APPENDIX 3. SURVEY ON ENVIRONMENTAL ASPECTS

3.1 Survey of Water Quality (Land)

3.2 Survey of Water Quality (Sea)

3.3 Survey of Composition Analysis of Solid Waste

3.4 Nois Measurement in Pattaya

Appendix 3.1 Survey of Water Quality (Land)

REPORT

ON

SURVEY OF WATER AND WASTEWATER QUALITY IN PATTAYA

Submitted to

PACIFIC CONSULTANTS INTERNATIONAL, JAPAN

by

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Contents

List of Tables

List of Figures

CHAPTER I INTRODUCTION

Tourism development at Pattaya, Thailand which is one of the most popular beaches for the tourists, has been planned, and a detailed feasibility study is underway by Pacific Consultants International (Japan). This report is the result of the agreement between Pacific International Consultants and the consulting group for the survey of water and wastewater quality related to Pattaya Tourism Development Project, Thailand, within the terms and conditions laid-out and agreed at the time of execution of the work.

SCOPE OF THE WORK

1. Sampling Stations

The wastewater survey covered the leading hotels, tapioca starch factories and water quality in water supply wells, public water supply taps, stagnant bodies of water, rivers and sea. Twenty eight sampling stations shown in Fig. 1.1 were investigated in the study. The list of sampling locations and the number of samples collected at each location is given in Table 1.1. The sampling scheme and locations were fixed by the personnel of Pacific Consultants International (Japan).

Table 1.1 List of Sampling Stations

Sampling Station No.	Location	No. of Sampling	Sampling Station No.	Location	No. of sampling
1	Orchid Lodge	2	15	Water supply well	1
2	Weekender Hotel	1	16	Water supply well	1
3	Holiday Inn	2	17	Naklua River (Nearby Tapioca Industry)	1
4	Nang Nual Restaurant	1			
5	Siam Bayshore	1	18	2nd Grade Tapioca Factory	2
6	Pattaya Canal	1			
7	Royal Cliff	2	19	2nd Grade Tapioca Factory	3
8	Asia Pattaya	2			
9	Nachom Tiem River (underneath the bridge on Sukumvit Highway	1	20	NaKlua River (underneath the bridge on Sukumvit Highway)	1
10	Nachom Tiem River (River Mouth)	1	21	NaKlua River (River Mouth)	1
11	1st Grade Tapioca Factory (Cho Chaiwat)	5	22	Water supply well (Na Klua Residential Area)	1
12	Water supply well	1	23	Public Water supply Tap	1
13	Water supply well	1	24	Swamp	1
14	1st Grade Tapioca Factory (Koh Chang Eah)	8	25	Sea (Offshore of Na Klua)	1
			26	Sea (Offshore of Nang Nual Restaurant)	1
			27	Sea (Offshore of South Pattaya)	1

Cont'd.

Table 1.1 cont'd.

Sampling Station	Location	Nos. of Samples
R	Hotel Regent Pattaya	9 samples (24 hr sampling, once every 3 hr)

2. Water and Wastewater Sampling

Wastewater grab samples were collected every three hours interval over twenty four hours at Hotel Regent Pattaya for both the influent and the effluent from the waste treatment plant. One influent and one effluent wastewater grab samples were collected at each hotel where the treatment facility was located and working. Obviously only one wastewater grab sample could be taken at hotels which did not have treatment facilities. One grab sample for water quality analysis was collected at each well, river station, canal, swamp and sea, mentioned in Section 1. Adequate grab samples were collected at the tapioca starch factories to assess wastewater characteristics from various stream sources.

3. Water and Wastewater Parameters Analysed

The grab samples of water and wastewater were analysed, where appropriate, for:

(a) pH - Glass Electrode Method
(b) Air Temperature - Alcoholic Thermometer
(c) Water Temperature - Mercury Thermometer
(d) BOD_5 (at 20^oC) -
(e) Suspended Solids - Glass Fiber Filter Method
(f) COD - Dichromate Method
(g) Total Nitrogen - Kjehldahl Method
(h) Total Phosphorous - Ascorbic Acid Method after Wet Digestion
(i) Dissolved Oxygen - Winkler Method - Modified
(j) Chlorides - Silver Nitrate Method
(k) Coliform bacteria - MPN Count

Ambient temperature, water and wastewater temperatures and dissolved oxygen determinations were carried out at the site. Samples were fixed where appropriate, kept in ice box and then transported to Environmental Engineering Division Laboratory of the Asian Institute of Technology for other determinations.

All analyses were carried out according to Standard Methods[1/].

4. Water and Wastewater Quality Studies

After the analysis, the results were discussed and appropriate recommendations when applicable, were made.

1/ APHA, AWWA, and WPCF (1975), Standards Method for the Examination of Water and Wastewater, 14th Edition.

