liquid waste solution containing organic matter and inorganic pulping chemicals derived as waste from a pulping operation. During treatment by the Container-Copeland Process, the liquid nature of the waste effluent was destroyed by evaporation of the contained water, the organic matter was converted to gaseous carbon dioxide and water vapor and the residual inorganic chemicals were recovered as dry, pelleted, and granular products. Since color and oxygen demand of the original waste material were primarily caused by the organic matter content, destruction of it by oxidation in the fluidized-solids reactor permanently and completely removed any possibility of subsequent pollution.

The salient part of the process is the use of the fluidized-solids technique. Fluidized-solids systems, although first proposed prior to the turn of the century for metallurgical use, are relatively new in industrial applications. They were developed extensively in the 1940's by the petroleum industry and have been used since in the chemical and metallurgical industries. Fluidized-solids systems function by virtue of the fact that solid particles can be set in fluid motion by passing a stream of gas, under carefully maintained conditions, up through the solid particles making up the bed or reaction zone. In travelling through the bed, the gas forces a passage between the particles of the bed and suspends them, setting these particles in heterogeneous motion and causing the entire mass or bed of solid particles to take on a fluid character. In this condition, the fluidized bed resembles a boiling liquid and obeys many of the laws of hydraulics. Mixing of the solid particles in a fluidized bed is rapid and complete, and gas-to-solid and solid-to-solid heat exchange is excellent. A fluidized bed, using air as a fluidizing gas, presents a large surface area of the solids in contact with the air because of the small particle size of the bed material. The gas and solids are in a state of intimate mixing, the efficient gas-solids contact obtainable provides optimum conditions for reaction, and close control of combustion or oxidation reactions is readily possible through simple adjustment of the fluidizing air flow.

Figure 1 illustrates the fundamentals of fluidized solids processing. As shown, a bed of solid material is confined in a suitable reaction vessel with an orifice or distribution plate. This plate distributes the fluidizing gas introduced at the bottom of the reaction vessel through the fluidized bed so as to keep the solids in fluidization. The solid material in the bed forms a dense fluidized phase with a clear line of demarcation between a dilute phase of solid particles and fluidizing gas which exists above the bed of fluidized material.

This dilute phase results from entrainment of the finer solids particles in the fluidizing gas passing out of the reactor. In most applications, this entrained material is separated in a cyclone collector and returned to the fluidized bed. The exhaust gases, devoid of particulate material, are passed to the atmosphere or to subsequent heat recovery or treatment phases of the specific process. The size of the solid particles in the fluidized bed is generally less than one quarter inch and ranges downward to micron or sub-micron sizes. Provision can be made to remove some of the bed material from the reaction vessel and to feed in new material as the process requires or as material accumulates in the fluidized bed.

Various reaction environments can be maintained in the fluidized-bed reaction zone. For example, if the feed material contains a combustible constituent and is fluidized with air, it is only necessary to raise initially the temperature of the reaction zone to the ignition temperature of the combustible material. The oxygen contained in the fluidizing air then causes oxidation or combustion of the combustible material. If the feed material contains sufficient combustible matter, autogenous oxidation can be carried on without the application of external heat. In like manner, if a reduction atmosphere is required in the reaction vessel, a fluidizing gas having a reducing potential is used. Heat energy can be furnished by external means if the specific reaction is endothermic.

It is evident from Figure 1 how a feed material containing organic combustible material can be introduced into a fluidized bed reaction vessel and the organic or combustible material oxidized and converted to carbon dioxide and water vapor, which then are discharged as gaseous products to the atmosphere. In this manner, which is the basic concept of the Container-Copeland Process, the pollutive elements of the feed material are completely destroyed and converted to a form which causes no pollution problems, either of a stream or air pollution nature. Any inorganic material contained in the feed remains in the reaction vessel and can be discharged as required. Various applications of the Container-Copeland Process employ certain modifications of this basic system. These modifications will be explored in detail subsequently.

The application of the Container-Copeland Process in waste treatment has proved to be primarily of an oxidative nature. This is true because most waste solutions having pollution-causing capabilities are organic in nature. Advantage is taken of the fact that oxidation of this organic material is thermodynamically favorable and furnishes thermal energy which can be employed to evaporate the water content with which most of these polluting materials is associated. In this way, the economics of waste treatment by the Container-Copeland Process is enhanced because it is not necessary in most cases to furnish heat or thermal energy by external means.

Because the nature of the Container-Copeland Process is essentially oxidative, it represents a permanent and complete solution to the treatment of many waste materials. By this method, the pollutional characteristics of the waste are eliminated with no danger of causing subsequent pollution. This is not true of some techniques currently being used for waste disposal, such as deep well methods, lagooning, etc.

APPLICATION OF THE CONTAINER-COPELAND PROCESS IN THE PULP AND PAPER INDUSTRY

Stream pollution as attributed to pulp and paper mills generally results from the discharge of that wood fraction which is digested or cooked out of the wood in the preparation of cellulose fibers for paper making. This fraction is organic in nature and consists of wood sugars, hemi-celluloses and a cementing material of complex structure which binds together the cellulose fibers in wood, called lignin. In combination with the inorganic chemicals used for digestion of the wood - normally, sulphur compounds of calcium, sodium, magnesium or ammonia - the waste material is dark brown or black in color and pollutes largely because of its reducing character and its consequent oxygen demand from receiving waters. The color that it imparts to the receiving waters also is objectionable.

The use of the Container-Copeland Process for treatment of waste pulping liquors from the paper and pulp industry is based upon the technique of preconcentrating the wastes so that the organic constituents, which possess fuel or heating values, are present in sufficient quantity to support combustion without the application of external heat. The degree of preconcentration is variable depending on the type of pulping employed and the kind of wood used; however, preconcentration to 25-35% total dissolved solids (organic plus inorganic) is normally sufficient to support autogenous operation as maintained in a Container-Copeland unit.

After preconcentration, the waste, containing from 65% to 75% water, is introduced into the fluidized-solids oxidation reactor. The combustible organic material is oxidized at an elevated temperature (i.e., from 1200 to 1800 degrees F.), and the heat liberated during oxidation is sufficient to maintain the desired operating temperature. The organic material is converted to carbon dioxide and water, and the inorganic constituents are oxidized to their most stable oxidation state. The inorganic constituents normally remain in the fluidized bed as a dry, granular, material and form the material of the bed. As the product of chemical accumulates in the bed, it can be discharged as a solid product. In some cases it would not appear practical to attempt to convert these inorganic products to pulping chemicals; however, in the majority of cases, the inorganic product has a tangible value, can be re-used directly to regenerate cooking liquors, or can be converted to chemicals usable in the pulping process.

The two major areas of pulping in which the Container-Copeland Process is capable of eliminating stream pollution problems are those of sulphite and sulphate pulping, clearly the two most important techniques used today for pulp production.

Sulphite Pulping Applications

In most cases, sulphite pulping installations must dispose of their waste liquors because of the lack of suitable chemical recovery techniques. This is true particularly in calcium and sodium base sulphite pulping and, to a lesser degree, in magnesia and ammonia-base sulphite pulping. In the majority of instances the spent liquor is simply discharged into adjoining water courses, thus creating a stream pollution problem.

The Container-Copeland Process is applicable to treatment of spent liquor from all types of sulphite pulping and leads to a permanent solution of the stream pollution problem. In addition, the process provides pulping chemical recovery directly in the case of magnesia and ammonia-base liquors and indirectly in the case of sodium-base liquors. This chemical recovery provides a positive economic return not usually associated with waste treatment techniques.

Sodium Base Sulphite Pulping Application

The original application of the Container-Copeland Process was made in connection with a NSSC pulp mill. A flowsheet depicting this application is shown in Figure 2.

The black liquor waste feed, on a 24-hour basis, amounted to about 575 tons. This waste had a concentration of about 9½% total dissolved solids as it was discharged from the pulp mill, with the remainder being water. The dissolved solids, distributed roughly equally between the organic constituents extracted from the wood and the residual inorganic pulping chemicals, amounted to about 55 tons per day and represented a total biological oxygen demand of about 21 tons per day. This waste material had formerly been introduced into impoundment lagoons and periodically released to an adjacent water course during periods of high water flows.

After installation of the Container-Copeland Process unit, the dilute waste is being treated as shown in the flowsheet. It is first introduced into a triple-effect forced-circulation evaporator unit to provide a concentration of about 35% solids. At this concentration, the organic or combustible content of the solution is sufficient to maintain autogenous combustion or oxidation in the subsequent fluidized bed oxidation step.

The concentrated feed, containing about 35% solids and 65% water, is introduced as a dispersed liquid spray into the top or freeboard area of the fluidized bed reactor. In the reactor, the organic material is oxidized and converted to carbon dioxide and water vapor and heat is liberated. This heat is sufficient to evaporate the water contained in the feed solution and to maintain the fluidized bed at a constant reaction temperature of about 1325 degrees F.

The exhaust gases are passed through a cyclone separator and any solid particles of bed material entrained in the gases are separated and returned directly to the bed. The exhaust gases then are subjected to a wet scrubbing step where any remaining fine particles of solids are removed. The final vent gases consist essentially of nitrogen, carbon dioxide, water vapor and oxygen. Sulphur compounds, such as sulphur dioxide or hydrogen sulphide that could cause air pollution problems, have not been detected in the exhaust gases.

The inorganic chemicals present in the waste are converted to their fully oxidized state, remain in the fluidized bed, and serve as the material of the fluidized bed. In the case of this particular NSSC installation, the inorganic chemical product is a mixture of sodium sulphate and sodium carbonate. During operation, these compounds tend to agglomerate in the fluidized bed, the particle size increases, and the particles assume a spherical shape. Size of the particles can be controlled by varying the characteristics of the method of feed introduction. The product is discharged from the bed at a rate consistent with the accumulation of product so as to maintain a fluidized bed of constant volume.

Figure 3 shows a photograph of a typical solid product from a commercial installation. This product consists of 65% sodium sulphate and 35% sodium carbonate within a particle size range of 20-65 mesh. This product cannot be used as such to prepare NSSC cooking liquor; however, continuing research and development work on recovery methods indicate some promising possibilities for a completely closed waste treatment and chemical recovery cycle in the near future. The present product does have value as a make-up chemical in kraft or sulphate pulping and present commercial sodium base installations using the Container-Copeland Process are marketing the mixed sodium-sulphate sodium-carbonate product to kraft mills and are realizing an economic return on its sale.

Thus, it can be seen that the Container-Copeland Process has eliminated stream pollution from this particular NSSC pulp mill. Almost 600 tons of a waste liquor per day, representing over 20 tons per day of oxygen demand, is converted to about 20 tons of a dry, pelleted inorganic residue which possesses no biological oxygen demand. It has eliminated any need at all for using water courses for disposal of waste pulping liquors.

The product can be marketed at an economic return, reconverted to pulping chemicals, or, if necessary, because it has no biological oxygen demand, can be dissolved in water for release to streams - within allowable dissolved solids and turbidity limitations - without serious danger of stream pollution.

Calcium Base Sulphite Pulping Application

Calcium base sulphite pulping employs calcium bisulphite as the active digestion chemical. The waste liquors from calcium-base wood digestion contain the extracted organic material from the wood and the residual inorganic chemicals used for pulping.

Figure 4 shows how the Container-Copeland Process could be applied to calcium-base sulphite waste, strictly on a waste disposal basis. The application is basically similar to that for sodium-base sulphite pulping.

The major difference in treating calcium-base wastes as opposed to sodium-base is in the nature of the solid, inorganic, product which would be obtained. Calcium sulphate would be the stable oxidized form of the residual pulping chemicals and would be the product discharged from the fluidized bed reactor. This compound is not particularly amenable for recovery of original pulping chemicals, nor is it of any substantial tangible value in itself. It is relatively insoluble, however, and little danger would be associated with disposing of it by landfilling or other similar methods. Contamination of run-off or ground water by such material would not be likely.

The Container-Copeland Process thus can be used to eliminate stream pollution problems associated with calcium bisulphite pulping wastes. Its advantages include a low cost, self-contained and essentially self-maintaining operation as far as utility and thermal requirements are concerned.

Magnesia-Base Sulphite Pulping Applications

Figure 5 shows application of the Container-Copeland Process to treatment of magnesia-base sulphite pulping waste effluents. The approach is similar to that of the basic Container-Copeland Process concept, except that not only is the waste disposal problem eliminated, but complete closed-cycle chemical recovery is obtained.

The initial phases of the treatment of magnesia base effluents follow the normal route. However, on oxidation within the fluidized bed reactor, the magnesium-sulphur compounds are decomposed into solid magnesia (MgO), which serves as the bed material and is discharged as the bed product, and sulphur dioxide (SO_2), which is contained in the exhaust gases. These two compounds represent the basic components of magnesia-base sulphite cooking liquors and, by a simple contacting of these two compounds in an absorption tower, cooking liquors can be reconstituted for re-use in the pulping process.

For magnesia-base sulphite pulping, therefore, the Container-Copeland Process represents not only a method to prevent stream pollution from waste pulping liquors, but also a method which allows substantial and economic recovery of pulping chemicals.

Ammonia Base Sulphite Pulping Applications

The application of the Container-Copeland Process to the treatment of ammonia-base sulphite pulping waste effluent parallels that described for magnesia. It, too, provides not only a means for prevention of stream pollution, but also permits substantially complete recovery of the pulping chemicals.

Figure 6 shows the application to ammonia-base waste effluents. Neutralization of the waste effluent with magnesia liberates a substantial portion of the ammonia as free ammonia. After evaporation, oxidation of the preconcentrated waste liquor in the fluidized-bed reactor decomposes the sulphur-bearing compounds so that sulphur dioxide is contained in the exhaust gases. The ammonia and sulphur dioxide then are recombined in an absorption tower to form the ammonium bisulphite cooking liquor.

Sulphate Pulping Applications

Stream pollution from kraft or sulphate pulping operations is less prevalent than other types of pulping. This is true because economic considerations usually dictate recovery and re-use of pulping chemicals from kraft waste liquors, and a successful technique is available, at least for the larger capacity kraft mills.

Figure 7 shows a typical application of the Container-Copeland Process for the treatment of kraft pulping waste effluent. The solid product obtained from the waste liquors would be sodium sulphate or a sodium-sulphate sodium-carbonate mixture, which would need to be converted to kraft pulping chemicals before return to the pulping process. It is believed that the major application of the Container-Copeland Process in the kraft pulping industry will be in the area of small kraft mills where present and conventional treatment and recovery techniques are not particularly economical. In such cases, the Container-Copeland Process will eliminate any need for discharge of waste pulping effluent into streams and will provide complete waste disposal and chemical recovery for these smaller mills.

APPLICATION OF THE CONTAINER-COPELAND PROCESS IN OTHER INDUSTRIES

As has been described, the basic concept of the Container-Copeland Process is applicable to many phases of the pulp and paper industry toward which the original development was directed. Additionally, however, there are applications in many other industries with the general objective to mitigate liquid waste disposal problems and to prevent stream pollution. Rather definite potential and actual applications can be cited in the steel, chemical, petroleum and food industries; however, there are certainly many other applications in these and other industries where use of the basic concept of the Container-Copeland Process would result in the successful solution of current waste disposal and stream pollution problems.

Steel Industry Applications

In the steel industry, various steel products are cleansed of surface scale, rust, and dirt by immersing in solutions of sulphuric acid. This operation is termed "pickling" and a waste acid product containing iron sulphate (from solution of some of the base metal in the acid) is produced. This product is difficult to reclaim and in many cases is discharged to streams or rivers either with or without neutralization.

Figure 8 shows the potential application of the Container-Copeland Process to this type of waste with the chemical reactions which would be involved. By treatment in this manner, the liquid nature of the waste is destroyed, the iron and sulphur contents are converted into usable compounds, and sulphuric acid is provided for re-use in the process.

Such an application would eliminate any possibility of stream pollution from acid pickling wastes from the steel industry.

Chemical Industry Applications

In many chemical operations, particularly of a catalytic nature, waste solutions are produced which contain some fraction of organic or combustible material. These solutions can be either acidic or non-acidic in nature. In many cases the solutions represent a pollution problem because they contain, in addition to the organic and inorganic constituents, a considerable amount of water, which eventually must find its way to the stream or river system. It is necessary, therefore, to remove the objectionable organic and inorganic constituents, which may be toxic, odiferous, have a considerable chemical and biological oxygen demand, or impart unwanted color, turbidity or suspended and dissolved solids to the stream.

Figure 9 shows the application of the Container-Copeland Process to a typical chemical industry waste solution. Essentially, all objectionable organic pollutants are destroyed and the only product, if inorganic or undecomposable salts or chemicals are present, is a solid, dry product of considerably less volume than the original waste and, normally, in a highly stable form which eliminates any future source of pollution.

Petroleum Industry Applications

In many petroleum industry operations, aqueous waste solutions are encountered which contain oil or organic sludge with certain solid materials, such as clay, sand, catalyst fines, etc. The organic constituent, of course, possesses fuel value; if the waste can be concentrated to the appropriate degree, it can be oxidized autogenously in a fluidized bed unit to destroy the liquid nature of the waste and to eliminate the objectionable pollutive characteristics of the organic matter.

This application is illustrated in Figure 10, where the organic matter itself furnishes the fuel values necessary for operation and no external fuel is required. If sufficient fuel values are available, some excess heat in the form of steam for other applications can be produced.

The solid product discharge in Figure 10 represents stable waste constituents, such as sand, silt, clay, catalyst material, etc., present in the original waste material.

Food Industry Applications

In certain stages of beet sugar refinery and molasses production operations, aqueous waste solutions are encountered which have a considerable carbohydrate content and which also contain various inorganic salts, such as potassium, sodium, etc. The carbohydrate portion, being organic, possesses fuel value and also imposes a pollutive load if the waste is discharged into a stream or river.

Figure 11 shows an application of the Container-Copeland Process to this problem. In this procedure the organic fraction is oxidized to destroy its pollutive nature, the evolved thermal energy is used to evaporate the water contained in the aqueous waste, and a dry solid product high in potassium oxide content is produced. This latter product may well have application as a fertilizer or plant nutrient material.

Application of the Container-Copeland Process to Municipal Sewage Wastes

Continued increases in the world's population have accentuated the problems of disposal of municipal sewage wastes while maintaining a suitable quality of our streams and rivers. Fluidized solids technology has been applied to the treatment of municipal sewage sludges and it would appear that this general approach of fluidized-solids oxidation in this application has many advantages.

Figure 12 shows the application of the Container-Copeland Process to the treatment of sewage sludge whereby the offensive and objectionable nature of the sludge is permanently destroyed and the only resultant product is a small volume of the inert material originally contained in the sludge. The completeness and simplicity of such processing compared to more conventional techniques is obvious.

SUMMARY

The successful application of the Container-Copeland Process to the treatment of waste effluents from portions of the paper and pulp industry to eliminate stream pollution has been described. Other applications of potential interest on a more universal plane have also been outlined.

It is apparent that stream pollution must be minimized and, certainly at some point in time, completely eliminated. To do this successfully and most efficiently will require the

thinking, co-operation, and action of many technical and non-technical disciplines. Many new techniques need to be studied and evaluated in specific applications before the most useful, most efficient, and most economical method can be chosen.

The basic concept of the Container-Copeland Process has the capability of making many of our stream pollution problems less bothersome by providing a permanent and complete destruction of many of the bothersome constituents of industrial waste products and, in some cases, by providing useful by-products as a result of the treatment. Generally, any waste product containing a combustible constituent represents a very promising candidate for the Container-Copeland fluidized bed process; the absence of a combustible constituent, however, does not necessarily limit its application.

One general point should be emphasized. Permanent solutions to our pollutional problems should be of primary interest in our efforts. Only in that way can our stream pollution problems forever be eliminated for ourselves and for our children. Oxidative processes by combustion, as in the Container-Copeland fluidized bed process, converts the elements of pollution-causing constituents of our wastes into innocuous gases and inert solids which do not require further treatment or cause worry that the products of our waste treatment methods may, in themselves, cause a pollution problem.

