COMBINED TREATMENT: AN ECONOMICAL ALTERNATIVE APPROACH TO STREAM POLLUTION CONTROL

Foreword

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One of the most pressing environmental problems facing many cities today is managing the water quality of rivers and waterways. Rapid industrial growth, steady increase in population, and weak enforcement of environmental regulations contribute to the poor quality of surface water. In the Philippines, only 36% of the rivers can be used as sources of potable water supply, according to the Philippines Environment Monitor[1] *in 2003. The same study reported that the annual production of organic pollution amount to 2.2 million tons, which are being contributed mainly by domestic sewage (48%), industrial effluents (37%) and agricultural activities (15%).*

Water quality management schemes can be implemented at many stages of the pollution- producing process. Changes can be made regarding the raw materials being used in the case of manufacturing plants and reduction of volume of wastewater are some of the ways to manage water quality. Likewise, there are end-of-pipe solutions, or pollution control technologies that are being used to be able to reduce the amount of pollution load being dumped in receiving bodies of water.

In the following article written by the late Professor and former College of Engineering Dean Marino M. Mena, the idea of treating industrial wastewater in sewage treatment plants is being broached as an economical alternative in managing pollution. He considers it beneficial for small industries who cannot afford the high capital costs of putting up its own wastewater plant. Although written more than a quarter of a century ago, the need to be able to come up with efficient pollution control technologies still holds true up to this day.

The proposed scheme as discussed in the paper is not suitable for all types of industrial wastewater. In the paper, the example cited is that of textile wastewater being treated together with sewage. The feasibility of treating industrial wastewater in sewage treatment plants should consider issues on: uniformity of flow, composition of wastes, toxicity and scum-forming characteristics of the wastewater.
Combined treatment of sewage and industrial wastewater is not being practiced in the Philippines today. What we have in place are sewage treatment plants for some parts of Metro Manila and individual on-site treatment plants for industries, as mandated by law.

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[1] The World Bank (2003). Philippines Environment Monitor, Philippines.

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1. INTRODUCTION

A highly significant difference in the Philippine situation today as compared to 10 or 15 years ago is that public opinion is moving towards strong support of environmental protection. The consequences of uncontrolled environmental contamination are mentioned prominently in news media. Government efforts, in cleaning the Pasig River of industrial pollutants and domestic sewage, have been started recently with encouraging response from private sectors. Since watercourses are vital to our continued development, and since the public at large rightfully demands that streams be conserved as a source of recreation all must cooperate to make this possible.

The Metropolitan Manila Area is now facing an unprecedented problem of waste disposal as a result of the rapid industrial growth. The complex problem lies not only in the large quantity of waste produced but also in the varying degrees of treatability of wastes. The large capital investment and high generating cost are inhibitive for a small industry to take care of its own waste. It is not surprising if there are cases where a waste disposal problem changes the decision of an industry to produce a certain product if the treatment of the waste cannot be done with minimal cost.

In general, industry can be expected to be more cooperative in treating their waste when treatment costs are not excessive. Considering that construction cost for treatment facilities and operation cost are rising, there is an increased need for research on more economical methods of treatment.

2. INDUSTRIAL POLLUTION IN THE METROPOLITAN MANILA AREA

A 1968 survey of all large industrial establishments in the Philippines shows that about 50 per cent of these are located in the Metropolitan Manila Area. The area includes Manila, Quezon City, Pasay City, Caloocan City and suburban towns in Rizal and Bulacan like San Juan, Mandaluyong, Makati, Malabon and Parañaque.

It is estimated that about 40 million gallons per day was discharged as waste in 1968 by industries within the area. A percentage breakdown of this waste is given in Table I in accordance with the type of the contributing industry.