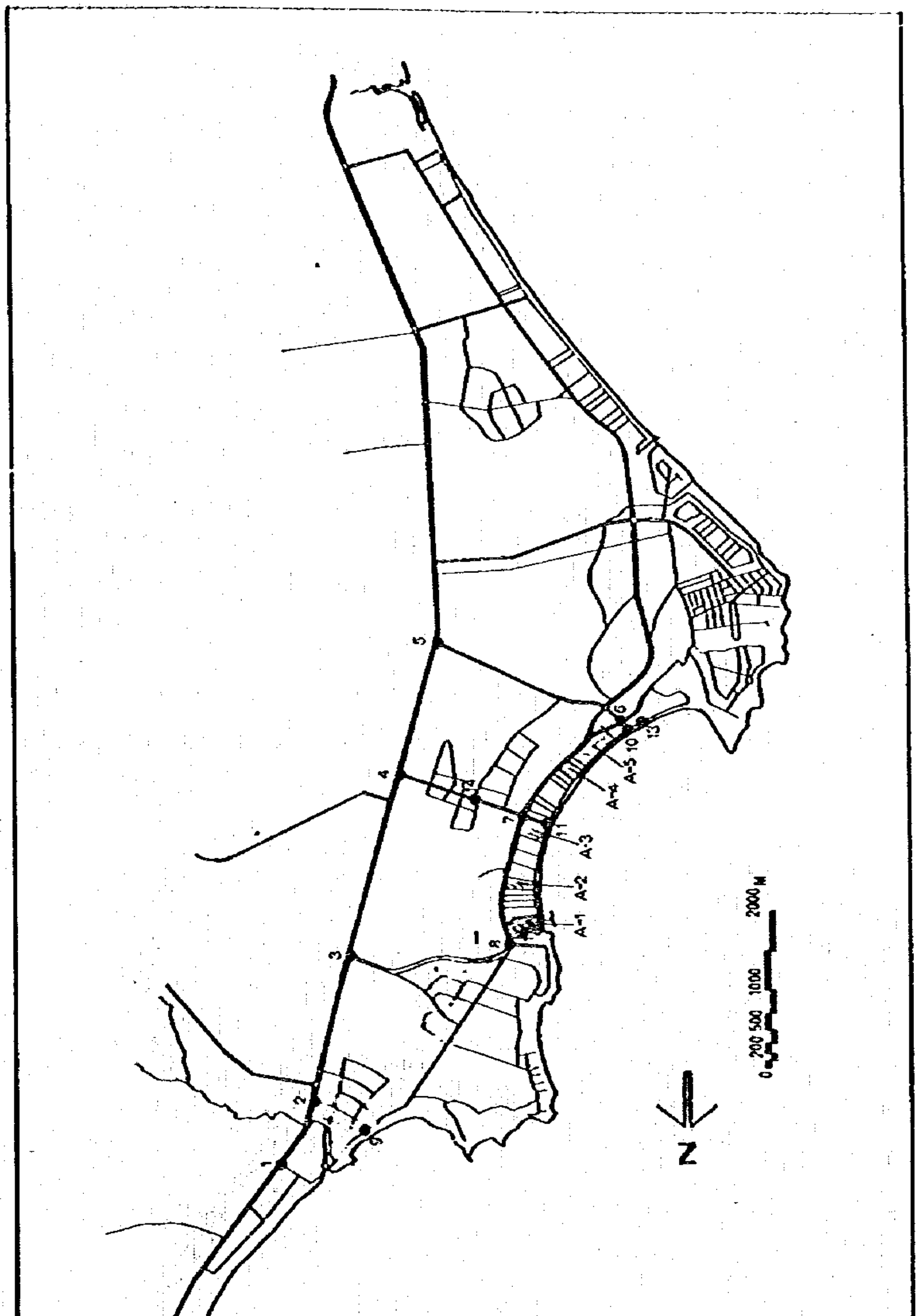

Fig.1.1 Location of Sampling Stations

CHAPTER II CHARACTERISTICS OF WASTEWATER DISCHARGES FROM HOTELS AND RESTAURANTS

Wastewater characteristics of the discharges from seven leading hotels and one restaurant were studied. Almost all the hotels under investigation have some sort of treatment facilities. Wherever treatment facilities were located, samples were collected at both influent and effluent from the treatment plant. However, if the hotel or restaurant had no treatment device, only one sample, that is the wastewater discharge, was collected and analysed. Influent and effluent of the treatment plant, at one of the hotels (i.e. Hotel Regent Pattaya) were collected every three hours for 24 hours to study the variation in the characteristics of the wastewater and the performance of the treatment plant. The study of the wastewater characteristics of the discharges from all the hotels is presented in the following sections:

1. Hotel Regent Pattaya

The hotel has an activated sludge system followed by an up-flow sand filter for effluent polishing. It is the best system observed among the hotels in Pattaya. The wastewater discharged from the hotel is received in a pond and then pumped to the activated sludge plant and settled in a clarifier and the effluent from the clarifier is further taken to the sand filter. Sludge dewatering is carried out by sand bed drying system.