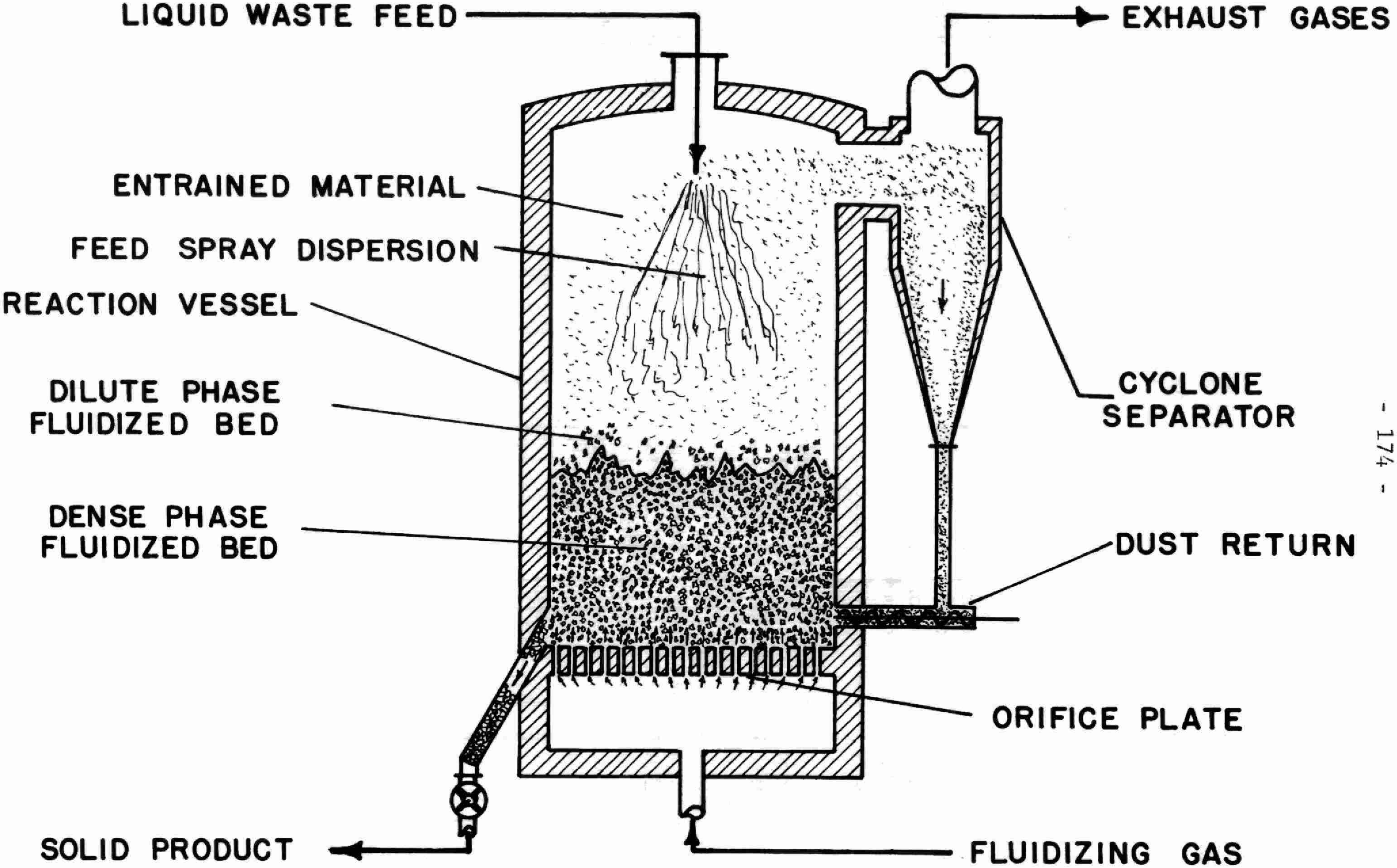


FIGURE I. FUNDAMENTALS OF FLUIDIZED SOLIDS PROCESSING

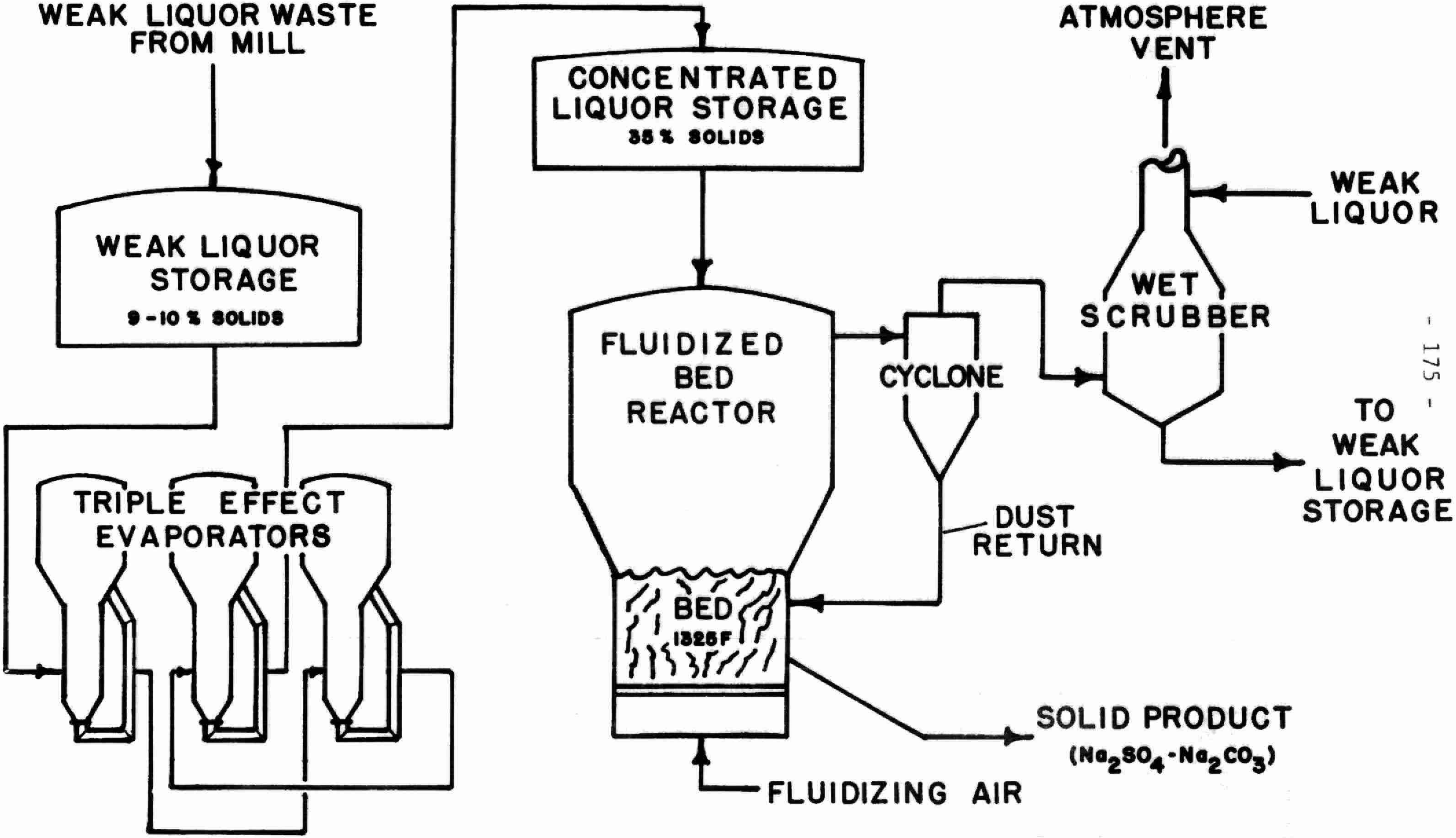


FIGURE 2. TREATMENT OF NSSC WASTE EFFLUENT

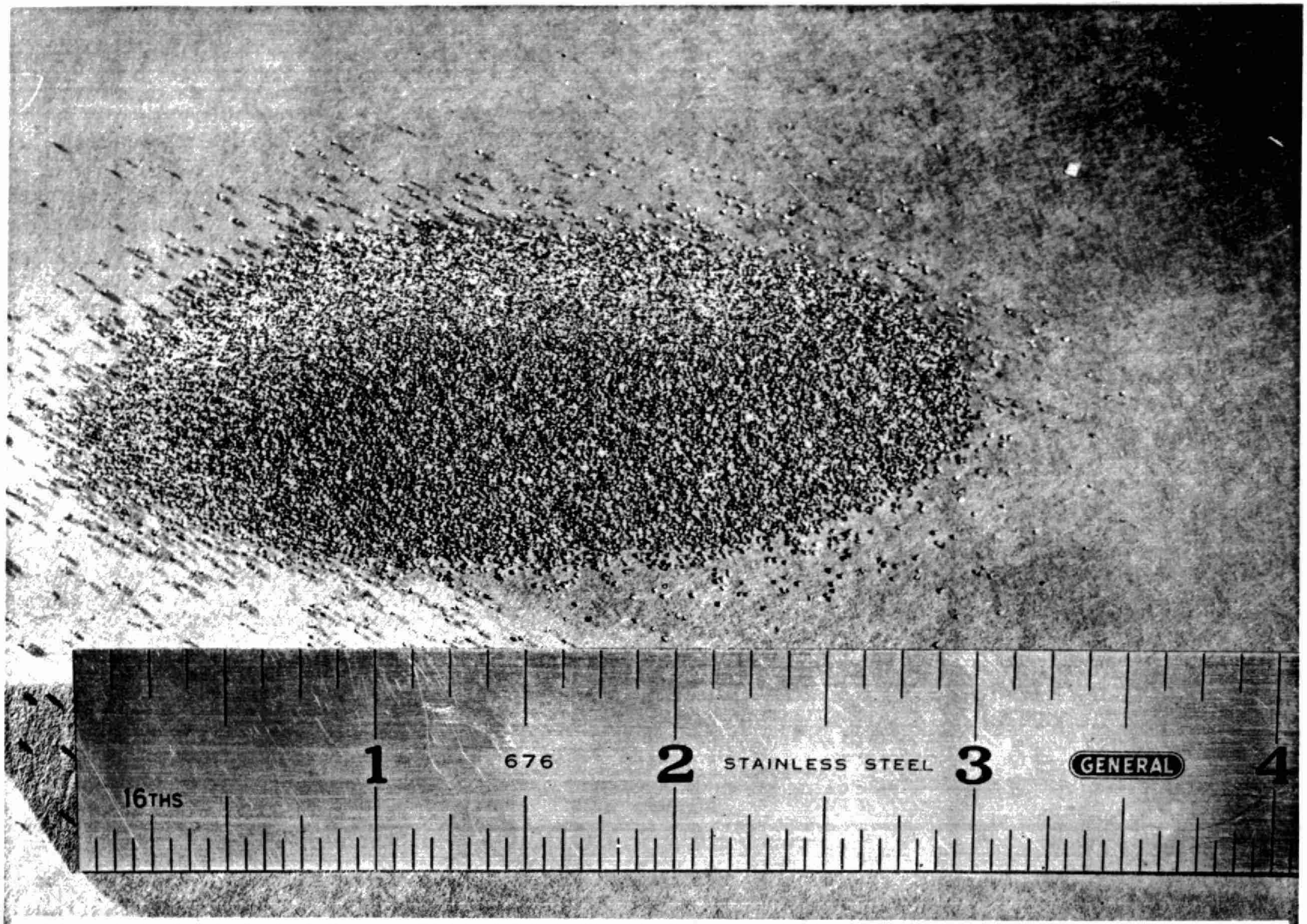


FIGURE 3. TYPICAL NSSC PRODUCT

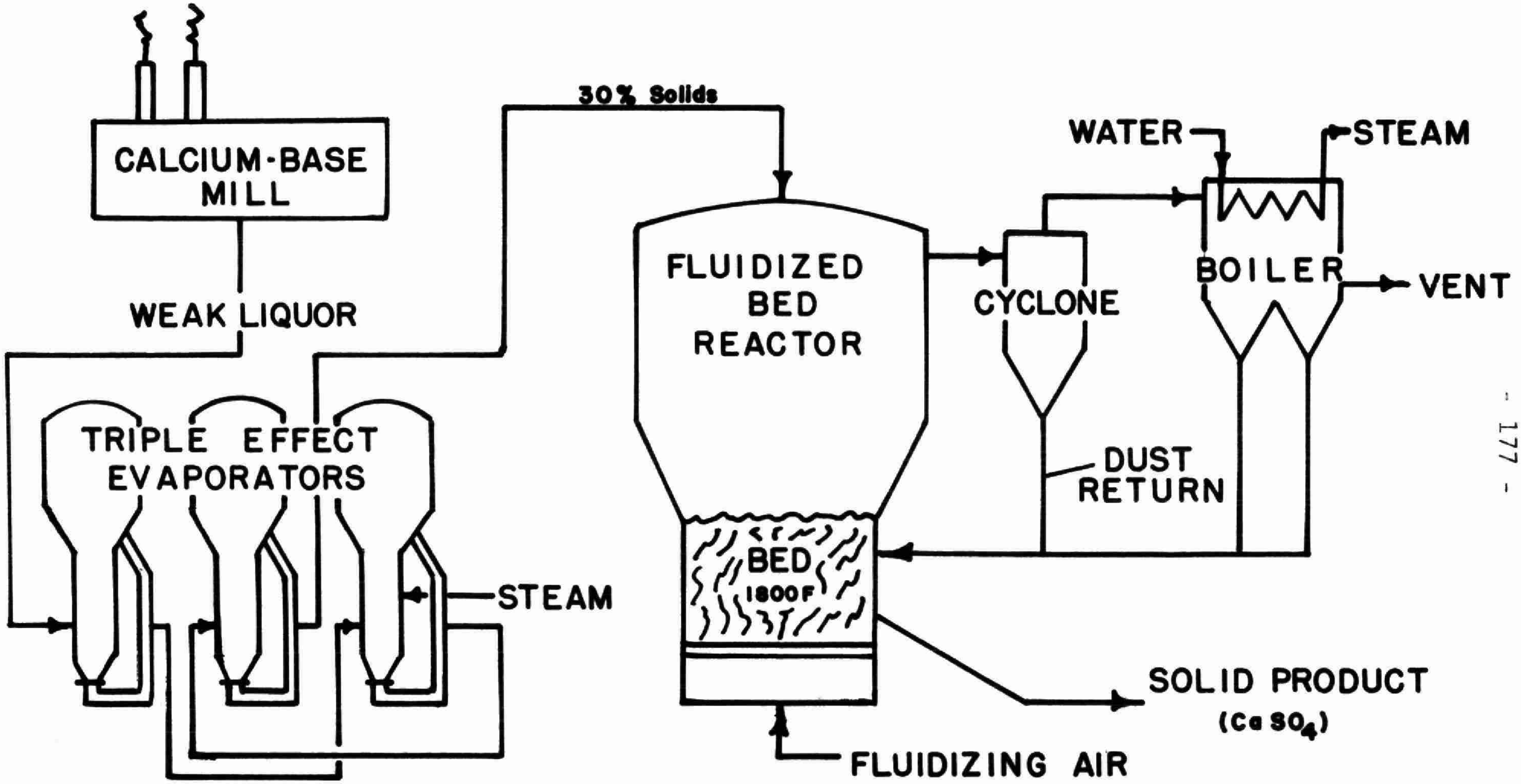


FIGURE 4. TREATMENT OF CALCIUM-BASE WASTE EFFLUENT

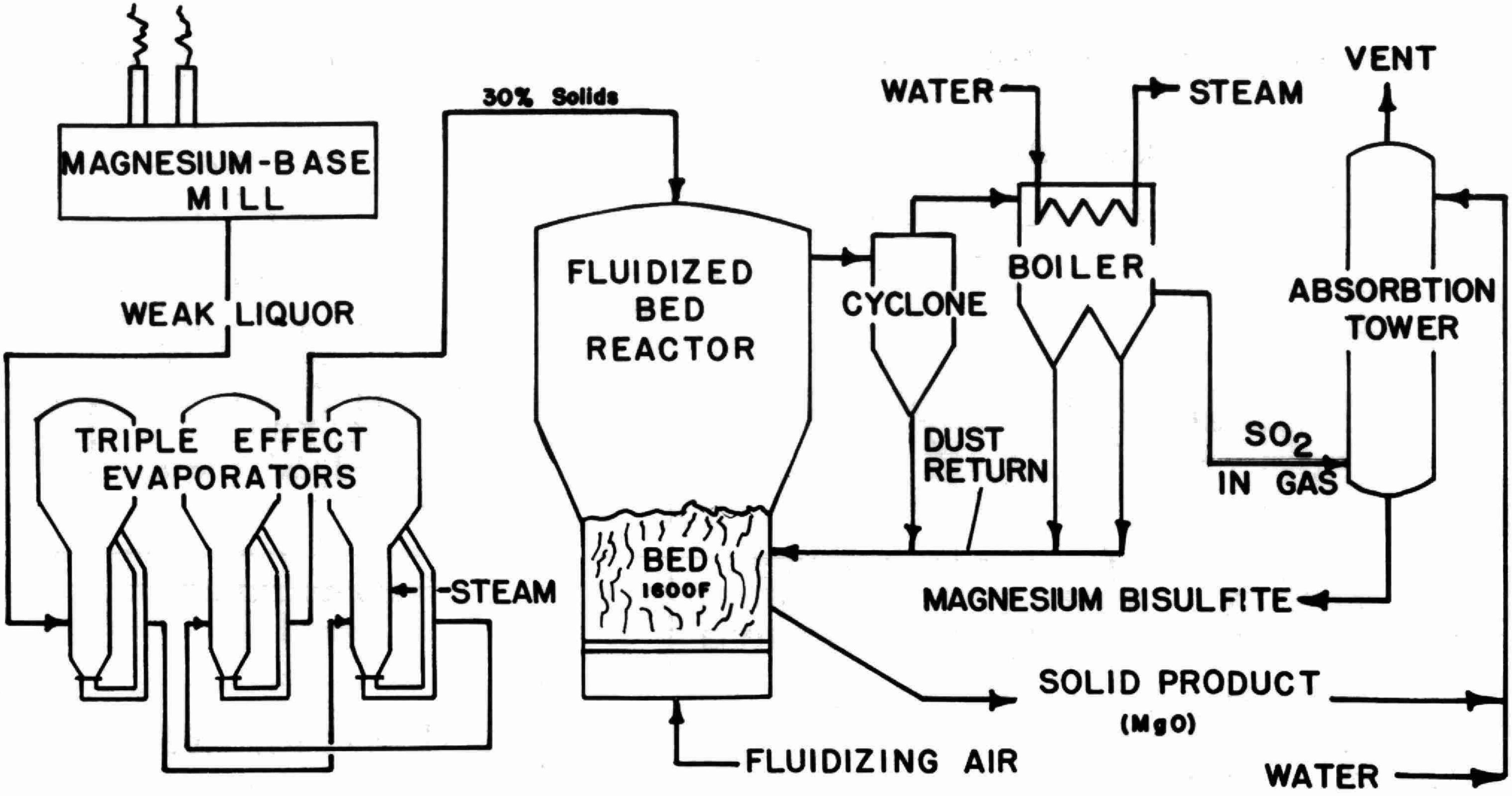


FIGURE 5. TREATMENT OF MAGNESIUM-BASE WASTE EFFLUENT

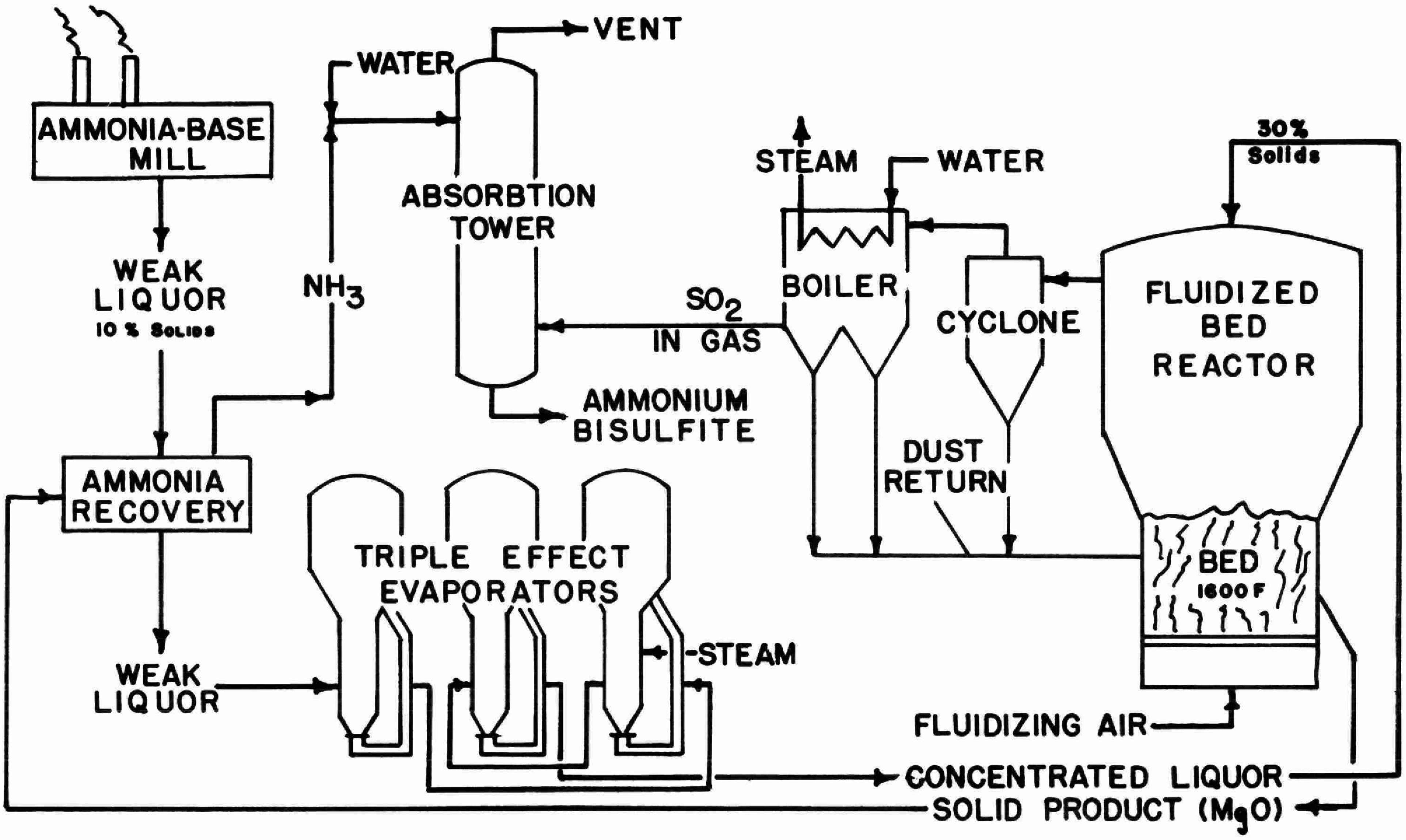


FIGURE 6. TREATMENT OF AMMONIA-BASE WASTE EFFLUENT

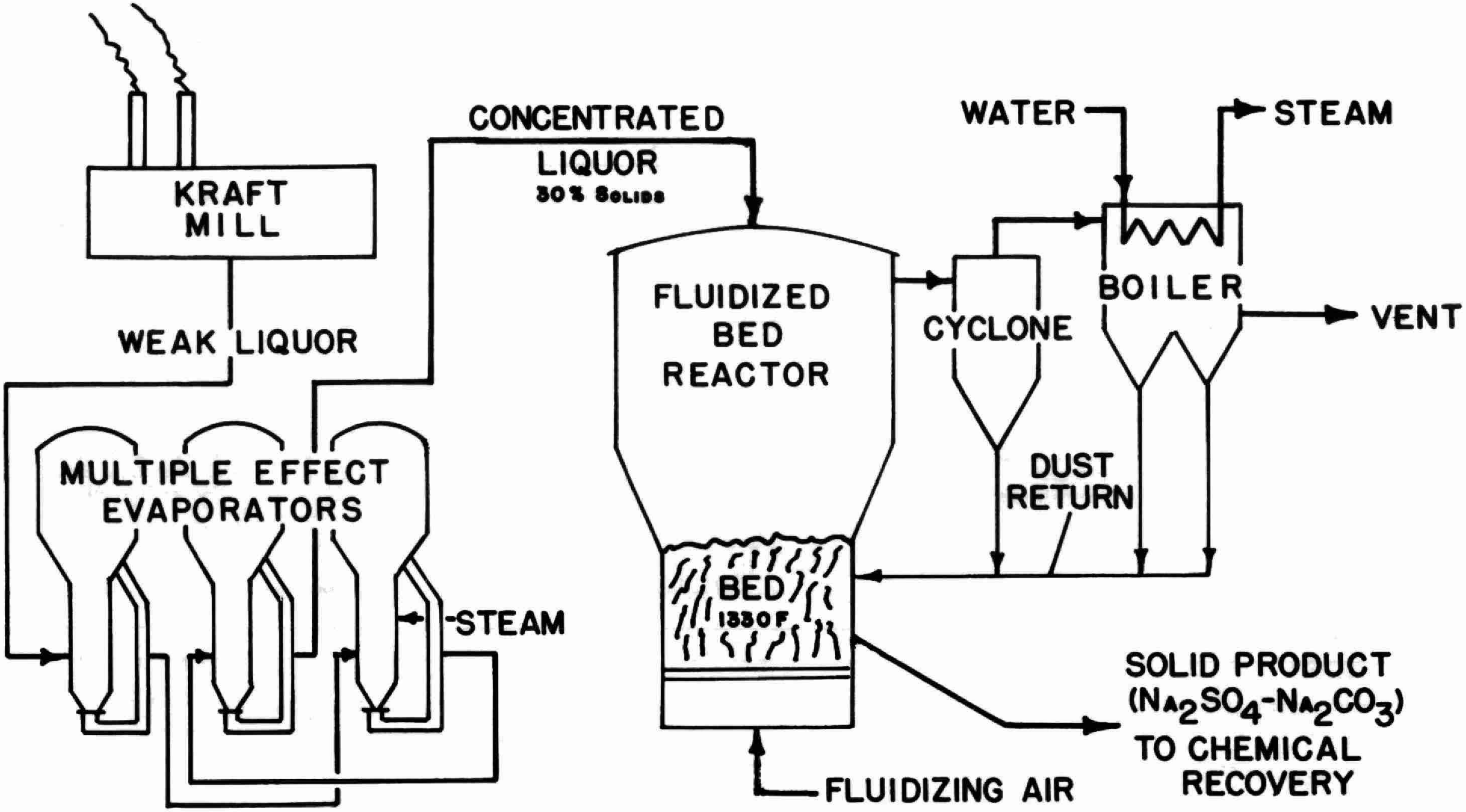


FIGURE 7. TREATMENT OF KRAFT WASTE EFFLUENT

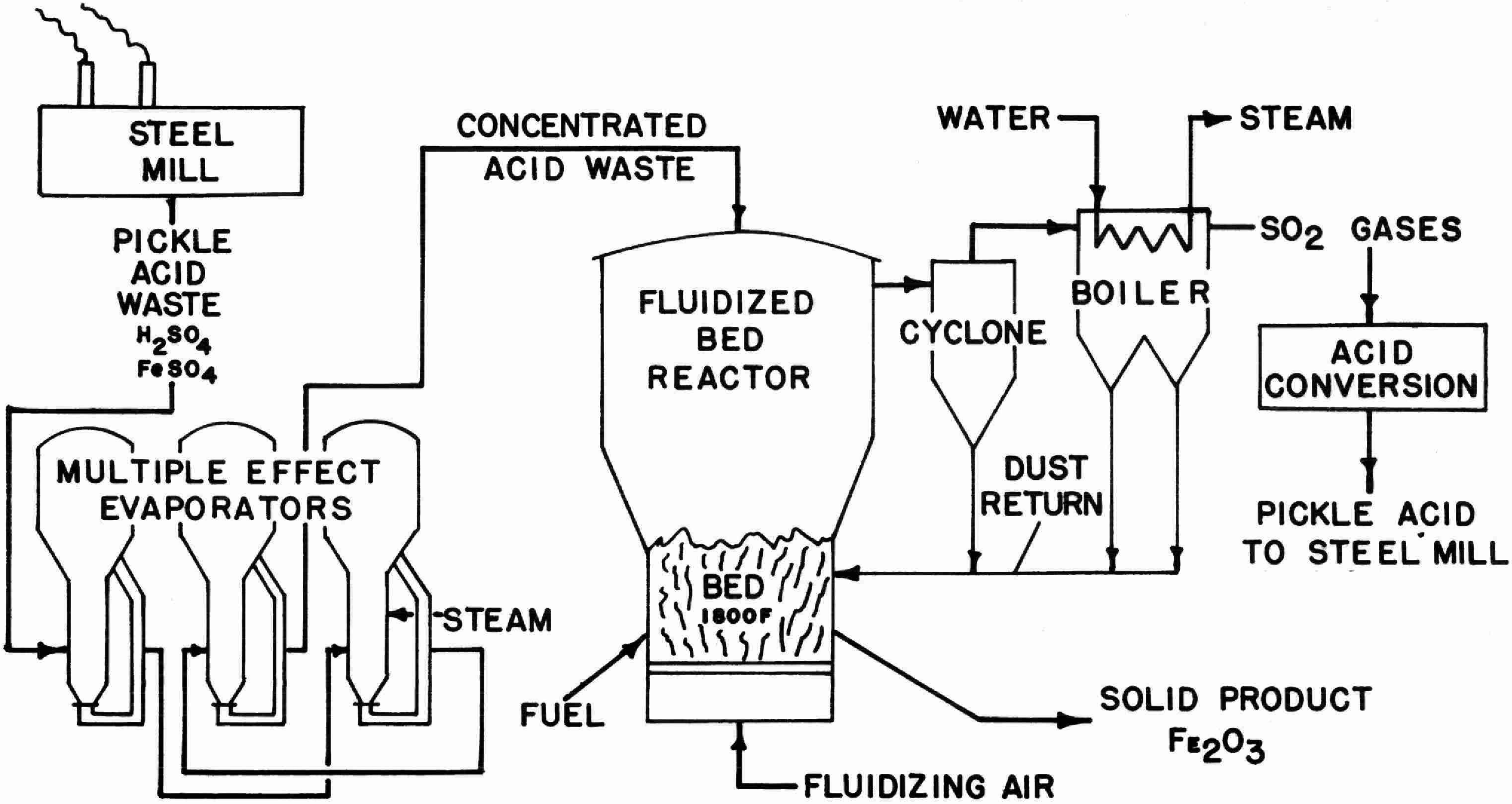


FIGURE 8. TREATMENT OF PICKLE ACID WASTE EFFLUENT

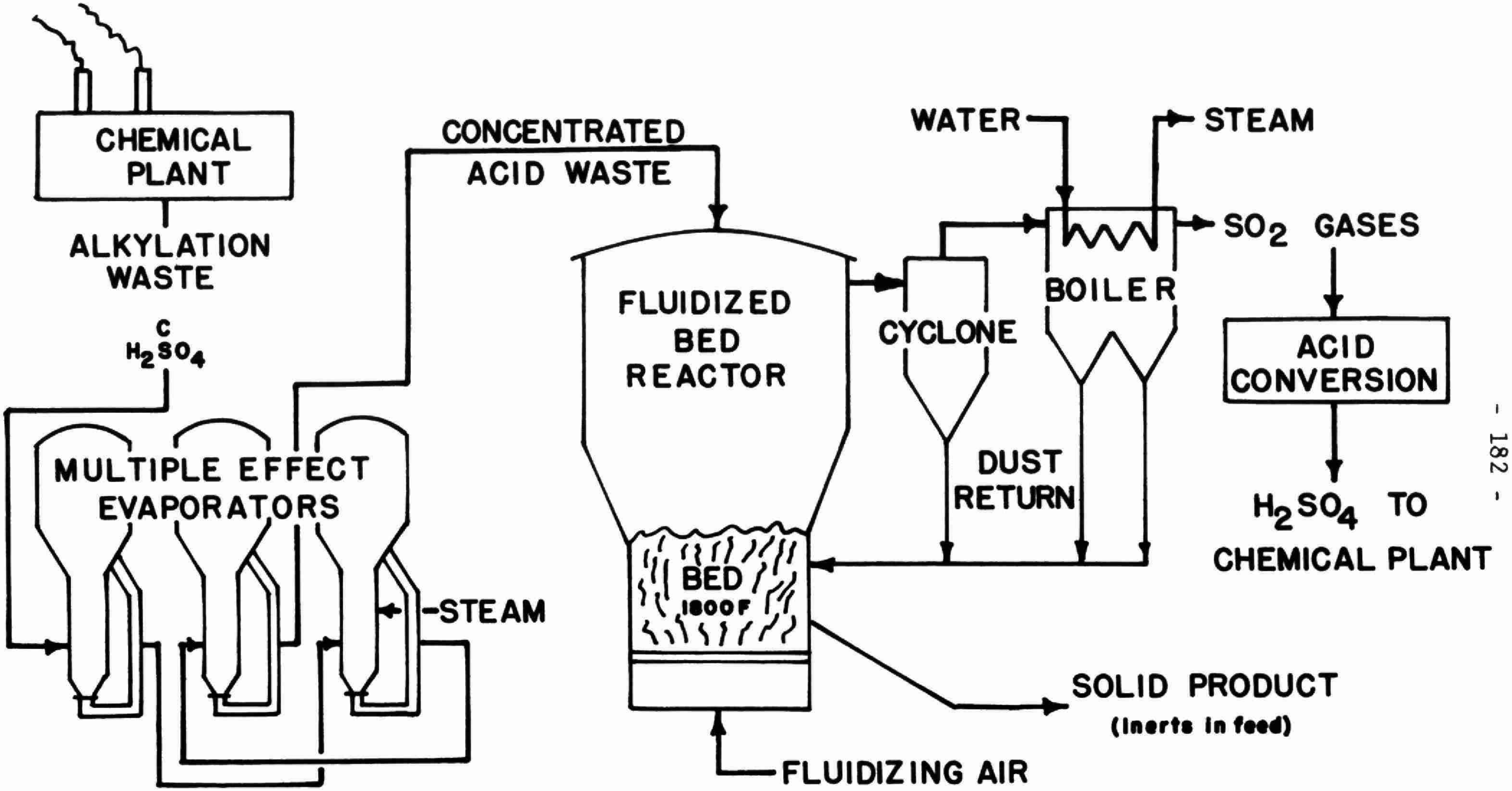


FIGURE 9. TREATMENT OF CHEMICAL PLANT WASTE EFFLUENT

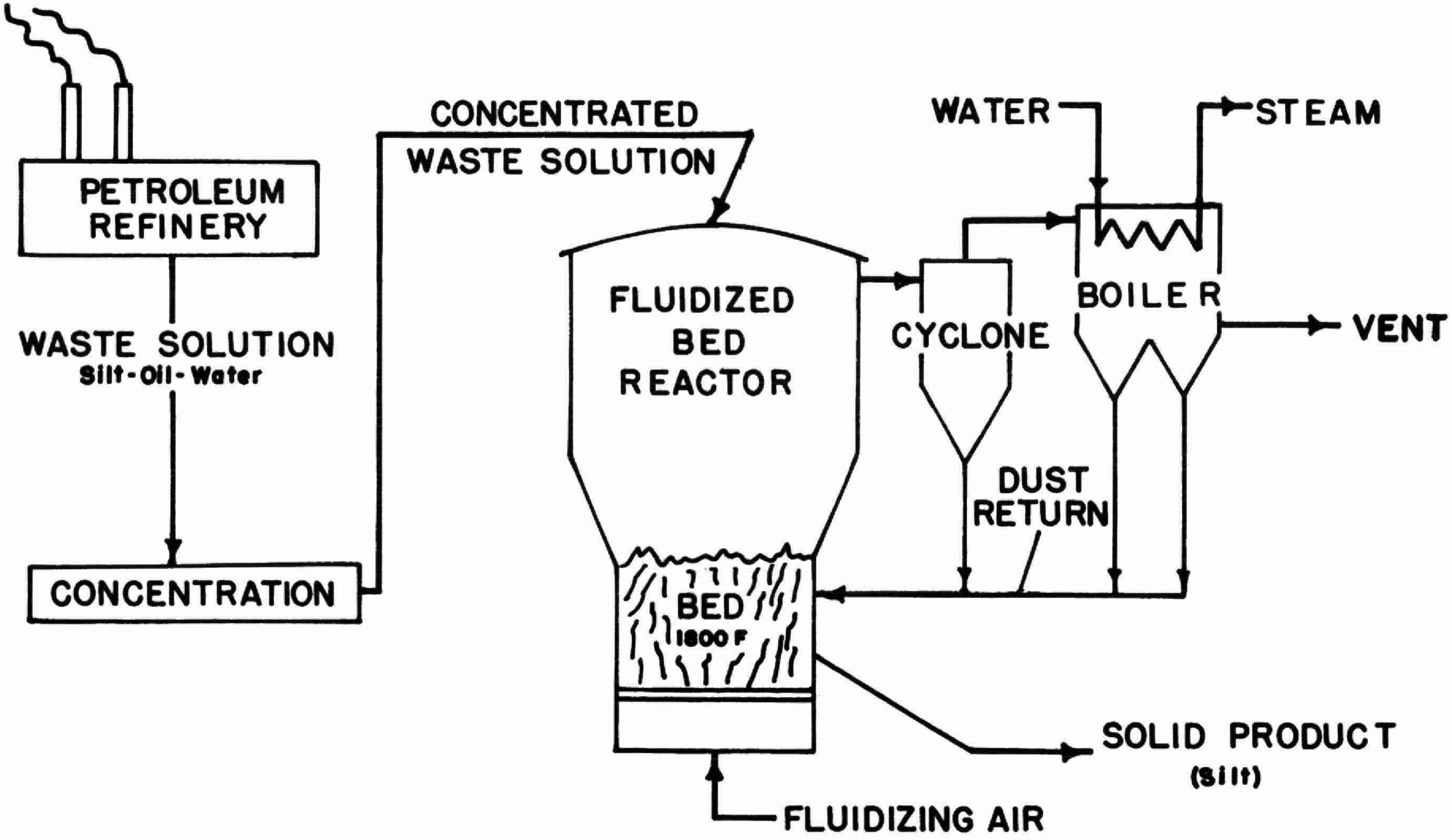


FIGURE 10. TREATMENT OF PETROLEUM REFINERY EFFLUENT

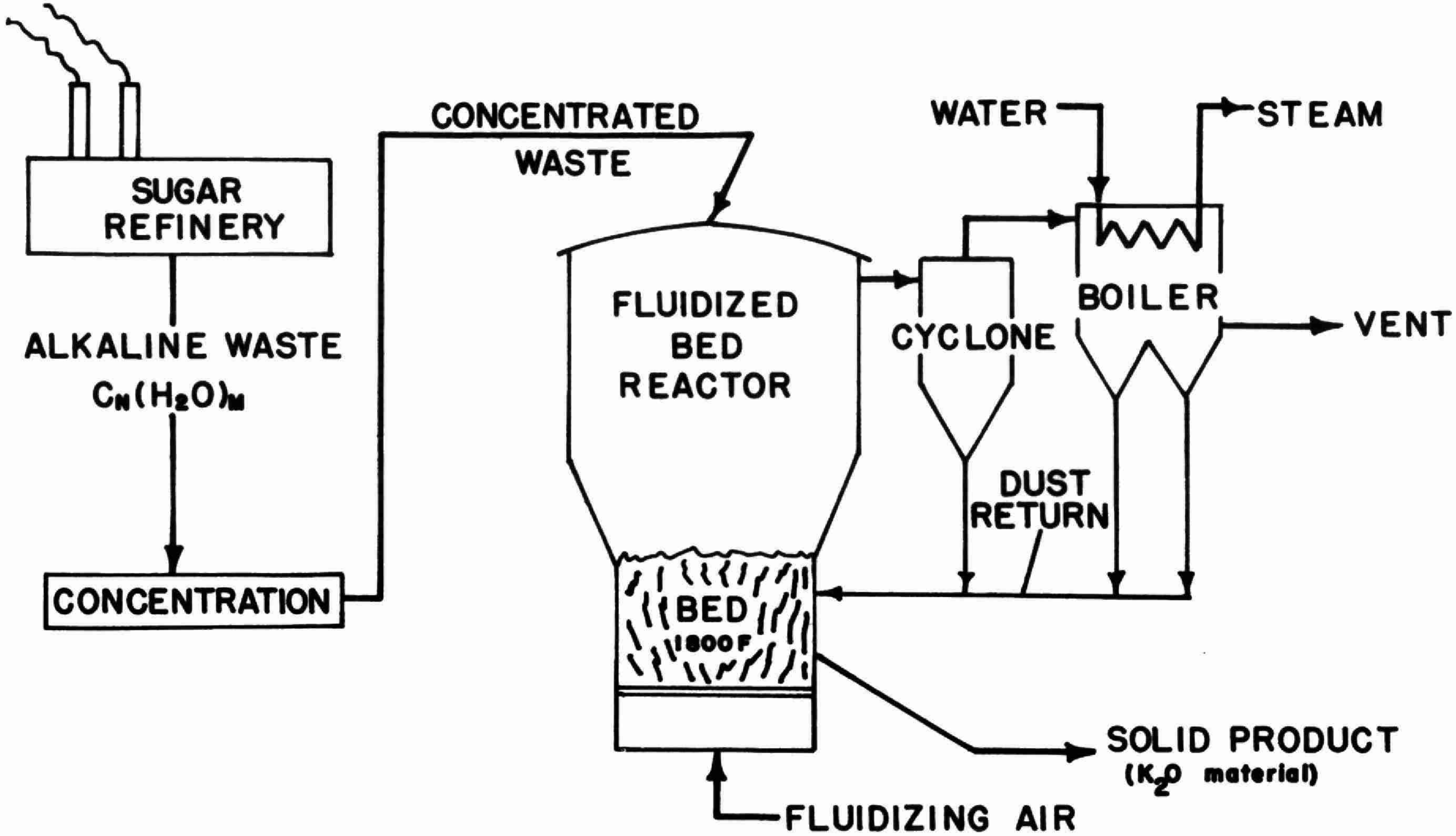


FIGURE 11. TREATMENT OF SUGAR REFINERY EFFLUENT

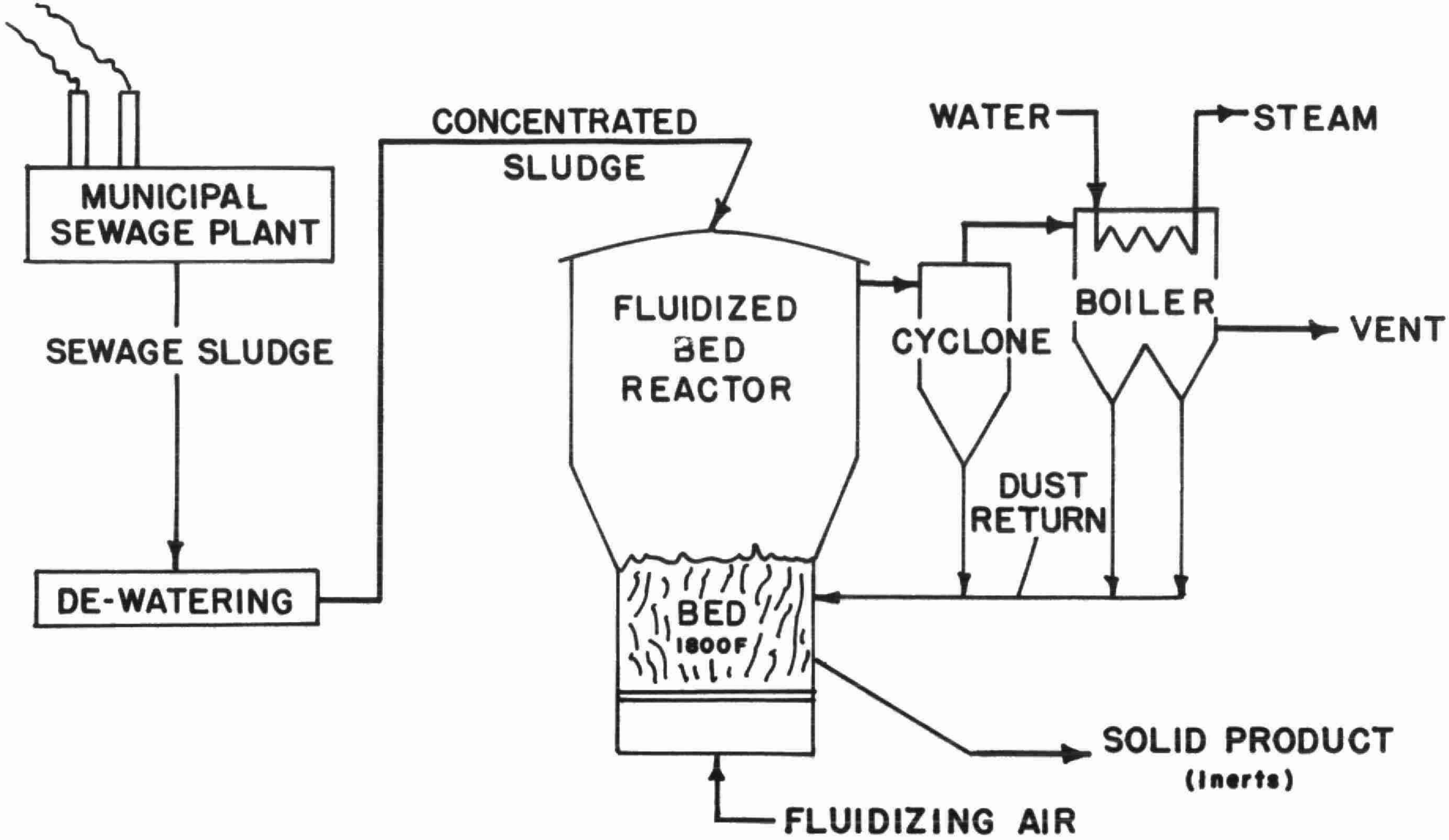
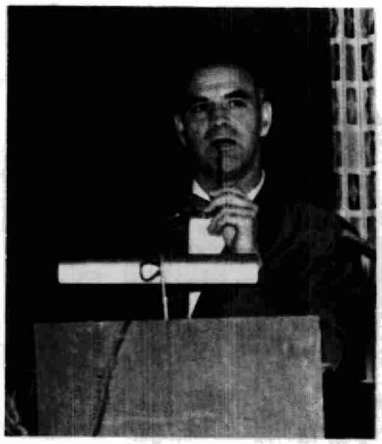


FIGURE 12. TREATMENT OF SEWAGE PLANT EFFLUENT

Mr. J.H.H. Root, M.P.P.,
Vice-Chairman, Ontario Water Resources Commission

Dr. A.E. Berry,
Secretary-Treasurer
Canadian Institute on Pollution Control

AFTER DINNER SPEAKERS



"WATER POLLUTION CONTROL PLANNING WITH MATHEMATICAL MODELS AND PEOPLE - THE DELAWARE ESTUARY COMPREHENSIVE STUDY"

by

E. L. **MACLEMAN**

SUMMARY

This paper aims to present a simplified picture of the new organizational and analytical techniques being devised by the U.S. Public Health Service in its development of a comprehensive water pollution control plan for the Delaware Estuary. Of special interest is the manner in which the mathematical models have permitted the organizing and operation of a unique committee structure in which the people of the area continuously participate and share in formulating this plan.

INTRODUCTION

Generally speaking, water quality forecasting procedures, as being developed by the Delaware Estuary Comprehensive Study (DECS), will basically describe a physical system in a mathematical manner to determine the future state of the system. Through use of these mathematical models, we hope to be able to determine where and how much waste must be eliminated from the waterway to attain specified quality goals and the associated costs. While water quality forecasting is basic to any comprehensive water pollution control plan, I would emphasize that no matter how good the plan, one might as well forget about forecasting unless the people of the basin concur and follow through with a good implementation program.

