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POLLUTION CONTROL IN SUGAR INDUSTRY 1/

Pakit Kiravanich*
Yothin Unkulvasapaul **

* Head of Environmental Standard Division, National Environment Board, Bangkok, Thailand

** National Environment Board, Bangkok, Thailand

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CONTENTS

INTRODUCTION

The purpose of this paper is to describe briefly the pollution problem in the Mae Klong River which was caused by the wastewater discharges from sugar mills, the method and approach used in the abatement of pollution. This will consist of a brief description of the sugar industry in Thailand, the efficiencies of sugar production, the damages caused by the pollution, the action by Ministry of Industry, and finally the study being made by the National Environment Board and a few prospects of future policies.

I BACKGROUND INFORMATION

A. The Sugar Industry in Thailand.

Thailand is now the world's fifth largest sugar exporting country or the second largest in Asia after the Phillipines. Last year (1976) Thailand exported more than one million tons of sugar, a record in domestic sugar history, bringing in more than 300 million dollars in foreign exchange, Sugar is now the second largest foreign exchange earner of Thailand after rice.

Sugar in Thailand is solely produced from sugar cane. Records show that as far back as the 15th century sugar cane was grown here and by the early 19th century Chinese merchants had established themselves in the industry and were producing sugar on a commercial basis. However develoment of this industry into exporting status is a relatively new phenomenon. In the beginning of the 1960s Sugar was still imported to meet domestic requirements, at that time there were 40 sugar mills operating. During 1970 - 71 sugar fortanes declined and only 27 mill were working. There after, the industry staged a recovery and at present there are 42 modern mills with a total capacity for crushing up to 32 million tons of cane per season.

Table I gives the sugar production and export value of sugar from 1961 to 1976.

Sugar cane is cultivated mainly in the provinces of Karnchanaburi, Ratchburi, Petchburi and Prachubkirikhan. At present a great variety of cane types are being planted. The life of a sugar cane plant is three years. The cane is planted on the prepared seed bed, and 8 to 12 months later it can be harvested. After the first crop is harvested, the cane is cut close to the ground, Then the stump starts sprouting again to produce the second crop, which is called the first ratoon crop. A similar process of harvesting and cutting follows to produce the second ratoon crop. The sugar content of the cane falls with each succeeding crop. After the second ratoon crop the whole crop is dug up and the three year cycle starts again.

The cane matures once a year with harvesting and processing taking place from December to May, which unfortunately coincides with the dry season in Thailand. This has resulted in water pollution crisis during the milling season in certain localities.

B. Production Efficiency.

Thailand's sugar industry has achieved its expansion over the past few years not by developing more efficient methods of production, but merely by becoming physically bigger and spreading itself over a wider geographical area. Table II shows that the total tonnage of sugar cane grown is steadily rising. In the 1972/73 season, 9.5 million tons of sugar cane were harvested, the yield of sugar cane per hectare was 52.44 tons. But in the subsequent seasons the yield decreased. There is a marked lack of interest in scientific research to find the most appropriate strain to grow in Thailand.

Table I Sugar Production and Exports.

Year	Production (tons)	Export (tons)	Export Value (10^6 US $)
1961	150,000	1,537	0.15
1962	151,344	43,019	2.30
1963	125,031	52,823	6.10
1964	169,937	48,908	10.55
1965	319,967	83,834	5.00
1966	269,168	54,858	4.10
1967	232,412	15,013	1.85
1968	188,177	52	-
1969	318,120	16,102	2.35
1970	406,640	56,248	4.70
1971	580,000	174,571	19.10
1972	585,557	407,501	63.20
1973	725,000	275,409	58.05
1974	967,950	444,910	187.85
1975	1,060,320	595,431	284.75
1976	1,603,592		

Table II Plantation Area and Yield per Hectare

Growing Season	Plantation Area (ha)	Cane Harvested (ton)	Yield (ton/ha)
1961/62	70,400	2,200,000	31.25
1962/63	54,400		
1963/64	72,000	4,733,000	65.74
1964/65	84,800	5,074,200	59.83
1965/66	83,200	4,480,000	53.85
1966/67	57,600	3,827,000	66.44
1967/68		4,526,000	
1968/69	103,397	5,879,000	56.85
1969/70	118,173	5,102,300	43.18
1970/71	137,889	6,585,900	42.44
1971/72		5,925,600	
1972/73	181,350	9,512,794	52.44
1973/74	258,609	12.678,480	45.31
1974/75	309,640	14,592,300	49.25
1975/76		19,099,000	
1976/77 *	512,000	22,600,000	44.14

* Estimated

Poor yields from the plantations also have their parallels in the mills where productivity in terms of kilograms of sugar produced per ton of cane is well below world standards. Thai mills can only manage to produce an average of 83 kg/ton cane compared with 120 kpt in Taiwan and 145 kpt in Australia.

One reason for the low yield is the method of cutting, often too many leaves are left on the cane along with other undesirable portions, these can absorb some of the sugar from the cane during transportation.

Another reason is the time for transporting the cane to the mills takes from 10 to 36 hours. There are 10 to 36 hours of further delay at the mills before the cane is crushed. The total delay between cutting and crushing cane is between 30 to 70 hours.

Other reasons for low yield include the method of buying where most mills bay cane on the weight basis so the farmers do not have incentives to improve sugar content, and that most machinery are locally made which have a poorer performance than foreign products.

C. Cane Sugar Processing.

Fig 1. is a typical flow diagram of cane sugar processing. The cane is first crushed in a series of rollers, a spray of water or thin juice is directed on the cane to aid in extraction of the juice. The bagasse from the rollers contains 40 - 50 % water, it is used for fuel and raw material for paper pulp.

The extracted juice is acidic, turbid and dark green in colour. It is treated with lime, sulfur dioxide and heated. The heated juice is passed to a sedimentation unit in which clarification is achieved.

The sludge from sedimentation is sent to a vacuum filter, the filter cake is discarded or return to the field. The clear liquid from the sedimentation unit contains approximately 88 % water, and is sent to multiple effect evaporators and crystallized in a vacuum pan. The sugar crystals are separated by a centrifuge, and dried in a drier, this product is grade A sugar. Susequent two stages of evaporations produce grade B and grade C sugars respectively.