Wastewater grab samples collected at three-hour intervals over twenty-four hours (January 8-9, 1978) were analysed for the important wastewater parameters. At each time, samples were taken at the influent and effluent of the treatment plant. A summary of the wastewater characteristics of the influent and effluent is given in Table 2.1. The activated sludge plant and the sampling locations are shown in Fig. 2.1. The variation of the wastewater characteristics of all the parameters over the twenty four hour-period is plotted in Fig. 2.2

Fig. 2.1(a) - Sewage Holding Pond

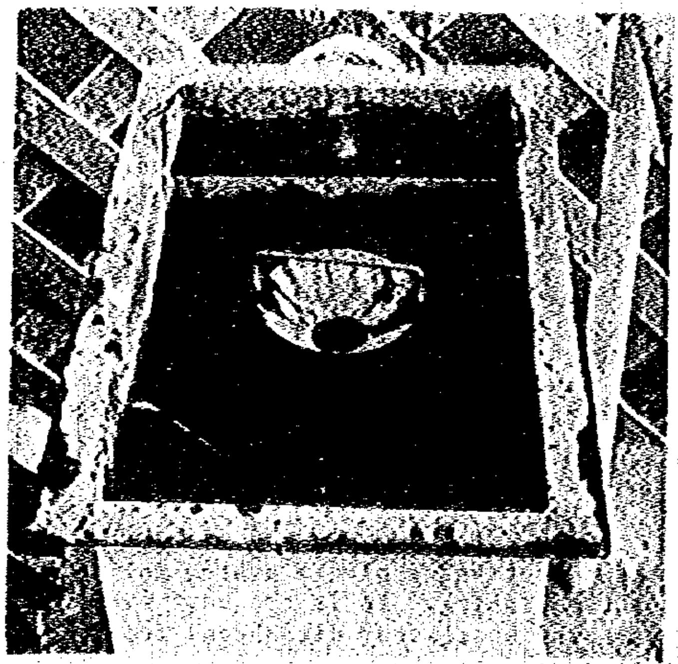

Fig. 2.1(b) - Flow Measurement (V-Notch Weir)