On the basis of the figures in Table I more than 75% of industrial wastewater in the Metropolitan Manila Area come from the chemical, textile, paper and pulp, food and brewery industries. However, it has to be noted that the estimated wastewater volume for each industrial category represents the total from various establishments. For example, an estimated waste volume of 7.40 million gallons per day for the textile industry comes from about

Table 1. Estimated Metropolitan Manila Industrial Pollution

Industry Category	*Percentage of Total Waste Volume*
Chemicals	22.40
Textile industries	18.70
Paper and pulp	14.80
Food, except dairy	14.70
Breweries and distilleries	4.82
Soap and cosmetics	2.15
Non-metallic minerals	2.15
Soft drinks	1.67
Rubber products	1.54
Dairy products	1.47
Basic metal products	1.39
Wearing apparel	0.86
Electrical products	0.608
Petroleum products	0.329
Footwear	0.278
Pharmaceutical	0.203
Tobacco products	0.127
Cordage	0.127
Furniture and fixture	0.127
Paint and ink	0.127
Wood and cork products	0.076
Leather products	0.076
Fabricated metal products	0.076
Machinery	0.076
Miscellaneous	0.329

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22 major textile establishments in the Metropolitan Manila Area. The wastewater volume from each textile plant ranges from 0.02 mgd to 2.1 mgd and most of these plants have less than 0.5 mgd of wastewater. A similar situation prevails in the other industrial categories where small industrial establishments may find it economically difficult to treat their liquid waste not only because of the inhibitive cost of wastewater treatment but also of space limitations. There are industrial establishments who just do not have sufficient space for a complete wastewater treatment It is for these reasons that the author strongly feels that dual or combined treatment should be considered as an alternative long-term approach in our present efforts to control stream pollution.

Most of the industrial wastes in the Metropolitan Manila Area flow into the following natural basins: Pasig river, San Juan river, Marikina and Tenejeros rivers. These rivers are presently heavily polluted.

3. DUAL TREATMENT OF SEWAGE AND INDUSTRIAL WASTES

The dual treatment of sewage and industrial wastes has been the subject of many investigations abroad because of the advantages it offers whenever possible. Usually, the combined treatment of industrial waste and sewage is more economical than separate treatment in a number of small plants. The present trend abroad is toward super sewage plants which can handle large amounts of wastes at a low unit cost. Furthermore, a big sewage treatment plant usually has better supervision and control than a small industrial wastes plant since a small plant may not have a full-time superintendent, a chemist, or adequate operating personnel. A larger plant also means more available funds for hiring better-trained and qualified personnel.

There are also a number of industries, particularly those concerned with food processing, which have a seasonal waste disposal problem. Where municipal plants are available or can be built, food processing wastes can be treated with year-round sewage. Chemical treatment during the processing season will help to remove excessive solids and BOD. Thus, industry can avoid construction of a wastes plant which would be idle much of the year.

A study of the location pattern of industrial plants in the Metropolitan Manila Area indicates a lack of industrial zoning. Similar industries are not generally grouped in one area. The only noticeable trend is that many industries are located along the Pasig, Marikina, San Juan and Tenejeros rivers. However, the area could possibly be divided into zones and a combined treatment plant could be designed to treat wastewaters from each zone. The feasibility of this approach will depend on an evaluation of the effluents coming from the various establishments in each zone. The evaluation will determine the amenability of the various wastes to combined treatment and the degree of pre-treatment required.

One argument against combined treatment is the high initial capital cost for interceptors. However, if viewed over the long term, it is generally less expensive. Experiences in other countries show that as plant size increases, the average per-unit cost decreases. For example, Nemerow (1) showed that textile wastes can be handled more economically in one municipal waste treatment plant than in two separate plants — one municipal and one industrial plant. The plant could be designed to take care of most problems that would occur from treating textile wastes; consequently, economies of scale may exist. Nemerow further showed that there are many advantages such as having only one plant operator, lower construction costs, and lower operation and maintenance costs. Even in terms of manpower needs, therefore, combined treatment could offer a solution to an existing important problem of finding enough trained and qualified personnel to operate wastewater treatment plants. There are cases where unqualified personnel seem to have difficulty detecting and taking care of trouble resulting in an expensive treatment plant that cannot be operated efficiently under its design criteria.