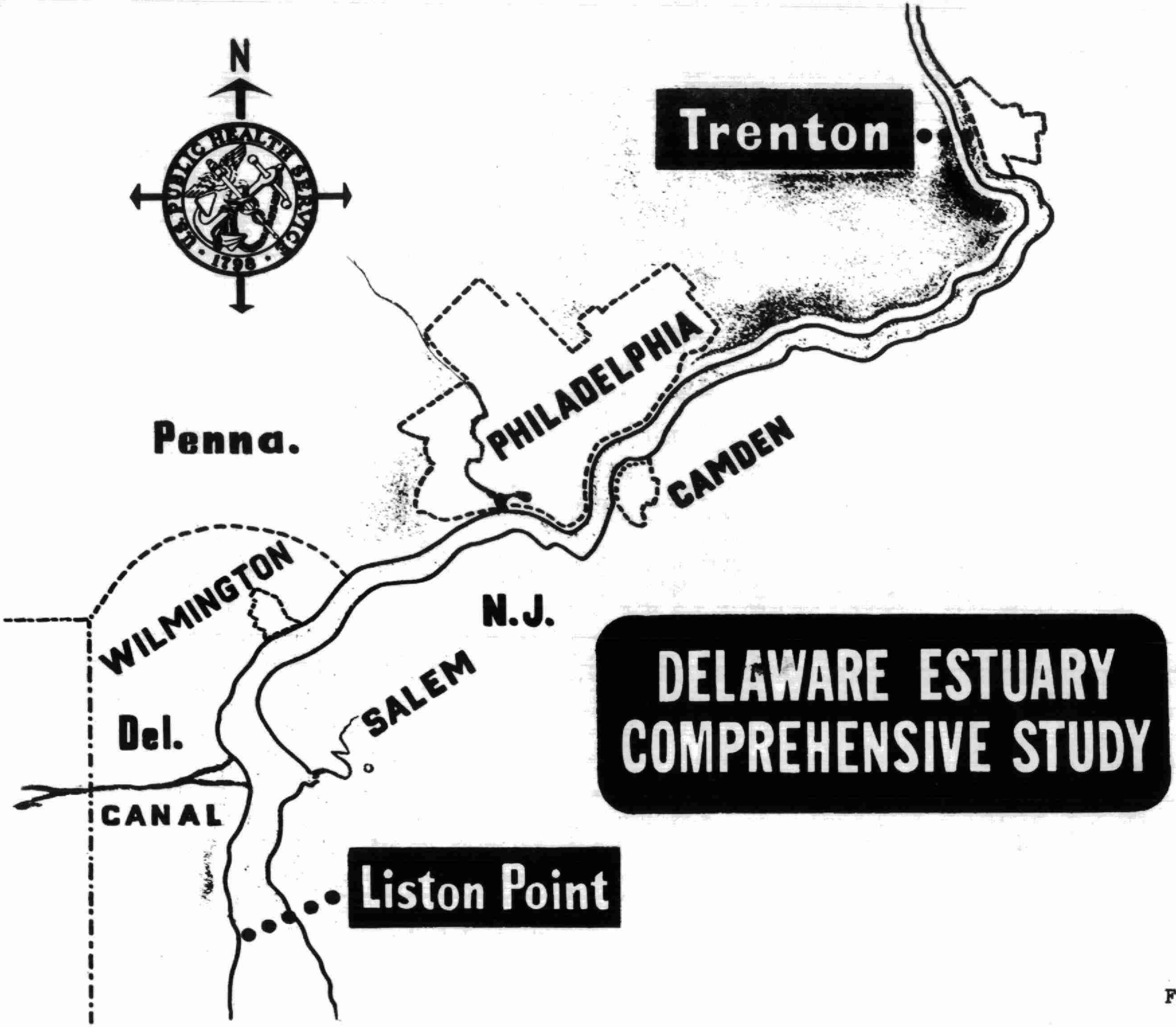

N
Trenton
PHILADELPHIA
Penna.
CAMDEN
WILMINGTON
N.J.
DELAWARE ESTUARY
COMPREHENSIVE STUDY
SALEM
Del.
CANAL
Liston Point

FIGURE 1

In late 1961 the Division of Water Supply and Pollution Control of the Public Health Service (PHS) initiated the Delaware Estuary Comprehensive Study. The PHS is in the U.S. Department of Health, Education, and Welfare. The study was initiated at the request of the interested states and covers the 86-mile stretch of the Delaware River from Trenton, New Jersey, to Liston Point, Delaware. This portion of the river is the estuary and its basin is one of the most heavily populated and industrialized areas in the country. (See Figure 1)

AUTHORIZATION

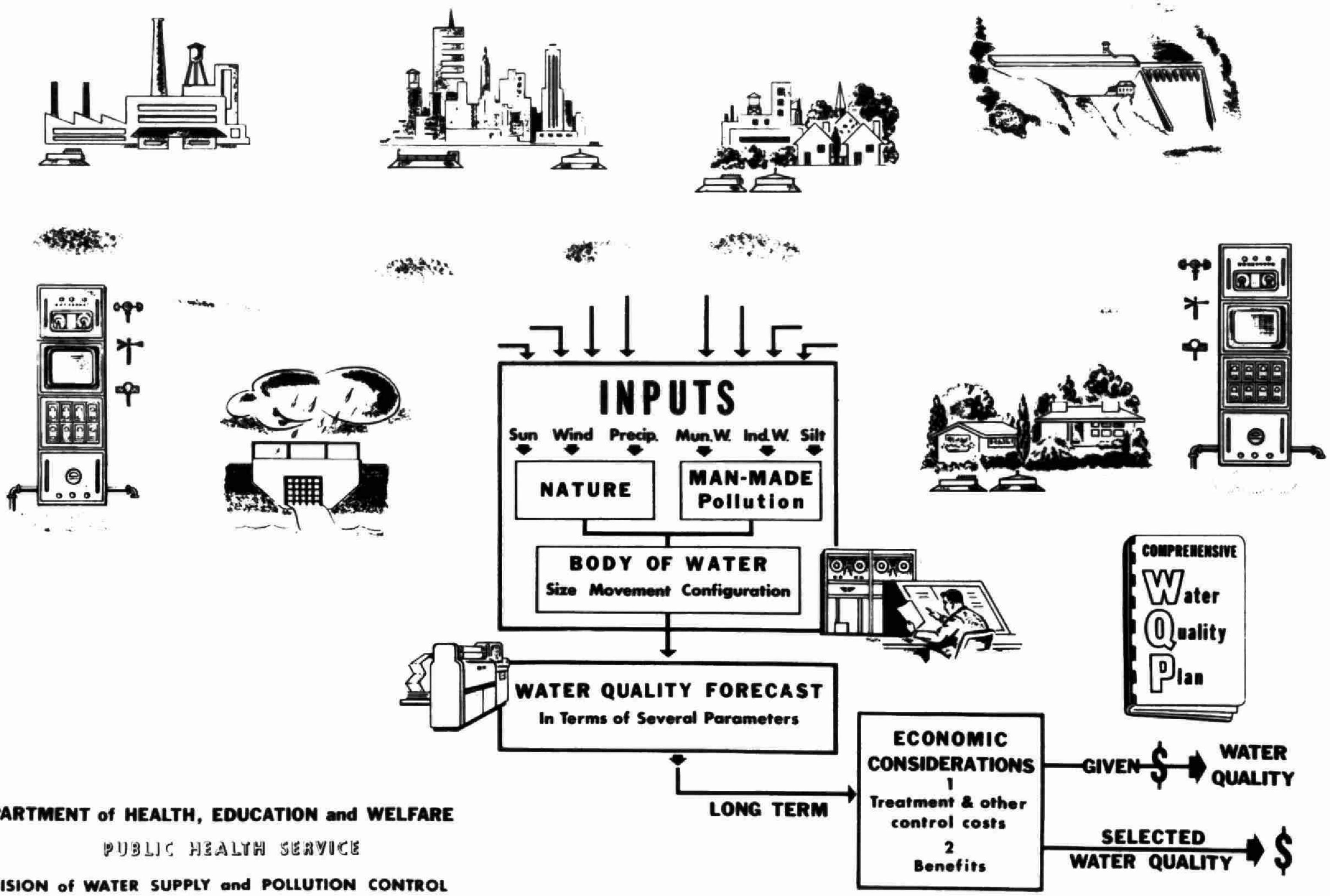
Authorization for the study is derived from Public Law 660, the Federal Water Pollution Control Act. Section 2(a) of the Act reads:

> "The Secretary of Health, Education, and Welfare shall, after careful investigation, in co-operation with other Federal agencies, with State water pollution control agencies and interstate agencies, and with the municipalities and industries involved, prepare or develop comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses. For the purpose of this section, the Secretary is authorized to make joint investigations with any such agencies of the condition of any waters in any State or States, and of the discharges of any sewage, industrial wastes, or substance which may adversely affect such waters."

MATHEMATICAL MODELS

In developing a comprehensive water pollution control plan the engineers have the chief role. If but one or two treatment plants are involved, planning is fairly simple and the engineer is soon able to make his recommendations. The greater the number of such facilities, the greater the problems to be solved. In an area as complex as the Delaware Estuary basin accurate engineering solutions are not readily possible.

DELAWARE ESTUARY COMPREHENSIVE STUDY



DEPARTMENT of HEALTH, EDUCATION and WELFARE

PUBLIC HEALTH SERVICE

DIVISION of WATER SUPPLY and POLLUTION CONTROL

FIGURE 2

As I have indicated, the Study is working out procedures by which the engineers can handle the complex problems involved. To do this, the influences of such natural elements as sun, wind, river shape and volume, dispersion and diffusion, stream flow and tides are set up as mathematical expressions. This is also done for such man-created factors as industrial and municipal wastes, stormwater overflow, and silt from spoil areas due to channel dredging and land disturbance.

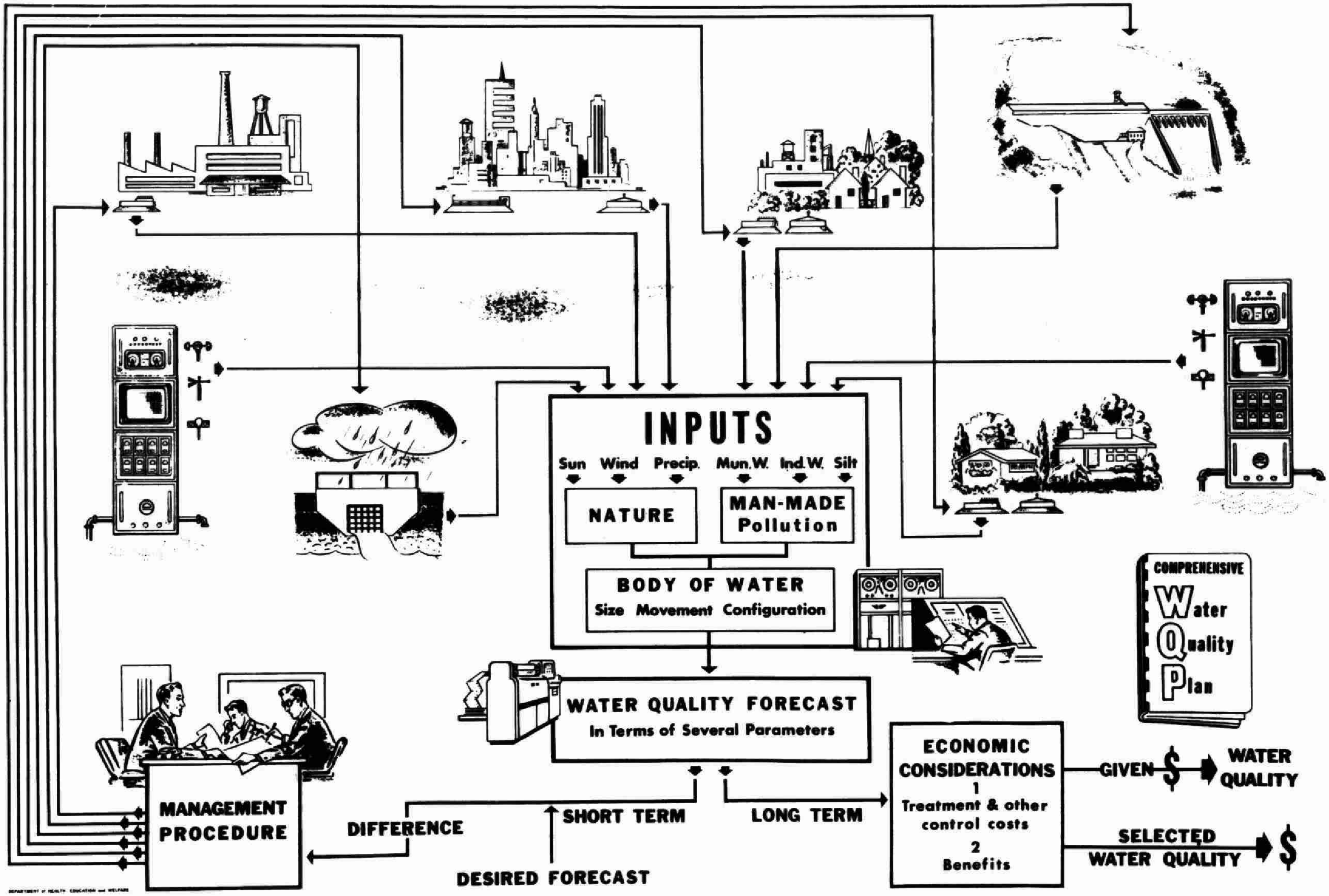
Considering these latter items as inputs, mathematically defined systems or models may be developed. (See Figure 2) The models being devised are of a general pattern and may be adapted to forecast any one of several water quality parameters such as dissolved oxygen, chlorides, or turbidity.

The use of mathematical models in conjunction with high speed computers will permit basing water quality schemes on dynamic rather than static analyses. Feeding data in from monitoring stations, stormwater overflow points, and domestic and industrial waste treatment plants will permit relatively quick checks upon progressing water pollution control programs.

The models will permit accurate appraisal of the effect of new or enlarged municipal and industrial water supply systems or waste treatment facilities before they are built and might even determine the best locations for them. Interestingly, the models may be used to generate valuable information during the early stages of planning, long before completion of their more sophisticated counterparts. For example, the models may indicate that the collecting of certain data can be discontinued while showing the need for obtaining other data. As information is generated, it is coded and incorporated into the models immediately. This includes data which may expand or refine the models themselves - as for example, information obtained from dye, tidal current meter, and photosynthetic studies, as well as changes in hydrography and new methods of waste treatment.

The Delaware Estuary Comprehensive Study is also working on economic models which, when tied in with the estuary models, will provide cost estimates for different selected water qualities for the whole or sections of the estuary. Also, reversing the process, given a specific amount of money, a level of water quality may be determined.

FUTURE WATER QUALITY MANAGEMENT



DEPARTMENT of HEALTH, EDUCATION and WELFARE

DIVISION of WATER SUPPLY and POLLUTION CONTROL

FIGURE 3

The models, when used with computers, will provide engineers with the same control for complex areas as for the simple areas where only one or two facilities must be considered.

COMPREHENSIVE WATER POLLUTION CONTROL PLAN

As indicated, the Delaware Estuary Comprehensive Study will blueprint a comprehensive water pollution control plan. However, my foregoing remarks should indicate that the plan will never be final. While the Study prepares the "Plan" for water pollution control, the models may be continuously modified and further refined to reflect new conditions. This will provide interim checks on the plan and indicate points requiring revision. The result will be a dynamic water pollution control plan, flexible and adaptable to area changes and growth.

As you see, Figure 3 is an expansion of Figure 2. Here we illustrate water quality management as we envision it for the future. Adding lines of communication direct to a computer center will permit short term forecasting - on a weekly or monthly basis. Through management procedure it might then be possible to control the short term variations.

DELAWARE RIVER BASIN COMMISSION

We are fortunate in the Delaware Basin to have the newly formed State and Federal partnership - the Delaware River Basin Commission. This agency has water resources management authority. In January 1963, the Commission assumed the water pollution control responsibilities of its predecessor, INCODEL (the Interstate Commission on the Delaware). Article 13 of the present Commission Compact states that "the Commission shall annually adopt a water resources program..." for the ensuing six years. Also the Commission is responsible for the review of all proposed projects for compliance with its overall plan.

The work of the DECS complements both of these aims. At a February 24, 1965,meeting, the Commission passed Resolution No. 65-7 whereby the Commission will "utilize the results of the Delaware River Estuary Study."

The assistance which the mathematical models may provide in preparing the water pollution control phase of the annual Water Resources Plan and in checking compliance of proposed projects with the plan is quite evident.

COMMITTEE STRUCTURE

Just as Congress realized in enacting Section 2(a) of Public Law 660, which I have quoted, so too is it evident to the DECS staff, that the success of any water pollution control plan, both in its development and implementation, must depend on the participation and co-operation of industries, civic organizations, and government agencies whose interests would be affected.

Bearing in mind this and the advantages to be obtained through the mathematical model, we undertook the formation of a rather unique committee structure, namely: a Policy Advisory Committee (PAC), a Technical Advisory Committee (TAC), and a Water Use Advisory Committee (WUAC).

Policy Advisory Committee

Membership of the PAC includes personnel from State, Interstate, and Federal Agencies which have legal power to abate pollution. Other agencies with related interests in the field of water resources were invited to attend meetings as guests and receive minutes of meetings. Meetings are held bimonthly.

The functions of this Committee are to:

A. Attain consent among states on pollution abatement policy and plans and assure full co-ordination of effort and understanding.

B. Co-ordinate and assist in the inclusion of established water pollution control plans in the over-all comprehensive water pollution control plan.

C. Relate the Study to possible interim procedures for pollution abatement.

D. Advise the PHS relative to the present DECS and future studies involving water pollution control in the estuary.

Technical Advisory Committee

Membership of the TAC includes personnel familiar with the technical aspects of water pollution control from agencies participating in the work of the Study. Meetings are scheduled every six to eight weeks.

The functions of this Committee are to:

A. Keep agencies represented apprised of the status of the DECS - in this manner the agency has one of its personnel who has a complete understanding of the technical phases of the DECS.

B. Assist PHS in planning and co-ordinating DECS.

C. Provide technical assistance;

   1. in the organizing of various projects
   2. by providing additional qualified personnel for special phases of study
   3. by reviewing preliminary drafts of reports
   4. by advising Policy and Water Use Advisory Committees on technical matters.

As an example of Committee assistance, it was through a joint recommendation of TAC and PAC that a decision was made to base the Study's investigations mainly on these three systems:

I. Equal per cent removal for all waste discharges along the entire length of the estuary to attain a given level of water quality.

II. Least cost solution without regard to equal per cent removal to attain a given level of water quality.

III. Least cost solution to attain a given level of quality with equal per cent removal in any combination of the 30 sections into which the Delaware Estuary was divided for purposes of the Study.

Examples of I and II are presented later in this paper - work is still in progress on III.

Water Use Advisory Committee

Formation of the WUAC required a procedure different from that of the other two. In reviewing the nature of the Basin, the Staff decided to form four subcommittees: 1) Recreation, Conservation, Fish and Wildlife; 2) General Public; 3) Industry; and 4) Local Governments and Planning Agencies.

FIGURE 4

DELAWARE ESTUARY COMPREHENSIVE STUDY

Committee Structure (as of February 1965)

- 1 I. Policy Advisory Committee
- 2 II. Technical Advisory Committee
    - Subcommittees
        - 3 A. Industry
        - 4 B. Fish and Wildlife
- 5 III. Water Use Advisory Committee
    - Subcommittees
        - 6 A. Recreation, Conservation, Fish and Wildlife
        - 7 B. General Public
        - 8 C. Local Government and Planning Agencies
        - 9 D. Industry
            - Work Groups
                - 10 a. Chemical
                - 11 b. Electrical Utilities
                - 12 c. Food
                - 13 d. Paper
                - 14 e. Petroleum
                - 15 f. Steel
                - 16 g. Manufacturers' Associations
                - 17 h. Miscellaneous

Ninety organizations were invited to the initial meetings. At the second meeting each subcommittee elected a Chairman who also would represent the subcommittee on the parent WUAC. The WUAC meets bimonthly with additional meetings scheduled as necessary.

Functions of the WUAC are to:

A. Indicate the needs and desires of the people of the estuary relative to water use with water quality as a criterion.

B. Act as a public relations group.

C. Assist in special non-technical phases of the DECS.

It is interesting to note that, from the original three committees, we now have 17 committees or work groups. (See Figure 4) Presently participating through the committees are: three State water pollution control agencies, one interstate agency, three Federal agencies, nine cities, 12 planning agencies, 30 civic organizations, and 45 industries for a total of 103.

The 103 organizations provide over 200 participants on the various committees.

INDUSTRY'S ROLE

In the Fall of 1962, the State water pollution control agencies of Delaware, New Jersey and Pennsylvania prepared a preliminary industrial waste inventory based on return information in a special form sent to the basin industries. The inventory determined that 91 per cent of the industrial waste load was from 22 plants, including seven oil refineries, one distillery, and 10 chemical, one steel, and three paper plants. At the same time, it was revealed that 94 per cent of the municipal waste load was from eight municipal waste treatment plants. Thus, in undertaking a sampling program the work load was considerably reduced. Each of the 30 waste sources was sampled monthly for a period of approximately one year.

Based on the inventory and the sampling program (the latter now almost 90 per cent complete) first stage ultimate oxygen demand figures in lbs./day were estimated at:

	Inventory	Sampling Program
Industry	472,300	376,300
Municipal	547,100	618,600
TOTAL	1,019,400	994,900

Once the sampling was completed, a meeting was held with each individual plant at which the average waste load to be used in the mathematical models was agreed upon.

The industries' assistance in the waste sampling program entitled them to representation on the TAC. A meeting was called of the 23 industries which were to participate and the group elected a member and an alternate to represent them on the TAC. Within a week after each TAC meeting this industrial group meets and is kept completely informed of the status of our Comprehensive Study.

All Study papers and memoranda are made available to members of the TAC. Numerous meetings have been held with various industrial groups to answer questions and also assist the Study. This is all done through their TAC representative.

One good example of the type of information made available is the Study's Technical Memorandum No. 2 entitled "The Effects of Environmental Conditions on the Cost of Water

Pollution Control - Progress Report". This memorandum contains all the data obtained up to the time it was prepared, plus information estimated by the staff. Under these circumstances it was labeled preliminary; however, as with other papers, it reveals the possibilities of the models and permits questioning and comment long before final steps of the plan are underway.

In Table 1, three typical cost solutions from Technical Memorandum No. 2 have been selected as an example. For attaining various levels of dissolved oxygen (DO) in the river, the cost and treatment required for five of the many waste sources are shown. The solutions selected were for the same hydrodynamic conditions. (While it might appear from this example that the maximum possible attainable DO in the estuary is 4 milligrams per liter (mg/l), it must be kept in mind that this memorandum was preliminary and does not include such waste load data as stormwater overflow, bottom deposit and nitrification.)

From this example, one may readily visualize the many possible solutions that may be made available to the engineers for review and decision. Also, as rapidly as committee members provide better information or data, the Study immediately codes the data for inclusion in the models.