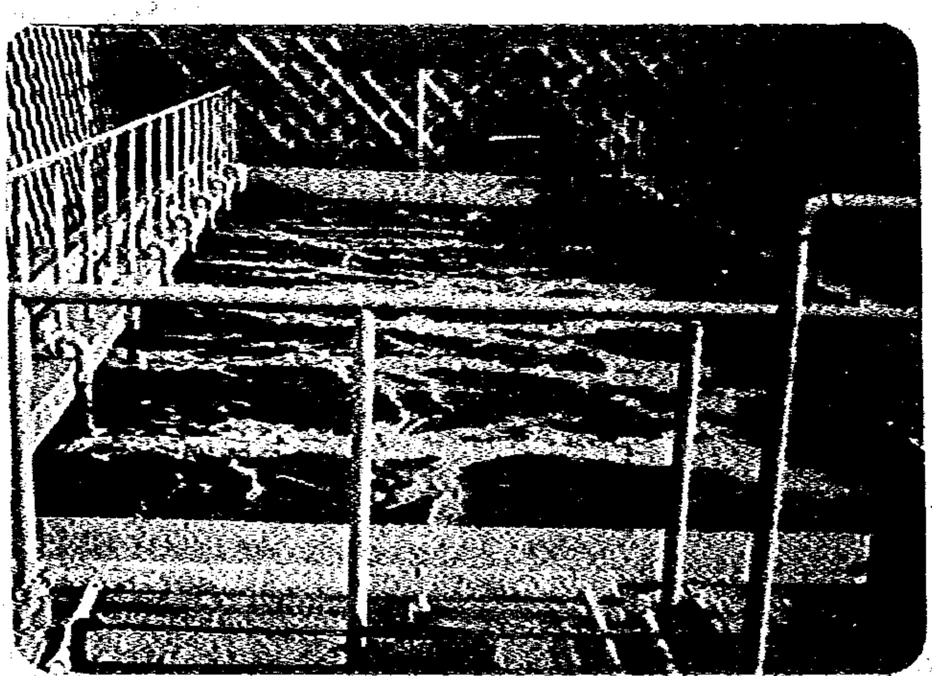

Fig. 2.1(c) - Activated Sludge System

Fig. 2.1 (Cont'd) - Sewage Activated Sludge Plant at Regent Pattaya Hotel

Fig. 2.1(d) - Effluent from Activated Sludge System

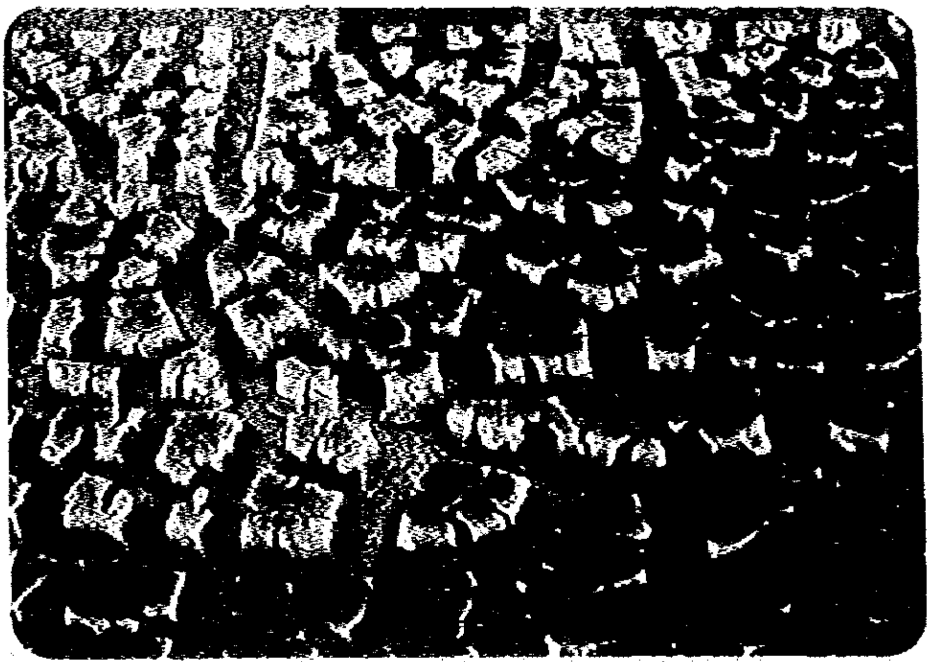

Fig. 2.1(e) - Sludge Sand Bed Drying

Fig. 2.1 (Cont'd) - Sewage Activated Sludge Plant at Regent Pattaya Hotel

Fig. 2.1(f) - Dissolved Oxygen Determination on the Site

Fig. 2.1 (Cont'd) - Sewage Activated Sludge Plant at Regent Pattaya Hotel

Table 2.1 - Variation of Influent and Effluent Wastewater Characteristics at Hotel Regent Pattaya (Sampling date - January 8-9, 1978).

No.	Location	Time	BOD_5	COD	DO	SS	Total N	Total P	pH	Air temp.	Water temp.	Remarks
R-1-1	Influent	1000	120	278	0	83	40.5	9.6	7.5	30	31	flow = 13.75 m^3/hr
R-1-2	Effluent		10	95	0.8	20	nil	4.7	7.4	30	31	
R-1-F	Effluent from Sand Filter		9	88	0.3		2.1	4.7	7.6	30	31	
R-2-1	Influent	1300	135	335	0	113	36.2	8.7	7.8	30	34	flow = 17.49 m^3/hr
R-2-2	Effluent		10	97	0.4	17	3.0	4.7	7.5	30	32	
R-3-1	Influent	1600	130	298	0	133	37.9	10.6	7.6	31	33	flow = 9.68 m^3/hr
R-3-2	Effluent		12	69	0.5	30	3.5	6	1.3	31	31	
R-4-1	Influent	1900	110	222	0	70	40.4	7.5	7.8	29	32	flow = 13.45 m^3/hr
R-4-2	Effluent		15	85	0.1	31	5.0	6.5	7.4	29	32	
R-5-1	Influent	2200	125	234	0	74	45.0	8.0	7.7	26	31	no influent
R-5-2	Effluent		30	113	0.4	50	6.9	7.7	7.4	24	31	
R-6-1	Influent	0100	120	230	0	77	43.6	8.0	7.7	24	31	no influent
R-6-2	Effluent		30	120	1.0	52	6.5	6.5	7.4	24	31	
R-7-1	Influent	0400	-	-	-	-	-	-	-	-	-	no influent and
R-7-2	Effluent		-	-	-	-	-	-	-	-	-	no effluent
R-8-1	Influent	0700	155	268	0	94	27.6	8.7	7.2	23	29	flow = 16.98 m^3/hr influent pump worked for 2 min. and then stopped
R-8-2	Effluent		30	116	1.0	33	15.7	5.2	7.4	23	31	
R-9-1	Influent	1000	171	272	0	91	22.6	8.5	7.6	30	32	flow = 13.75 m^3/hr
R-9-2	Effluent		20	96	0.6	22	3.7	4.7	7.4	31	32	

