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INVESTIGATION OF RATIONAL EFFLUENT AND STREAM STANDARDS FOR TROPICAL COUNTRIES

by

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ABSTRACT

Water quality standards were reviewed and tentative stream standards proposed for use in developing countries of Southeast Asia on the basis of legitimate water uses and adaptation of available data to local conditions. A survey of stream standards and water uses applied in the Southeast Asian region indicated that few countries had adopted standards and practically no attempt had been made to adjust to suit local conditions. Experimental studies suggested that oxidation pond effluent would have a beneficial effect on the oxygen balance of a stream under tropical conditions provided that the algal concentration was not more than 1×10^5 cells/ml after dilution in the stream. Oxidation ponds were assessed as being more attractive than either trickling filter or activated sludge treatment plants for populations less than 175,000 and land rental costs of U.S.$0.10 per square meter per year or less.

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I DESIRABLE SURFACE WATER QUALITY STANDARDS

The most important uses of surface waters in the developing countries of Asia are fishing, irrigation and potable water supply. Maintenance of proper quality standards for these uses is an important responsibility of development planners in all countries of the Asian region. Neglect of this could neutralize future development gains if society has to pay more than necessary for its basic water needs. Developing countries must not pursue development programs without considering their impact on future uses of watercourses. On the other hand, these countries cannot afford to spend limited resources on intensive wastewater treatment, waste discharge monitoring and receiving water modelling which are necessary for evaluating the optimum allocation of water resources to present and expected future users. One of the simplest ways of achieving a reasonable allocation in practice is by imposing a stream standard to meet the quality requirement of the most sensitive use of a particular watercourse. In this way, control can be exercised using a minimum number of sampling stations.

A rational stream standard must neither be too lax, and destroy a possible future use of the river, nor too strict, and require more waste treatment than necessary. A lax standard forgoes the future benefits to be derived from potential uses of the watercourse, while a very strict standard forgoes the alternative investment opportunities of the capital which would be used for unnecessary waste reduction.

A comprehensive literature review of the critical parameters that affect uses of watercourses for fishing, irrigation, potable water supply, power, navigation and sport or recreation was made. The survey included published research conducted in tropical developing countries as well as in temperate countries of the developed world. This literature survey allowed a preliminary set of standards to be proposed for different water uses. Emphasis was placed on the three most important uses of surface waters in tropical countries of Asia, namely fishing, irrigation and potable water supply.

Fishing

The fishing industry is an important sector in developing countries as a principal source of badly needed protein in the diet. The main parameters that affect fish catch are dissolved oxygen concentration, presence of toxic compounds such as cyanide and heavy metals, temperature, the presence of non-biodegradable substances which are concentrated in the food chain (such as DDT), and substances which impart an undesirable odor and taste to the fish. The recommended levels of stream standards are shown in Table 1.

Table 1. PROPOSED INTERIM STREAM STANDARDS FOR FISHING

Quality Parameter	Suggested Level of Stream Standard
CO_2	12 mg/1
pH	6.5-8.5
NH_3	less than 1 mg/1
Heavy metals	less than 1 mg/1
Copper	less than 0.02 mg/1
Arsenic	less than 1 mg/1
Lead	less than 0.1 mg/1
Selenium	less than 0.1 mg/1
Cyanides	less than 0.012 mg/1
Phenols	less than 0.02 mg/1
Dissolved solids	less than 1,000 mg/1
Detergents	less than 0.2 mg/1
Dissolved Oxygen	2 mg/1 or above

Fishing as a sport is relatively unknown in tropical developing countries with respect to the freshwater habitat. Neither do game fish, in the western sense, exist and so the water quality requirements for this use are not considered.

Irrigation

The main water quality parameter for irrigation water is the concentration of salts which causes plasmolysis of plant cells. The lethal concentration of salts varies from plant to plant, and is dependent on contact period and ambient temperature. The second problem with salts, especially those containing sodium, is the displacement of calcium ion from the soil, causing permeability to decrease. A good drainage system and proper irrigation management lowers the contact period between the plant and saline water so that a well-drained field may tolerate a lower irrigation water quality. High temperature increases water consumption of plants, and this demands a better irrigation water quality than would be required in a cold climate.

Besides those parameters mentioned, an excessive concentration of metal ions retards plant growth and sometimes causes death, even though the same metal ions are essential micro nutrients in very low concentrations. The recommended stream standards for irrigation use are shown in Table 2.

Potable Water Supply

The critical aspects of a potable water supply are the presence of toxic materials and pathogenic organisms. There is great uncertainty concerning the toxic levels to man of compounds in water and the standards imposed by the World Health Organization (WHO, 1971) and the United States Public Health Service (USPHS, 1962) are necessarily conservative. The literature review revealed that the WHO (1971) standard for coliforms in raw water is very strict for tropical developing countries. Research by PRASAD & KAUSHIK (1964) showed that very few water sources could meet the criterion, although many water sources have been used for a long time by the local population. It is suggested that, apart from during epidemics, stream standards introduced to protect a surface water for direct use as a potable water supply should be related to its natural state, before receiving waste discharges. Stream standards for metallic contaminants are taken directly from the WHO (1971) International Standards for Drinking Water. The recommended list of standards is given in Table 3.

Table 2. PROPOSED INTERIM STREAM STANDARDS FOR IRRIGATION

Quality Parameter	Suggested Level of Stream Standard
Total dissolved solids (TDS)	Not more than 400 mg/1 where there are poor drainage, saline soil and inadequate water supply. (EC_e less than 0.75 millimhos per cm. at 25°C.) Not more than 1,000 mg/1 where there are good drainage and proper irrigation management. (EC_e less than 1.75 millimhos per cm. at 25°C.) Not more than 2,000 mg/1 where there are salt-resistant crops, good drainage, proper water management and low sodium adsorption ratio (SAR) of water. (EC_e less than 2.25 millimhos per cm. at 25°C.)
Sodium adsorption ratio (SAR)	Not more than 10 where there is poor drainage. Not more than 18 where there is good drainage.
Boron	Not more than 1.25 mg/1 where there are sensitive crops. Not more than 4 mg/1 where there are tolerant crops.
Dissolved oxygen	Greater than 2 mg/1. A level of 2 mg/1 should not occur for more than 8 hours out of any 24-hour period.
Pesticides	
DDT	0.002 mg/1
Endrin	0.004 mg/1
B.H.C.	0.21 mg/1
Methyl parathion	0.10 mg/1
Malathion	0.16 mg/1

Table 3. PROPOSED STREAM STANDARD FOR POTABLE WATER SUPPLY

Quality Parameter	Suggested Level of Stream Standard
Most probable number of coliforms (MPN)	Effluent quality similar to the natural state of surface water.
pH	6.5-8.5
Dissolved oxygen	greater than 2 mg/1
Arsenic	less than 0.05 mg/1
Lead	less than 0.05 mg/1
Chromium (hexavalent)	less than 0.05 mg/1
Cyanide	less than 0.2 mg/1
Phenolic substances	less than 0.002 mg/1
Chlorides	less than 1,000 mg/1
Total dissolved solids	less than 4,000 mg/1

However, it is strongly recommended that potable water supply criteria not be accepted as stream standards except where no alternative water supply can be provided for a sizeable population. If this water use is widely adopted as the major controlling use for which a surface water must be managed, it will seriously restrict other uses which might be of high regional benefit and increase the costs of water quality control over those imposed by less quality-demanding uses. It will generally be more economical for water quality management authorities to provide alternative potable water supplies to communities contiguous to surface waters rather than maintain a quality in the surface water which would be safe for drinking.

Minor Uses of Streams

Surface waters may also used as industrial cooling and process waters, and for communication, bathing and recreation. The major requirement for these water uses with which a public authority in a developing country should concern itself is a dissolved oxygen level above zero, simply to maintain aerobic conditions. Industry should generally provide its own water treatment processes and will normally locate in an advantageous position to minimize costs. Recreation and water sports demanding high quality water are luxury uses which should not be controlling in water quality management at the present stage of development of most tropical countries in Asia. In general, people experiencing a significant degree of poverty are not very sensitive to poor surface water quality (unless extreme), and this would not restrict their recreational use of a body of water.

II CURRENT WATER QUALITY STANDARDS IN ASIA

As most of the available publications on water quality parameters discussed in Section I covered research carried out in temperate conditions of developed countries, a questionnaire was sent to different government and research agencies in South East Asia concerned with fishery, irrigation, power development and water supply. Along with the questionnaire, the interim project report (PESCOD, 1973) was sent to all the agencies, to inform them of the project and make them aware of the approach to water quality standards being taken. The questionnaire inquired if there were local adaptations of existing potable water standards (say from the WHO or USPHS standards) to suit national or regional conditions, as well as requesting information on the management alternatives considered when a stream's water quality fell below the standard. With regard to irrigation, the questionnaire inquired about the predominant crops of the country, the tolerance of those crops to various types of contaminants in the water, and the present stream standards for irrigation water. For fisheries, it inquired about the most common freshwater fish in the country, research conducted on the tolerance of the different fish species to toxic compounds commonly found in watercourses and the present stream standards for fishing. A sample questionnaire is provided in Appendix I.

The number of questionnaires sent out and the responses received from each country are shown in Table 4. Approximately 50% of the contacted agencies had responded within seven months of the questionnaire being sent out. Many wrote of the absence of any stream standards or research related to the tolerance of crops and fish in the country. All agencies replying indicated that they were pleased to receive the interim project report and would welcome a copy of the final report when prepared.

Potable Water Supply

Pakistan, Malaysia, Hong Kong and Thailand have adopted the WHO (1971) drinking water standards without modification, while the Philippines has adopted the USPHS (1962) potable water standards. No research has been conducted in any country on the possibility of modifying the standards to suit local conditions.