Wastewaters from cane sugar processing vary according to local conditions. Generally the wastewatere may be divided into :

(a) Condenser water,

(b) Process water, which include roller lubricant water, floor sweeping and boiler blowdown.

D. Effluent Standards.

Presently effluent quality of industrial discharges is regulated by the Ministry of Industry. In 1960 the MOI has issued a set of standards which all factories are required to comply in order to get a license to operate. The standards are shown in Table III

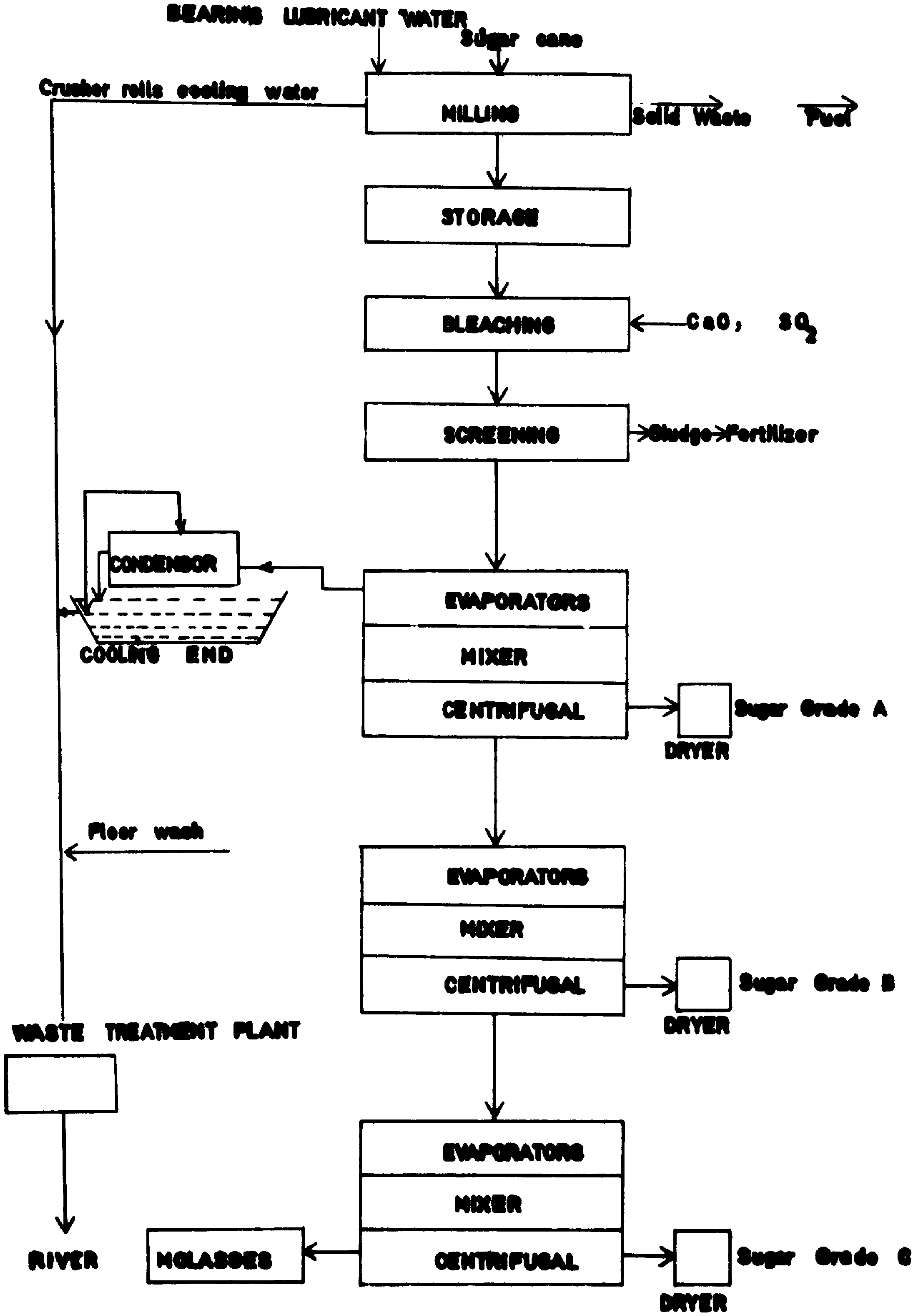


FIG. 1 SUGAR REFINERY PROCESS & WASTE WATER FLOW DIAGRAM

Table III Industrial Effluent Standards: Ministry of Industry.

Characteristic	Maximum Concentration Limit, mg/l
BOD (5 day, 20°C)	20 - 60
Suspended solids	30
Dissolved solids	2000
Permanganate value	60
Sulphide (as H_2S)	1
Cyanide (as HCN)	0.2
Oil and Grease	nil
Tar	nil
Formaldehyde	1
Phenol and Cresol	1
Free Chlorine	1
Heavy Metals	individual or total 1
- Zinc	"
- Chromium	"
- Arsenic	"
- Silver	"
- Selenium	"
- Lead	"
- Nickel	"
Insecticides	nil
Temperature	40°C

II POLLUTION IN THE MAE KLONG RIVER

A. The Mae Klong River

The Mae Klong River is located on the western region of Thailand, The river is formed from the confluence of two main tributaries, Kwae Yai and Kwae Noi, which meets at the Kanchanaburi province and flows southward past Ratchaburi province and finally discharges into the Gulf of Thailand at Samut Songkhram province. The total length of the Mae Klong River is about 140 kms, it passes through 10 districts. The total population along the river is about 200,000. Fig 2 shows the catchment area of the river.

The drainage area is the largest sugar cane plantation area in the country. At present there are 18 sugar mills in the basin which account for 55 % of the total processing capacity of all sugar mills in Thailand. Besides the agricultural and industrial activities, the estuarine reach of the basin is important for fishing and aquaculture, primarily shrimp and cockle farming.

Since 1969 water quality has rapidly deteriorated. The problem created public outcries and demands for corrective actions on the part of concerned authorities.