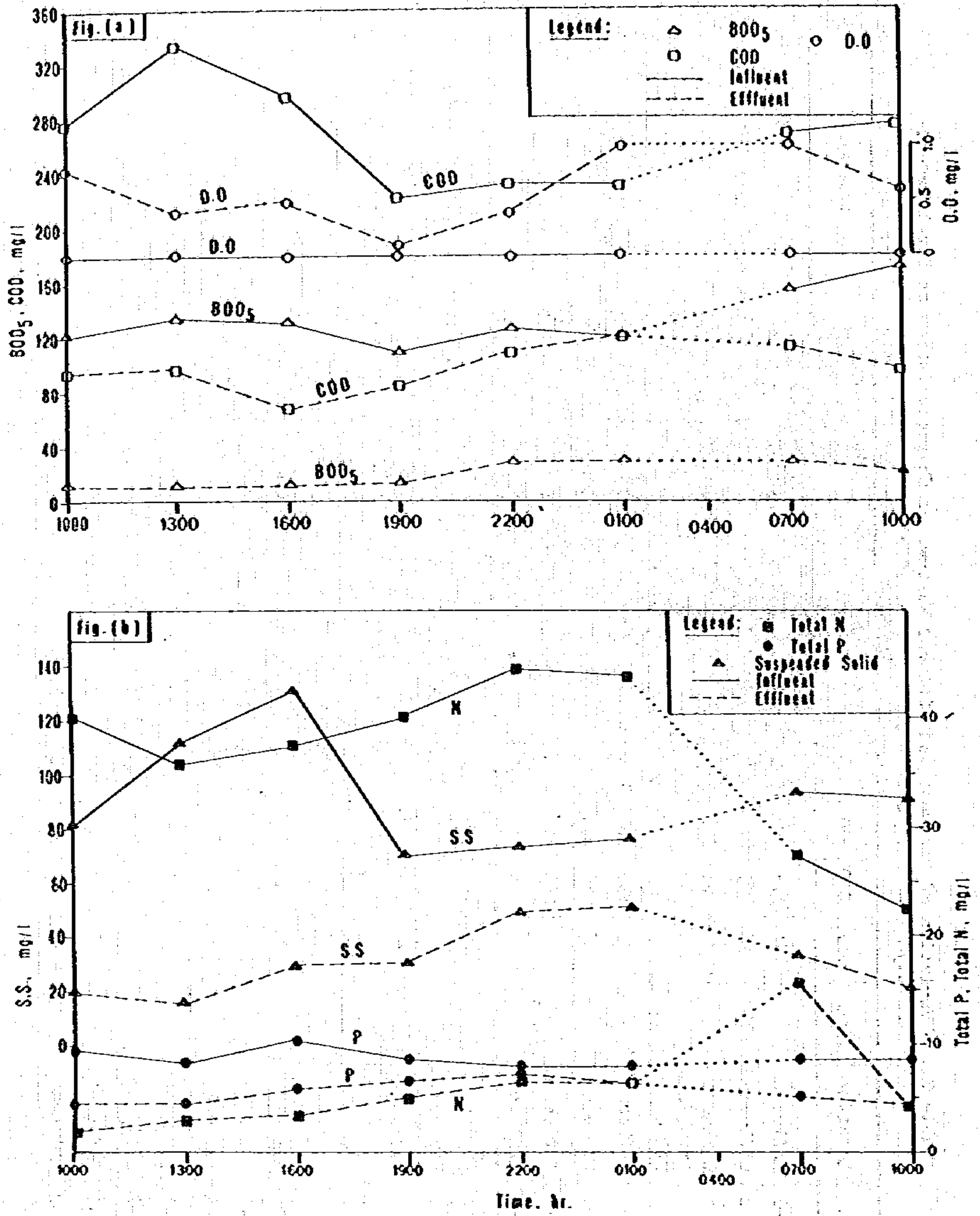

Fig. 2.2 Variation of Wastewater Characteristics at Hotel Regent Pattaya

From Table 2.1, it can be observed that there was no influent from 10 p.m. to 4.00 a.m. and at 4.00 a.m. no effluent was observed. At 7.00 a.m. in the morning the influent pump worked only for two minutes and stopped. Due to the variation of influent wastewater characteristics of some parameters, it was thought useful to present the results of those parameters in the form of cumulative relative frequency diagram as shown in Fig. 2.3. The 50, 70, 80 and 90 percentiles of the wastewater characteristics of the influent to the activated sludge plant is given in Table 2.2. Table 2.3 gives the minimum and maximum values of the wastewater characteristics for the 24 hour study period.