The Republic of China has modified drinking water standards which allow for a higher concentration of arsenic and lead at 0.1 mg/l, compared with the 0.05 mg/l of the WHO standard. However, the phenolic substances concentration is more stringent, at 0.001 mg/l, as well as the dissolved solids concentration at 1000 mg/l, compared with 0.002 mg/l and 1,500 mg/l, respectively, recommended by WHO (1971). A wider range of pH is allowable in Taiwan, from 6.0 to 9.0. The chloride con-

Table 4. SUMMARY OF QUESTIONNAIRES SENT TO AND RESPONSES FROM DIFFERENT COUNTRIES IN SOUTH EAST ASIA

Country	Questionnaires	Responses
Burma	4	0
Hongkong	6	2
India	6	5
Indonesia	4	0
Khmer Republic	2	0
Malaysia	4	3
Pakistan	4	4
Philippines	5	4
Republic of China	6	6
Singapore	5	1
Sri Lanka	4	0
Thailand	7	5
Vietnam	3	1
	60	31

centration, although set at 300 mg/1, is flexible when excessive chloride is present in a natural water and when no alternative source is available.

Vietnam follows the WHO (1971) standards with modification of the chloride concentration, from 200 mg/1 to a maximum of 650 mg/1. Similarly the pH range is extended, from a minimum of 6.5 to a maximum of 9.2.

Irrigation

Malaysia's only criterion is a total dissolved solids limit of less than 600 mg/1. Singapore and Pakistan have no stated standards. The Philippines has no official standards but the Agricultural Research Center of the National Institute of Science and Technology recommends the following guidelines:

TDS	200 - 500	mg/1
Sodium ion max.	60	mg/1
Boron	0.5 - 1.0	mg/1
Dissolved Oxygen	3	mg/1

PARKER (1971) recommended the following standards for Thailand:

D.O.	not	less	than	3.0 mg/1
BOD	"	more	"	6.0 mg/1
COD	"	"	"	10 mg/1
Ammonia - N	"	"	"	2.0 mg/1
Zinc	"	"	"	.5 mg/1
Copper	"	"	"	.5 mg/1
Iron	"	"	"	1.5 mg/1
Total Heavy Metals	"	"	"	2.0 mg/1
Arsenic	"	"	"	.1 mg/1
Cyanide	"	"	"	0.02 mg/1
Phenols	"	"	"	.005 mg/1

pH	not more than	6.5 - 8.5
Temperature	" " "	35°C

Color and Turbidity should relate to natural conditions. These standards for irrigation water were also recommended for fishing because water use for irrigation and fishing could not be differentiated in Thailand.

For arid conditions, the Central Arid Zone Research Institute has been conducting studies on various water qualities applied to different crops. Acceptable standards for different types of crops and soil are shown in Table 5. The crop yields at these maximum salinity levels are approximately 50% of those irrigated with "sweet" water. However, these salinity concentrations in the irrigation water are acceptable in that there will be no deterioration of soil quality, and hence could be used for irrigation if no other source is available.

Fishing

Hong Kong does not have any stream standards for fishing but the Agriculture and Fisheries Department regularly monitors the dissolved oxygen level and pH of streams. Singapore and Malaysia do not have any stream standards to protect fisheries. Standards for Thailand are similar to the standards for irrigation. The Philippines standards for fishing as promulgated by the National Water and Air Pollution Control Commission are shown in Table 6.

Waste Disposal

Thailand uses an effluent standard but does not enforce any stream standards. There are two standards available in Thai literature, the first one as recommended by PARKER (1971) to the Ministry of Public Health, and the effluent standard enforced by the Ministry of Industry. These standards are given in Table 7. The Philippines stream standards as promulgated by the National Water and Air Pollution Control Commission are given in Table 8.

The Republic of China enforces the standards for effluent discharges as shown in Table 9.

Table 5. STANDARDS OF UNDERGROUND IRRIGATION WATER IN THE ARID ZONE

Crop	Texture of Subsoil		
	Light	Medium	Heavy
Wheat			
Crop every year	3,000	2,500	1,700
Crop alternate years	-	8,000	6,000
Barley			
Crop every year	5,500	3,000	2,500
Crop alternate years	-	10,000	8,000
Mustard			
Crop every year	3,000	2,000	1,300
Crop alternate years	5,500	3,000	2,500
Chillies			
Crop every year	1,700	1,000	650
Cumin and Coriander			
Crop every year	1,500	850	500

Qualifying notes

a) The dominant salt in the underground waters used for irrigation is sodium chloride and S.A.R. ranges between 8 and 30. Often, the waters also contain appreciable quantities of nitrates and phosphates.

b) The soils are generally calcareous with a fairly pervious concretionary strata at depth of 40-100 cm and low water table.

c) Yields of crops, obtained with above waters are about 50% of those obtained with sweet water. However, they are considered remunerative enough for socio-economic situation prevailing in the arid zone.

Table 6. QUALITY STANDARDS FOR CLASS C WATERS* IN THE PHILIPPINES

Items	Specifications
1. Coliform--MPN/100 ml, max.	1000
2. Turbidity--Units, max.	5-10
3. Color--Units, max.	5-10
4. Odor--Threshold Odor Number, max.	10-50
5. Temperature--^{o}F max.	93^{o}
6. Floating Solids--max.	None
7. Toxic Substances--mg/l, max.	None alone or in combination with other substances or wastes in sufficient amounts as will render the water injurious to fish or impair the waters for any other best usage established for this class.
8. Fluoride--mg/l, max.	1.5-3.0
9. Total Solids--mg/l, max.	3000
10. Hardness--mg/l, max.	30
11. Chlorides--mg/l, max.	1000-2500
12. pH Range	6.5-8.5
13. Phenolic Substances--mg/l, max.	0.1-0.2
14. Oil--mg/l, max.	0-5
15. BOD (5-day)--mg/l, max.	10-30
16. D.O.--mg/l, min.	5
17. Ammonia--mg/l, max.	1.5
18. Specific Conductivity-mho x 10^{o}- 25^{o}C, max.	150-500
19. CO_2--mg/l, max.	20

* Class C Usage of Waters: Fishing and any other usage except for bathing or as a source of domestic water supply.

Conditions related to Best Usage : The waters will be suitable for fishing and for other uses requiring waters of lower quality.

Table 7. EFFLUENT STANDARDS IN THAILAND

Characteristic	Recommended values of Ministry of Public Health	Ministry of Industry requirements for industrial wastes
B.O.D.	40	20-60 (depending on dilution)
C.O.D.	100	-
Suspended solids	60	30-150
Heavy metals (total)	5.0	1.0
Arsenic	0.1	-
Zinc	2.0	-
Copper	2.0	-
Iron	5.0	-
Cyanide	1.0	0.2
Ammonia Nitrogen	5.0	-
Sulphide	3.0	1.0
Oil and grease	15.0	nil
Tar	none visible	nil
Phenols	0.05	1.0
Pesticides	0.01	nil
Detergents	1.5	-
Total dis. solids	2000	200
pH	5-9	5-9
Permanganate values	-	60
Chlorine	5.0	1.0
Temp.	40^oC	40^oC

Table 8. QUALITY STANDARDS FOR CLASS E WATERS* IN THE PHILIPPINES

Items	Specifications
1. Floating Solids and Sludge Deposits	None in sufficient amounts as to cause a public nuisance.
2. Oil--mg/1, max	10
3. Dissolved Oxygen--mg/1, min.	1
4. Color--units, max.	20-100
5. Odor--Threshold Odor Number, max.	80
6. pH--min.	5

* Class E Usage of Waters: Navigation and waste disposal and any other uses except for agricultural and industrial water supply, fishing, bathing or source of domestic water supply.

Conditions Related to Best Usage : Waters will be suitable for navigation where navigable waters are involved and will be used for waste disposal to the extent that it will not cause a nuisance and that the waters can accommodate the waste disposal within the limits of the prescribed specification for this class. This class will not be assigned to waters which can be properly assigned to a higher class.

Table 9. EFFLUENT STANDARDS IN THE REPUBLIC OF CHINA

Item	Level	
BOD	40-150	mg/l
Suspended Solids	400	mg/l
Cyanides	0.1	mg/l
Lead	1.0	mg/l
Chromium (hexavalent)	.5	mg/l
Cadmium	0.5	mg/l
Phenolic Substances	.01	mg/l
Chlorides	300	mg/l
pH	5-9	
Coliform	1/100	ml

Summary

From the questionnaires returned it is evident that very few Asian countries have set up any stream standards for the management of their watercourses. Where the need for a stream standard has been urgent, such as in potable water supply, the WHO (1971) or USPHS (1962) standards have been adopted without any attempt being made to modify the standards to suit local conditions. From those countries which have conducted research to modify the WHO and USPHS standards it is apparent that most of the changes made have been conservative.

Although fishing is one of the most important uses of Asian streams, research on the parameters likely to affect the fishing industry has been very limited. In most countries, the most that has been done is a monitoring of dissolved oxygen level in streams. Similarly for irrigation waters, monitoring of salinity has been the prime consideration without any attempt being made to use the information to control use of the source. However, research at the Central Arid Zone Research Institute in India has shown that a wide range of water salinity is tolerable by various types of crops. In fact, when irrigation water is scarce a trade-off can be made between lowering the crop yield and providing an alternative water source.

Most countries surveyed adopted effluent standards for wastewater discharges without any allowance for streamflow dilution. With this approach, a stream could be polluted although all dischargers might have complied with the effluent standards. On the other hand, another stream's assimilative capacity might not be utilized to its fullest extent and some vital industry or industries might be forced to invest in unnecessary wastewater treatment. It is evident that more rational evaluation of the quality demands of major water uses and the adoption of realistic stream standards associated with particular reaches of surface streams will allow the greatest benefit from water resources in developing countries.

III EFFECTS OF OXIDATION POND EFFLUENT ON TROPICAL STREAMS

The presence of toxic substances such as cyanide, chromium, mercury, arsenic, etc, in a stream will normally be due to industrial discharges which will vary from one industry to another. A more common effect of waste discharges on stream water quality is the depletion of dissolved oxygen level due to the discharge of municipal sewage and other organic wastes. In tropical developing countries oxidation ponds have often been suggested as the ideal treatment method for handling sewage and organic wastes due to their low cost of installation, ease of operation and high efficiency. Oxidation ponds can effect a high degree of treatment but invariably discharge significant numbers of algae in their effluents. These algae will exert BOD in the standard BOD test, due to incubation in the dark, and oxidation pond effluents regularly show BOD levels of 50 or 60 mg/l, related mainly to the algae; filtered effluent BOD levels are usually 20 mg/l or less for a properly designed oxidation pond system.