B. Pollution Crisis in the River.

Development of sugar plantation and sugar milling industry is very rapid along the river. Ever since 1969 the river experienced anaerobic conditions for short periods during the dry season. The pollution became more severe as the number of mills increased. In 1972 there were altogether 11 sugar mills with a total milling capacity of 47,000 tons per day. Pollution of the river became most severe during the dry seasons of 1971, 1972 and 1973 when the whole reach of the river went anaerobic.

Fig. 2 Catchment Area of the Mae Klong River Basin

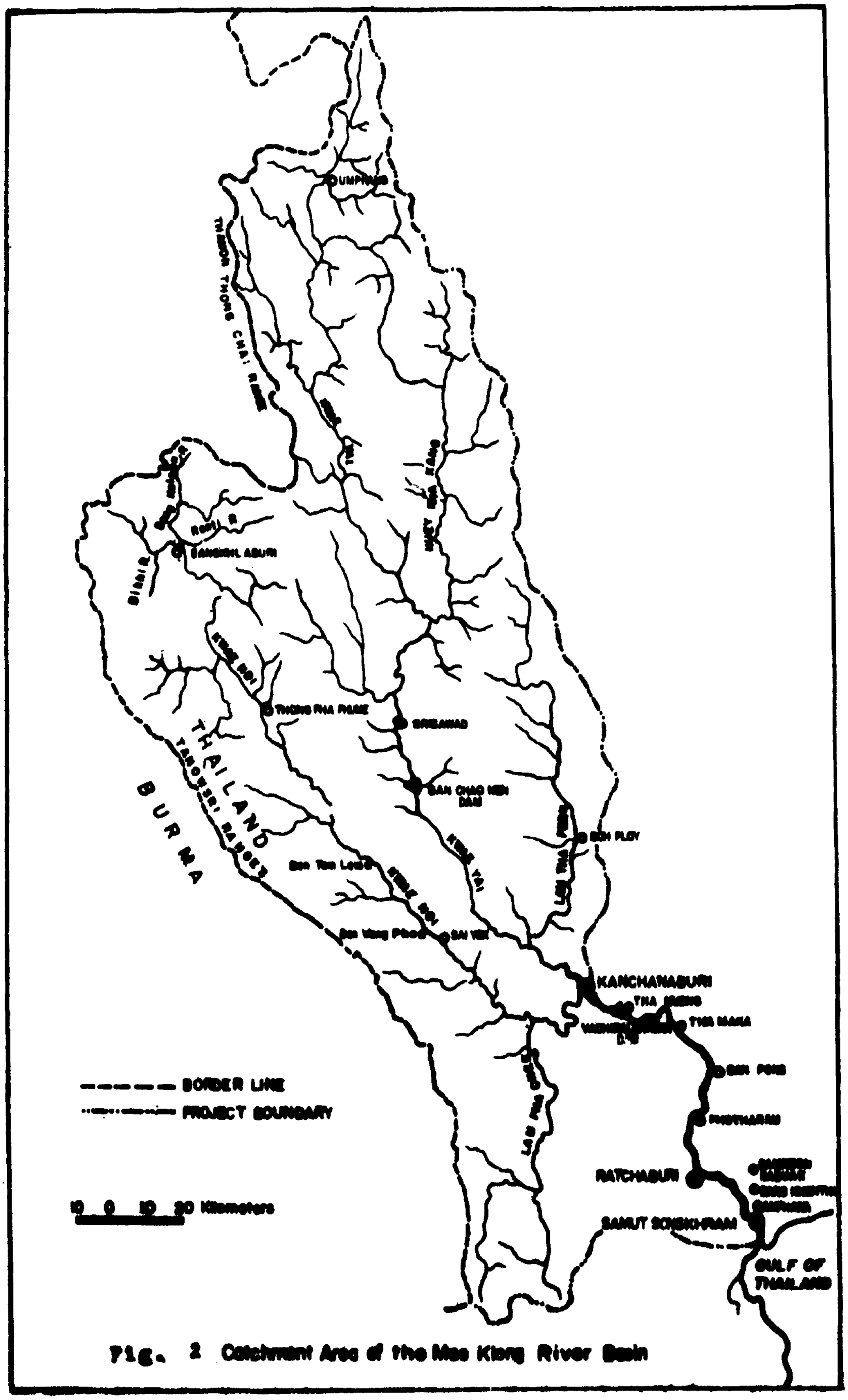


Fig. 2 Catchment Area of the Mae Klong River Basin

In may 1971, according to a report by a local police officer, the Mae Klong River that flowed through Ratchaburi had been polluted by sugar factories, people living on the river banks had complained that "black liquid" had contaminated the river, depriving many of them their only source of water. The foul smelling waste which floated along the river was carried into irrigation channels threatening village vegetable gardens. At that time many fish were killed and floated along the river. The pollution later spread to Samut Songkhram. Actual data on wastewater volume were not available, but it was estimated that there were 12 sugar mills operating,and the daily water use for the mills were 100,000 m^3/day. The diversion dam was releasing only 2,000 m^3/hour.

In June 1972, a similar situation occured.

May 1973 was probably the time of the worst pollution crisis. It was reported that Ratchburi, the town with 120,000 residents, had lived without clean tap water. The tap water was reported to be smelly, water plant operators tried heavy doses of chlorine solution. Attempts to close down the waterworks had been stalled by the absence of the provincial governer who was on an official trip to Japan. Local authorities used 17 water trucks distributing clean water to town residents around the clock. The provincial hospital reported 160 diarrhoea cases that had been associated with drinking tap water.

The polluted conditions spread down to Samut Songkhram province. Fish kills in the areas covering Amphawa and Bang Khonthi districts were reported. Local shrimp and cockle farming had been seriously affected. At the river mouth, there used to be 121 shrimp and cockle farms, the number had dwindled to about 30. The Governor of Samut Songkhram reported severe shortage of fresh water in many districts.

Hundreds of complaints from angry residents flooded into the provincial offices. One enraged resident said. "There is not a single factory in this province but the innocent residents here have to suffer for all the evils done by unscrupulous factories in another province." The Governor reported 10 tons of fish killed in that province.

C. Sugar Mill Wastes.

Wastewaters resulted from sugar cane processing can be separated into two groups. The first group is the process water, it includes the floor sweepings and roller lubricant water, the BOD of this wastewater is high. The second group is the condensor water, the temperature of this waste ranges from 42 to 48° C. The BOD of the condensor water is caused by sugar entrainment and the carry-over in the evaporators and vacuum pans. For each single pass the condensor water will pick up from 30 to 60 mg/l of BOD with an average of about 40 mg/l. The sugar mill waste characteristics are summarised in Table IV.