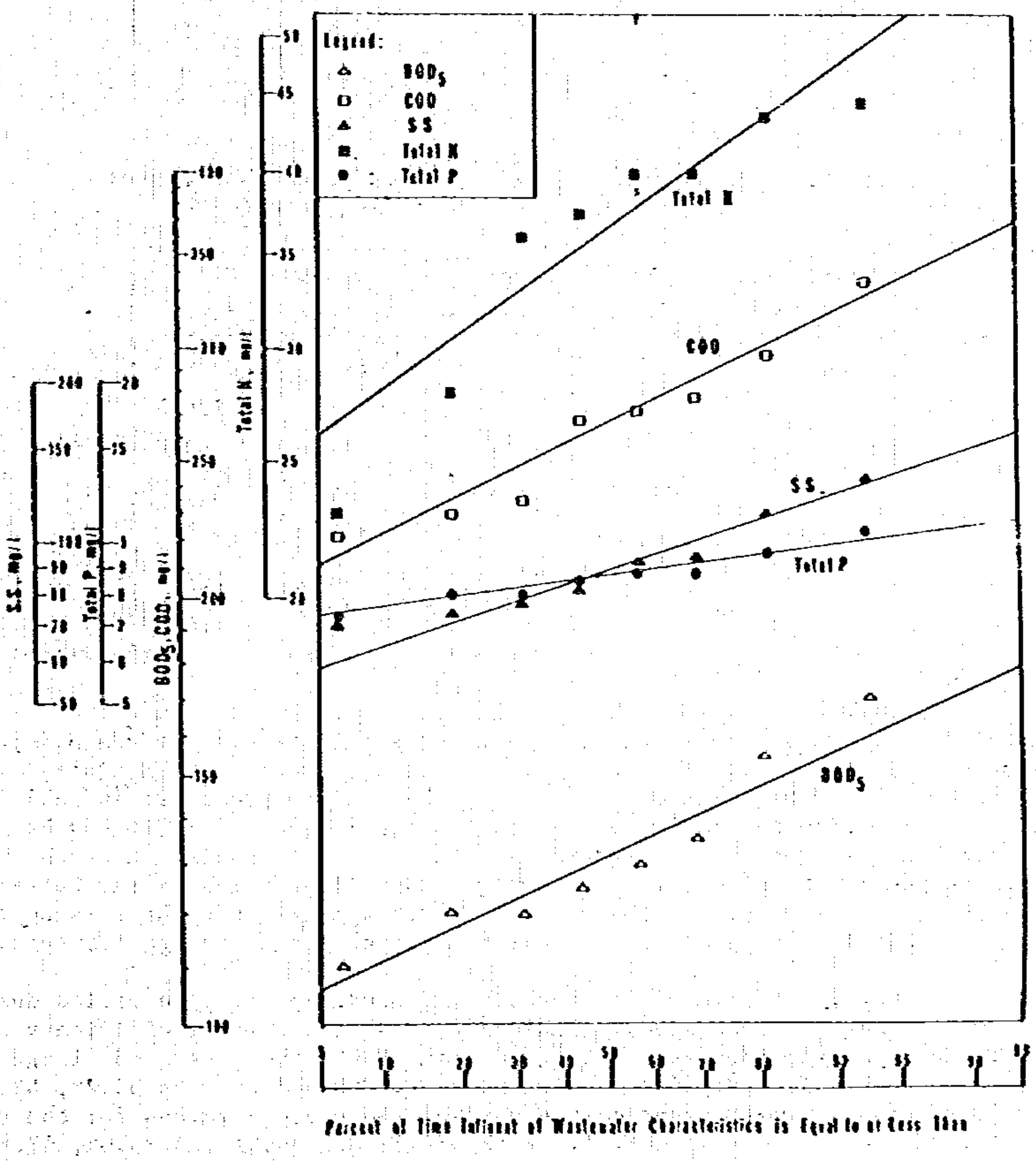

Fig. 2.3 - Probability of Wastewater Characteristics at Hotel Regent Pattaya

Table 2.2 - Fifty, Seventy, Eighty and Ninety Percentile Levels of Influent Wastewater Characteristics at Hotel Regent Pattaya.

Wastewater Parameter	Percentile Value, mg/l			
	50	70	80	90
BOD_5	132	141	147	156
COD	265	287	300	320
SS	90	96	105	125
Total N	36.5	38.5	44	47.5
Total P	20.8	21.2	21.5	21.9

Table 2.3 - Minimum and Maximum Values of the Wastewater Characteristics at Hotel Regent Pattaya.

Wastewater Parameter	Minimum, mg/l		Maximum, mg/l	
	Influent	Effluent	Influent	Effluent
BOD_5	110	10	171	30
COD	222	69	335	120
SS	70	17	133	52
N	22.6	0	45	15.7
P	7.5	4.7	10.6	7.7
pH	7.2	7.3	7.8	7.5
DO	0	0.1	0	1.0

Effluent Quality - The quality of the effluent from the activated sludge system is reasonably good and meets the effluent standard imposed by authorities of Thailand. The effluent standard adopted by Ministry of Public Health and Ministry of Industry in Thailand is presented in Table 2.4 and comparing with the effluent characteristics in Table 2.1, it may be observed that the effluent standards are met. Table 2.1 also shows the characteristics of the effluent from the up-flow filter which is far better than the allowable limit by the standards. It appears that there is no need of up-flow filter to produce effluent to meet the standard requirements.

The removal efficiency of the activated sludge plant also varied during the twenty-four hours of study. Table 2.4 shows the removal efficiency of the three important parameters, BOD_5, COD and SS by the activated sludge system. Average removal efficiencies of BOD_5, COD and SS were 85.2%, 62.0% and 62.4%, respectively, whereas the maximum and minimum values for the same three parameters were respectively 92.6%, 76.8% and 84.9% and 75.0%, 47.8%

and 32.4%. The removal efficiencies of the activated sludge system appear satisfactory.