4. AMENABILITY OF INDUSTRIAL WASTES TO COMBINED TREATMENT

There are several factors that have to be considered in determining the acceptability of dual treatment such as the type of treatment process used at the sewage plant, the size of the receiving stream or the degree of treatment to which the effluent of the plant must conform before it is discharged, the quantity of wastes and its relation to the capacity of the sewage works, the amenability of the wastes to treatment, and the type of pretreatment given the wastes prior to discharge to the interceptor. The effects of some wastes on biological processes are discussed in the succeeding section.

Imhoff and Fair (2) stated that most industrial wastes can be treated in municipal treatment plants along with domestic wastes. Several exceptions were made. "Grease and oil, hot liquids (above 95°F,), gasoline and flammable solvents, concentrated acids and poisonous substances, if present in sufficient amounts, are destructive or dangerous to sewage conduits (corrosion, clogging, explosion, or other damage) and to treatment works and processes. Therefore, municipal authorities should be empowered: (1) to exclude objectionable wastes from the sewage systems; (2) to regulate the rates at which potentially dangerous wastes may be admitted to sewers; (3) to prescribe the degree of pretreatment to which wastes should be submitted before discharge; and (4) to determine how much of the cost of treatment of the mixed domestic and industrial wastewaters should be properly paid for by industry."

Let us consider textile wastes which rank as second largest contributor to industrial pollution in the Metropolitan Manila Area in terms of waste volume. Because textile waste at present has very high B.O.D. and is high in carbonaceous content, it should lend itself to bacteriological decomposition as a method of treatment if the pH is not too high or low and if appropriate nutrients, which can be supplied by domestic wastes, are present.

A typical cotton finishing mill effluent contains starch, dextrin, gums, glucose, waxes, pectins, alcohols, acetic acid, soap, detergents, sodium sulfate, sodium silicate, sodium chloride, hydrochloric acid, etc., and has the following characteristics:

(a) pH between 8.0 and 11.0
(b) gray colloidal turbidity (the color depending on the dye most used)
(c) total solids 1,000 to 1,600 ppm
(d) B.O.D. 200 to 600 ppm
(e) total alkalinity 300 to 900 ppm
(f) suspended solids 30 to 900 ppm

Certain components of the textile waste produce the following pollution pattern:

Component	Percentage of the Total B.O.D.
Natural compounds in fibers	20 — 30
Desizing	35
Color shop	7
Wash after printing	6
Finishing wastes	0.5*
Soap	10 — 30**
Acetic Acid	11
Dyeing	5

Another fininshing mill produces the following pollutional waste pattern:

Component	Percentage of the Total B.O.D.
Desizing waste	52.5
Dyeing	37.2
Bleaching	10.3

Review of the literature strongly indicates that textile wastes can be treated economically in municipal wastewater treatment plants provided these wastes meet certain requirements so as not to destroy the municipal plant efficiency. For example, a wastewater treatment plant was constructed in February, 1969 for the town of Stanley, N.C. It was designed to treat wastewater consisting of industrial wastes and domestic sewage. The industrial waste consist of spin dyes and other chemicals from a dyeing and finishing plant. The treatment plant consists of an aeration lagoon, settling tanks and aerobic digester for the waste sludge, and a sludge drying bed.

The effects of various factors on satisfactory biological treatment of textile waste have also been previously investigated (3). Among these factors include the concentration of textile waste in mixed sewage and waste, alkalinity and pH, temperature changes, presence of some compounds, and their toxicity. Results of pilot-plant studies indicate that the proportion of the textile waste to sewage in the mixtures has no appreciable effect on the treatability of the mixtures. Mixtures of up to 84 per cent textile waste with 16 per cent domestic sewage have been treated in high-rate trickling filters and aeration units with excellent results.