Table IV Typical Volume and Characteristics of Wastewaters.

Waste	Daily Volume m^3/ton cane	Daily BOD kg/ton cane
Process Water	0.1	0.20
Condensor Water	24	0.96

D. Sugar Mill **Waste Management.**

In order to solve The river pollution problem, the Ministry of Industry decided to build a central treatment plant. The plant was completed in July 1974. It consisted of a series of anaerobic lagoons followed by oxidation ponds. The plant was built on a 16 hectare plot of land provided by the Ministry of Industry at a cost of US. $ 140,000. The plant itself was estimated to cost US. $ 650,000. The money to finance the construction was advanced by the Government to be repaid by nine sugar factories **served by the system within three years at US. $ 0.05 for every ton of sugar cane processed.**

Due to inadequate design information, the central treatment plant could hardly handle the process water and the effluent quality was still unacceptable. The condensor water which contributed a greater BOD load was still discharged untreated into the river. Therefore the Ministry of Industry required all sugar mills to treat the condensor water to an effluent standard of 20 mg/l. By late 1975 all individual plants were operated.

Fig 3. shows the typical wastewater treatment scheme adopted by all sugar mills. The process water which contains high BOD are separated and either pumped to the central treatment plant or stored in holding ponds for the entire milling season. The condensor water is cooled in atmospheric cross flow cooling tower and recirculated, about 10 % of the condensor water is continuously replaced by clean water to prevent septicity. The condensor water bleed off contains about 600 mg/l of BOD, it is sent to a treatment plant for BOD reduction before being released into the river.

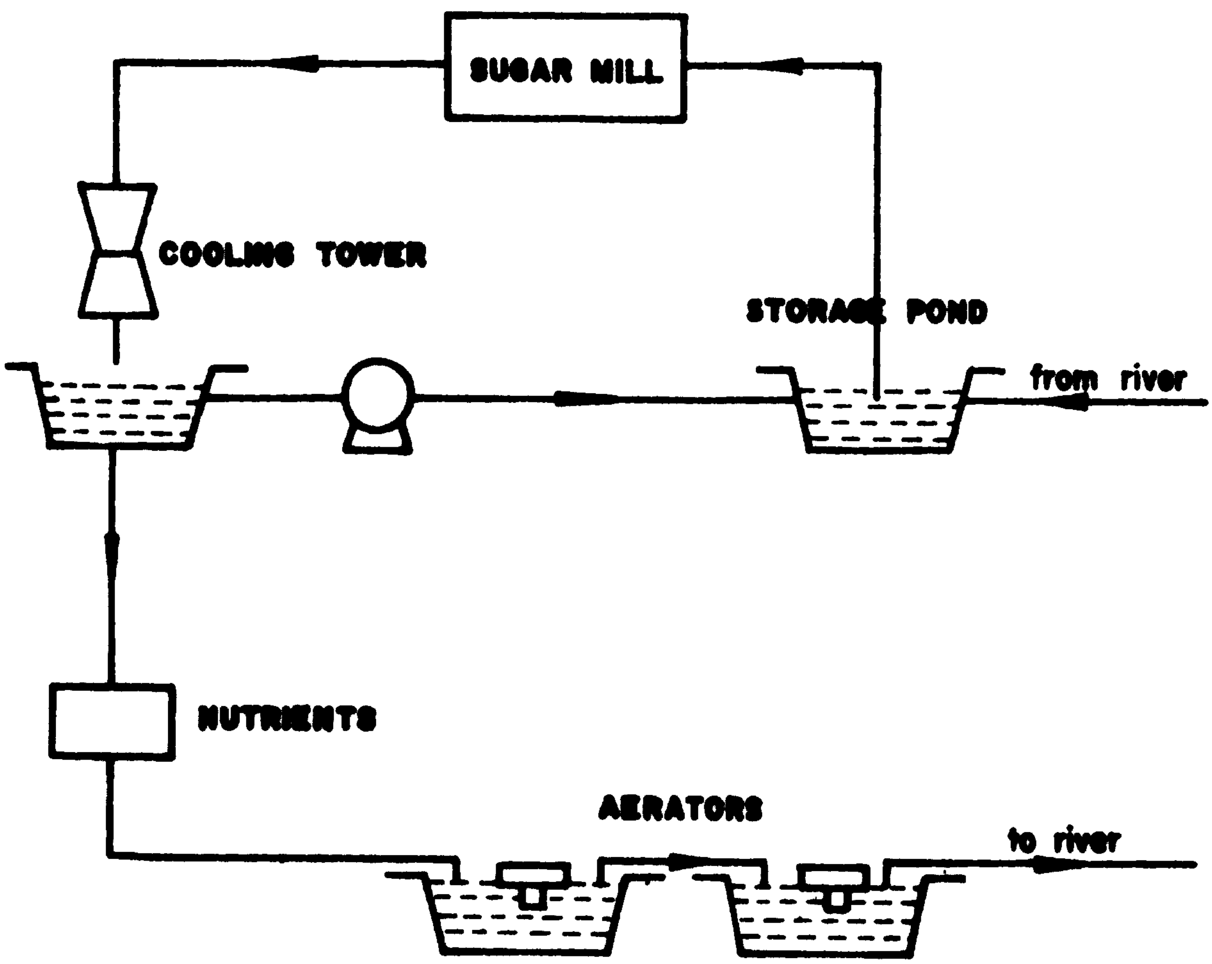


Fig. 3 The Typical Waste Management Scheme Adapted by All Sugar Mills.

For the new sugar mills, there is no condensor water bleed off. The condensor water after cooling is treated to an acceptable quality and reused in the process.