Table 2.4 - Effluent Standards in Thailand

Characteristics*	Recommended Values of Ministry of Public Health	Ministry of Industry requirements for Sewage and Industrial Wastewater
BOD	40	20 - 60 depending on dilution
COD	100	-
Suspended Solids	60	30 - 150
Heavy Metals (total)	50	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 dissolved Solids	2000	200
pH	5-9	5 - 9
Permanganate Values	-	60
Chlorine	5.0	1.0
Temperature	40°C	40°C

* All values are in mg/l, except pH and temperature.

Table 2.5 - Removal Efficiency of Activated Sludge System at Hotel Regent Pattaya.

Date	Time	Percentage Removals		
		BOD_5	COD	SS
8 January 1978	10:00	91.7	65.8	75.9
	13:00	92.6	71.0	84.9
	16:00	90.8	76.8	77.4
9 January 1978	19:00	86.4	61.7	55.7
	22:00	76.0	51.7	32.4
	01:00	75.0	47.8	32.5
	04:00	-	-	-
	07:00	80.6	56.7	64.9
	10:00	88.3	64.7	75.8
Average		85.2	62.0	62.4
Maximum		92.6	76.8	84.9
Minimum		75.0	47.8	32.4

2. Orchid Lodge - Another activated sludge plant showing good performance is at Orchid Lodge, as shown in Fig. 2.4. Samples at the influent and the effluent from the plant were collected and analysed. The results are shown in Table 2.6 under the code 1-1 and 1-2 respectively. The levels of BOD_5, COD, SS and pH in the effluent are within the allowable standard limits set by the Ministry of Thailand for sewage and industrial wastes. The ratio of BOD_5:N:P of the influent is 100:0.53:1.07. Normally the ratio BOD_5:N:P of 100:5:1 is considered as the minimum requirement and in view of this, the concentration of nitrogen in the wastewater is lower. The performance of the activated sludge system might be improved if the level of nitrogen could be increased by adding some nutrients.

3. Hotel Weekender - This hotel has an activated sludge plant which was not operating at the time of sampling and thus only one sample was collected at the discharge, as shown in Fig. 2.5. The characteristics of the discharge are shown in Table 2.6 under the code 2-1. There is a need that this waste should be treated before discharged in any receiving stream. The ratio of BOD_5:COD is 0.75 and the ratio of BOD:N:P is 100:17.1:3.4. There is enough nutrients in the wastewater and the BOD_5:COD ratio is well within the desired range of 0.6 to 0.8 for biological treatment of the wastewater.