On discharge of oxidation pond effluent to a surface stream in the tropics, growth conditions for the algae are different from those in an incubated BOD bottle and the actual effects on the oxygen balance in the stream are not obvious. During daylight hours the algae will photosynthesize, depending upon their location over the depth of stream and the light transmission, and in the dark will respire. Unless light inhibition occurs there will normally be a net oxygen production over a full 24 hour period. However, in the tropics, surface waters are generally highly turbid and this will seriously affect the total oxygen production by suspended algae.

The experimental portion of the work was designed to evaluate the effects of oxidation pond effluent discharges on the oxygen balance of tropical surface streams. Most experiments were conducted using the Asian Institute of Technology first-stage oxidation pond effluent, whose characteristics were as shown in Table 10. This pond effluent was used as a concentrated algal suspension and diluted with surface water to give a range of algal concentrations for study.

Table 10. CHARACTERISTICS OF AIT OXIDATION POND EFFLUENT

Unfiltered COD	165-252 mg/l
Filtered COD	104-130 mg/l
Total Kjedahl Nitrogen	11-36 mg/l
Suspended Solids	60-145 mg/l
Algal Population	1.0×10^5 to 3.0×10^5 per ml
Algal Species	mostly euglena and chlorella
Temperature	tropical conditions (20 - 30°C)

Experimental Procedure

The pond effluent was diluted with stream water in the ratios 1:1, 5:1, 10:1, 50:1 and 100:1. The stream water used had turbidity between 56 and 133 JTU in its natural state but was filtered to remove algae prior to dilution, to prevent contamination of the oxidation pond effluent algal population. Replicate samples of diluted pond effluent were placed in light BOD bottles and incubated at depths of 0.0 m, 0.25 m, 0.5 m, and 0.75 m below the stream surface. Filtered and unfiltered pond effluent, at similar dilutions, were placed in dark BOD bottles and incubated at a depth of 0.75 m below the stream surface. The duration of each run was 36 hours and samples were tested for dissolved oxygen (DO) once every three hours.

Experimental Results

The dissolved oxygen levels in the light BOD bottles incubated at the surface and at a depth of 0.25 m were plotted against time as shown in Fig. 1 and 2. Dissolved oxygen was found to vary according to the sunlight availability and the algal concentration. At higher algal concentrations, higher maximum DO was obtained, due to the photosynthetic process. The peak was reached with all levels of algal concentration at 5:00 P.M., declining steadily during the night time. The decline is due to algal respiration which uses up DO in the water in the absence of light. It was observed that the second day DO concentrations were higher than the initial levels of DO. The DO values in all cases never reached zero.

In Fig. 1 an algal concentration less than 2.0×10^3 per ml at the high dilution ratio, gave a D.O. level in the bottle which was essentially independent of the sunlight intensity. At this level of algal concentration at the surface, the dissolved oxygen level was not affected by the algal photosynthetic rate or the respiration rate and in practice would depend only on the surface diffusion of oxygen affected by the hydraulic properties of the stream. At the depth of 0.25 m, the effect of algal photosynthesis and respiration is more evident at all levels of algal concentration. It should be noted in Fig. 2 that although the highest DO level was obtained with the highest concentration of algae, the lowest DO level also occurred with this algal concentration. It could be concluded that although algae aid the oxygenation of a stream during daytime, their effect during the nighttime could be detrimental to aquatic life when they compete in the utilization of dissolved oxygen. However, it is safe to say that within the normal range of effluent dilution (as used in the experiments) there is no danger of net oxygen depletion in a shallow stream (up to 0.25 m deep) due to algal growth at algal concentrations below 1.5×10^5 per ml.

The experimental points for dark and light periods were connected

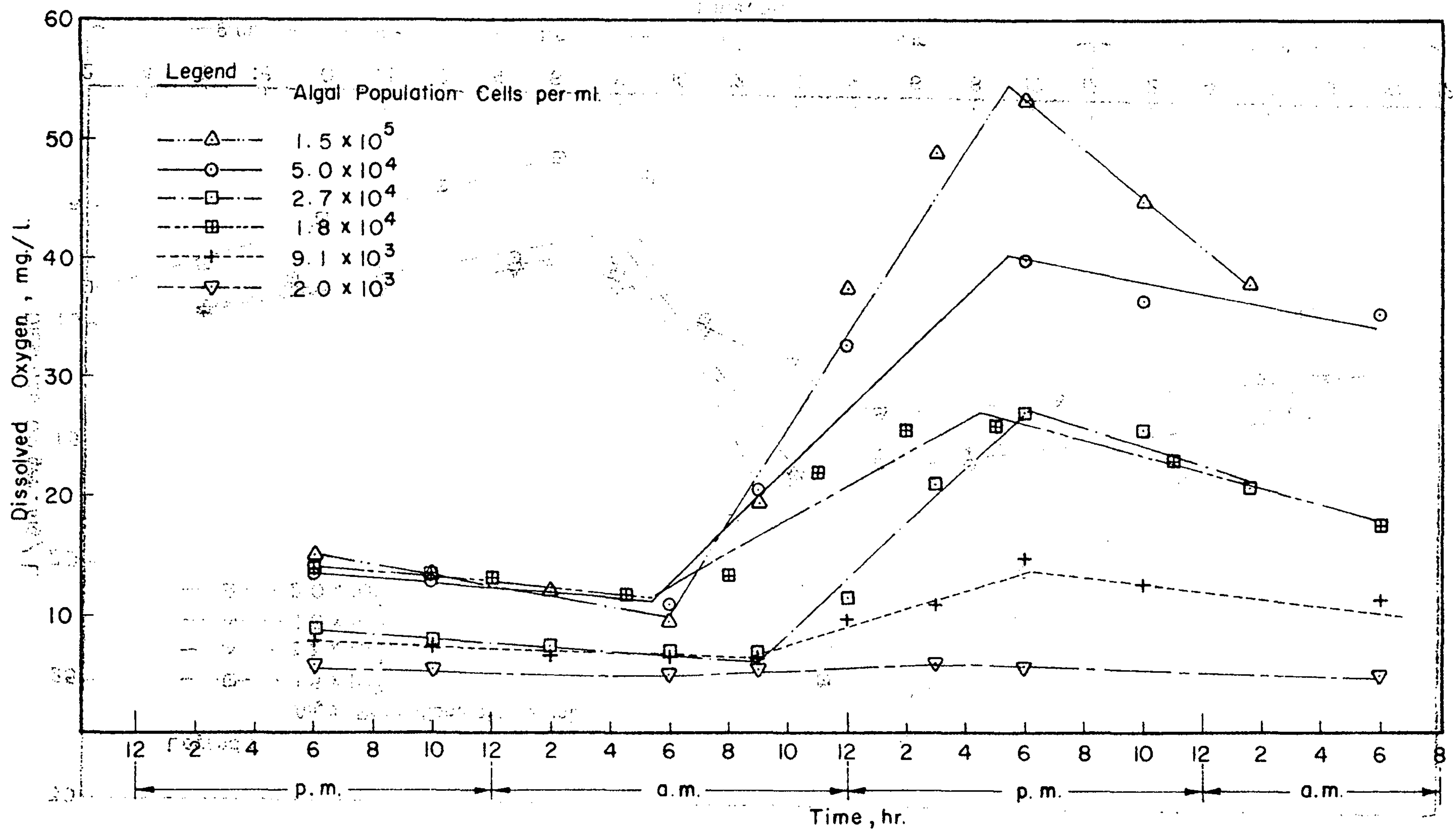

Fig. 1 — Oxygen Production in Light Bottles Incubated at the Surface of a Turbid Stream.