Thus the technical membership is constantly kept abreast of development, since it is directly involved in the Study's work.

The Industrial Subcommittee of the WUAC on the other hand has a somewhat different role.

At the second meeting of each of the WUAC subcommittees, the following request was made:

> "The Delaware Estuary Comprehensive Study requests that the subcommittees of the Water Use Advisory Committee undertake, as their initial task, the preparation of the first part of a report on the present and future use and needs (objectives) of the organizations represented relative to the waters in the estuary. These uses and needs or water quality objectives should make use of indicators (or parameters) in the descriptive material, but as objectives they need not include quantitative information. Limits or ranges should be reserved for the second phase of the report.

> The second phase will be requested after the Study, along with the Policy Advisory Committee and Technical Advisory Committee, have reviewed and returned the initial report to the Water Use Advisory Committee. Inter-committee discussions might delay the second phase to some extent. This should allow sufficient time for all subcommittee members to be able to obtain the information necessary for the second phase."

For several reasons we requested that the work be submitted in two phases. First, it permitted familiarization in the first phase for members new to this particular field. By the time the second phase was undertaken, the DECS staff or members of the TAC could be called upon to provide assistance. Second, organizations which had declined initially to participate might, upon reviewing the first phase report, decide to participate in the second phase in the best interest of their organization.

Third, the report produced from the first phase would serve as a firm basis for all members in the development of their final report. It would also permit review of and possible change in original ideas.

To comply with the DECS request, the Industrial Subcommittee meets monthly and its eight working groups meet as necessary. It is expected that phase one of the request will be completed by the end of May.

CONCLUSION

This then is where the Study stands today. So far, co-operation of all the people and organizations has been excellent. We of the Study staff have been expecially impressed with the interest shown by the industrial groups and their enthusiastic, efficient reporting.

By June 1967, the Study is scheduled to submit its comprehensive program for pollution abatement in the estuary. Since the States, the Commission, and the people, including industry, will have been a part of the planning Study through the Committee Structure, implementation should be forthcoming with a minimum of delay.

TABLE 1*

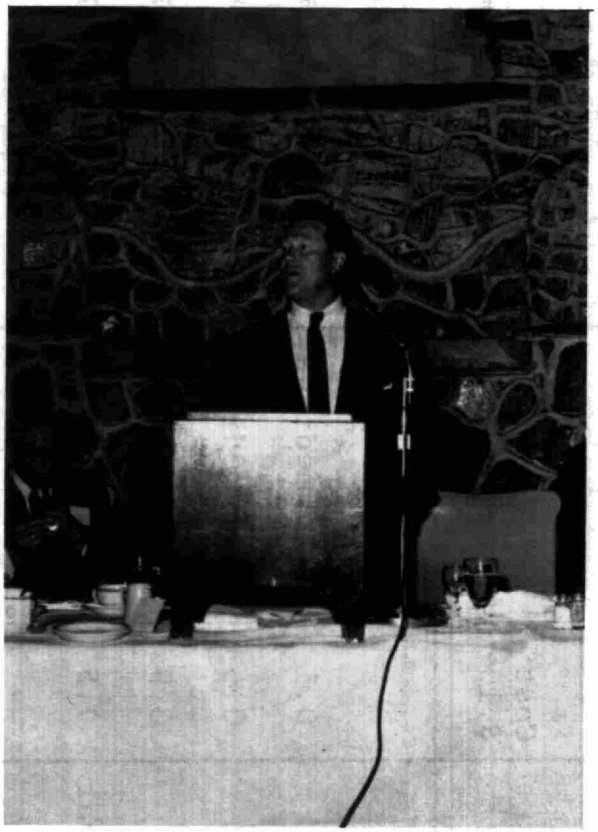
EXAMPLES OF COST SOLUTIONS FOR THE DELAWARE ESTUARY

Type of Cost Solution		Least		Uniform Treatment		Least	
To obtain a DO level of:		2 mg/1		2 mg/1		4 mg/1	
Waste Source	Present Treatment	Cost $\$.10^6$	Treatment	Cost $\$.10^6$	Treatment	Cost $\$.10^6$	Treatment
1	Secondary	-	Secondary	0	Secondary	-	Secondary
2	Primary	0.2	Secondary	0.1	Intermediate	1.0	Total Removal
3	None	-	None	0.6	Intermediate	1.6	Total Removal
4	Primary	-	Primary	3.9	Intermediate	42.5	Total Removal
5	Primary	1.2	Total Removal	0.5	Intermediate	1.9	Total Removal
-	-	-	-	-	"	-	" "
-	-	-	-	-	"	-	" "
-	-	-	-	-	"	-	" "
Relative Total Cost **		1.0		1.8		25.0	

NOTE: Flow, diffusion, reaeration and decay coefficients are the same for all conditions.

* From a draft of a preliminary study.

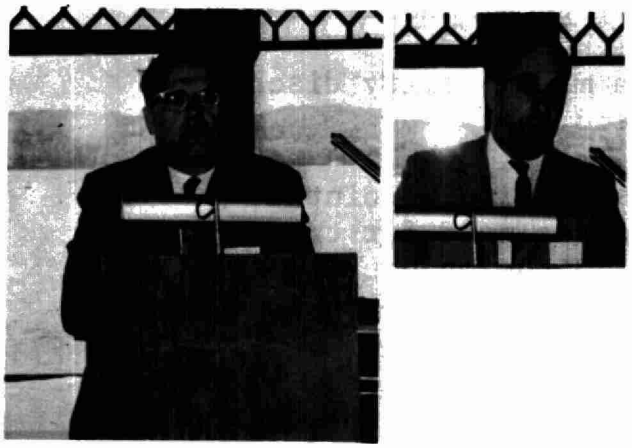
** Total for least cost 2 mg/1 solution equals unity.



Mr. G.E. Gathercole
1st Vice-Chairman
Hydro-Electric Power Commission of Ontario
BANQUET SPEAKER

Mr. F.A. Voege
Assistant General Manager
Ontario Water Resources Commission

SESSION FIVE



F. A. Voege
Ontario Water Resources Commission
Session Chairman

"THE ROLE OF THE MUNICIPALITY IN TRADE WASTE CONTROL"

by
W. M. **SWANN**

My talk to-day will digress from the technical papers which have been presented to the Conference and will cover certain administrative and philosophical aspects of Trade Waste Control. Please bear with me if I digress slightly from the exact wording of my subject and broaden it out at times to cover "the Role of the Municipality in Pollution Control."

I think it is relatively simple to define "the Role of the Municipality in Trade Waste Control." The responsibility of the municipality in trade waste control is:

Firstly - to promote and, where necessary, to legislate for the disposal of trade wastes in such a manner as to provide for a sanitary environment for its inhabitants and the inhabitants of its neighbouring municipalities in as economical a manner as possible, and

Secondly -to counsel and assist industry in the disposal of trade wastes in as economical a manner as possible, and to these should probably be added a

Third - to promote and, where necessary, to legislate for the disposal of trade wastes in such a manner as to protect the aesthetics of the community for the enjoyment of the inhabitants.

The manner in which a municipality discharges these responsibilities can depend:

Firstly - on the awareness of its appointed officials as to the need for trade waste control and the effects of lack of such control;

Secondly - on the awareness of its elected officials as to the need for trade waste control and the need to expend public funds to achieve same;

Thirdly - on the awareness of its populace as to the need for trade waste control and the dire results that could result to its environment and that of its neighbours if trade waste discharge to our land, water and air is not controlled;

Fourthly - on the awareness of industry as to its responsibilities in the disposal of the trade wastes generated by our modern industrialized society.

It is at once apparent that communications and education are all important if the various agencies and individuals are to be aware of their responsibilities.

At this point I begin to wonder if I should not have placed in first position - the need for the populace to be aware of the dire results on their sanitary environment and enjoyment of life if trade waste discharge is not controlled. After all, they basically pay the bills, either directly or indirectly, and history has shown repeatedly that unless well and properly informed they will not be prepared to pay the bills, either directly in construction of sewage treatment plants, or indirectly in the price of the products they purchase; and if they are not prepared to pay the bills then control of trade waste will certainly be curtailed severely or even be non-existent.

The physical method by which a municipality accomplishes disposal of trade wastes will vary greatly from municipality to municipality, depending on the size and location of the municipality and the type and nature of the trade wastes generated in the municipality.

Although trade wastes have been defined on many occasions, I believe it is pertinent to re-define it for the purposes of this paper and I would do so in the following manner:

> "Trade wastes are those materials which are created by industry during the manufacture of a primary saleable product or products and which have so little economic value that it is impractical to recover or sell them and they must therefore be disposed of as a waste material in some manner such as a solid, liquid or gas."

Utopia in trade waste control would, of course, be when modern technological advances find an economical use for every such waste product. We probably smile to ourselves at the improbability of such an Utopia, but is it nevertheless towards such a target that we should direct our efforts. Surely the technical knowledge of human beings which has solved the secrets of nuclear fission and space travel can solve the problems of trade waste control.

I personally believe that all that is required is for us to put our minds to the problem of trade waste control and to solve it. Also, as I indicated earlier, to be aware of the need for trade waste control and the dire effects on our lives if trade wastes are not controlled.

Before I continue and before I outline a part of my own philosophy on trade waste control, and just in case my subsequent comments may be misinterpreted, may I say that I believe most strongly that we should work towards the Utopia I mentioned earlier and, more importantly perhaps we should direct our efforts individually and collectively towards the preservation of our land, our air and our streams, lakes and seas in as pure a condition as it is humanly possible. Having said this, I now wish to give some indication of the difficulties facing a municipality which has become aware of its responsibilities and embarks on a course of action to fulfill these responsibilities. Immediately, it comes face to face with two conflicting philosophies with respect to trade waste control. The first philosophy is that propounded by the conservationists and idealists who maintain that the streams, lakes, or other receiving waters, land or air should remain as pure, clean and sparkling as they were when the area was a forest primeval, inhabited by a few natives, even though it is now a highly civilized urban municipality with a concentrated urban population thousands of times greater. When accepted by the public as their right and prerogative, this philosophy comes home to haunt us.

The second philosophy holds to the theory that the streams, lakes and other waters are a natural resource the same as soil, forest, minerals, etc., which are there to be used for the greatest benefit of the people. This philosophy propounds the theory that water is to be used for human consumption, animal consumption, irrigation, fishing, boating and other recreational activities, as well as for the disposal of trade wastes or whatever other uses that are of the most value to the inhabitants, and which will not create an unsanitary or a completely unaesthetic environment.

I personally believe that every municipality should have a Trade Waste Control By-law but I also believe that such By-laws should be "tailored" to fit the particular situation of the area and that such By-laws should and would, if properly prepared, vary from region to region or area to area.

Let me digress to a certain extent to illustrate a point. I am sure all of us at some time have driven for mile after uninhabited mile through our Canadian Northland and marvelled at the vast unspoiled expanses of the millions of square miles of this country of ours - only to come upon a mine in a small clearing where a half square mile or so of a "tailings" dump is a blight in the forested wilderness. Yet when we consider the contributions of this mine to our national economy, is a half square mile of blight in a million square miles of wilderness a serious matter? Nature will heal the scar or blight in time and no real harm is done. On the other hand, a half square mile of "tailings" dump in Metropolitan Toronto or Montreal or Tokyo would be a different matter.

I could give you other examples and I am sure each of you could recall a situation or situations with which you are personally familiar, but I have used this one example to illustrate in a completely inadequate manner the second philosophy on trade waste control.

I must admit that I personally believe we should work towards the objective of the first philosophy at all times while at the same time I subscribe to the second philosophy which, to repeat, says that our streams, lakes, etc. are resources to be used to the best advantage of the greatest number of people. At the risk of antagonizing the fisherman, may I illustrate my viewpoint by asking the question: "If the only harm which would arise from disposal of trade wastes to a fishing stream is the loss of fishing, why should a million people be forced to pay large sums for trade waste disposal in order to preserve the cleanliness of the stream so that a few fishermen can enjoy their pleasure fishing?" On the other hand, why should a multi-million dollar commercial fishing industry be destroyed because one small industry pollutes the waters to the extent that the fish are destroyed. Between the two extremes could be every degree of variation. True, these are exaggerated examples but I believe it illustrates my point that trade waste control by-laws, if in the best interests of the populace generally, can, and will, vary greatly depending on the size and location of the municipality.

The communities of Trail, British Columbia, and Sudbury, Ontario, to name only two of many, still bear the scars of ignorance of trade waste treatment or utter disregard for the effects of wanton trade waste discharge.

I am fully aware of the cold, hard facts of industrial economy (unless the industry is fortunate enough to have a monopoly) and the need for a firm to "make a buck" in a competitive market, but if man's greed for profit is to destroy or degrade our environment, then governmental control must step in.

Trade waste control in our modern society is a much more complicated and difficult job than it was prior to our development in this modern technological age. To analyze, and trace to its source, the trade waste which is being intermittently discharged to a large modern sewerage system is often a monumental task in itself. To find a satisfactory method of disposing of the trade waste may be an even more monumental task. To discharge to waters is perhaps to pollute the waters, to burn is perhaps to pollute the air, and to dispose on or in the soil is perhaps to pollute the earth and/or the waters.

In Etobicoke, we have a classic example of this problem. Daily newspapers recently carried colour pictures of pollution of the waters of Lake Ontario with a red pigment discharge from a pigment manufacturing company in our Township. The particular incident was the direct result of an attempt on the part of the firm to reduce air pollution which they had been causing. A solution will be found but it will take time and money.

The trade waste disposal problem ranges the gamut from non-degradable detergents, increasing temperatures of receiving waters due to discharge of water used for cooling, and radioactivity to complex chemical compounds.

In a large community, officials must watch for a most troublesome trade waste problem - the home industry. An employee in a firm acquires knowledge at his work or elsewhere and sees a chance to make a dollar or two at home in his basement by working with chemicals or plastics. Don't underrate the number of such home industries and the effect they can have on sewerage systems or treatment processes. Due to the odd hours of operation and the secrecy of operation in a residentially-zoned area, these home industries are most difficult to trace.

In this modern technical age in which we live, it is not only impractical but it is not possible for any one individual to be sufficiently knowledgeable to be able to test for and identify all pollutants in our air, water and land. Although we are all familiar with the visible pollutants to our waters such as debris, oil, scum, discolouration, etc., these represent only a small portion of the pollutants and often the least dangerous. Nevertheless they are certainly warning signs which should not and cannot be ignored. Most of us would, however, be hard put to identify the invisible pollutants which constitute a much greater hazard to our health and to our sanitary environment. Invisible pollutants such as viruses, bacteria, radioactivity, toxic chemicals, etc., require highly trained personnel and technical apparatus if they are to be detected.

It is my opinion and experience that, in so far as trade waste disposal is concerned, modern society has not kept pace with our industrialization and development of new products. There appears to be a dearth of adequately trained personnel in the trade waste disposal field and a dearth of research into the problem and a dearth of funds for such research. Governments have always been notoriously reluctant to expend public funds on research or experiments.

Smaller municipalities are not in a position to maintain the necessary qualified personnel and equipment to check for pollutants and to ensure a practical solution to the problem of eliminating such pollutants. Even a large municipality, with considerable more financial facilities, is often not capable of dealing with the many types of pollutants which result from the many industrial processes of our modern technically-oriented society.

Thus, almost without exception, whether small or large, the municipality must look for assistance. Therefore, it is not illogical in any way for it to provide certain basic facilities and then look to higher levels of government (such as the OWRC) and to industry itself to supplement these facilities - to higher levels of government because, since they are providing service to many municipalities, they can provide much larger, better equipped and better staffed facilities - to industry because normally who is, or who should be, more knowledgeable of their own products, by-products and waste products than their own personnel?

In Ontario, the municipalities look to the Ontario Water Resources Commission for leadership in the field of pollution control. In many cases they are now much more appreciative of the problems and are ready to participate in field research in pollution control. Again, they look to the Ontario Water Resources Commission for leadership and for co-ordination and guidance in such field research. It is to be hoped that the Ontario Water Resources Commission will enter to a greater and greater extent into this particular role of guiding and co-ordinating the efforts of the larger communities.

I said earlier that every municipality should have a Trade Waste Control By-law "tailored" to its own needs. I do not, at this time, propose to develop the detailed technical side of what trade waste discharge should be or should not be, permitted to sewers or streams, nor the problems of preparing such a By-law - this is a subject in itself.

It perhaps would have been most appropriate that this paper should be followed by another on the technical aspects of what should be, or should not be, included in a Municipal Trade Waste By-law.

Until we achieve the Utopia I referred to earlier and as long as there are trade wastes, then means must be found to dispose of them. If we cannot eliminate them, then the By-laws must control them.

Etobicoke is fortunate in one sense as it does not have to worry about trade waste treatment at a central plant. Since Etobicoke is a part of Metropolitan Toronto, this is a Metropolitan responsibility. I should probably take back my words that I don't have to worry since our municipality is castigated most severely if industry in our Municipality disrupts Metropolitan Toronto's treatment processes.

I have brought with me a few visual examples of why a municipality must control trade waste discharge.

May I digress for just a moment to give you an example of some of our problems. A brass manufacturing company in our Township recently called to ask how they could dispose of some waste acid solution they had created. (Through mismanagement it could not be used further). I suggested certain firms which were in the business of handling such trade wastes. The executive said that he had contacted them all and none would handle it since one such firm had tried and the trade waste had corroded the valves on its truck and the acid had spilled over the highway before it reached the disposal site. The brass company executive said he would probably have discharged it surreptitiously to the municipal sewers except that he had had experience with the efficiency of Etobicoke Township trade waste sleuths.

A Municipal Trade Waste By-law should in my opinion do the following:

(1) Differentiate most distinctly between (a) toxic and injurious trade wastes which can damage sewerage systems, disrupt sewage treatment processes or which are incapable of treatment and would not be acceptable in the receiving waters and (b) non-toxic and non-injurious trade wastes which pose only a problem of adequate treatment facilities and the cost of treating the wastes.

(2) Since we cannot eliminate trade wastes completely, we must control them and the By-law must therefore

control the quality of trade wastes discharged to sewers or streams and again these should be clearly separated into two classes:

(a) Allowable limits of toxic and injurious trade wastes.

(b) Allowable limits of non-toxic and non-injurious trade wastes.

(3) Since quality of trade wastes is, almost without exception, in direct proportion to the degree of dilution and since dilution can pose problems of capacities of receiving sewerage systems, the By-law should also contain control on the quantity of trade waste which may be permitted.

(4) Since the treatment of some non-toxic and non-injurious trade wastes can more economically be carried out at the source of the trade waste (i.e. at the industry itself) and in other cases can better be carried out at a central municipal plant, the By-law should establish that if industry wishes to discharge non-toxic and non-injurious trade wastes in excess of the allowable limits they may do so upon payment to cover the cost of such treatment. The By-law should clearly indicate the scale or basis of such payments.

(5) Since it is probable that there will be at least an occasional transgressor of the By-law, the By-law should establish penalties for such transgressors.

The role, therefore, of the municipality in pollution control and trade waste control may be summarized as follows:

(a) Maintaining the necessary qualified and up to date personnel and technical facilities, commensurate with the size of the municipality and the degree of industrialization, to be able to cope with pollution control with the assistance of higher levels of government (and where applicable or necessary, of individual industries):

(b) Maintain the necessary liaison with the higher level or levels of Government in order that pollution control will be carried on efficiently and without overlap;

(c) To adequately inform the residents, commercial establishments and industries of the hazards of pollution, the effect on our sanitary environment and the need for pollution control;

(d) To pass by-laws defining clearly the wastes which may or may not be discharged to sanitary sewers, to storm sewers, to streams or lakes, to the land and to the air;

(e) To be ever vigilant in detecting pollution, to sample and conduct all tests necessary to detect pollutants when they occur;

(f) To maintain such liaison and working arrangements with all industrial and commercial plants within the municipality, in order that the municipal staff may have a general knowledge of the processes carried on in each plant and the waste products to be disposed of and the best method of disposal of same. The liaison should be sufficiently well established that the industry considers the efforts of the municipal staff to be that of an assistant and advisor rather than that of policeman; it should be sufficiently well established that industry will automatically contact and discuss with the municipal staff contemplated changes in industrial processes and again when ready to implement the changes;

(g) To provide those municipal pollution control facilities and plants as may be necessary to effectively treat domestic wastes and those trade wastes which can best be treated in a central community plant;

(h) To enforce these by-laws to effectively control pollution within allowable limits when discussion, negotiation and all other means of control are unsuccessful;

(i) And unfortunately, occasionally to act as policeman when the proper liaison fails to materialize and industrial trade wastes pollute the municipal environment beyond the allowable limits.

If I may refer back to the point about liaison with all industrial and commercial plants for a moment, Mr. MacLeman in his paper spoke of the initial opposition of industry to their proposal. He also said that by co-operation and working with the industries they achieved not only acceptance of the proposals but full co-operation and, even more important in a business where trade secrets are jealously guarded, a free exchange of ideas.

Dr. Vance spoke of the need for co-operation between industry and governmental control agencies, and his opinion that co-operation would be far more effective than wielding the "big stick".

May I just say that without question, Etobicoke's experience bears this out and indicates that the establishment of good liaison between the municipality and each and every industry is of paramount importance.

Although I have summarized the role of the municipality in pollution and trade waste control, before I conclude, I would like to dwell for a few minutes on what seems to me to be those areas where the municipalities are not adequately discharging their responsibilities.

I feel, first of all, that the technical staff of many municipalities, including myself and many of may own confrères, have fallen down badly in not being vigilant in noting the increasing build-up of pollutants and bringing it to the attention of the people, to the attention of industry, and to the attention of the elected representatives.

I feel, also, that while perhaps many of us have brought it to the attention of the elected representatives, and recommended the remedial action which should be taken, probably too many of us have taken a defeatist attitude when the elected representatives have failed to take action. Too often, I'm afraid, we have taken the stand that we have fulfilled our duties when we have brought it to their attention and have sat back and said "I've done my duty; on their heads be the consequences". But have we done our full duty and discharged our responsibilities to those who employ us if we have not continued to fight to the bitter end for the necessary pollution control plants or whatever is necessary to control pollution? I personally believe that I have not discharged my responsibilities until I have convinced the necessary people, industries, or authorities to do whatever, in my opinion, they should be doing.

I am quite sure that most municipal staffs and councils have failed to adequately inform the people and industry of the existence of pollution, of the dangers of pollution and of the need for pollution control. Even more to their discredit is the fact that they have failed to even attempt to inform the people and industry.

I sometimes wonder whether Government, in a sincere desire to fulfill what it deems to be its responsibilities to its residents and ratepayers, is prone to over-legislate on one hand while underselling on the other hand. Governments are notorious for plugging "loopholes". Someone does something wrong or foolish which is against the interests of a resident or residents and in comes a new act or by-law to see that it doesn't happen again. It doesn't matter that it was the first occurrence in a 100 years and may never happen again in another 100 years. But in the meantime a multitude of individuals or firms are saddled with one new piece of "red tape".