When mixtures of textile waste with domestic sewage are treated, usually no seeding

* 50 to 60 per cent due to starch and its modifications.

** Can be replaced by detergent and cut to 20 percent or nutrients are required because the sewage furnishes both the seed and the nutrient material. However, specific textile wastes or mixtures of textile wastes when treated separately may require nutrients and/or seeding material. In these cases where nutrients are required, phosphate and nitrogen are added as phosphoric acid, ammonium chloride, potassium phosphate, urea, etc. Seed can be added as sewage or as excess activated sludge.

A study of some typical domestic wastewater in the Metropolitan Manila Area seems to indicate that the average 5-day B.O.D. contribution per capita per day is about 45 g (0.10 lb). This value is comparable with results from other countries. For example, the following 5-day B.O.D. per capita per day has been reported for other countries:

Country	5-day B.O.D. per capita per day	
	g	lb
USA	54 — 77	0.12 — 0.17
Seoul, Korea	60	0.13
Bangkok, Thailand	50 — 70	0.11 — 0.15

Results of previous investigations also indicate that the necessity for neutralizing the waste before biological treatment is more dependent on hydroxide alkalinity than pH. It has been found that high-rate trickling filters could operate successfully with good efficiencies at pH's as high as 10.5, but above 10.5 and up to 11.5 the efficiency would drop from 10 to 40 per cent, depending on the hydroxide alkalinity. Experiments have shown that high-rate trickling filters can operate effectively with as much as 100 to 200 ppm hydroxide alkalinity (total alkalinity 700 to 1,500 ppm) in the incoming waste. Above this concentration the efficiency suffers.

Sawyer, Frame, and Wold (4) also found in pilot-plant activated sludge treatment of a mixture of cotton kier liquor and a small amount of sewage seed at pH's from 7.5 to 10.5, that the pH effects were a function of temperature. The effects were magnified at low temperatures. They observed that levels of pH above 9 were definitely inhibitory at 10°C and levels above 10 were definitely inhibitory at 20°C. From the results of their experiments, they also concluded that biological purification of wastes with pH ranging from 5 to 11 can be accomplished by the activated sludge process, provided acids are not formed to depress the pH below 5.

5. POLLUTION REDUCTION PROGRAM

The pollutional waste load from an industrial plant can be reduced substantially by a good waste-reduction program inside the plant. The following are some of the methods available:

1. Process modification. Example: change in dyeing methods in the textile industry.
2. Reduction in volumes or flows. Example: Re-use of process water, segregation of weak waste for disposal without treatment.
3. Reduction in amount of chemicals by modern control methods.
4. Substitution of low B.O.D. chemicals for high B.O.D. chemicals. Example: Carboxymethylcellulose (CMC) for starch, detergents for soap.
5. Recovery of by-products. Example: heat recovery.
6. Good housekeeping practices.

Considerable reduction in pollution may be obtained by substitution of low B.O.D. process chemicals for high-B.O.D. chemicals normally used. In the textile industry, for example, some possible substitutes are synthetic detergents for soap; ammonium sulfate for acetic acid; carboxymethycellulose (CMC) and hydroxyethylcellulose for starch; polyvinyl alcohol, polyacrylic acid, and styrene-base sizes for gelatin; monochlorobenzene for o-phenyl phenol. A comparison of the B.O.D. producing capacity of these chemicals is given in the following table.

Table 2. Process Chemical B.O.D.

Chemical	B.O.D. (%)*
Soap	97 — 150
Synthetic detergents	0 — 166 (There are many detergents with less than 50% B.O.D.)
Ammonium sulfate	0
Acetic acid	52
Carboxymethylcellulose (CMC)	3
Hydroxyethylcellulose	3
Starch	50
Polyvinyl alcohol	1
Palyacrylic acid	1
Gelatin	100
Monochlorobenzene	3
Phenol	200

* Per cent B.O.D. is based on weight of chemical; for example, 140% B.O.D. indicates that such pound of chemical will exert 1.4 lb. of B.O.D.