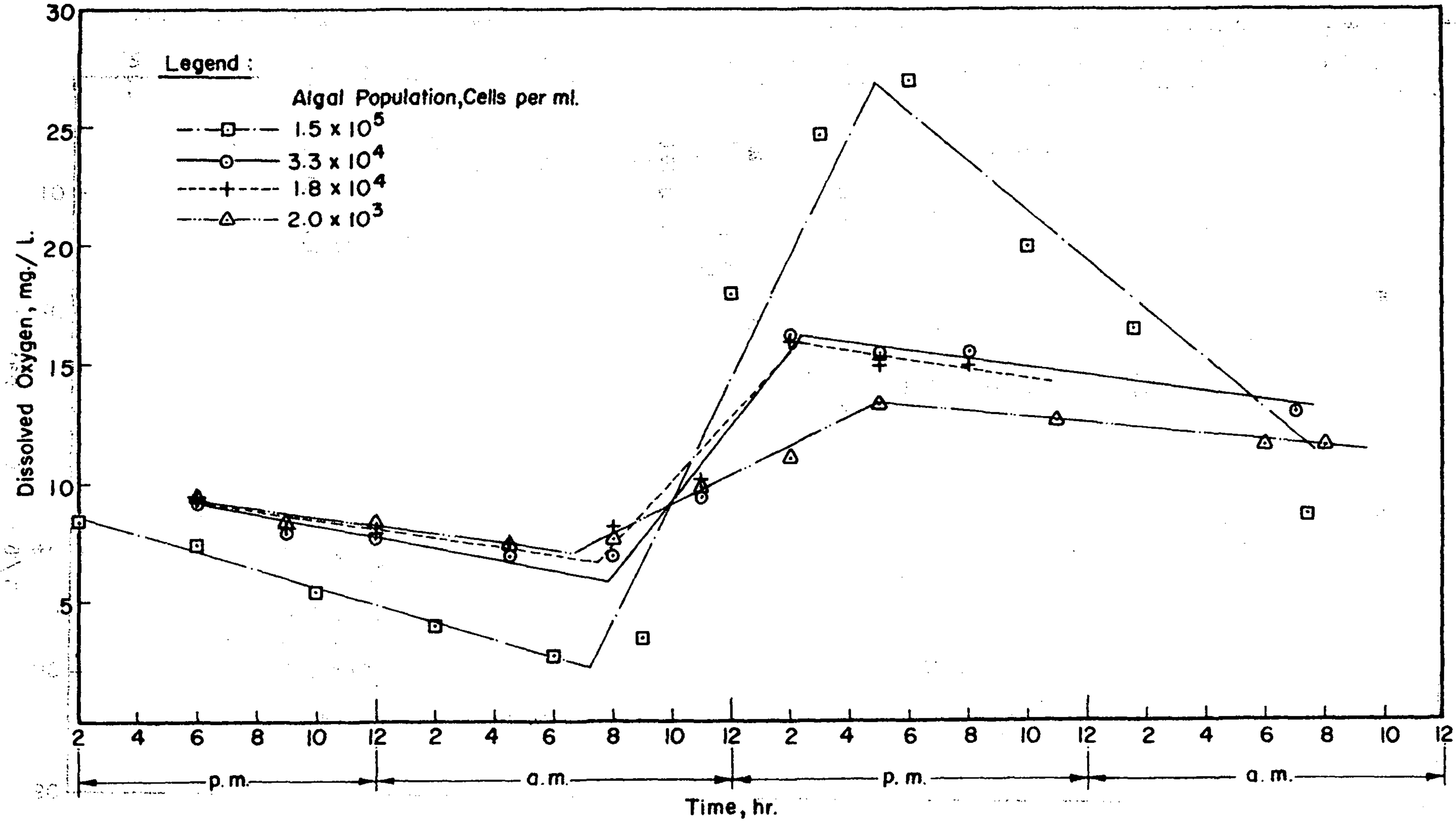

Fig. 2 – Oxygen Production in Light Bottles Incubated at a Depth of 0.25m. in a Turbid Stream.

by straight lines fitted using the method of least squares. The positive slope which occurs from 6:00 AM to 5:00 PM is the algal photosynthetic rate, reduced by the bacterial respiration rate. The negative slope which occurs between 5:00 PM and 6:00 AM the next day, is the sum of the algal respiration and bacterial respiration rates. Tables 11 and 12 show the different photosynthetic and respiration rates. The bacterial respiration rate was obtained from dark BOD bottles containing the filtered pond effluent placed at depths similar to the light bottles containing diluted effluent.

The photosynthetic rates at the two depth levels were plotted against algal concentrations as shown in Fig. 3. It is apparent that the algal photosynthetic rate is proportional to the algal concentration. The increase is linear above an algal population of 9.0×10^3 per ml and below this point the algal photosynthetic rate was higher at the surface than at a depth of 0.25 m.

Comparing the values in Tables 11 and 12 it is seen that the algal respiration rate during the night at the surface was slightly higher than the bacterial respiration rate. At the depth of 0.25 m the algal respiration rate was three times the bacterial respiration rate. This means that, due to the presence of algae, the DO at the surface is used up at a rate twice what it would be with bacteria alone, while at a depth of 0.25 m the rate of DO use is four times that with bacteria alone.

During daytime the photosynthetic rate at the surface was 3.8 to 22.7 times the respiration rate, while at the depth of 0.25 m the photosynthetic rate was 4.6 to 17.0 times the respiration rate. Although the overall photosynthetic production of oxygen during daytime was greater than the respiration rate during nighttime, the oxygen generated during photosynthesis would be partly released to the atmosphere once the DO level in the stream exceeded the saturation value. Recovery of dissolved oxygen from the atmosphere during nighttime respiration is controlled by the hydraulic turbulence of the stream, which is normally low in meandering tropical streams under low flow conditions. Depletion of oxygen during the night by high concentrations of algae is the critical aspect in the stream's oxygen balance.

For unpolluted streams, a typical DO level in the tropics is 6.5 mg/l. Using the photosynthetic rate and the algal and bacterial respiration rates determined in the experiments, the effects of various algal populations on the DO levels of a tropical stream may be predicted as in Tables 13 and 14. These show that algal concentrations of 1.5×10^5 or less are beneficial to a shallow turbid stream because the rate of photosynthetic production of oxygen is greater than the bacterial respiration rate. At the same time the lowest level of DO due to algal respiration is likely to be 3.6 mg/l, which allows sufficient DO for other aquatic life such as fish and freshwater crustaceans to thrive. This assumes

Table 11. ALGAL RESPIRATION AND PHOTOSYNTHETIC RATES AT THE SURFACE OF A TURBID STREAM

		1	2	3	4	5	6
Stream Water to Pond Eff. Ratios	Algal Population (per ml)	Bact + Algae Resp. Rate (mg/l-hr)	Algae Photosynthetic − Bact. Resp. Rate (mg/l-hr)	Bacteria Resp. Rate (mg/l-hr)	Algae Resp. Rate (mg/l-hr)	Algae Photosynthetic Rate (mg/l-hr)	Algae Photosynthetic / Algae Resp. Rate
1 : 1	1.5×10^5	0.445	3.916	0.201	0.244	4.117	16.9
1 : 1	5.0×10^4	0.203	2.400	0.093	0.110	2.493	22.7
10 : 1	2.7×10^4	0.179	1.826	0.130	0.130	1.956	15.0
10 : 1	1.8×10^4	0.225	1.393	0.041	0.184	1.431	7.8
10 : 1	9.1×10^3	0.096	0.843	0.047	0.049	0.890	18.2
50 : 1	2.0×10^3	0.062	0.097	0.029	0.033	0.126	3.8
100 : 1	1.0×10^3	0.032	0.070	0.032	negible	0.102	-

Table 12. ALGAL RESPIRATION AND PHOTOSYNTHETIC RATES AT A DEPTH OF 0.25 M BELOW THE SURFACE OF A TURBID STREAM

		1	2	3	4	5	6
Stream Water to Pond Eff. Ratios	Algal Population (per ml)	Bact + Algae Resp. Rate (mg/l-hr)	Algae Photosynthetic / Bact. Resp. Rate (mg/l-hr)	Bacteria Resp. Rate (mg/l-hr)	Algae Resp. Rate (mg/l-hr)	Algae Photosynthetic Rate (mg/l-hr)	Algae Photosynthetic / Algae Resp. Rate
1 : 1	1.5×10^5	0.367	2.596	0.201	0.166	2.797	17.0
5 : 1	3.3×10^4	0.202	1.533	0.052	0.151	1.585	10.5
10 : 1	1.8×10^4	0.185	1.316	0.041	0.144	1.357	9.4
50 : 1	2.0×10^3	0.171	0.599	0.033	0.138	0.632	4.6

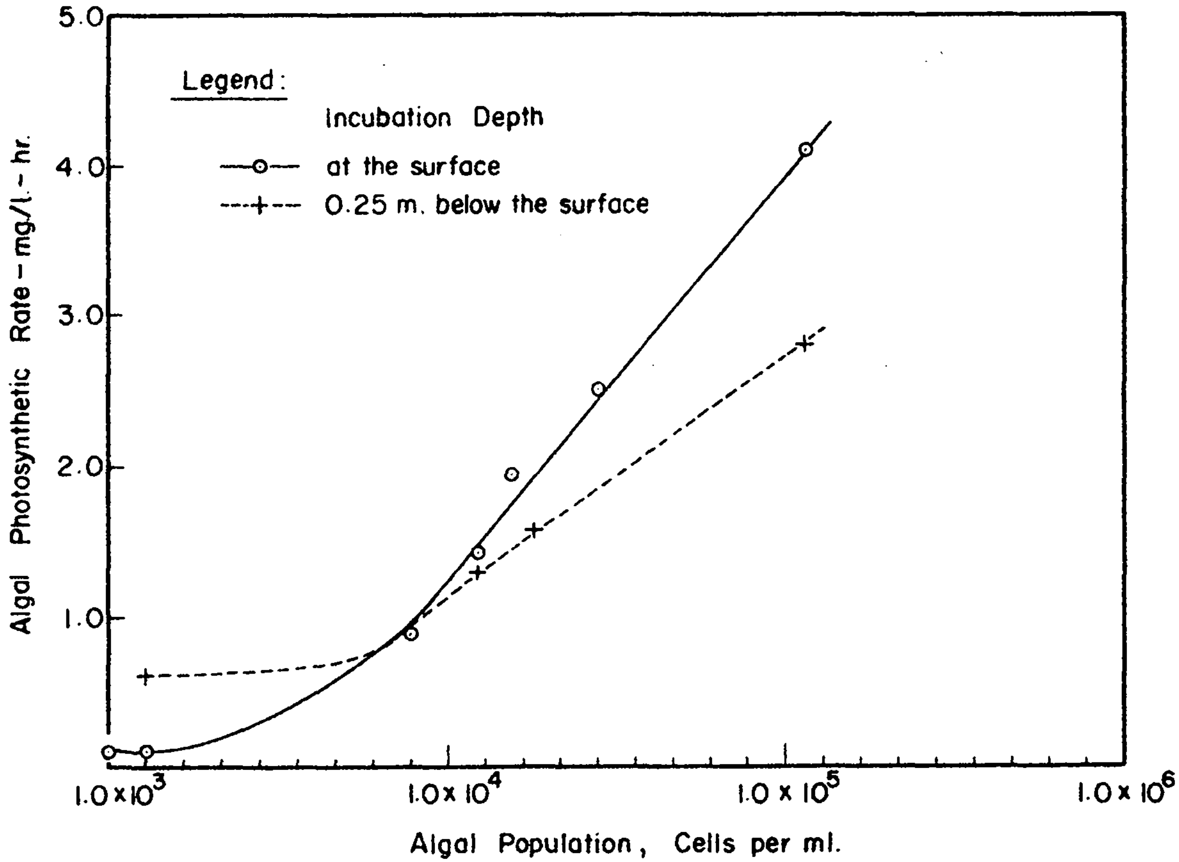

Fig. 3 – Algal Photosynthetic Rate as a Function of Algal Population At the Surface and 0.25 m. Depth in a Turbid Stream.