Originally the systems for treating condensor water bleedoff of some sugar mills were **designed as** anaerobic lagoons followed by extended aeration activated sludge process. Some systems were designed as aerated lagoons. However, in practice all treatment systems were operated as aerated lagoons. Aeration was accomplished by using floating mechanical surfade aerators. All lagoons functioned sucessfully except in two cases of overloading due to seepage of process water into the lagoons. The efficiency of the lagoons is about 70 %

Unfortunately in February 1975, a power breakdown at a sugar mill in Kancharaburi caused erosion in its main treatment plant and it fractured, spilling about 10,000 m^3 of polluted wastewater into **the Mae Klong River.** Fish kills were reported from Ban Pong and Ratchburi districts.

In the 1975/76 milling season, the Ministry of Industry upgraded central treatment plant by adding nine 40 HP surface aerators and constructed more ponds. The river quality during that season has improved to satifactory levels. Fig 4, F g 5, Fig 6, and Fig 7, show the DO and BOD profile of the river in January and March of 1976.

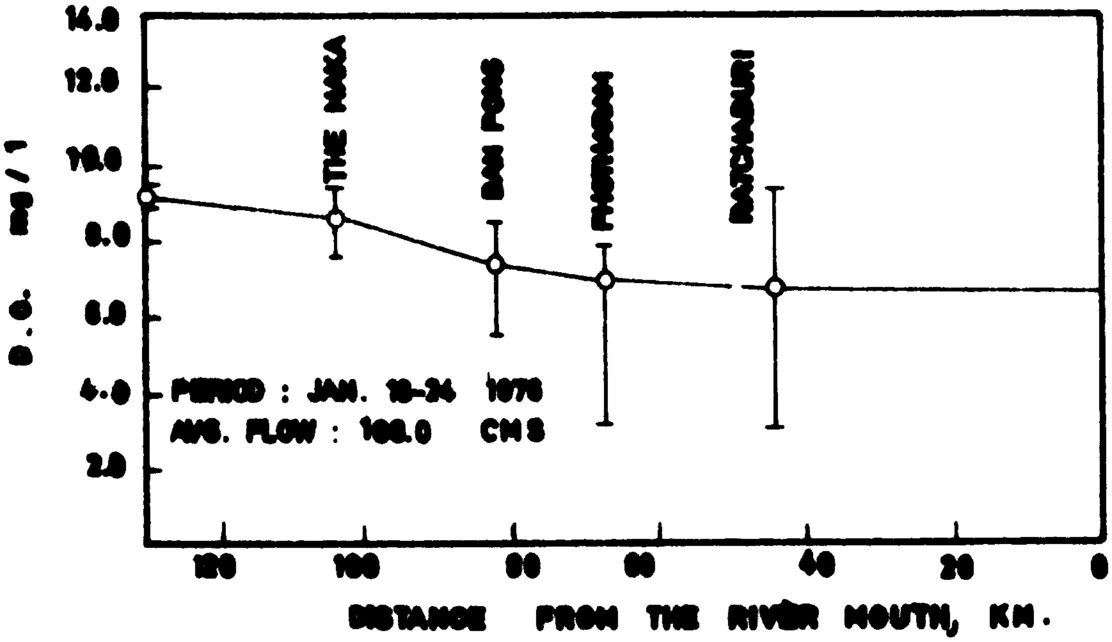
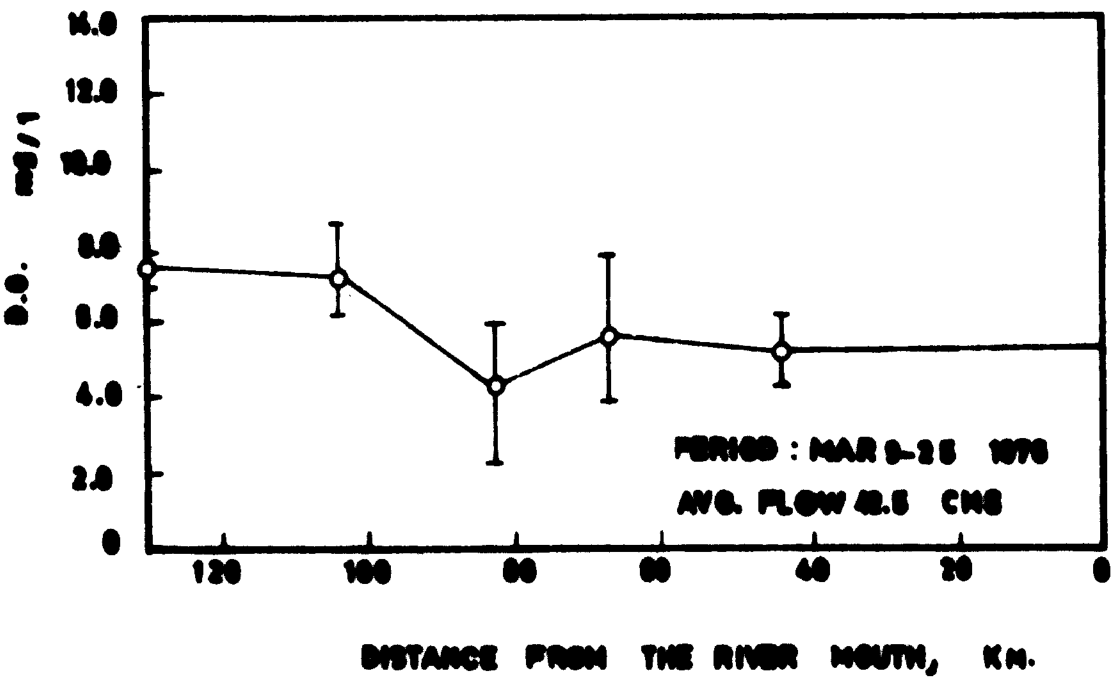