Of course, the above-mentioned substitutions seem to be acceptable as far as total B.O.D. reduction is concerned. However, such factors as cost, biological resistance, effect on the finished product, toxic characteristics, etc., have to be considered prior to the final choice of the chemical. For example, CMC is more costly than starch and gives a slightly inferior finish; CMC and some synthetic detergents have some biologically resistant forms, that is, they are not readily metabolized by sewage bacteria and require some adaptation for rapid metabolism. Adaptation to synthetic detergents and CMC will reduce the rate of oxidation since such adaptation would delay the over-all metabolism. Experience with high-B.O.D. compounds indicates that they are readily broken down by micro-organisms in the receiving body of water. Another aspect is the increase in the over-all phosphorous content of the waste if synthetic detergents will be used instead of soap. This may produce an excess of

TABLE 3

Process Waste	General Characteristics	Sewage Treatment Units or Processes Which May be Adversely Affected
1. Chemical, Pharmaceutical	Excessive inorganic solids, toxic and corrosive	May affect all biological processes. Sludge digestion.
2. Dairy Products	Excessive organic dissolved solids and excessive fats.	Amenable to treatment. Biological processes. Sludge digestion.
3. Fermentation (a) Antibiotics (b) Brewing (c) Distilling (d) Winery (e) Yeast	Excessive organic suspended and dissolved solids.	All biological processes. Sludge digestion.
4. Food Canning	Excessive inorganic suspended solids, organic suspended and dissolved solids and corrosive.	Amenable to treatment. Settling units and biological processes. Sludge digestion.
5. Garages and Filling Stations	Excessive oils and greases.	All treatment units by reason of scum-forming constituents.
6. Meat Packing	Excessive organic suspended and dissolved solids and fats and greases.	Amenable to treatment. Settling units and biological processes. Sludge digestion.
7. Metal Fabrication	Excessive oils and greases.	All units.
8. Metal Plating	Excessive inorganic dissolved solids and toxic materials.	Biological processes. Sludge digestion.
9. Oil Refining	Oils, greases, toxic materials and corrosive.	Not amenable to treatment in biological processes.
10. Paint Manufacture	Excessive inorganic suspended solids.	Settling units and sludge digestion.
11. Paper Making	Excessive organic suspended and dissolved solids.	All biological processes. Sludge digestion.
12. Power Laundries	Excessive organic dissolved solids and fats.	Amenable to treatment. Biological processes and scum-removing equipment.
13. Rubber, Synthetic	Excessive organic dissolved solids.	All biological processes. Sludge digestion.
14. Slaughterhouse	Excessive organic suspended and dissolved solids, fats and greases.	Amenable to treatment. All biological processes, scum handling and sludge digestion.
15. Starch Manufacture	Excessive organic dissolved solids.	All biological processes. Sludge digestion.
16. Steel Manufacture	Excessive dissolved organic solids and corrosive.	Settling unit. Biological processes. Sludge digestion.
17. Tannery	Excessive inorganic suspended solids, organic suspended and dissolved solids.	Settling and biological processes. Sludge digestion.
18. Textile	Excessive organic suspended and dissolved solids.	All biological processes. Sludge digestion.

nutrients and an algae problem could result if the receiving body of water is a lake or large stagnant reaches.

In a survey conducted by Masselli and Burford (5), it is observed that the chemicals used in the processing of cotton cloth in the surveyed plant produced 70 to 80 per cent of the total B.O.D. found in the plant effluent. It was observed that starch, soap, and acetic acid are the major B.O.D. producers among the process chemicals because of their high consumption and inherently high B.O.D. The above-named authors feel that B.O.D. reductions as high as 50 to 70 per cent may be obtained through the substitution of low-B.O.D. chemicals for high-B.O.D. compounds, without the installation of any treatment plants whatsoever. It is for this reason that they strongly urge the cooperation among process chemical manufacturers, textile engineers, and pollution abatement agencies in investigating these various possibilities of pollution reduction through process chemical changes before expenditures are made in the building of treatment plants.