Table 13. MINIMUM & MAXIMUM D.O. LEVELS AT THE SURFACE OF A TURBID RECEIVING WATER WITH INITIAL D.O. OF 6.5 mg/1, CAUSED BY ALGAE AT DIFFERENT CONCENTRATIONS

Stream Water to Pond Eff. Ratios	Algal Population (per ml)	Algae Respiration Rate (mg/1-hr)	Algae Photo-synthetic Rate (mg/1-hr)	Min. D.O. Level After 12 hr Respiration (mg/1)	D.O. Depleted After 12 hr (mg/1)	Percent D.O. Depleted (%)	Max. D.O.+ Level 12 hr Photo-synthesis	Min. D.O.* Level 12 hr Photo-synthesis
1 : 1	1.5×10^5	0.244	4.117	3.6	2.9	44.6	53.0	7.8
1 : 1	5.0×10^4	0.110	2.493	5.2	1.3	20.0	35.0	7.8
10 : 1	2.7×10^4	0.130	1.956	4.9	1.6	24.1	28.4	7.8
10 : 1	1.8×10^4	0.184	1.431	4.3	2.2	33.8	21.5	7.8
10 : 1	9.1×10^3	0.049	0.890	5.9	0.6	9.2	16.6	7.8
50 : 1	2.0×10^3	0.033	0.126	6.1	0.4	6.1	7.6	7.8
100 : 1	1.0×10^3	negligible	0.102	6.5	0.0	0.0	6.5	7.8

\+ Maximum DO occurs when stream is very slow that very high degree of supersaturation can occur.

* Minimum DO occurs when stream is fairly turbulent that supersaturation is minimal, as excess DO is released to atmosphere.

Table 14. MINIMUM & MAXIMUM D.O. LEVELS AT A DEPTH OF 0.25 M IN A TURBID RECEIVING WATER WITH INITIAL D.O. OF 6.5 mg/1, CAUSED BY ALGAE AT DIFFERENT CONCENTRATIONS

Stream Water to Pond Eff. Ratios	Algal Population (per ml)	Algae Respiration Rate (mg/1-hr)	Algae Photo-synthesis Rate (mg/1-hr)	Min. D.O. Level After 12 hr Respiration (mg/1)	D.O. Depleted After 12 hr (mg/1)	Percent D.O. Depleted (%)	Max. D.O.+ Level 12 hr Photo-synthesis	Min. D.O.* Level 12 hr Photo-synthesis
1 : 1	1.5×10^5	0.166	2.797	4.5	2.0	30.7	38.6	7.8
5 : 1	3.3×10^4	0.151	1.585	4.7	1.8	27.7	23.0	7.8
10 : 1	1.0×10^4	0.144	1.757	4.8	1.7	26.1	21.3	7.8
50 : 1	2.0×10^3	0.138	0.632	4.9	1.6	24.6	12.5	7.8

\+ Maximum DO occurs when stream is very slow that very high degree of supersaturation can occur.

* Minimum DO occurs when stream is fairly turbulent that supersaturation is minimal, as excess DO is released to atmosphere.

that oxygen tensions above saturation would be released to the atmosphere, which might not be true in practice as super saturation is often encountered. However, it would be a conservative approach to ensure that the stream DO standard was maintained.

Photosynthetic oxygen production at depths of 0.5 m and 0.75 m was insignificant compared with that at the surface and at a depth of 0.25 m. The diurnal DO variations were similar to the variations in the dark BOD bottles. Tables 15 and 16 show respiration rates at the depths of 0.5 and 0.75 meters. In the range of 1.0×10^3 to 2.7×10^4 algal cells per ml, the algal respiration rate was negligible compared with the bacterial respiration rate, but for an algal concentration of 1.0×10^5 the algal respiration was 3.6 times that of bacterial respiration. With low photosynthetic rates at depths greater than 0.5 m and high rates of respiration, with more than 1.0×10^5 algae per ml, the algae are likely to deplete stream DO in the case of deeper streams. However, algae exhibit heliotropic effects which would limit the growth of algae at lower depths in deep streams, so that the critical algal concentration of 1.0 $\times 10^5$ per ml is not likely to occur unless the original dilution of the oxidation pond effluent produces such a level.

Samples of final effluent taken over a period of several months in 1972 from oxidation ponds at the U.S. Air Base in Korat, Thailand showed a maximum algal concentration of 0.26×10^5 cells per ml. At the Applied Scientific Research Corporation, Bangkok the effluent from the oxidation pond has contained a maximum of 0.29×10^5 algal cells per ml, while at the Asian Institute of Technology the final effluent from the second stage oxidation pond has shown a maximum algal content of 0.99×10^5 cells per ml. If these are taken as typical oxidation pond effluents in tropical countries, then after dilution upon discharge to a surface stream it is not possible to achieve the critical level of algal concentration which would cause problems in deep streams.

Oxygen Production Rate

Net oxygen production rates averaged over the euphotic zone of the stream were calculated by subtracting the oxygen concentration in the dark bottles from that in the light bottles after one day of incubation, and multiplying the rate by the area of the bottle. Production rates were calculated at various depths of the surface layer in which photosynthesis occurred and averaged. Fig. 4 shows the exponential increase of oxygen production rate with increase in algal population at various dilutions.

Table 15. NET ALGAL RESPIRATION RATE AT 0.5 M DEPTH IN TURBID STREAM

(I)	(II)	(III)	(IV)	(V)	(VI)
Stream Water to Pond Eff. Ratios	Algal Population (per ml)	Algae+ Bact Net Resp. Rate at 0.5 m depth (mg/l-hr)	Algae + Bact Resp. Rate (in dark bottle) (mg/l-hr)	Bacteria Resp. Rate (mg/l-hr)	Net Algae Resp. Rate at 0.5 m depth (mg/l-hr)
10 : 1	2.7×10^4	0.118	0.309	0.130	negligible
50 : 1	2.1×10^3	0.049	0.073	0.058	negligible
100 : 1	1.1×10^3	0.035	0.044	0.032	negligible

Table 16. NET ALGAL RESPIRATION RATE AT 0.75 M DEPTH IN TURBID STREAM

(I)	(II)	(III)	(IV)	(V)	(VI)
Stream Water to Pond Eff. Ratios	Algal Population (per ml)	Algae+ Bact Net Resp. Rate at 0.5 m depth (mg/l-hr)	Algae + Bact Resp. Rate (in dark bottle) (mg/l-hr)	Bacteria Resp. Rate (mg/l-hr)	Net Algae Resp. Rate at 0.75 m depth (mg/l-hr)
1 : 1	1.0×10^5	0.459	0.524	0.096	0.363
5 : 1	3.3×10^4	0.066	0.195	0.052	negligible
10 : 1	1.8×10^4	0.068	0.174	0.041	0.007
50 : 1	2.0×10^3	0.031	0.066	0.033	negligible

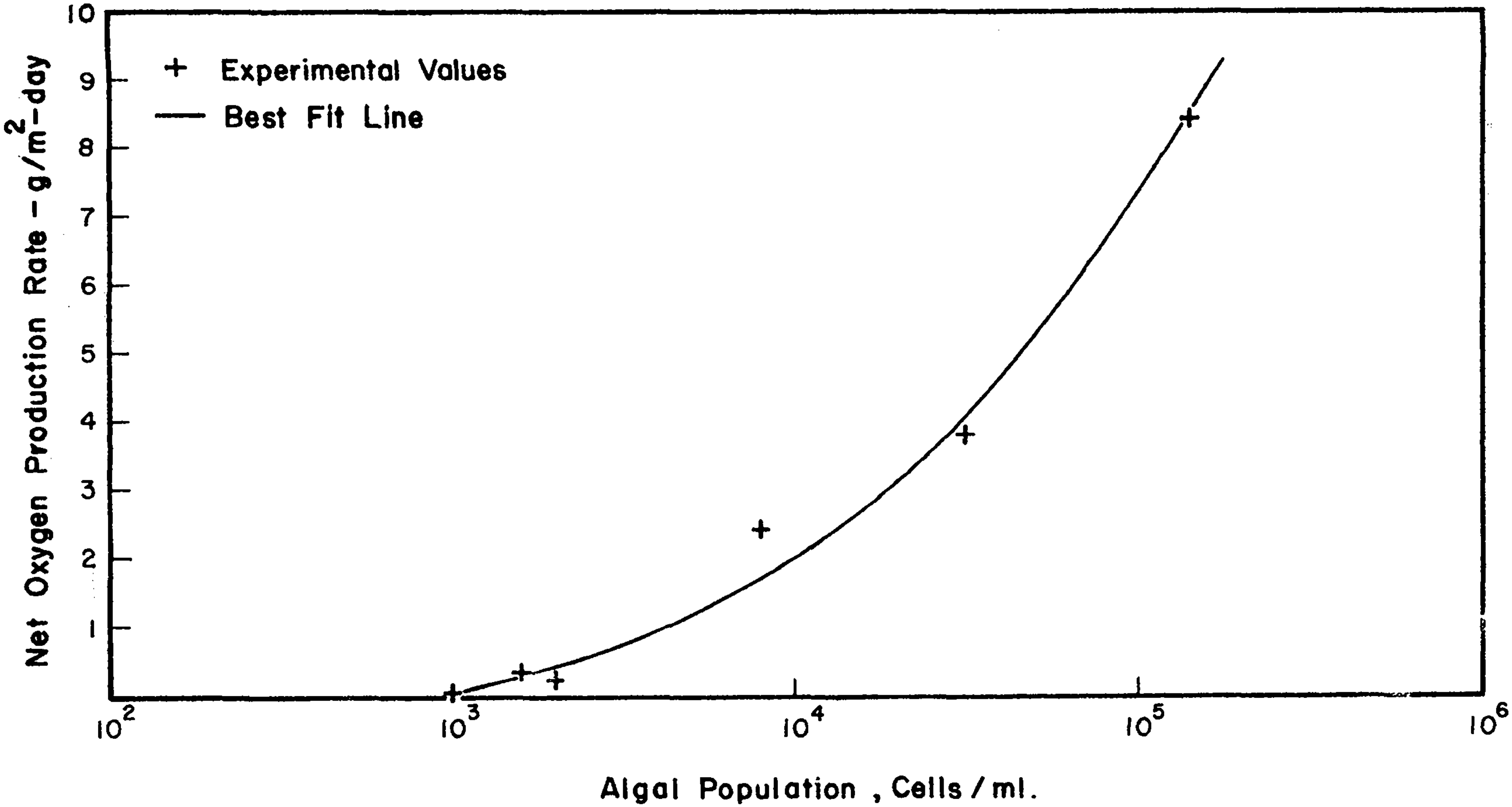

Fig. 4 Net Oxygen Production Rate in the Euphotic Zone of a a Stream as Function of Algal Population

Summary of Experimental Findings

The effluent from an oxidation pond system treating municipal sewage normally contains only a small amount of biodegradable organic matter which can deplete the stream dissolved oxygen. However, the effluent also contains algae which compete with bacteria and other aquatic life in the stream for dissolved oxygen during the night when undergoing respiration. During the daytime, algae near the surface produce oxygen by photosynthesis and sometimes can alleviate the dissolved oxygen deficit in the stream caused by bacterial breakdown of organic matter. Although the algae produce more oxygen during photosynthesis than they consume during respiration, excess oxygen produced may be released to the atmosphere when the dissolved oxygen concentration reaches saturation. No oxygen is produced by algae at depths greater than 0.5 m in turbid tropical streams as a result of the absence of light.