FIG. 4 D.O. PROFILE, JANUARY



D.O. PROFILE, MARCH 10-25, 1976

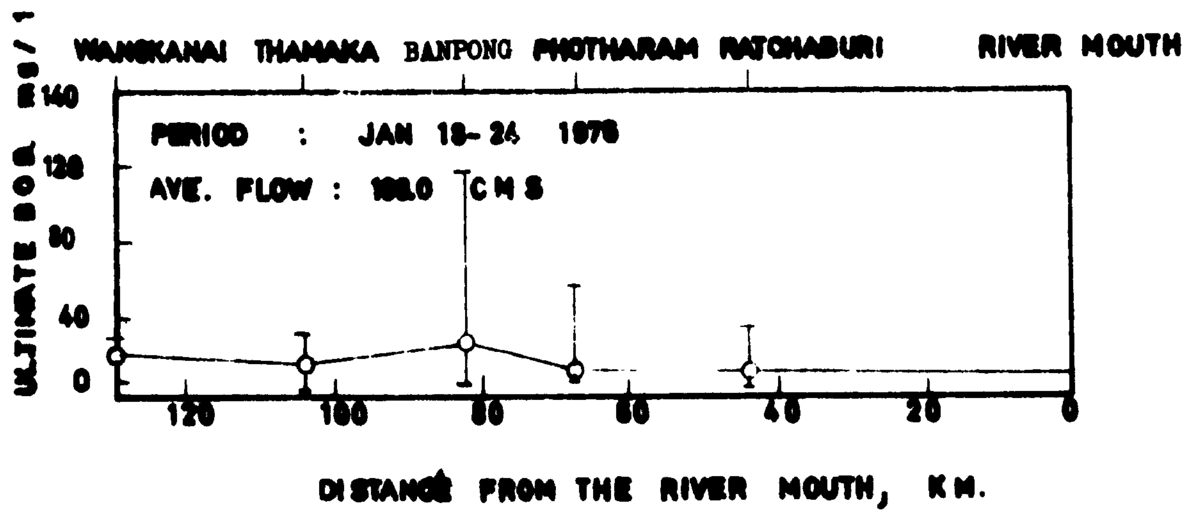


FIG. 6 BOD. PROFILE, JANUARY 18-24, 1976

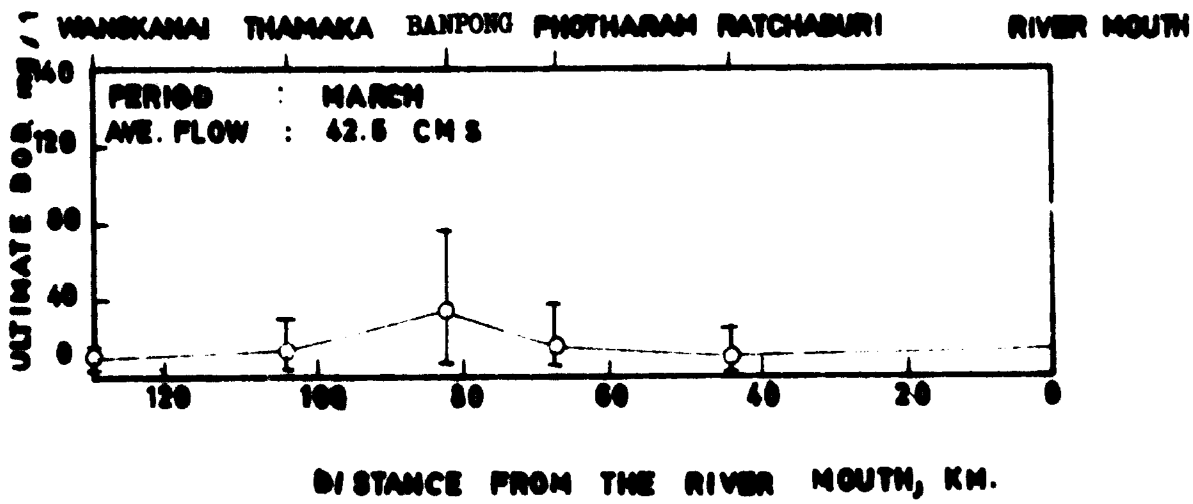


FIG. 7 BOD. PROFILE, MARCH 18-25, 1976

III MAE KLONG RIVER QUALITY MODELLING

The Mae Klong pollution problem was approached on a piecemeal and adhoc basis, although the pollution in the river is now under control, the problem is not yet finished. There still remains a few unanswered questions as to how the river is to be managed in the future, what is the optimal level of discharge, what level of the river quality is to be maintained and so forth. In order to arrive at a long term environmental plan, the National Environment Board is currently studying various aspects of this river basin. This chapter will describe the water quality model of thė Mae Klong River.

A. River Quality Model

A computer program was developed to model the river from Vachiralongkorn diversion dam down to the estuarine boundary. The schematic diagram of the river system is shown in Fig 8.

The model used was the classical Streeter and Phelp's equation, the quality parameter selected were DO and BOD. Two field sampling programs were conducted for model verification. When thus calibrated, the model is used for prediction of water qualities under various condition.

For example, Fig 9 is the result of DO prediction, using the once in ten year low flow volume of 30 CMS, and assuming that there is 10 % condenser water bleedoff from all sugar mills, and that all industries treat their wastewaters on a uniform percentage reduction basis.