6. EFFECT OF INDUSTRIAL WASTES ON SEWAGE TREATMENT PROCESSES

Some substances must usually be excluded from a combined treatment plant system except in very small amounts. The type of wastes affects the criteria to be considered in establishing a policy regarding disposal to public sewers. The uniformity of flow, the composition, the type of solids, the acidity and alkalinity, the toxicity and the scum-forming characteristics must be evaluated.

A tabulation of the basic types of wastes, their characteristics, and the effects of these substances on various types of sewage treatment processes is given in Table 3:

7. COST COMPARISON OF SEWAGE TREATMENT PLANT UNIT COMBINATIONS

As the size of plant is increased, some costs remain constant over some given range of plant size. For example, doubling the size of a waste treatment plant may not always require doubling the number of inputs to operate the larger plant. Some preliminary studies made by Black and Veatch (6) show the ranges of the number of personnel which would be required to operate various modes of treatment systems (Table 4).

Frankel (7) showed that for a given size of treatment plant the total annual cost per million gallons per day of wastes treated remained almost constant until one reached almost 80 per cent B.O.D. removal. Above 80 per

TABLE 4

Type of Plant	Plant Manpower Requirements						
	Average Capacity (MGD)						
	1	3	5	10	20	35	50
Primary	4.5-6	6.5-7.5	7.5-9	10-13	15.5-19	22-27	29-34
Secondary (including trickling filter)	6-7	7.5-9.5	9.5-11.5	13-16	19.5-24	28-34	37-44
Secondary (including activated sludge)	7-8	9.5-10.5	11.5-13	15-18	23-26	33-38	43-49

TABLE 5

(Million Cost Units)

Treatment	Plant Capacity (million m^3/day)							
	1	3	5		10	20	35	50
Primary Treatment	1.4	2.2	3.2	3.8	5.5	6.8	8	14
Secondary Treatment (Activated Sludge)	3.5	5.6	7.6	9.5	13	17	19	30