The experimental studies suggest that if the algal concentration in a shallow stream is greater than 2×10^5 cells per ml, the stream could turn anaerobic before sunrise even though it might be saturated with oxygen before sunset. To maintain a dissolved oxygen concentration of at least 2.5 mg/l at all times in a turbid tropical stream with depth not more than 0.5 m, the algal concentration should be less than 1.5×10^5 per ml. In the case of turbid streams with depth greater than 0.5 m, an algal concentration of 1.0×10^5 cells/ml or more would deplete dissolved oxygen because of the high respiration demands for oxygen of algae located below the limit of light penetration.

The algal concentration in final effluents from oxidation pond systems treating domestic wastes in Thailand has not been found to exceed 1×10^5 cells per ml. A minimum of dilution on discharge to a surface stream, even as low as 1:1, would result in an algal concentration which would not be expected to be a drain on the stream's oxygen resources. At this algal concentration, the photosynthetic oxygen produced by algae in the upper 0.5 m of depth would be beneficial to the stream's oxygen balance.

To ensure that an oxidation pond effluent would not adversely affect a tropical stream, it would be necessary to provide enough dilution so that the algal concentration in the stream would not exceed 1×10^5 cells/ml. Multiple stages of ponds would minimize the algal concentration in the final effluent from an oxidation pond system and should be encouraged in design.

IV EVALUATION OF WASTEWATER TREATMENT ALTERNATIVES

The experimental results have suggested that the effluent from an oxidation pond system can be discharged into a turbid stream in the tropics without having a detrimental effect on the oxygen balance provided that the algal population is kept below 1 x 10^5 cells per ml after dilution. Removal of nutrients from effluents to prevent subsequent algal growth in streams, as often practised in temperate countries, is unrealistic in tropical Asian countries considering that most streams are very turbid in their natural state and carry lots of nutrients from surface runoff. Algal removal will not serve any purpose in enhancing the aesthetic value of a stream and other important stream uses will not be affected by the presence of algae. Thus it would seem that the main consideration in the choice of wastewater treatment system in tropical regions should be economic rather than technological sophistication. Oxidation ponds are acceptable organic waste treatment devices but they must compete with alternative secondary processes on a cost basis.

Degree of Treatment Required

CHOU (1970) estimated the strength of typical domestic sewage in Asia at 376 mg/l of BOD_5 at a flow rate of 114 lpcd, giving a per capita discharge of 42.86 g of BOD_5 per day. Although sewage is not discharged uniformly throughout the day, in the case of oxidation ponds with long detention time compared with the interval between peak sewage discharges, the ponds will even out flow and strength fluctuations. Thus, assuming a uniform effluent discharge throughout the day, the BOD concentration at the point of discharge can be expressed as:

$$L_a = L_o + \frac{42.86\ P(1-e)}{Q + P(.114)} \qquad (1)$$

where, L_a is the instantaneous BOD of the stream at the site of discharge, mg/l,

L_o is the initial BOD of the stream before the discharge point, mg/l,

e is the degree of treatment,

P is the population served in thousands,

Q is the design stream flow rate in m^3/day

STREETER and PHELPS (1925) derived the expression for the minimum DO in the stream as:

$$D_c = \frac{L_a}{r \left\{ f \left[1-(f-1)^{D_a/L_a} \right] \right\}^{1/(f-1)}} \qquad (2)$$

where, D_c is the maximum dissolved oxygen deficit of the stream, mg/l,

D_a is the oxygen deficit in the stream just before the point of discharge,

r is the rate of stream reaeration, per day,

k is the oxygen uptake rate by microorganisms in the stream, per day.

QAIMKHANI (1968) found the oxygen uptake for tropical streams at 0.15 per day and SERMPOL (1968) obtained the stream reaeration rate of 0.25 per day which was practically constant over a wide variation of flow rates.

The Streeter-Phelps oxygen sag model is only a rough approximation of the mechanism of oxygen uptake and reaeration in a stream as it does not consider algal photosynthesis and respiration, nitrification, oxygen uptake of the stream benthos, and variation of reaeration coefficient along the stream. However, it is quite simple for direct application in the field without the need for sophisticated computing equipment.

Fig. 33-5 in FAIR, GEYER and OKUN (1968) gives the relationships between BOD concentration at a discharge point, the initial oxygen deficit and the maximum oxygen deficit downstream from the discharge point. Using these curves with the initial oxygen deficit and a recommended stream standard for D.O., the necessary value of the initial ultimate BOD_5 in the stream (L_a) can be determined. This will allow the degree of treatment to be evaluated by:

$$e = 1 - \frac{(L_a - L_o)\ (Q + 0.114\ P)}{P\ (42.86)} \qquad (3)$$

Wastewater Treatment Systems

Alternative organic wastewater treatment systems to oxidation ponds are trickling filters and the activated sludge process. However, FRANKEL (1968) found the incremental cost of secondary treatment using trickling filters and activated sludge to be very small within the range of 30% to 80% removal of BOD_5 from sewage. It therefore seems uneconomical to construct an activated sludge or trickling filter plant and operate it at less than 80% removal efficiency. On the other hand, the optimum stream standard will take advantage of the assimilative capacity of a stream to its fullest extent without causing extensive damage to present users of the stream. Hence, if the necessary degree of treatment is less than 80% a split flow system would meet the lower treatment requirement and yet maintain the cost effectiveness of these secondary treatment processes. The mixture of untreated and treated waste streams would give an equivalent removal efficiency to that calculated using Eq. 3. In practice it would be necessary to provide primary treatment to the whole waste flow. By means of a mass balance the fraction of total wastewater flow which must receive secondary treatment would be given by:

$$P = e/_f \tag{4}$$

where, P is the fraction of the wastewater flow that must be treated,

f is the treatment plant optimal removal of biodegradable waste, and

e is as defined before.

The portion that is allowed to by-pass secondary treatment is then equal to:

$$P_b = 1 - e/_f \tag{5}$$

where, P_b is the fraction that has to be by-passed.

The relationships between initial oxygen deficit in the stream, the initial organic load in the stream after mixing of the discharged waste, the degree of waste treatment required and the stream DO standard as calculated by the Streeter-Phelps oxygen sag model using parameter values previously stated are shown in Fig. 5. It is clear that as the standard becomes more stringent, that is the oxygen deficit becomes smaller, the required efficiency of removal of BOD increases considerably. Similarly, applying Eq. 4 it can be shown that the required portion of wastewater which must receive secondary treatment increases considerably with increase in the stream dissolved oxygen standard, until all the wastewater must be treated when the removal required is equal to the optimal removal efficiency of the unit, e = f. The optimal removal efficiency is approximately 80% for trickling filters, 90% for activated sludge and 70-80% for oxidation ponds.