I believe that Dr. Vance touched briefly on this same point in his talk and uttered a warning to industry by indicating that co-operation with government could go a long way to avoid this possibility.

Don't get me wrong, I am not naive enough to say that we can function without laws and by-laws. What I am leading up to is the fact that municipalities are "underselling"- and what are they "underselling"? It is the fact that everyone has a moral responsibility to maintain a healthy environment for themselves and for their neighbours and friends. By everyone, I mean individuals, groups, firms, corporations or "what have you".

I believe that every municipality should use persistently and continuously every means available to awaken the people and industry to their moral responsibility to themselves and their neighbours to maintain a sanitary environment. Liaison and communication with the people and industry must be established if they are to become aware of and discharge these moral responsibilities. Liaison and communication will not only make them aware of their moral responsibilities but it will also make them aware of the benefits and advantages which will accrue from pollution control. I have no doubt that every one of us has decried the throwing of candy wrappers and/or empty cigarette packages on our streets and in our parks, etc., and yet I have no doubt that each and every one of us has been guilty of the same transgression. An awakening to or a better appreciation of each and every one of our moral responsibilities has to occur if we are to cope with the problems of air, water and land pollution. We can start ourselves with the small things such as the candy wrapper, the empty cigarette package, the oil spillage from our outboard motor, etc. Our municipalities must do everything possible to awaken the people and industry to the seriousness of the problem and to institute any necessary remedial action.

We have been dazzled by a number of complex technical formulae in the previous technical papers and not to be outdone, I sat up last night and came up with my own formula. Please don't laugh, because I am quite serious in my opinion that this formula will measure the degree of success in trade waste pollution control which will be achieved by any given industry.

$$\frac{A \times D \times K \times R}{100M} = \text{Degree of success in elimination of trade waste pollution}$$

Where A indicates the degree of awareness of the need for pollution control in the range of 1 to 10

D indicates the degree of desire to eliminate pollution in the range of 1 to 10

K indicates the extent of knowledge of processes creating trade wastes and the treatment of such trade wastes

R indicates the amount of research and thought which is put into industrial plant layout to prevent trade waste pollution

and finally

M indicates the extent to which the particular industry has a monopoly in the market for their particular product.

The evidence of the failure of individuals, appointed officials, elected representatives, municipal government and industry to properly and adequately discharge their responsibilities can be seen in the litter on our streets to which most of us contribute, the debris we see everywhere in many of our communities and to which most of us contribute, the smog which is injuring the health of the citizens of certain industrialized communities and even causing deaths, the streams and beaches banned for bathing, and the reports by OWRC of the polluted environment surrounding so many of our communities and the need for action.

The fact that we are aware of and are discharging our responsibilities as individuals, appointed officials, elected representatives, municipal governments and industry will be evident when we ourselves place our candy wrappers, empty cigarette packages, bottles, etc., in an appropriate provided container, when we reprimand (in a nice way of course) our children, our friends and our neighbours when they do not do likewise, and when the OWRC information bulletins have no complaints about the unsanitary condition of our communities.

"INDUSTRIAL WASTE CONTROL PROGRAM IN ONTARIO"

by

R. H. MILLEST

Much has been written and said during the past few years of the growing water supply crisis facing us and future generations in North America. Low water levels in the Great Lakes, increasing pollution resulting from rapid urban and industrial growth, and the growing demand for water for irrigation, have brought clearly to public attention the need for prompt and vigorous action to ensure that available water resources will continue to serve an ever-expanding demand on a perpetual basis.

Although recurring water shortages do present very serious problems in several areas on this continent, it seems incongruous that shortages should occur in the Great Lakes basin, containing, as it does, approximately 1/5 of the world's fresh water supply. Indeed, ours is not a problem of water shortage but rather of distribution and quality control. As water-use intensifies, the challenge will be to develop the means to deliver it to consumers, together with the means to ensure that the quality will be maintained for re-use over and over again. Pollution control, then, is a vital part of water resources management, because even abundant water supplies are of little value if they do not serve all of the multiple uses of modern society.

The importance of pollution control was recognized in the initial drafting of the Ontario Water Resources Commission Act, and broad statutory authority was provided for this purpose. Before discussing the intensified program which the Commission has recently undertaken in applying the terms of the Act to industrial waste control, I should like to comment on the program that has been carried out since 1957 and on some aspects of the Commission's responsibilities and activities which will, perhaps, bring the present industrial waste program into perspective.

As you may know, the Commission was established in 1956 with the enactment of the Ontario Water Resources Commission Act, and became fully operative in 1957 with the appointment of staff, mostly by the direct transfer of a large part of the Sanitary Engineering Division of the Ontario Department of Health. Most of the responsibilities of that Division were transferred to the Commission under the terms of the Act, and, as a result, the supervision of water supplies, sewage treatment and disposal, and stream sanitation were continued without interruption. Approval of all municipal water supply and sewage works, formerly a function of the Department of Health, was also assigned to the Commission.

The OWRC Act was unique, and I believe it still is, in that provision was made at the outset for the Province, through the Commission, to enter into agreements with municipalities, whereby the Commission would undertake to finance, construct, and operate water supply and sewage treatment facilities for municipalities, with repayment of capital and operating costs being extended over a period of years. Participation by the Province in this way has been a major factor in the control of pollution from municipal sources. Many financial and technical difficulties which had been encountered for many years, particularly in the smaller municipalities, were largely overcome. By the end of 1964 the Commission had constructed and was operating 134 sewage works projects and 96 waterworks projects throughout the Province at a capital cost of over $100 million. A recent departure from the Commission-Municipal arrangement has been indicated by the decision by the Province to build the Lake Huron-to-London water supply pipe-line as a wholly Commission-owned facility. No municipal agreement is involved, other than contractual arrangements for the purchase of water. It would be pure speculation now to comment on the extension of this type of arrangement to other water supply areas or to sewage or waste treatment, although studies are being made elsewhere to determine the applicability to other water supply systems.

Until just recently the activities of the Commission in the investigation, control, and regulation of industrial wastes have been the joint responsibility of the Industrial Wastes Branch of the Division of Laboratories and the Division of Sanitary Engineering. In a reorganization within the Commission this spring, the Industrial Wastes Branch was established as a separate division as a first move in bringing the administration of industrial wastes control in line with the control that has been exercised over municipal water supply and sewage treatment and disposal.

A measure of the scope of the work of the Division is seen in the summary of activities in 1964, in which investigations were made at 421 industries, ranging from detailed (and often repeated) studies at larger basic process industries to routine field reviews of waste disposal at a large number of relatively small industries.

In addition, 635 inspections of canneries, dairies and milk processing plants, slaughterhouses and packing plants, and gravel washing and other non-chemical industries were carried out by the staff of the Sanitary Engineering Division.

Seven municipalities were surveyed in 1964 to evaluate industrial loadings to municipal sewers and public waters. Industries throughout four counties were similarly dealt with as part of comprehensive county water resources and waste disposal surveys that were undertaken by the Commission.

Of special interest in the industrial waste field was the continuing broad examination of pulp and paper wastes disposal throughout the Province. This study program, carried out since the formation of the Commission, led, earlier this year, to the setting out of objectives for a five-year program of effluent improvement toward which the industry, with the direct participation of senior management, is proceeding. A province-wide assessment of problems within the industry is now being made by a special technical committee of the industry under the direction of an Ontario sub-committee of the Policy Board Committee of the Canadian Pulp and Paper Association. Proposals for waste treatment and control are being prepared, with the installation of primary treatment or equivalent control of suspended solids discharges as the initial objective to be achieved by the end of 1966.

Another highlight of the work of the Commission was the completion of an extensive study of waste disposal from the major industries along the City of Hamilton Bay-front. Prompt co-operation by the City led to re-direction of some wastes to the municipal sanitary sewer system for treatment in the municipal sewage treatment plant. Large-scale planning for the treatment of wastes that could not be so-handled was undertaken by the major steel producers, and proposals calling for expenditures of several million of dollars for a massive assault on the problems were submitted to the Commission as requested. These control programs are now under way.

In all field studies, the need for in-plant control as the initial step in waste control has been recognized. Because this depends, to a great extent, on revisions to industrial processes and equipment, initial emphasis is placed on process studies and consultation with industrial management and technical personnel. Schedules of effluent improvement are sought with this in mind so that as much pollution control as possible can be effected by practical and economic means. An acceleration in this phase of pollution control is being sought now, however, as the public demands for pollution control continue to press for prompt and complete solutions to waste disposal. Unless in-plant controls are effected promptly, the demands for treatment may well be such that unnecessarily large or complex works will have to be provided which otherwise could be minimized by eliminating wastes at the source.

Although the Commission does not exercise direct control of industrial wastes that are discharged to municipal sewers, surveys are nevertheless carried out to evaluate industrial loadings and to assist municipalities in effecting controls to protect sewerage systems and to control sewage treatment plant loadings. Most of the municipalities in Ontario in which industrial waste loadings are significant or in which sewer-use problems have arisen have been surveyed and detailed reports made available for municipal use. Municipalities have been urged to enact and enforce sewer-use by-laws as the basis for control, and it is to be noted that there is wide-spread acceptance and use now of a fairly uniform schedule of requirements throughout the Province. Close liaison is maintained with the City Engineers' Association by Commission participation in the activities of an advisory committee of that organization. Close liaison is also maintained with other departments and agencies of the Provincial and Federal Governments in dealing with industries and resources development in which multiple interests are to be served.

In setting out the responsibility of the Commission for pollution control in the Province, the OWRC Act broadly defines sewage as including "drainage, storm water, commercial wastes, and industrial wastes", and sewage works as "any works for the collection , treatment, transmission, and disposal of sewage, or any part of such works", but not including plumbing which falls within municipal or local responsibility or which is subject to regulation under the OWRC Act. This interpretation, then, indicates that industrial wastes are subject to the same terms of control as is municipal waste, and it is on this basis that the control program is being brought forward.

The provision for enforcing pollution control is set out in Section 27 of the OWRC Act which reads as follows:

"Section 27 (1) - Every municipality or person that discharges or deposits or causes or permits the discharge or deposit of any material of any kind into or in any well, lake, river, pond, spring, stream, reservoir or other water or watercourse or on any shore or bank thereof or into or in any place that may impair the quality of the water of any well, lake, river, pond, spring, stream, reservoir or other water or watercourse is guilty of an offence and on summary conviction is liable to a fine of not more than $1,000 or to imprisonment for a term of not more than one year, or to both. 1961-62, c. 99, s. 5.

(2) - The discharge into any lake, river, stream or other water or watercourse of sewage from sewage works that have been constructed and are operated in accordance with the approval of the Department of Health or the Commission or in conformity with any order of the Board is not a contravention of subsection 1. R.S.O. 1960, c. 281, s. 27 (2)."

The question of what constitutes impairment of water quality is therefore obviously of significance. It should be noted that the Commission has not felt it desirable to set up effluent or water quality standards, but has chosen instead to examine each case of waste disposal and water pollution on its own merits. Guide lines have been necessary, of course, and these have been defined in Water Quality Objectives For the Province of Ontario. Interpretation is based on field data acquired in each case, in which the chemical, physical, biological, and bacteriological effects on the receiving waters dictate the need for treatment. Complete control of pollution, while not always practicably attainable in the short term, is nevertheless the over-all objective. Rather than establish stream classifications or varying standards, which the Commission feels would lead to irrecoverable conditions, in some instances at least, the goal of the control program is to obtain and maintain clean water throughout the Province.

In addition to the general provision in the Act for pollution control, Section 31 requires that all sewage works must be approved by the Commission before installation. This provision, as quoted below, has been applied to sanitary sewage works since 1957, having been transferred at that time, as mentioned earlier, from the Public Health Act.

"Section 31 (1) - When any municipality or any person contemplates the establishment of any sewage works, or the extension of or any change in any existing sewage works, the plans, specifications and an engineer's report of the works to be undertaken, and the location of the discharge of effluent, together with such information as the Commission may require, shall be submitted to the Commission, and no such works shall be undertaken or proceeded with and no by-law for raising money to finance such works shall be passed until the proposed works have been approved by the Commission. R.S.O. 1960, c. 281, s. 31 (1).

(1a) - Every municipality that or person who contravenes any provision of subsection 1 is guilty of an offence and on summary conviction is liable to a fine of not more than $2,000. 1964, c. 86, s. 8, part.

(2) - Where any person undertakes or proceeds with the establishment of any sewage works, or the extension of or any change in any existing sewage works, without having first obtained the approval of the Commission, the Commission may order the person to afford at his own expense such facilities as the Commission may deem necessary for the investigation of the works and the location of the discharge of effluent and in the works as the Commission may deem necessary, and any changes directed by the Commission to be made in the works shall be carried out by the person at his own expense.

(3) - Where in the opinion of the Commission it is in the public interest to do so, the Commission may refuse to grant its approval or grant its approval on such terms and conditions as it deems necessary. R.S.O. 1960, c. 281, s. 31 (2, 3).

(3a) - Every person, except a municipality, who,

(a) fails to comply with any direction or order given or made by the Commission under subsection 2: or

(b) contravenes any of the terms and conditions of the approval granted by the Commission under subsection 3,

is guilty of an offence and on summary conviction is liable to a fine of $500 for every day upon which such default or contravention continues. 1964, c. 86, s. 8, part.

(4) - This section does not apply,

(a) to a sewage works from which sewage is not to drain or be discharged directly or indirectly into a ditch, drain or storm sewer or a well, lake, river, pond, spring, stream, reservoir or other water or watercourse;

(b) to a privately-owned sewage works designed for the partial treatment of sewage that is to drain or be discharged into a sanitary sewer;

(c) to a privately-owned sewage works serving only five or fewer private residences;

(d) to a sewage works the main purpose of which is to drain agricultural lands;

(e) to a drainage work under The Municipal Drainage Act, The Ditches and Watercourses Act, The Cemeteries Act, The Highway Improvement Act or The Railways Act;

(f) to such sewage works as may be exempted therefrom by regulations made under this Act;

but this section does apply to a sewage works for the distribution of sewage on the surface of the ground for the purpose of disposing of the sewage. 1961-62, c. 99, s. 9."

These provisions are now being applied to industrial waste treatment or disposal works as well as municipal works. It is intended that all works that fall within the scope of the definition of sewage works in the OWRC Act shall be subject to this control. An extensive review was made in 1964 by the Commission of the methods by which plans for industrial waste treatment were received and approved by most of the states in the United States, to take advantage of the prior experiences in that country. This information, together with the established procedures used in handling municipal applications and approvals in Ontario has formed the basis for applying the terms of the OWRC Act to industrial waste approvals here. Although a formal application for approval has not yet been brought into use, the program is in effect with the following procedures:

As indicated in Section 31 of the OWRC Act, an engineering plan of proposed industrial waste disposal facilities must be submitted to the Commission for approval. Since the ability of the treatment and disposal works to meet the Objectives of the Commission must be assessed prior to issuing an approval, and much of the success of industrial waste control is related to control at unit process operations, the information requested in an application is fairly extensive. All or part of the following may be required, depending on the type and size of the industry under consideration:

(i) a property lay-out sketch showing, to approximate scale, the size and location of the industrial process works and ancillary buildings, the location and sizes of principal sewers, and the point(s) of discharge of the outfall sewer(s) in relation to the receiving water. The direction of flow in the sewers shall be plainly indicated on the sketch. If land disposal is planned, all wells or other water supplies within 200' of the disposal area should be identified.

(ii) Engineering drawings in sufficient detail to show the size, location, and material-flow of wet-process units in which water, or expendable liquids, is used as a carrier or reaction medium for temperature control, or in which water, or other liquids, is removed for separation from the industrial process or products.

(iii) A written description of the industrial process(es) in sufficient detail to indicate the purposes of water-use. The quantity of water used in specific unit processes and/or industrial operations or process areas shall be given, together with the quantity and estimated or measured quality of the wastes arising from the water-use. Where the quantity and/or quality of the wastes varies according to industrial operating procedures, the variation in rates of flow (normal, maximum, and minimum) and the maximum and average concentrations of significant waste components shall be given.

(iv) Lay-out plans, if applicable, of proposed works or equipment for the treatment or modification of the wastes in question, together with a written description to indicate operating procedures or schedules. The description should include the quantity of treatment chemicals, if used.

(v) A written indication of the expected degree of reduction in pollutional load to be effected by the operation of the system. The reduction should be clearly established.

(vi) Plans and profiles of the outfall sewer(s) related specifically to the location with respect to the receiving waters. It is intended that an application form will be brought into use later this year, simplifying the preparation of this information.

The Objectives For Water Quality For the Province of Ontario, supplemented by similar Objectives For Industrial Waste Control, are made available with this information as a broad guide to the degree of effluent control that is required. These latter Objectives refer to industrial wastes as follows:

Objectives For Industrial Waste Control In Ontario

Protection of Receiving Water

In keeping with The Objectives For Water Quality Control in the Province of Ontario and the overall policy of protecting water quality, while recognizing essential use for waste water disposal, the Commission may require industries contributing wastes, not specified in the following, to limit, destroy, remove or modify any waste constituents that may be in question. This may apply to waste constituents that are not readily removed by conventional treatment and are only reduced by dilution and other natural stream purification processes.

In order to maintain acceptable water quality conditions in the receiving water it may be necessary for the industry to provide more intensive waste treatment as the density of industrial and other development increases.

Acceptable Receiving Water and Effluent Characteristics

1. Biochemical Oxygen Demand (BOD) - The concentration of BOD at any point in the receiving water after initial dilution shall not exceed 4 parts per million by weight, and the concentration of dissolved oxygen in the receiving water shall not fall below 4 parts per million by weight, at any time.

2. Suspended Solids - The concentration of suspended solids in waste water at the point of discharge to a receiving water shall not exceed the concentration of suspended solids in the industrial water supply by more than 15 parts per million by weight.

3. Oils and Greases - The concentration of oils and greases of vegetable, animal, or mineral origin in waste water shall not exceed 15 parts per million by weight at the point of discharge to the receiving water.

4. Toxic Substances - Materials or waste components that are toxic to aquatic life or render the water unsuitable for potable or recreational uses shall be eliminated or destroyed.

5. pH - the pH or relative acidity or basicity of waste waters shall be controlled and maintained within the range of 5.5 to 10.6 in the pH scale.

6. Taste and Odour - Waste materials or components that impart tastes and odours to the receiving waters or to fish, that would render the waters or fish unsuitable for use, shall be eliminated or destroyed. Phenol or phenolic equivalents should not exceed an average of 2 parts per billion or a maximum of 5 parts per billion in the receiving waters following initial dilution.

7. Aesthetic Qualities - Treatment or control shall be effected to ensure that waste discharges do not impair the aesthetic qualities of the receiving water by imparting colour, by giving rise to accumulations of solids, oils or greases, by inducing foaming, or by other adverse effects.

Upon receipt of a proposal, technical field staff of the Industrial Wastes Division review the information with the industry concerned, and, where necessary assist in compiling additional data or advise as to further information that is required.

Upon completion of the submission, a final review of plans and proposals leads to formal consideration by the Commission of a Certificate of Approval to which conditions may or may not be added or appended, depending on the nature of the problem at hand. It should be noted again that final approval will very often depend on the ability of the treatment or control works to meet the Objectives of the Commission, and, because of the wide variety of problems to be expected, operating demonstration of performance capability may be a more-or-less normal requirement.

Returning to the legislation for a moment, a section was added to the Act in 1964, to provide the means whereby the Commission could compel industry to comply with the terms of Section 31. Section 50 was added for this purpose and states as follows:

"Section 50 - If an industrial or commercial enterprise makes arrangements for sewage disposal that are deemed unsatisfactory by the Commission, or makes no arrangements for sewage disposal, the Commission, with the approval of the Minister, may require such industrial or commercial enterprise to install, construct or arrange such sewage treatment facilities or additional sewage treatment facilities as the Commission deems necessary, and to maintain, keep in repair and operate such facilities in such manner and to such extent as may be directed from time to time by the Commission. R.S.O. 1960, c. 281, s. 50."

This section clearly indicates the forthright approach that the Commission is making to industrial waste control, and, while it is expected that these terms would be enforced only as a last resort, the Commission will turn to this section of the Act if necessary to get the job done.

It is obvious, in looking over the industrial waste situation in Ontario, that many long-standing and difficult problems are to be solved, many of which are made all the more difficult by poor location, antiquated sewer lay-out and so on. Nevertheless, a start must be made and, if necessary, staged programs of effluent improvement scheduled. The terms of the Act will be applied firmly to new plant locations, however, so that waste treatment and control will be a necessary consideration at the outset.

In conclusion, then, the rules for pollution control have been set out in the legislation and are brought into practice by the application of Water Quality and Industrial Waste Control Objectives which permit a practical and realistic approach to all problems throughout the Province. The Commission will be prepared as it always has been, to negotiate time schedules for the installation of waste treatment works, to ensure that undertakings are programmed in keeping with the ability of industry to support them. The degree of treatment required and the performance capabilities of proposed works will also be subject to negotiation so that waste treatment can serve its real purpose and not become an end in itself.

Industry has much to contribute in this regard and it is hoped that discussions with the Commission will not be dampened by the fear that suggestions for effluent control will be interpreted as commitments to actions that industry cannot perform. This fear, I assure you, is unwarranted if it does exist. An equitable solution, arrived at by negotiation and discussion, will be more economical and will provide better public relations for all concerned than allowing the law to run its full course. We merely ask that you meet us half way so that we can work with you to seek solutions to your problems.

A reminder of Tsar ineptitude.
The Bell that wouldn't ring. Cast 1733-35.
Within the Kremlin Wall.

Famous Clock Tower, one of twenty in the Kremlin Wall.

St. Basil's Cathedral in right background.

Inside the Kremlin.
Ultra modern marble and glass Palace of Congresses on the left.

Inside the Kremlin Wall.
View of Moscow's ancient cathedrals with their golden cupolas.

BANQUET ADDRESS

"IMPRESSIONS OF RUSSIA"

by

GEORGE E. GATHERCOLE

Sir Winston Churchill once described the Soviet Nation as an enigma wrapped up in a riddle. Would I find it so? What were the characteristics of this huge land populated by 225-million people and stretching 3,000 miles from north to south, 6,500 miles from east to west, with twice the time differential that we have in Canada? What kind of people were these Russians? Were they poor, hungry, an unkempt and unhappy lot? Were living conditions as deplorable as they had sometimes been depicted? Could men and women who had designed and manned the Sputniks also produce the genius to emulate our Western World democracy? These were but a few of the questions that crossed my mind as we flew into Moscow on April 30th, a year and a half ago, on a visit to Russia as guests of the State Committee for the Co-ordination of Science and Research.

No one, of course, could speak authoritatively about a country after only a two-week visit, particularly when that country is as vast and complex and puzzling as Russia. But even impressions from a short stay may help to promote a better understanding of a nation and a people who have made their imprint on world affairs and with whom in one way or another we must learn to live.