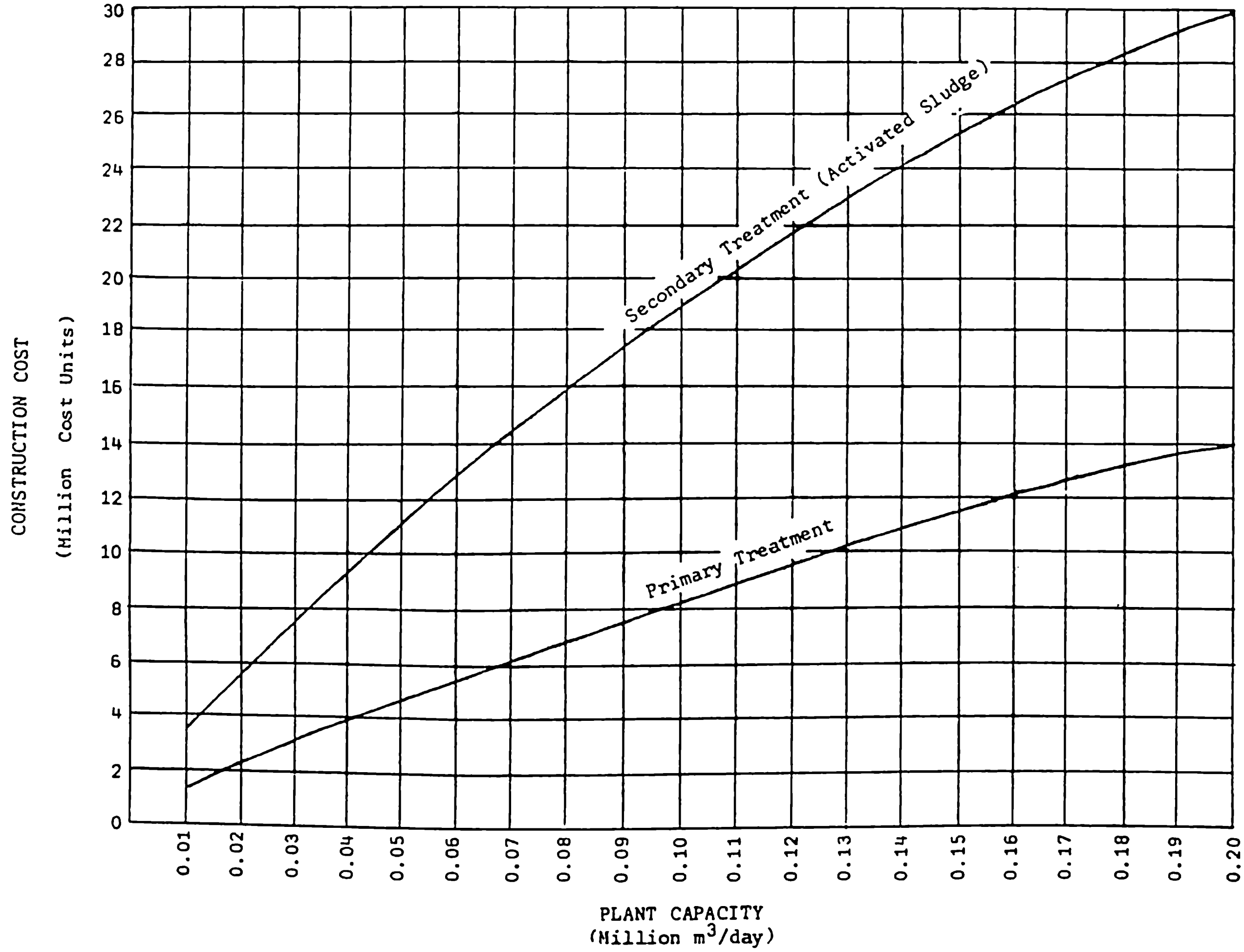

Fig. 1. Treatment plant construction cost. gal/day = 0.003785 m³/day

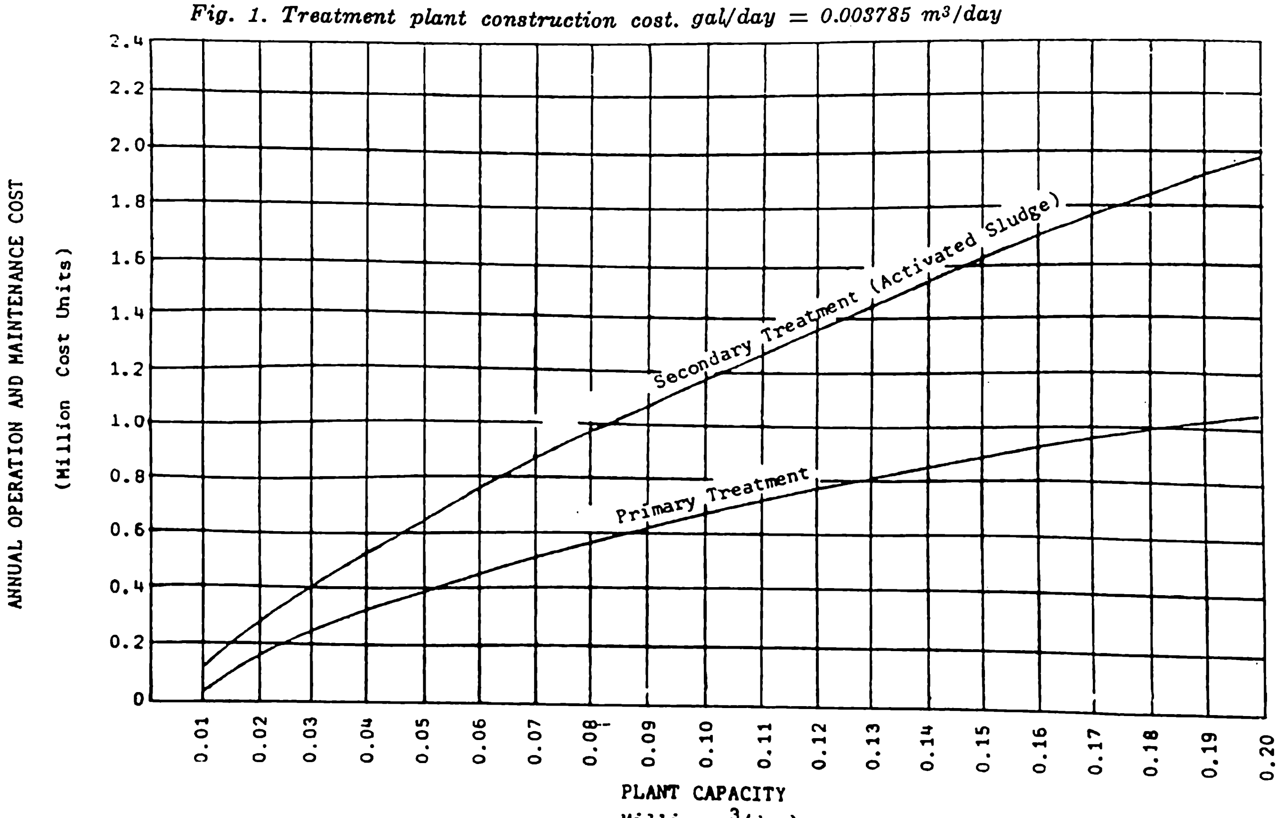

Fig. 2. Annual operation and maintenance cost.

TABLE 6
Comparative Annual Operation and Maintenance Cost
Million Cost Units)

Treatment	Plant Capacity (million m^3/day)						
	1	3	5	10	20	35	50
Primary Treatment	0.05	0.2	0.28	0.35	0.48	0.58	0.7	1.25
Secondary Treatment (Activated Sludge)	0.16	0.31	0.44	0.55	0.75	0.95	1.2	2

cent B.O.D. removal, the total annual costs per million gallons per day of wastes treated increased slightly until 90 per cent B.O.D. removal, and thereafter the annual costs increased sharply.

A comparative study of the construction, operation and maintenance costs for biological treatment plants with various capacities indicates that it is more economical to have one large plant than two or more smaller plants with the same total capacity. In other words, as plant size increases, the marginal (incremental) costs are lower than the average costs. Some estimated figures for the purpose of showing this trend are given in Tables 5 and 6 and Figures 1 and 2. The considerable increase of prices of materials, labor and supplies during the past few months make these estimates too low but for purposes of comparison. the trend still holds.

8. CONCLUSIONS

1. Review of literature indicates that industrial wastes can be treated with domestic sewage provided that these wastes meet certain requirements that do not destroy the sewage treatment plant efficiency.
2. Study of the establishments with major effluents in the Metropolitan Manila Area shows that there are many small industrial plants with relatively small volume of wastewater. The large capital investment and high operating cost of a treatment plant are inhibitive for a small industry to take care of its own waste.
3. Comparative studies of manpower needs, construction costs, maintenance and operation costs of sewage treatment plant unit combinations also indicate that dual treatment could be more economical than separate treatment.
4. Treatment costs will definitely be considered by industry as part of the regular process costs and must be included in the final sale price of the product. Thus, economical treatment methods mean low process costs and low sale price of the product.

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