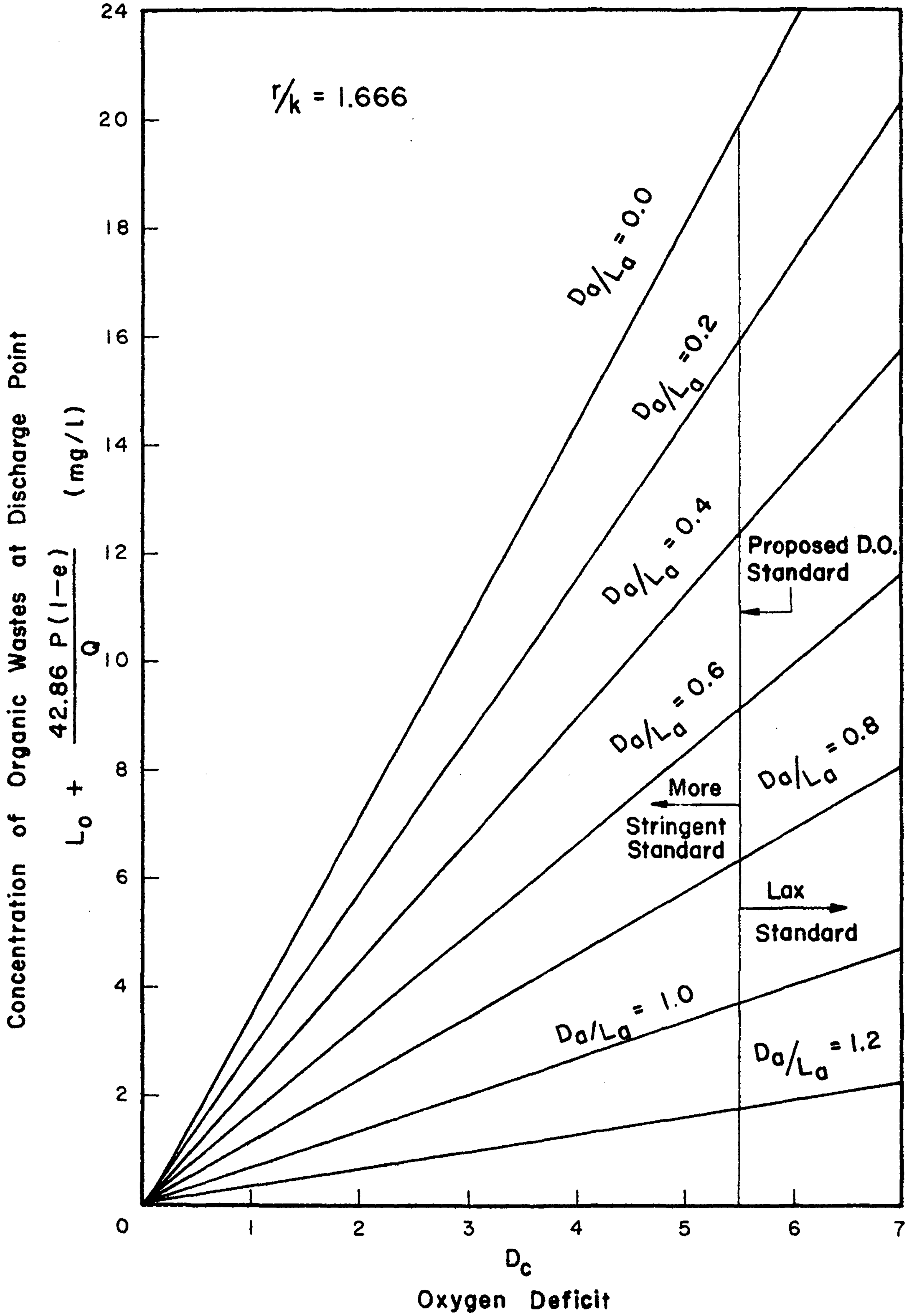

Fig. 5 Relationship between Stream DO and Concentration of Organic Wastes Discharged into a Stream

Comparative Costs of Wastewater Treatment Systems

The total cost of the activated sludge process is primarily dependent on the construction cost, operation and maintenance costs, which are relatively constant within any particular country. Total costs of trickling filter and oxidation pond treatment plants are dependent on the land cost which makes cost evaluation highly dependent upon location.

Due to the lack of regional construction cost data, and costs of operation and maintenance for activated sludge and trickling filter plants, total annual costs were estimated on the basis of data given by SMITH (1968) and updated using the 1973 ENR cost index of 1892 (1913=100). The costs for oxidation ponds were determined using actual cost data from the Asian Institute of Technology and the Applied Scientific Research Corporation of Thailand updated to 1973 using the ENR cost index adjustment. Fig. 6 shows the estimated total annual costs (including capital depreciation, operation and maintenance) for trickling filters and oxidation ponds at different land values. This figure also shows the total annual costs for activated sludge and primary treatment processes.

For purposes of comparison, land cost is allowed for as a rental rate per square meter. This overcomes the problem of land value appreciation over a period of time and takes into account the financial benefit forgone as a result of not using the land for alternative purposes during the life of the treatment plant.

Fig. 6 indicates that the main constraints in the choice of a wastewater treatment system are the population served and the cost of rental for the land used. For populations less than 175,000 (20,000 m^3/day) and when land is very cheap, oxidation ponds are most attractive, followed by trickling filters. However, when the population served becomes very large, the land required becomes large so that even at low land rental costs, the trickling filter becomes more attractive. At very high land rental costs, as commonly found in urban areas, and for large populations the activated sludge process becomes competitive with trickling filters.

The decision on the choice of wastewater treatment process for military installations in tropical developing countries will thus depend principally on the value attached to the land used. For populations less than 175,000, which would include most military bases, and land rental costs less than U.S.$ 0.10/m^2 per year, oxidation ponds will be the most economic system providing secondary treatment. The need for secondary treatment and the proportion of the waste flow requiring secondary treatment will be strongly influenced by the stream standard for dissolved oxygen applied. Oxidation pond effluent will not adversely affect the oxygen balance of a stream provided that the concentration of algal cells after dilution in the stream does not exceed 1 x 10^5 cells/ml.

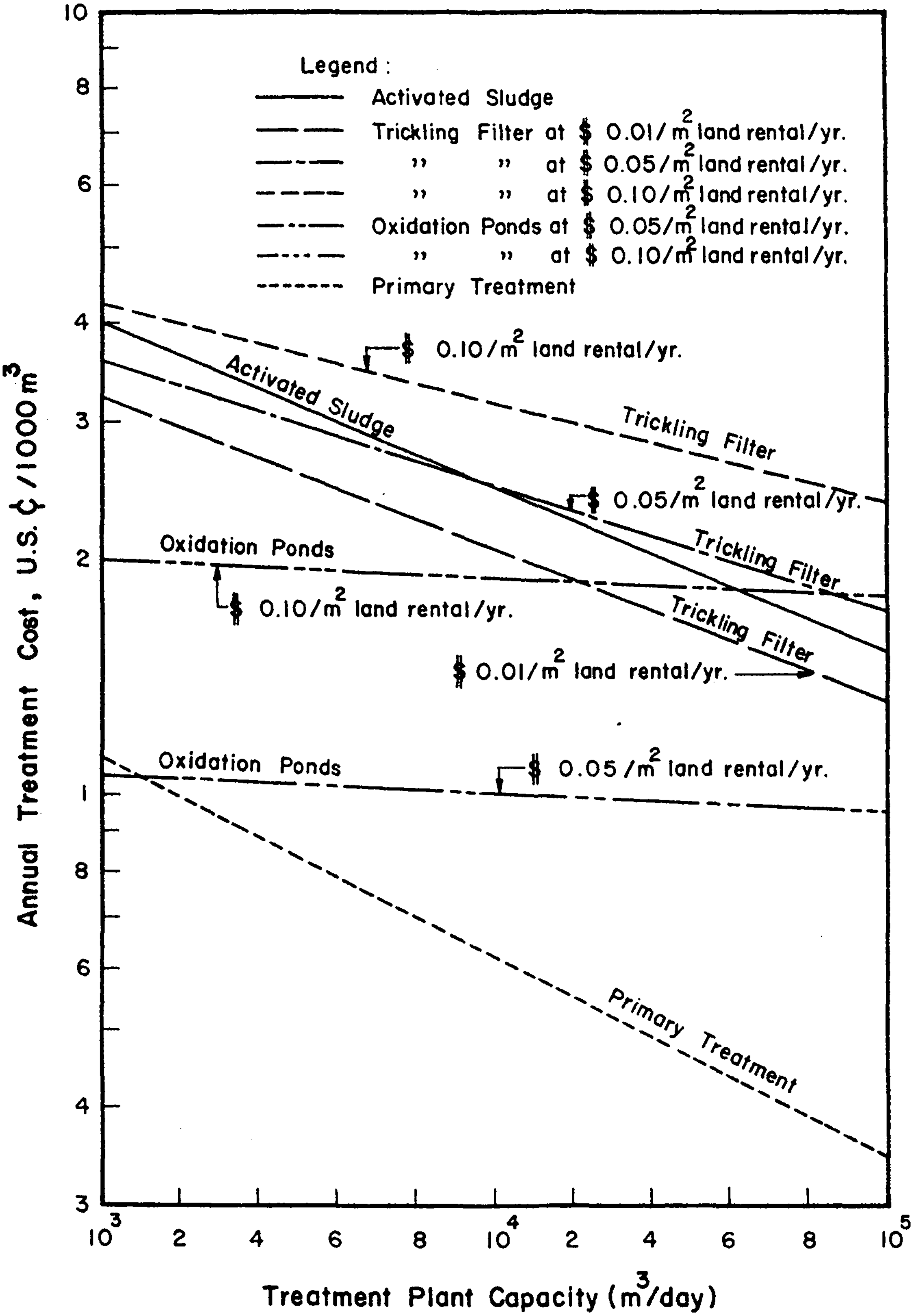

Fig. 6 Relationship between Treatment Plant Capacity and Cost

V CONCLUSIONS AND RECOMMENDATIONS

1. Stream standards in developing countries of Asia at the present time should be based on fishing, irrigation and potable water uses. Of these uses, the quality requirements for drinking water suggest that alternative sources of potable supply should be provided rather than attempt to maintain such a high quality for direct use of a surface stream.

2. It is now only possible to suggest tentative stream standards for tropical countries because of the lack of data appropriate to the environmental conditions prevailing. More research is required to adjust these tentative standards to the least stringent levels possible so that maximum use can be made of the assimilative capacity of surface waters, and thereby minimize investment in wastewater treatment.

3. Few countries in Southeast Asia have adopted stream or effluent standards. Those that delineate standards have generally adopted those developed in western temperate countries without attempting to adapt them to local conditions. Where effluent standards have been established, no consideration has been given to their relationship with stream standards and stream assimilation capacity has not been used advantageously.

4. Experimental studies have shown that a satisfactory effluent standard for oxidation ponds in tropical countries could be established on the basis of a stream standard for algal cell concentration, assuming that other characteristics of the effluent (for example, filtered BOD_5) are at acceptable levels. An oxidation pond effluent can be expected to have a beneficial effect on a stream's oxygen balance provided that after dilution the algal concentration in the stream is not more than 1×10^5 cells per ml. This will be the case even with deep streams, although photosynthetic oxygen production in turbid tropical streams is limited to a depth of approximately 0.5 m from the surface.

5. The stream standard for dissolved oxygen adopted will determine the efficiency of waste treatment necessary. If this required efficiency of treatment is less than 80%, a split-flow system incorporating only primary treatment for part of the flow and secondary treatment for the remainder will meet the stream standard at minimum investment.

6. A study of comparative costs of secondary treatment processes suggests that for a population of less than 175,000 and land rental costs of U.S.$0.10/m^2 per year or less, oxidation ponds would provide the most economical treatment for organic wastewaters.

7. It is recommended that each country in Southeast Asia should develop more rational stream standards for important surface water resources based on justifiable water uses and their particular quality requirements. Further research and data collection in the region is necessary to achieve this objective.