Our visit in the Soviet Union took us from Moscow to Leningrad and Pushkin in the north, Voronezh, Zaporozyhe and Volgograd (formerly Stalingrad) in the south. As might be expected, the countryside, even in European parts of Russia, changes significantly. The region from Moscow north bore a resemblance to our clay belt in northern Ontario with an abundance of forest cover, lakes and rivers. The land to the south with its black soil and open rolling plains relieved only by occasional patches of dwarf trees had characteristics of our Canadian prairies and offered an explanation that had not occurred to me before of the magnetic drift of so many Ukrainians to the Canadian West.

I can say now that many of my earlier impressions of Russia were coloured if not inaccurate. Living conditions were austere and comforts meagre compared with our own, but in general the people were clean, healthy and reasonably well attired. There was no apparent shortage of food, though the range of choice was more limited. The people seemed contented and happy. If there was dissatisfaction with the regime or their way of life, it was not evident. In travelling some four or five thousand miles in the Soviet Union, we met many persons in different walks of life, and invariably we were treated with courtesy and good-will.

I was surprised, though perhaps I should not have been, by the affection and care that Russian parents lavish on their children. This showed up in a number of ways. At the May Day celebration in Red Square, at which attendance had to be strictly limited because of the lack of space, a large proportion of the audience was composed of young children gaily dressed and festooned with paper flowers in a variety of colours. But it was best revealed in the children themselves; with their merry and bright faces they were indistinguishable from our own.

The Soviet citizen's range of travel is much more restricted than ours. Except for State officials, few could afford to travel abroad. Within Russia itself only high government officials and those prominent in the opera, ballet or science would have access to an automobile. The smallest automobile in the Soviet Union would cost over $4,000-- for even a skilled worker, three years' income--and to acquire one carries with it an obligation to disclose the source of the money. While the number of motor vehicles is increasing, the lack of adequate roads extending beyond the municipal boundaries is in itself a severe limitation on their use. In the two weeks we were in the Soviet Union I saw only two gasoline service stations, both of which had a line-up of cars waiting for service.

Incidentally, this queuing up for service, whether it be to make a purchase, board a bus or enter a theatre, is an instilled habit, a time consuming process that is almost a way of life. The discipline of the Soviet people in this regard was also observable when on occasion we were ushered into museums and on or off trains or planes ahead of those who had been patiently waiting. At no time was there the slightest protest at this intrusion. The Russians accepted it with the good grace born of long practice.

I saw a few motor scooters in the Soviet Union, but surprisingly rarely a bicycle. Most of the urban people live in concentrated quarters and if they are required to travel, take the subway, the bus or the train. Aircraft travel is increasing and in Volgograd there were illuminated signs extolling its virtues. This was one of the few evidences of Soviet advertising that we encountered, but certainly this is an industry which, even in the Soviet Union, will expand rapidly to ensure the effective marketing of their production as their society becomes more affluent.

Soviet recreation takes the form of a visit to the palaces and museums, a walk along the broad vistas, a night at the opera, or the ballet, or dancing. Almost any night in the hotels dance bands grind out the same popular rhythms that can be heard in Canada.

Although the Russians we met were of serious mien, as might befit the purpose of our visit, as a people they are fun loving; singing in the streets was quite common, and they are obviously not devoid of a sense of humour. One of their most popular stage and television entertainers, Mr. A. I. Raikin, has become a great hit by his skits of hapless individuals being caught up in Soviet red tape and administrative bungling. We heard Mr. Raikin at the Festival of Stars performance in the Palace of Congresses and he recognized our presence by doing one of his acts in English.

Prior to visiting Russia, I had never fully appreciated the value of the countless restaurants and sandwich shops that blanket most Canadian cities, providing in some cases round-the-clock service to a restless, consumer population. In Russia the paucity of such places meant that meals had to be obtained in the hotel dining rooms where service was an unreliable thing that might take from one to three hours.

Borsch soup with heavy fish, meat or poultry stock was a common menu item. Fish, black and red caviar, and eggs were plentiful. Occasionally we ordered steaks but by the time they were delivered they were cold. Apples, oranges and lemons were available, but oranges were 55¢ and lemons 44¢ each. I saw

Statute of Peter the Great, Leningrad.

Depicts Peter breasting the breaking waves with the serpent of trouble at horse's heels.

St. Isaac's Cathedral. Leningrad.

Now a tourist attraction.

Street scene. Leningrad.

Paul's Summer Palace. Outside Leningrad.

bananas only once, on a table at a meeting with the State Committee for Power and Electrification. Bottled apple cider, pear-flavoured and ginger ale drinks were plentiful as vodka, Georgian cognac and brandy. The Russians produce a very good chocolate, but this was very expensive as were many other items.

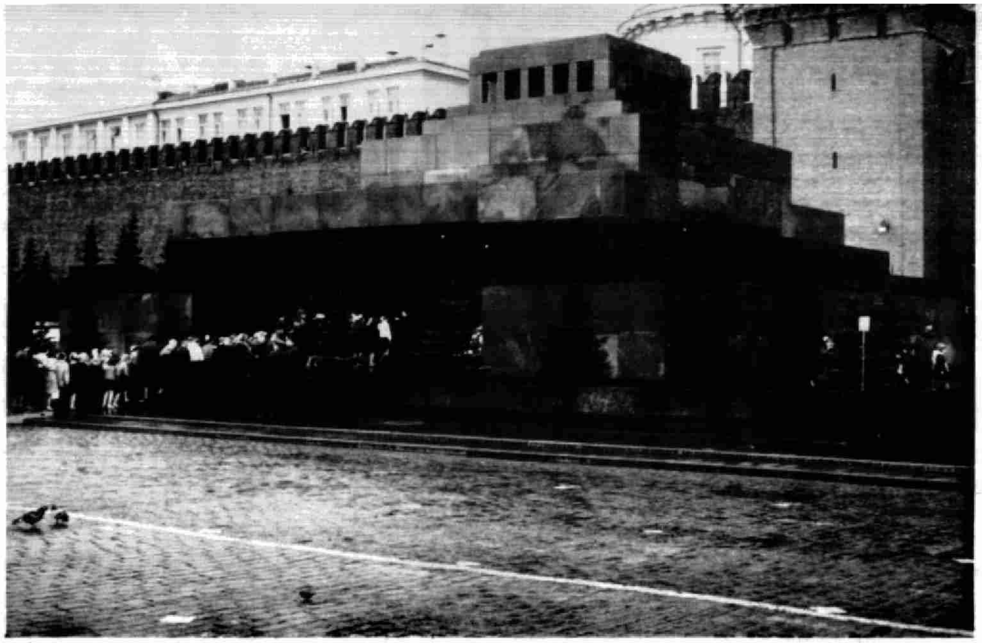
The GUM department store in Red Square, Moscow, does more business than any other store in the world. This is partly because there are relatively few merchandise outlets in the Soviet Union and most of these are unappealing. Many goods seemed to be in adequate supply, but would not have attracted an American or Canadian buyer in terms of either quality or price. Fine goods, such as shoes and cloth from England, hose and dress apparel from France or from Switzerland or even Czechslovakia, are highly prized. A portable television set sold for about $400, equivalent to about three to four months' salary for a skilled Russian worker. Many items such as refrigerators were not available.

Despite a number of redeeming features--such as the wide avenues, the immaculately clean streets (kept that way by frequent flushing and a band of women drudges), the ornate subways and the exquisite interiors of some of the palaces--the Canadian visitor is likely to find the Soviet scene bleak and somewhat depressing. Most urban buildings are finished in a rough plaster or stucco painted a shade of yellow, brown or green.

To overcome the desperate housing shortage, the government has undertaken a prodigious construction program of rows of small flats, which, despite the intense demand and need for them, will constitute a problem for the future because of their shoddy standards of construction. These apartments or flats are made available on a controlled rental basis, usually equivalent to 4% of income. This, coupled with a very low income tax and welfare benefits, helps to make life manageable.

No one is permitted to own land. Recently it has become possible for the Soviet citizen to join a co-operative housing venture in which he will invest his own funds, supplemented by a loan from his union, his employer or the State Bank. In this way, he (or she) acquires the right of ownership to one of the flats in the building, but not the land, and it is capable of being sold to another buyer.

The work week in the Soviet factories we visited was five and a half days. A skilled tradesman would earn about $150. a month. Even the most lucrative positions in the Soviet Union would not provide a salary above $700. per month, although in



Lenin's Mausoleum in Red Square.

Long queues form almost daily to pay homage.

Kremlin Wall in the background.

Red Square, Moscow. May Day 1964.

Central banner shows Lenin, Marx and Engels.

State GUM store in background.

Moscow State University - higher learning for 35,000 students.

Bolshoi Theatre.

In the background, Moscow.

some cases there would be perquisites. Soviet workers do not indulge in coffee breaks, but from time to time they may be seen standing talking to one another over a cigarette. I saw nothing to suggest that they were more industrious or hard working than Canadians.

Workers who excel are singled out for special attention. Each factory will have its honour roll and a photograph of workers whose performance has been distinguished. Sometimes an award, decorated by a plant, will be set up out in the factory adjacent to the machine and its operator. Gradually other incentives are being devised. Some employees are on piece work; others augment their income by a production bonus up to about 50% of the basic wage.

The Russian worker enjoys an assortment of welfare benefits such as state paid vacations and rest cures. All workers are entitled to a job, it is their duty to work, and they may not be dismissed without permission of the Union which is state controlled. If the employee's performance is unsatisfactory, the union officials take him aside for a talk in the hope that he will mend his ways.

Some of the most menial, grubby and heavy tasks are performed by women. So great is the emphasis upon production, combined with their shortage of capital for expansion, that little attention has yet been given to the provision of industrial safety devices. However, these will come. The men and women we encountered in high positions in industry and government impressed us as able and competent, and improvements across a broad front will be made.

To raise productivity great emphasis is being placed on research and education. Education has a bias toward the scientific and technical. A large portion of the 35,000 students enrolled at the University of Moscow is engaged in science courses. The government's policy also is to multiply the number of reciprocal visits of scientists between Russia and other lands.

The Russian industrial structure is like that in other nations--a mixture of old and new--although the contrasts are more marked. Some plants still in service and performing valuable work such as the Metallursky plant in Leningrad are well over a century old. The cluttered house-keeping in such factories reflected the attempt to make do with inadequate and obsolete space. The newer plants, such as the giant transformer manufacturing factory in Zaporozhe, compare favourably with ours. In these, production is well organized and efficient. Undoubtedly, the allocation of funds for modernization and expansion is inadequate and the demand for both capital and consumer goods is of such dimensions as to require the utilization of all plant and equipment that is capable of being operated.

Electric power occupies a unique and special position in the Soviet Union. It was Lenin who visualized the development of electric energy as a means of enhancing production and well-being. In 1920 he initiated the Goelrod Plan for creating an integrated network of electric power generation and transmission, thereby elevating electric power to a position of top priority. Even to-day, while other state committees report through Regional Economical Councils, the State Committee for Power and Electrification reports directly to the Council of Ministers. Russia now produces more electrical power than any other nation except the United States. Goals have been established to expand capacity from the present level of about 90-million kilowatts by 12-million kilowatts a year.

As in the past, most of this power will come from hydraulic and coal-fired thermal stations. The Soviet Union has two or three small nuclear stations in operation, but as they have enormous undeveloped hydraulic sites as well as deposits of coal, their major program will be in the traditional areas of hydraulic and coal-fired thermal generation.

Because their large hydraulic sites are located hundreds and in some cases thousands of miles from the major load center, the Russians have been engrossed in research to unlock the technological keys to long distance transmission. It has been estimated that the Yeniesi and Lena Rivers, which run into the Arctic, have a potential electric power capability of 30-million kilowatts. Before these huge developments can be fully realized, either greater progress must be made in overcoming the problems of long distance transmission or industries must be located closer to the sites. The Russians are working feverishly to achieve both of these objectives. They have had more experience than other countries in the transmission of alternating current power at extra-high voltages over long distances and have attained greater success than any other nation, save perhaps Sweden, in the transmission of power by direct current.

Russia is not a country to which one would go for a restful holiday, unless it be to one of the Black Sea resorts such as Souchi or Yalta. The accommodation for tourists is far below the standards to which Canadians are accustomed. Moreover, while the use of English is increasing, and under the mass educational system the object is to make English their second language, only a few of the Russian population outside of top government officials and the tourist guides, who are excellent, have any facility in our tongue. This makes travelling in Russia without an interpreter an extraordinarily difficult task unless, of course, one is conversant in their language.

Nevertheless, a visit to Russia is a fascinating experience as the annual influx of 20,000 tourists now testifies.

For one interested in history, in priceless treasures, in ballet, opera and music, in art, palaces and monuments, a visit to the Soviet Union provides a delightful feast.

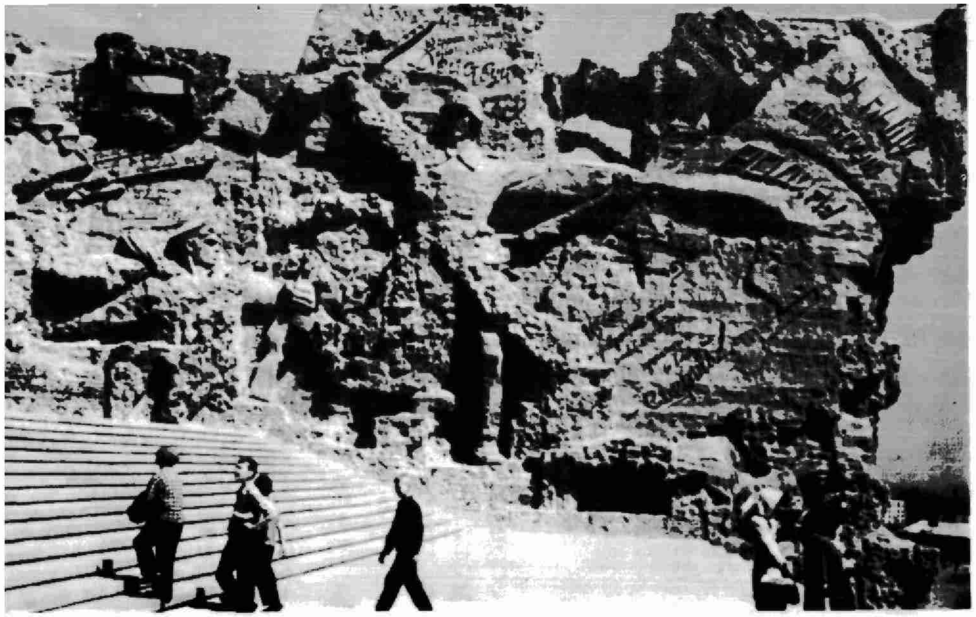
There are many things to excite one's interest.

In Leningrad there is the cottage of Peter the Great constructed in 1703, the only building of the original city (St. Petersburg) that stands; there is Peter and Paul's fortress on the Neva. There is St. Isaac's Cathedral, now for tourists not religion; there is the rich collection of paintings of Gaugin, Cezanne, Matisse, Picasso, Van Gogh, Raphael; there is the Winter Palace where Kerensky and members of his provisional government were arrested by the Bolsheviks.

In Moscow there is the compelling magnetism of the Kremlin; Lenin's Mausoleum and Museum; the golden cupola of the Bell Tower of Ivan the Great and Assumption, Annunciation and Archangel Michael Cathedrals; the world-famous St. Basil's Cathedral that dates back to the 16th century; nearby the ultra-modern Palace of Congresses; the ornate and massive Bolshoi Theatre and many other sights that mirror the past as well as the present.

The new city of Volgograd, reconstructed and renamed after Stalingrad, is full of interest. Here paralleling the Volga River for 37 miles is a city of memory with its graceful Avenue of Heroes, mammoth War Memorial on Mamai Hill and Krasny Oktyabr Steel Mills.

During our visit we had the privilege of an audience with Mr. Mikoyan, at that time Deputy Premier. Mr. Mikoyan said that in spite of idealogical differences, Canada and the U.S.S.R. had a number of things in common, which could form



Memorial to Heroes of the Great Patriotic War, 1941-45, Mamai Hill, Volograd.

A happy group of Russian school children.

Novo Voronezh, home of a 200,000 KW nuclear electric power plant.

Some typical rows of flats.
Zaporosyhe in the Ukraine.

On the outskirts of Moscow.

the basis for closer relations. Our two countries shared somewhat similar characteristics of climate and geography. He urged that we should learn to trust one another. He acknowledged that Russia had encountered problems and difficulties and alleged that these obstacles would give Russians the drive and strength to surmount them. The Soviet government was not free from error, but it would profit from its experience and be prepared to change when improvements could be made.

There is no doubt that the basic concepts on which the Soviet system is founded are being re-examined. As their society has grown more productive and more affluent, it has become plain that the cumbersome system, under which the state controls everyone from the ice cream vendor to the managing director of a large manufacturing plant and attempts to allocate resources of manpower and material to all purposes, is grossly inefficient and wasteful. I am confident that sooner or later the Russian economic system must move towards the adoption of a market mechanism which makes fuller use of the interplay of the forces of supply and demand.

It is also realized that even in Russia the state may be too paternalistic. Mr. Khrushchev sensed this before being forced out of office. Some of his statements could have been uttered by the head of one of Canada's free enterprise organizations. "We must struggle against wage levelling," said Mr. Khrushchev. "That kind of levelling has always been harmful." There should be greater incentives and more generous rewards for workers who excel. He also inveighed against the growing practice of transferring incompetent workers from one producer to another.

It is significant that Lenin's dictum, "from each according to his ability, to each according to his needs" has been amended to "from each according to his ability, to each according to his work".

This suggests a significant change in philosophy and objectives. How far it will go under Mr. Kosygin and Mr. Brezhnyov, it is impossible to predict. However, we do know that a re-appraisal is taking place.

The adoption of an economic system that more resembles that of the West is, of course, no guarantee that Russia will evolve as a democracy in the sense that we know it. In the Soviet Union there is no choice between political parties. There is only one party and therefore elections are not meaningful. Until the right of free choice, the right to choose between alternative representatives in government, is established, it is difficult to see how a transition to a democratic state can be realized. And those who are in office have the best of reasons to perpetuate a system that guarantees them the security of their positions.

Nonetheless, it is timely for a variety of reasons to look at our relations with the Soviet government and its people. The Russians are a blunt and yet practical people. They are sensitive to indifference and unjustified criticism. Every nation, as every individual, has a right to be judged against the background of its evolution. The Russian people have known little stability of government. For centuries they were divided, exposed to a fratricidal tribal warfare, overrun by aggressors, victims of oppression and a ruthless autocracy under a self-centered regime whose only claim to govern was that endowed by birth. Whatever their faults, the administration has united the country and given the people a measure of justice, a sense of security and greater production and material and well-being, along with expectations of a richer life ahead, of better things to come.

Since Mr. Khrushchev's departure, one no longer hears of threats of the Soviet Union's intention to bury the West. There is no doubt of their desire for peace. The Russians are no strangers to hardship and suffering. During World War II alone they sustained up to 20-million casualties. They have endured frightful conditions. They are beginning to enjoy a smattering of the comforts of life. They are proud of what they have accomplished. They want to make greater progress and to attain a greater measure of material well-being. Why not make it a time for getting to know one another better?

TWELFTH ONTARIO INDUSTRIAL WASTE CONFERENCE

REGISTRATION LIST

ALLAN, W.
Superintendent,
Township of Scarborough,
2001 Eglinton Ave. East,
Scarborough, Ontario.

ANDERSON, R.V.
Consulting Engineer,
R.V. Anderson Assoc. Ltd.,
194 Wilson Avenue,
Toronto 12, Ontario.

ARNOLD, DR. O.
Director,
Ajem Laboratories,
38899 Schoolcraft Road,
Livonia, Michigan, U.S.A.

ASTON, R.S.
Chief Chemist,
Courtauld's (Canada) Ltd.,
Montreal Road,
Cornwall, Ontario.

BAKER, J.D.
Vice-President,
Baker Instruments Ltd.,
185 Davenport Road,
Toronto 5, Ontario.

BAKER, S.M.
Factory Engineer,
The Procter & Gamble Co.
of Canada Ltd.,
Burlington Street East,
Hamilton, Ontario.

BANFILL, Hugh M.
Quality Control Superintendent,
Howard Smith Division,
Domtar Pulp & Paper Ltd.,
Cornwall, Ontario.

BARKER, D.G.
Associate,
Canadian-British Engineering
Consultants,
P.O. Box 250,
Toronto 19, Ontario.

BAROLET, PAUL E.
Waste Treatment Engineer,
Dept. 279,
Northern Electric Co.,
P.O. Box 6123,
Montreal, Quebec.

BEAK, Mrs. Joan F.
Vice-President,
T.W. Beak Consultants Ltd.,
P.O. Box 220,
Collins Bay, Ontario.

BERRY, Dr. A.E.
Secretary-Treasurer,
Canadian Institute on Pollution
Control,
Box 66,
Don Mills, Ontario.

BISSAILLON, E.J.
Manager Technical Division,
Electric Reduction Co. of
Canada Ltd.,
137 Wellington Street West,
Toronto 1, Ontario.

BLOCH-HANSEN, R.
Power House Chief,
Northern Electric Co. Ltd.,
P.O. Box 2157,
London, Ontario.

BLUNDY, Philip J.
Engineer Pollution Control,
B.A. Oil Co. Ltd.,
Clarkson, Ontario.

BRADY, E.F.
Cyanamid of Canada Ltd.,
Box 240,
Niagara Falls, Ontario.

BRECHIN, W.
Gen. Supts. Office,
Canada Packers Ltd.,
2200 St. Clair Avenue West,
Toronto 9, Ontario.

BREMNER, Norman W.
Supv. Chemical Section,
Technical Service and
Development Dept.,
Dow Chemical of Canada,
#40 Highway,
Sarnia, Ontario.

BRIERLEY, John
Production Supt.,
Domtar Chemicals Limited,
Tar & Chemical Division,
801 Lake Shore Blvd. East,
Toronto 8, Ontario.

BRIGGS, T.J.
Contracting Engineer,
Horton Steel Works, Limited,
Room 401,
25 Adelaide Street West,
Toronto, Ontario.

BRIGHTY, R.H.
Applications Engineer,
The Glendon Instrument Co. Ltd.,
777 Warden Avenue - Unit #2,
Scarborough, Ontario.

BRODIE, J.D.
Economist - Special Research
& Surveys Branch,
Dept. of Economics & Development,
950 Yonge Street,
Toronto 5, Ontario.

BROWNE, Harold,
District Engineer,
Sanitary Engineering Div.,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

CAMPBELL, Lorne
Director,
Applied Microbiology,
Ontario Research Foundation,
43 Queen's Park Cres. East,
Toronto, Ontario.