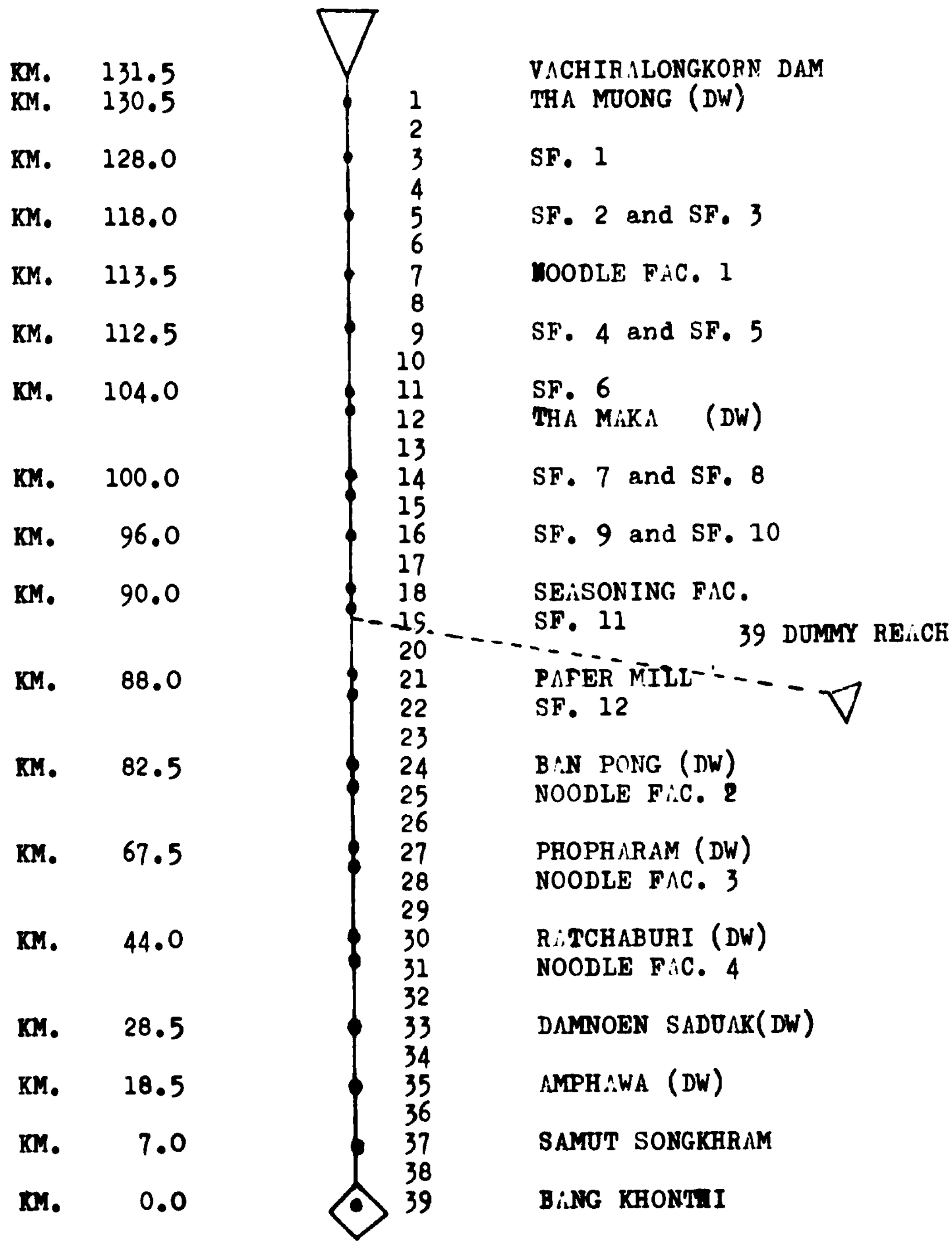


Fig. 8 Schematic Diagram for the Mae Klong River System

B. Waste Loads Used in the Model.

At present There are 6 Types of industries along the river, the number of factories for each type is shown in Table V

Table V. Industries Along The River

Type of Industry	Number
Sugar Mill	18
Pulp and Paper Mill	1
Seasoning Mill	1
Noodle Factory	7
Slaughter House	1
Distillery	2

Almost all industries along the Mae Klong River are situated on the thirty kilometer reach from Amphoe Tha Maka to Amphoe Ban Pong. By far the majority are the 18 sugar mills.

The total BOD load which would have been discharged into the river is estimated. Table VI gives the estimated domestic BOD load, assuming the per capita BOD is 45 mg/day. Table VII gives the BOD loads of other industries along the river, using data from ministry of Industry. Table VII gives the BOD loads of all the sugar mills, assuming the BOD concentration of bleed off condensor water is 600 mg/l. These data were used in the river model calculations.

Table VI Estimated Domestic BOD Load

Province	District	Population	BOD Load kg/d.
Kanchanaburi	Thamuang	12,398	557
	Thamaka	13,184	593
Rajchaburi	Banpong	17,905	805
	Photaram	16,036	721
	Muang	32,501	1,462
	Damnoeon-saduak	16,651	749
Samut Songkram	Bang Khonti	7,168	322
	Ampawa	10,508	459
	Muang	60,160	2,707
	Total	186,475	8,375

Table VII Estimated BOD Load From other Industries

Number	Industries	Waste-water cmd	BOD of Effluent mg/l	Total BOD Load kg/d	Note
1	Paper mill	20,000	60	1,200	treated eff.
1.	Seasoning factory	500	2,850	1,425	Untreated
1	Distillery	200	1,500	300	"
7	Noodle factories	2,800	1,100	3,080	"
10	Slaughter House	2,000	1,500	3,000	"
20	Total	25,500		9,005	

Table VIII Estimated BOD Loads from Sugar Mills

No.	Factory	Production ton/d	Flow Rate of Condensor Water, cmd	Bleed-off cmd	BOD Load kg/d
1.	Th[illegible]buri	4,200	100,800	16,800	10,080
2.	Mitpol	8,000	192,000	20,000	12,000
3.	Mitkaset	7,500	180,000	20,000	12,000
4.	Thairung-roeng Group	16,200	388,800	16,800	10,080
5.	Krungthai Roumkamlab	5,800	139,200	6,200	3,720
6.	Newkrongthai	8,400	210,600	3,800	2,280
7.	Thai sugar	6,500	156,000	20,000	12,000
8.	Kanchanaburi	6,700	160,800	7,500	4,500
9.	Thamaka	7,000	168,000	3,800	2,280
10.	Prajuab	8,000	192,000	20,000	12,000
11.	Thaipermpol	7,500	180,000	20,000	12,000
	Total	85,800	2,059,200	154,900	92,940