8. Where effluent standards are adopted for pollution control, it is suggested that maximum use be made of a stream's assimilative capacity so that the allocation of social benefits may be optimized.

9. On the basis of the present study, it is recommended that military installations in Southeast Asia and other tropical developing regions of the world should adopt oxidation pond treatment for wastewaters so long as land is available at a rental cost (or equivalent) of less than U.S.$ 0.10/m^2 per year.

10. It is recommended that multi-stage design of oxidation ponds should be adopted in tropical regions to minimize the algal concentration in the final effluent, to ensure no adverse effects on a receiving stream under normal operating conditions and with a reasonable level of dilution.

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VII APPENDIX I

QUESTIONNAIRE

ON

WATER QUALITY

FROM

ENVIRONMENTAL ENGINEERING DIVISION

ASIAN INSTITUTE OF TECHNOLOGY

P.O. Box 2754, BANGKOK, THAILAND

NAME OF ORGANIZATION: ______________________________

MAILING ADDRESS: ______________________________

____

____

____

NAME OF RESPONDENT: ______________________________

TITLE AND POSITION OF RESPONDENT: ______________________________

____

____

PLEASE CHECK THE APPROPRIATE BOXES AND FILL IN AS NECESSARY.

A. Your Organization is concerned with:

- /__/ Potable Water Supply
- /__/ Public Health
- /__/ Wastes Disposal
- /__/ Irrigation
- /__/ Agriculture
- /__/ Fishing

B. Your Organization is engaged in:

- /__/ Research
- /__/ Development and Design
- /__/ Management

/__/ Education

/__/ Construction

/__/ Other ______________

I. FOR ORGANIZATION CONCERNED WITH WATER SUPPLY AND PUBLIC HEALTH

1. What standards are used in your country for raw water sources?

/__/ WHO International drinking water standards

/__/ USPHS drinking water standards

/__/ Other(specify please) ______________

2. a) If you are using the WHO or USPHS drinking water standards has there been any research to modify the standards according to existing local conditions?

/__/ Yes /__/ No /__/ In progress

b) If there has been research conducted, is it possible for you to furnish us with a copy of the modified standards?

/__/ Yes /__/ No /__/ Write to: ______________

____

____

c) If you cannot furnish us with a copy of the modified standards will you please fill in the blanks below as applicable:

Parameters	Suggested Range
A. Coliform (MPN)	______________
B. pH	______________
C. Dissolved Oxygen	______________
D. Arsenic	______________
E. Lead	______________

F. Chromium(hexavalent) ____________________

G. Cyanide ____________________

H. Phenolic Substances ____________________

I. Chlorides ____________________

J. Dissolved Solids ____________________

K. Others ____________________

3. How often does raw surface water quality normally fail to meet the standards adopted?

	Less Than 10%	20%	40%	60%	80%	100%
A. Coliform	____	____	____	____	____	____
B. pH	____	____	____	____	____	____
C. Dissolved Oxygen	____	____	____	____	____	____
D. Arsenic	____	____	____	____	____	____
E. Lead	____	____	____	____	____	____
F. Chromium	____	____	____	____	____	____
G. Cyanide	____	____	____	____	____	____
H. Phenolic Subs.	____	____	____	____	____	____
I. Chlorides	____	____	____	____	____	____
J. Total Dissolved Solids	____	____	____	____	____	____
K. Others	____	____	____	____	____	____

4. When raw water quality falls below the standard what is usually recommended? (please check)

	relax standard	stop using	improve treatment
A. Coliform	____	____	____

B. pH	________	________	________
C. Dissolved Oxygen	________	________	________
D. Arsenic	________	________	________
E. Lead	________	________	________
F. Chromium	________	________	________
G. Cyanide	________	________	________
H. Phenolic Subs.	________	________	________
I. Total Dissolved Solids	________	________	________
K. Chlorides	________	________	________

II. FOR ORGANIZATION CONCERNED WITH WASTES DISPOSAL:

1. Does your organization enforce effluent standards for wastewaters?

/__/ YES /__/ NO /__/ The appropriate authority is:__________

____

Address:______________________________

____

2. a) If Yes, can you please send us a copy of the regulations?

/__/ YES /__/ NO /__/ Order from______________________________

____

b) If you cannot send us a copy, will you please fill up the form below, when applicable.

Parameters	Standard	Unit.
Biochemical Oxygen Demand(BOD_5)	________	________
Chemical Oxygen Demand (COD)	________	________
Suspended solids	________	________
Cyanides	________	________
Pesticides:		
DDT	________	________

BHC ______ ______

Endrin ______ ______

Methyl Parathion ______ ______

Parathion ______ ______

<u>Heavy Metals</u>:

Lead ______ ______

Chromium (hexavalent) ______ ______

Cadmium ______ ______

Mercury ______ ______

Phenolic Substances ______ ______

Chlorides ______ ______

pH ______ ______

Coliform ______ ______

Others ______ ______

3. Are standards relaxed during the wet season in your country?

/__/ YES /__/ NO

4. Is your organization authorized by law to penalize offenders in any of the following ways?

/__/ impose fines

/__/ set and change standards

/__/ stop and close plant operations

/__/ collect effluent samples.

/__/ license new companies

/__/ inspect wastewater treatment facilities

III. <u>FOR ORGANIZATION CONCERNED WITH IRRIGATION AND AGRICULTURE</u>:

1. a) Do you have any standards for irrigation water?

/__/ YES /__/ NO

b) If YES, is it possible for you to furnish us a copy of the standards?

/__/ YES /__/ NO /__/ Order from: ____________________

____

____

c) If it is not possible, please fill up the blanks below:

	Unit	Plant Tolerance		
		Sensitive	Average	Tolerant
Total Dissolved Solids	____	____	____	____
Sodium Adsorption Ration	____	____	____	____
Boron	____	____	____	____
Dissolved Oxygen	____	____	____	____
Pesticides:				
DDT	____	____	____	____
Endrin	____	____	____	____
B.H.C.	____	____	____	____
Methyl Parathion	____	____	____	____
Malathion	____	____	____	____

2. How often does irrigation water quality in your country fall below the above standard? (please check)

	Percentage Less than				
	20	40	60	80	100
Total Dissolved Solids	____	____	____	____	____
Conductivity	____	____	____	____	____
Boron	____	____	____	____	____
Sodium Adsorption Ratio	____	____	____	____	____

	20	40	60	80	100
Dissolved Oxygen	___	___	___	___	___
Pesticides:					
DDT	___	___	___	___	___
B.H.C.	___	___	___	___	___
Methyl Paration	___	___	___	___	___
Malathion	___	___	___	___	___

3. When water quality falls below the standard what action do you take?

	Augment Flow	Shift Crop	Non-Critical Parameter	Stop Using
Total Dissolved Solids	___	___	___	___
Sodium Adsorption Ratio	___	___	___	___
Boron	___	___	___	___
Dissolved Solids	___	___	___	___
Pesticides:				
DDT	___	___	___	___
Endrin	___	___	___	___
B.H.C.	___	___	___	___
Methyl Parathion	___	___	___	___
Parathion	___	___	___	___

4. What are the five major crops in your country? (Please fill in blanks below in order of importance)

A. ______________________

B. ______________________

C. ______________________

D. ______________________

E. ______________________

5. a) Has there been any research conducted on the tolerance of these crops to water impurities?

/__/ YES /__/ NO

b) If YES, is it possible for you to send us a copy of any reports?

/__/ YES /__/ NO /__/ Order from: ____________________

____

____

c) If not will you please fill up the form below:

Expected or Assumed Tolerance of:

	Crop A.	Crop B.	Crop C.	Crop D.	Crop E.
Total dissolved Solids	____	____	____	____	____
Sodium Adsorption Ratio	____	____	____	____	____
Boron	____	____	____	____	____
Dissolved Oxygen	____	____	____	____	____
Pesticides:					
DDT	____	____	____	____	____
Endrin	____	____	____	____	____
B.H.C.	____	____	____	____	____
Methyl Parathion	____	____	____	____	____
Parathion	____	____	____	____	____

IV. FOR ORGANIZATION CONCERNED WITH FISHERIES:

1. Please state the five major freshwater fish important in your country?

Commercially important	Important in rural areas (Subsistence)
A. ____________________	A. ____________________
B. ____________________	B. ____________________
C. ____________________	C. ____________________
D. ____________________	D. ____________________
E. ____________________	E. ____________________

2. a) Has there been any research on the tolerance of these fish to water impurities?

/__/ YES /__/ NO

b) If YES, is it possible for you to send us a copy of any reports?

/__/ YES /__/ NO /__/ Order from: ______________________

____

____

c) If it is not possible, please fill up the blanks below:

Commercial Fish variety

	A	B	C	D	E
Carbon dioxide					
Dissolved Oxygen					
pH					
Ammonia					
Cyanides					
Heavy Metals:					
Copper					
Arsenic					
Chromium					
Cadmium					

Subsistence Fish Variety

	A	B	C	D	E
Carbon dioxide					
Dissolved Oxygen					
pH					
Ammonia					

Cyanides ______ ______ ______ ______ ______

<u>Heavy Metals</u>:

Copper ______ ______ ______ ______ ______

Arsenic ______ ______ ______ ______ ______

Chromium ______ ______ ______ ______ ______

Cadmium ______ ______ ______ ______ ______

Selenium ______ ______ ______ ______ ______

Dissolved Solids ______ ______ ______ ______ ______

Detergents ______ ______ ______ ______ ______

3. a) Are there any water quality standards for fish protection in your country?

/__/ YES /__/ NO

b) If YES, is it possible for you to send us a copy of these standards?

/__/ YES /__/ NO /__/ Order from: ______________________

____

____

c) If it is not possible will you please fill up the blanks below:

<u>Acceptable Range</u>

Dissolved Oxygen ______________________________

Carbon Dioxide ______________________________

pH ______________________________

Ammonia ______________________________

Cyanides ______________________________

<u>Heavy Metals</u>:

Copper ______________________________

Arsenic ______________________________

Chromium ______________________________

Cadmium ______________________________

Lead ______________________________

Dissolved Solids ______________________________

Detergents ______________________________

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