CAPLICE, Dennis,
Ass't. Supervisor,
Div. of Industrial Wastes,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

CAVERLY, D.S.
General Manager,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

CHAMBERS, T.R.
Manager,
Municipal & Highway Chemicals,
Dow Chemical of Canada Ltd.,
Sarnia, Ontario.

CHARNOCK, E.T.
Technical Service Supt.
The Great Lakes Paper Co. Ltd.,
Fort William, Ontario.

CIEBIEN, E.T.
Works Chemist,
BP Refinery Can. Ltd.,
Box 520,
Oakville, Ontario.

CLARKE, H.C.
Process Engineer,
The British American
Oil Co. Ltd.,
800 Bay Street,
Toronto, Ontario.

CLAUDI, Ronald E.
Senior Mechanical Engineer,
Shawinigan Engineering Ltd.,
620 Dorchester Blvd.,
Montreal, Quebec.

COUSINS, W.G.
Engineer,
Permutit Co. Canada,
207 Queens Quay West,
Toronto 1, Ontario.

CRAMP, W.S.
Manager,
Technical Services,
Domtar Newsprint Limited,
840 Sun Life Building,
1155 Metcalfe Street,
Montreal 2, Quebec.

CURRAN, John F.
Deputy Commissioner of Works,
City of Sarnia,
City Hall,
Sarnia, Ontario.

CZORNYJ, Nestor,
Chief Chemist,
Sun Oil Company Limited,
Box 307,
Sarnia, Ontario.

DAVIS, C.B.
Consulting Engineer,
Crysler, Davis & Jorgensen Ltd.,
5803 Yonge Street,
Willowdale, Ontario.

DAY, R.F.
Product Supervisor,
Alchem Limited,
Burlington, Ontario.

DELAPORTE, A.V.
R.R. #2,
Oakville, Ontario.

DELAVIGNE, F.L.
Engineer,
Dams & Water Resources,
Dept. of Lands & Forests,
Room 1820,
2 Carlton Street,
Toronto, Ontario.

DEWART, G.B.
Maintenance Supervisor of all Mills,
Abitibi Power & Paper Co. Ltd.,
408 University Avenue,
Toronto, Ontario.

DICKSON, C.G.M.
Vice-President,
Separator Engineering Ltd.,
1703 Victoria Park Avenue,
Scarborough, Ontario.

DOLMONT, B.P.
Manager,
Central Region Sales,
Robert Morse Corporation Limited,
270 Evans Avenue,
Toronto 18, Ontario.

DORAN, A.S.
Vice-President,
Ames Crosta Mills (Canada) Ltd.,
90 Eglinton Avenue East,
Toronto 12, Ontario.

DUCHARME, A.A.
Vice-President & General Manager,
Belle River Canning Ltd.,
P.O. Box 35,
Belle River, Ontario.

DUFFELL, F.E.
Designer,
R.V. Anderson Assocs. Ltd.,
194 Wilson Avenue,
Toronto 12, Ontario.

DUNCAN, J.G.
Supervisor,
Purification Processes Branch,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

DUTTON, C.S.
Associate Partner,
Proctor & Redfern,
Consulting Engineers,
75 Eglinton Avenue East,
Toronto 12, Ontario.

EDWARDS, J.
Assistant Director,
Tourist Industry Development Branch,
Dept. of Tourism & Information,
185 Bloor Street East,
Toronto, Ontario.

EVANS, Dewey,
General Manager,
Centri-Spray (Canada) Limited,
6161 Tecumseh Road East,
Windsor, Ontario.

FANCY, W.S.
Project Engineer,
Fischer & Porter,
P.O. Box 135,
Downsview, Ontario.

FEE, A.E.
Consulting Engineer,
J.L. Richards & Assocs. Ltd.,
864 Lady Ellen Place,
Ottawa, Ontario.

FELL, W.F.
Control Supt.,
Ontario Paper Co. Ltd.,
Thorold, Ontario.

FERGUSON, D.
Information Branch,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

FERGUSON, J.M.
Gen. Supt. of Alkaline Pulping,
Domtar Pulp & Paper Ltd.,
Cornwall, Ontario.

FERGUSON, R.H.
Water Pollution Engineer,
Dept. of Public Health,
Government of Alberta,
Administration Building,
Edmonton, Alberta.

FIELDING, H.
Engineer,
Fielding Crossman & Assocs. Ltd.,
1570 Midland Avenue,
Scarborough, Ontario.

FINDLAY, J.B.
Mechanical Engineer,
Falconbridge Nickel Mines Ltd.,
Falconbridge, Ontario.

FISHER, D.R.
Project Engineer,
Proctor & Redfern,
Consulting Engineers,
75 Eglinton Avenue East,
Toronto 12, Ontario.

FLATT, F.L.
Vice-President & General
Manager,
Spruce Falls Pulp & Paper
Co. Ltd.,
Kapuskasing, Ontario.

FOWLER, D.
Supt. of Pollution Control Works,
City Engineer's Department,
City of London,
Hamilton Road,
R.R. #8,
London, Ontario.

FRANKLIN, J.N.
Consultant,
113 Hawthorne Drive,
Baie d'Urfe, P.Q.

FRENCH, G.
Councillor,
Town of Levack,
Box 250,
Levack, Ontario.

FRY, F.E.J.
Professor,
University of Toronto,
Dept. of Zoology,
Toronto 5, Ontario.

GALIMBERT, G.M.
18 Glenaden Avenue West,
Islington, Ontario.

GARVIE, W.R.
Head Brewer,
The Carling Breweries Ltd.,
155 King Street South,
Waterloo, Ontario.

GATHERCOLE, G.E.
1st. Vice-Chairman,
The Hydro-Electric Power
Commission of Ontario,
620 University Avenue,
Toronto 2, Ontario.

GAUDY, Dr. A.F. Jr.
Professor,
Oklahoma State University,
Stillwater, Oklahoma.

GAUER, H.J.
Department Head,
Lever Brothers Limited,
299 Eastern Avenue,
Toronto 8, Ontario.

GAUKROGER, G.J.
Chief Metallurgist,
McKinnon Industries Limited,
St. Catharines, Ontario.

GORMAN, A.H.
Factory Manager,
Naugatuck Chemicals Division,
Dominion Rubber Company Ltd.,
Elmira, Ontario.

GRANT, W.J.
Utilities & Pollution Engineer,
British American Oil Co.,
Box 100,
Pointe aux Trembles,
Province of Quebec.

GRAY, E.G.
Technical Sales,
Sweco Canada Ltd.,
21 Jutland Road,
Toronto, Ontario.

GUILLAUME, F.
Chemical Engineer,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

HANWAY, J.E., Jr.
Director of Engineering,
Copeland Process Corporation,
120 Oak Brook Mall,
Oak Brook, Illinois, 60523.

HARRIS, A.J.
Director of Research,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

HENDERSON, J.B.
District Manager,
Wallace & Tiernan Ltd.,
925 Warden Avenue,
Scarborough, Ontario.

HENRY, S.K.
Acting Control Supt.,
Canadian International Paper Co.,
Gatineau, Quebec.

HISCOCK, A.J.
Director,
W.H. Crandall & Assocs. Ltd.,
P.O. Box 36,
Moncton, N.B.

HISEY, J.D.
Partner,
Hisey & Barrington,
31 Yonge Street North,
Richmond Hill, Ontario.

HOLDER, D.A.
Engineering Associate,
Abitibi Power & Paper Co. Ltd.,
Central Research Division,
Huron Street,
Sault Ste Marie, Ontario.

HOLLAND, H.R.
Engineering Assoc.
Imperial Oil Enterprises Ltd.,
723 London Road,
Sarnia, Ontario.

HONEY, J.C.
Sales Manager,
Canadian Johns Manville Co. Ltd.,
565 Lakeshore Road East,
Port Credit, Ontario.

HOOPER, B.G.
Manager,
Central Division Sales,
Dorr-Oliver-Long Ltd.,
1819 Yonge Street,
Toronto 7, Ontario.

HOREMBALA, L.E.
Manager,
Ion Exchange Dept.,
Alchem Limited,
Burlington, Ontario.

HUBBS, D.E.H.
Technical Development,
National Silicates Limited,
P.O. Box 69,
Toronto 14, Ontario.

HUGGARD, R.E.
Product Development Supervisor,
Canadian Industries Limited,
"Fabrikoid" Division,
207 New Toronto Street,
New Toronto, Ontario.

HUGGETT, G.W.
Chief Process Engineer,
Texaco Canada Ltd.,
250 Lakeshore Blvd.,
Port Credit, Ontario.

HUNTER, C.C.
Chief Chemist,
Imperial Oil Ltd.,
142 Cecil Street,
Sarnia, Ontario.

JENKS, J.I.
Manager,
Humphrey & Glasgow (Canada) Ltd.,
2774 Leslie Street,
Willowdale, Ontario.

JOHNSTON, R.A.
Associate Professor,
Ontario Agricultural College,
Dept. of Microbiology,
Guelph, Ontario.

JONES, A.S.
Production Manager,
Lubrizol of Canada Ltd.,
1800 Thorold Stone Road, Box 598,
Niagara Falls, Ontario.

JONES, D.
Manager, Technical Section,
Canadian Pulp & Paper Assoc.,
2280 Sun Life Building,
Montreal 2, Quebec.

KAPPELE, J.L.
Consulting Engineer,
Kappele Wright & MacLeod Ltd.,
30 Hayden Street,
Toronto 5, Ontario.

KEHOE, F.
Commissioner,
Orillia Water, Light &
Power Commission,
Orillia, Ontario.

KINNEY, J.B.
Dir-Project Development,
James F. MacLaren,
321 Bloor Street East,
Toronto, Ontario.

KLASSEN, J.
Technical Manager,
Du Pont of Canada Limited,
Maitland Works,
Maitland, Ontario.

KOSHURBA, J.W.
Ass't. Sewer Engineer,
Corp. City of Hamilton,
c/o Department of Engineering,
City Hall,
Hamilton, Ontario.

KRAMER, A.E.
Facility Engineer,
Northern Electric Co. Ltd.,
8200 Dixie Road,
Bramalea, Ontario.

KRUK, T.
Plant Engineer,
Metro Works Dept.,
c/o Humber Treatment Plant,
130 The Queensway,
Toronto 18, Ontario.

LABERGE, Y.
Laval Industrial Assoc. Inc.,
6311 Merriam Avenue,
Ville d'Anjou,
Montreal 5, P.Q.

LACKIE, T.H.
Associate Professor,
College of Engineering,
University of Saskatchewan,
Saskatoon, Saskatchewan.

LAFONTAINE, E.O.
Partner,
C.G. Russell Armstrong,
Windsor, Ontario.

LANGLEY, D.G.
Project Engineer,
Domtar Pulp & Paper Ltd.,
343 Glendale Avenue,
St. Catharines, Ontario.

LEWIS, T.H.
General Manager,
Komline-Sanderson Ltd.,
72 Orenda Road,
Brampton, Ontario.

LIGHTWOOD, H.
Section Head,
Sewer Maintenance,
Township of Scarborough,
53 Fairwood Crescent,
Scarborough, Ontario.

LOCKHART, J.G.
Director,
New Brunswick Water
Authority,
P.O. Box 1240,
Fredericton, N.B.

LOVE, L.S.
Engineer,
Delaney, Love & Assocs.,
160 Bay Street,
Toronto 1, Ontario.

MACDIARMID, C.W.
Sr. Chemist,
Polymer Corp.,
Vidal Street,
Sarnia, Ontario.

MACLEMAN, E.L.
Project Director,
D.E.C.S. - U.S.P.H.S.,
321 Chestnut Street,
Philadelphia, Penn.

MACLURE, J.H.
General Manager,
Eng. Sales Division,
Robert Morse Corp. Ltd.,
1155 Dorchester Street West,
Montreal, P.Q.

MACNAMARA, Dr. J.
Ass't. Division Supt.,
The Algoma Steel Corp. Ltd.,
Sault Ste Marie, Ontario.

MARTIN, W.J.
Director of Medical Services,
Cyanamid of Canada Ltd.,
Box 240,
Niagara Falls, Ontario.

MASSE, F.A.
Research Engineer,
Price Brothers & Co. Ltd.,
Kenogami, P.Q.

MAYALL, K.M.
Biologist,
Dept. of Energy and
Resources Management,
19 Jason Road,
Rexdale, Ontario.

MCARTHUR, D.
Chairman,
Water Pollution Control Dept.,
1 Malaren Road,
Box 272,
Maple, Ontario.

MCCLEAN, R.
Sales Representative,
Canadian Johns-Manville Co. Ltd.,
565 Lakeshore Road East,
Port Credit, Ontario.

MCCUTCHEON, M.K.
Executive Director,
Dept. of Energy &
Resources Management,
Room 180, Main Building,
Parliament Buildings,
Toronto 2, Ontario.

MCMAHON, H.W.
Manager of Marketing,
Electric Reduction Co. of
Canada, Ltd.,
137 Wellington Street West,
Toronto 1, Ontario.

MCVEIGH, H.G.
Sales Manager,
Process Division,
Dorr-Oliver-Long Ltd.,
1819 Yonge Street,
Toronto 7, Ontario.

MCWILLIAMS, S.A.
148 Cummer Avenue,
Willowdale, Ontario.

MILLEST, R.H.
Director,
Div. of Industrial Wastes,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

MILLS, R.E.
Technical Supt., Waste Control,
Naugatuck Chemicals Division,
Dominion Rubber Co. Ltd.,
Elmira, Ontario.

MOIR, W.S.
Vice-President & General
Manager,
Wallace & Tiernan Ltd.,
925 Warden Avenue,
Scarborough, Ontario.

MORRIS, J.
Consultant,
Courtauld's (Canada) Ltd.,
Cornwall, Ontario.

MOSKOWITZ, M.J.
Chemical Engineer,
Beardmore & Co. Ltd.,
Acton, Ontario.

NAPADY, W.
Plant Engineer,
Metro Works Dept.,
82 Watson Avenue,
Toronto 9, Ontario.

NIERSTRASZ, H.
Chemical Engineer,
Northern Electric Co. Ltd.,
P.O. Box 3000,
Brampton, Ontario.

NISBET, J.D.
Principal,
James D. Nisbet,
P.O. Box 51,
Sarnia, Ontario.

PARASCHAK, M.
Technical Supervisor,
Allied Chemical Canada Ltd.,
Amherstburg, Ontario.

PARKER, R.R.
Vice-President,
Beardmore & Co. Ltd.,
Acton, Ontario.

PATTERSON, J.B.
Industrial Wastes Engineer,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

POLLARD, R.
Chemist,
Cromac Chemical Co.,
203 Bentworth Avenue,
Toronto 19, Ontario.

RANFORD, J.R.
Special Representative,
Canada Iron Foundries Ltd.,
Pipe Division,
169 Eastern Avenue,
Toronto, Ontario.

REEVE, K.H.
Plant Engineer,
Can. Johns Manville Co. Ltd.,
P.O. Box 610,
North Bay, Ontario.

RICE, W.L.
Chief of Civil Engineering,
Dept. of Public Works,
13th Floor, East Block,
Parliament Buildings,
Toronto, Ontario.

RIGNEY, J.M.
Ass't. Project Engineer,
James F. MacLaren Ltd.,
321 Bloor Street East,
Toronto 5, Ontario.

ROBB, L.A.
Plant Chemist,
Ethyl Corp. of Canada Ltd.,
Corunna, Ontario.

ROBINSON, M.C.
Chemical Engineer,
Atkins, Hatch & Assoc. Ltd.,
33 Price Street,
Toronto, Ontario.

ROOT, J.H.H.
Vice-Chairman,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

ROSEBOROUGH, J.D.
Supervisor,
Fisheries Section,
Ontario Dept. of Lands
and Forests,
Parliament Buildings,
Toronto, Ontario.

RUTHERFORD, C.C.
Engineer,
Sanitation and Industrial
Wastes,
City Engineer's Dept.,
City of London,
R.R. #1,
Denfield, Ontario.

SCHNICK, O.M.
Director,
Special Research and
Surveys Branch,
Dept. of Economics and
Development,
950 Yonge Street,
Toronto, Ontario.

SCHWENGER, F.C.
Mechanical Engineer,
Schwenger Const. Ltd.,
P.O. Box 7,
Burlington, Ontario.

SCOTT, G.T.G
Partner,
Can.-British Engineering
Consultants,
3089 Bathurst Street,
P.O. Box 250,
Toronto 19, Ontario.

SEED, G.K.
Woodroom & Yard Supt.,
Dryden Paper Co. Ltd.,
Box 1293,
Dryden, Ontario.

SHARPE, K.H.
Ass't. General Manager,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

SHAVER, R.A.
Refining Dept. (Pollution Control),
Texaco Canada Limited,
1425 Mountain Street,
Montreal 25, Quebec.

SHERIDAN, R.J.
Gibb, Underwood & McLellan,
42 Charles Street East,
Toronto 5, Ontario.

SHIKAZE, K.H.
Engineer,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

SIGWORTH, E.A.
Technical Representative,
West Virginia Pulp & Paper,
Chemical Division,
230 Park Avenue,
New York, New York, 10017.

SILVER, W.R.
Ass't. General Manager,
Harchem Ltd.,
715 Kipling Avenue South,
Toronto 18, Ontario.

SIM, C.
Ass't. Engineer,
Sewerage & Drainage,
City of Ottawa,
111 Sussex Drive,
Ottawa, Ontario.

SMITH, B.E.
Town Engineer,
Town of Orillia,
Box 7,
Orillia, Ontario.

SMITH, C.A.
Manager,
Property & Construction,
Canadian Canners Ltd.,
P.O. Box 540,
Hamilton, Ontario.

SMITH, R.L.
Chief Engineer of Mines,
Ontario Dept. of Mines,
Parliament Buildings,
Toronto, Ontario.

SOBOLOV, M.
Plant Bacteriologist,
Hiram Walker & Sons Ltd.,
P.O. Box 518,
Walkerville, Ontario.

STAFFORD, R.H.
Technical Director,
Spruce Falls P & P Co. Ltd.,
Kapuskasing, Ontario.

STANLEY, D.R.
Consulting Engineer,
Stanley, Grimble, Roblin Ltd.,
8908-99 Street,
Edmonton, Alberta.

STEGGLES, W.A.
Supervisor,
Water Quality Surveys Branch,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

STEVENS, T.G.
Chemist,
Canadian Canners Ltd.,
Box 540,
Hamilton, Ontario.

STEWART, R.C.
Division of Industrial Wastes,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

SUMMERFIELD, C.
Manager,
Canadian Municipal Utilities,
1061 St. Alexander Street,
Montreal, Quebec.

SWANN, W.
Township Engineer,
Township of Etobicoke,
550 Burnhamthorpe Road,
Etobicoke, Ontario.

TAIT, R.E.
Chem. Engineer Consultant,
P.H.E. Division,
Dept. of National Health
and Welfare,
Room 318,
45 Spencer Street,
Ottawa, Ontario.

TATTERSALL, J.K.
Engineer,
H.G. Acres & Co. Ltd.,
Niagara Falls, Ontario.

TAYLOR, A.G.
Chief Technical Engineer,
Township of Etobicoke,
550 Burnhamthorpe Road,
Etobicoke, Ontario.

THOMPSON, G.H.
Sanitation Engineer,
Corp. City of Kitchener,
City Hall,
Engineering Department,
Kitchener, Ontario.

THOMPSON, M.W.
Engineering Adviser,
International Joint Comm.,
Room 303,
75 Albert Street,
Ottawa 4, Ontario.

THORNTON, G.
Maintenance Engineer,
Hiram Walker & Sons Ltd.,
c/o Hiram Walker & Sons Ltd.,
Walkerville, Ontario.

TOBIAS, L.M.
Ass't. to the General Manager,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

TOLSON, D.S.
Division of Industrial Wastes,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

TSIVOGLOU, DR. E.C.
In-Charge, Physical &
Eng. Sciences,
R.A. Taft Sanitary Engineering
Centre,
4676 Columbia Parkway,
Cincinnati 26, Ohio, U.S.A.

TURNER, J.A.
Plant Engineer,
Libby, McNeill & Libby Ltd.,
330 Richmond Street,
Chatham, Ontario.

UNDUP, L.
Design Engineer,
Canada Packers,
2200 St. Clair Avenue West,
Toronto, Ontario.

VANCE, DR. J.A.
Chairman,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

VAN LUVEN, A.L.
Consulting Engineer,
A.L. Van Luven & Assocs.,
Suite 104,
315 Dorval Avenue,
Dorval, Quebec.

VENCHIARUTTI, L.
Commissioner,
Ontario Water Resources Comm.,
Venchiarutti & Venchiarutti
Architects,
7 Greenbrook Drive,
Toronto, Ontario.

VISCOUNT, C.
General Manager,
Flow Controls Ltd.,
87 Northline Road,
Toronto, Ontario.

VOEGE, F.A.
Ass't. General Manager,
Ontario Water Resources Comm.,
801 Bay Street,
Toronto 5, Ontario.

WAITE, D.E.
Technical Service Representative,
C.I.L.
130 Bloor Street West,
Toronto, Ontario.

WALLACE, A.R.
Waste Treatment Engineer,
Pumps & Softeners Ltd.,
P.O. Box 2332,
Terminal A.,
London, Ontario.

WALTON, H.G.
Sales Engineer,
Canadian Johns Manville Co. Ltd.,
565 Lakeshore Road East,
Port Credit, Ontario.

WARD, H.
Engineer Technician,
City of Cornwall,
P.O. Box 637,
Cornwall, Ontario.

WATSON, D.L.
Manager,
Quality Control,
Union Carbide Canada Ltd.,
P.O. Box 395,
Belleville, Ontario.

WATSON, J.A.
Plant Engineer,
McKinnon Industries Limited,
Ontario Street,
St. Catharines, Ontario.

WEBSTER, L.F.
Editor,
Canadian Municipal Utilities,
1450 Don Mills Road,
Don Mills, Ontario.

WEIR, R.A.
Engineer,
Fish & Wildlife Branch,
Ontario Dept. of Lands
and Forests,
Room 1820,
2 Carlton Street,
Toronto 5, Ontario.

WILLIAMS, P.W.
Manager,
District Pipe Department,
Canadian Johns-Manville Co. Ltd.,
565 Lakeshore Road East,
Port Credit, Ontario.

WILSON, G.E.
Director,
Research & Development - Pulp
Fraser Cos. Ltd.,
Research Laboratories,
Atholville, N.B.

WILSON, J.A.
Sanitation Specialist,
Rex Chainbelt (Canada) Ltd.,
1181 Sheppard Avenue East,
Willowdale, Ontario.

WOOD, G.M.
Project Supervisor,
Dept. of Health,
Environmental Sanitation Branch,
165 Bloor Street East,
Toronto, Ontario.

WORK, E.A.
Lab. Manager,
Shell Canada Limited,
Corunna, Ontario.

YATABE, M.
Chemical Engineer,
Gore & Storrie Ltd.,
980 Yonge Street,
Toronto 5, Ontario.