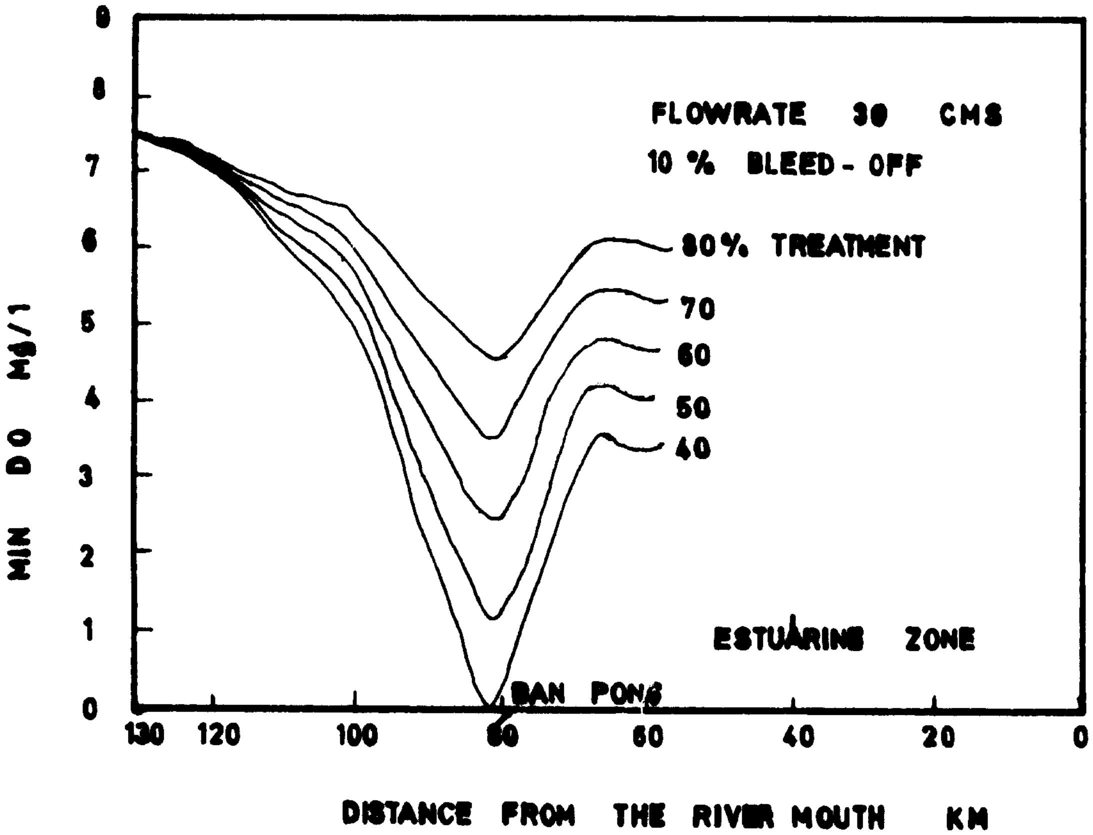


FIG. 9 PREDICTED DO PROFILE

IV ECONOMICS OF POLLUTION CONTROL

A. Damage Cost of Water Pollution

The damage cost to the Mae Klong River has been estimated at about 6.8 million US. dollars (Ref.2). The estimation is based on the results of surveys of damages done to :

(a) Cockle and shrimp farming. In 1970 grossly polluted freshwater from the upper reach of the Mae Klong River reportedly reduced 80% of the cockle productivity. The total damage cost, assuming the farmers had no other opportunities for employment, was estimated at 6 million US. dollars. Similarly, shrimp farmers suffer a lost of approximately 0.1 million US. dollars annually.

(b) Other beneficial water uses and related activities. A survey of 156 families concluded that the pollution caused damage to, in order of importance, rice farming, orchards, commercial and subsistance fishing, and public health. The total damage was estimated at about 0.5 million US. dollars per annum.

(c) Treatment Costs. The treatment costs for sugar mills are based on the annual cost of the central treatment plant and the individual system at each plant (Ref.1). Annual cost of the central treatment plant is estimated to be 153,000 US. dollars it is assumed that this cost will reduce the BOD of wastewater to 150 mg/l.

The individual treatment system costs were calculated with regard to primary treatment, secondary treatment by aerated lagoons. The change in treatment costs with changes in level of treatment is a straight forward engineering calculation.

However, the changes in damage costs with changes in levels of discharges require making the following assumptions :

(a) The total damage cost of 6.8 million US. dollars per year is related to zero dissolved oxygen concentration in the river.

(b) The total damage cost approaches zero when water quality is maintained at/or above 4 mg/l dissolved oxygen.

(c) The damagecost was assumed to vary linearly and in proportion with the dissolved oxygen concentration. This implies that the initial investment in the central treatment plant did not reduce damages because the minimum DO concentration was still zero. In reality, the production at the cockle farm did increase slightly and would have increased more if there had been a delay of the central treatment plant and the individual treatment plants.

Total cost to society was determined by summing damage and treatment costs. From Table IX it is seen that the minimum cost occurs at a treatment level between 75-80 %, which corresponds to effluent BOD of 140 mg/l .

SUMMARY

The results of economics study by NEB strongly support the decision of the Thai Goverment to assign priority to control residual discharges into the Mae Klong River. The investments to control residual was only about 10 % of the estimated damage. Even given the uncertainty about the damages magnitude of the damage estimate, the costs of control clearly are less than potential reduction in the damages.

With regard to the long term policy of pollution contrbl in the Maeo Klong River, the following tentative suggestions are deemed appropiate.

1. From the result of another study made by NEB, the minimum DO concentration in the river should be maintained at 4 mg/l .

2. To maintain this level of DO in the river, it must not receive more than 30,000 kg/day of ultimate BOD, when the flow in the river is at 30 CMS.

3. This assimilative capacity should be distributed to all industries along the river such that all industries are required to reduce their waste loads on a uniform percentage reduction basis.

4. Under the present conditions, the sugar mills should be allowed to discharge up to 0.232 kg BOD/ton oane capacity.

5. In the case that more sugar cane mills are constructed in the future, the assimilative capacity should be redistributed. The existing aerated lagoon systems can be easily upgraded to operate at higher efficiencies.

Table IX Composite Annual Cost of Pollution Control

Contral Treatment Plant Effluent BOD, mg/1	Individual Plant Effluent BOD, mg/1	% of Individual Treatment	Gentral Treatment Plant Annual Cost 10^6 US Dollars	Individual Treatment Plant Annual Cost 10^6 US Dollars	Total Treatmant Annual Cost 10^6 US Dollars	Damage Cost 10^6 US Dollars	Total Cost 10^6 US Dollars
			A	B	A + B	C	A + B + C
150	20	97	0.153	1.115	1.268	0	1.268
150	40	93	0.153	0.945	1.098	0	1.098
150	60	90	0.153	0.875	1.028	0	1.028
150	100	83	0.153	0.795	.945	0	.948
150	140	77	0.153	0.745	.898	0	.898
150	160	73	0.153	0.725	.878	0.33	1.208
150	200	67	0.153	0.650	.803	1.63	2.433
150	300	50	0.153	0.520	.673	4.86	5.533
150	600	0	0.153	0	.153	6.80	6.953
3,000	600	0	0	0	0	6.80	6.8

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