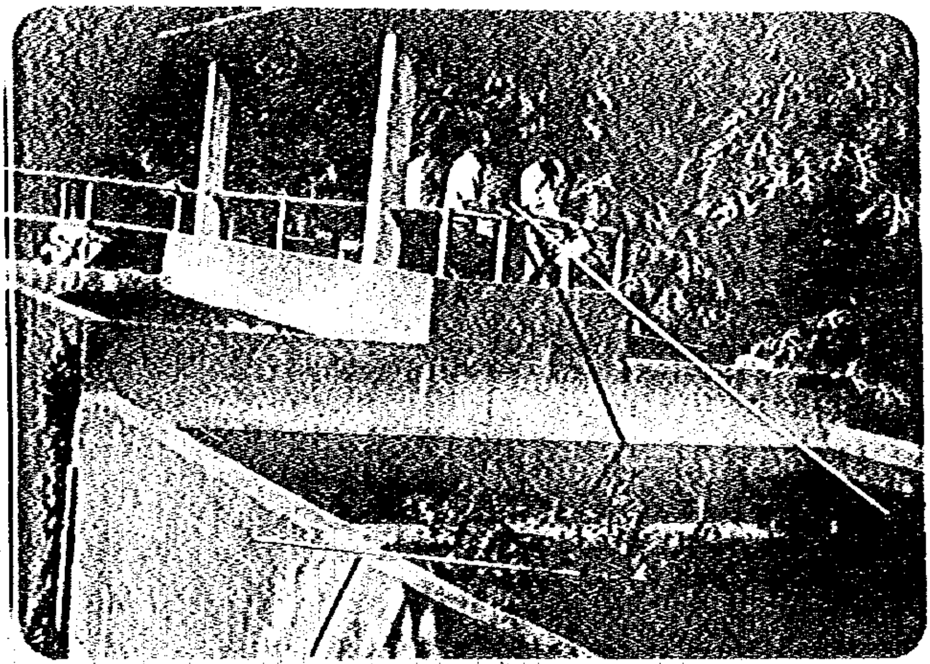

Fig. 2.4(a) - Aerator and Sedimentation Basin

Fig. 2.4(b) - PCI and AIT Teams at Work

Fig. 2.4 - Sewage Activated Sludge Plant at Orchid Lodge

Fig. 2.4(c) - Effluent Sampling

Fig. 2.4(d) - DO Determination

Fig. 2.4 (Cont'd) - Sewage Activated Sludge Plant at Orchid Lodge

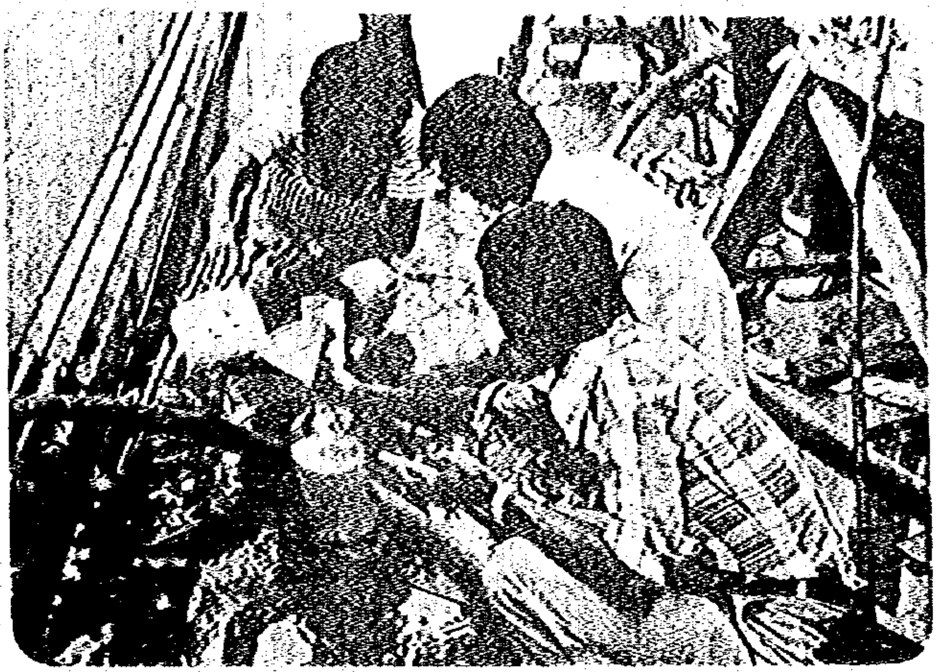

Fig. 2.5(a) - Sample Collecting

Fig. 2.5(b) - DO Determination at Site

Fig. 2.5 - Sample Collection and DO Determination at Weekender Hotel

Table 2.6 - Wastewater Characteristics of the Discharges from Hotels and Restaurants
(Date of Sampling : January 8, 1978)

Station No.	Location	Time	BOD_5 mg/l	COD mg/l	DO mg/l	SS mg/l	Total N mg/l N	Total P mg/l P	pH	Air Temp.	Water Temp.	Remark
1-1	Orchid Lodge	10:30	300	384	0.0	139	1.9	3.2	7.7	31	29	Activated Sludge performed satisfactorily
1-2			60	96	4.1	49	0	3.0	7.6	31	26	
2-1	Weekender	11:15	120	160	0.4	83	20.2	4.1	7.5	32.5	27.5	Activated Sludge was not in operation, or there was no effluent.
2-2			-	-	-	-	-	-	-	-	-	
3-1	Holiday Inn	13:20	180	540	0	315	33.8	5.6	7.2	33	34	No treatment system, just waste holding pond for plant and grass watering. Strong smell and black colour
3-2			175	352	0	138	27.7	5.4	7.2	33	31	
4	Nang Nual Res.	13:55	2070	2280	3.8	1360	62.7	44.0	7.7	29	28	Kitchen waste (dish wash wastewater)
5	Siam Bayshore	11:45	257	316	0	87	3.6	5.0	6.9	26.5	28	Septic tank
6-1	Royal Cliff	14:15	210	364	1.0	159	22.5	7.0	6.5	27	35	Secondary clarifier of Activated sludge was under-designed - Black colour
6-2			100	144	0	87	22.4	5.2	7.0	27	31	
7-1	Asia Pattaya	16:25	250	384	0	139	30.6	6.6	6.6	30	32	$KMnO_4$ was added to Aerated lagoon, in order to eliminate smell and odor, destroying microbial flora
7-2			85	236	0.5	128	25.4	5.4	7.2	30	20	

4. Holiday Inn - There is no treatment facility at this hotel. Sewage was simply retained in pond and then used for plants and grass watering through taps and hoses. At night, bad odor could be smelled in the hotel compound, as the result of prevailing anaerobic conditions in the holding pond (zero dissolved oxygen). The BOD_5 and COD values of the sewage are respectively 175 mg/l, and 352 mg/l higher than the allowable limits set by the Ministry of Industry, too high to be discharged in any receiving body. The hotel needs to have a better waste treatment facility for meeting effluent standards.

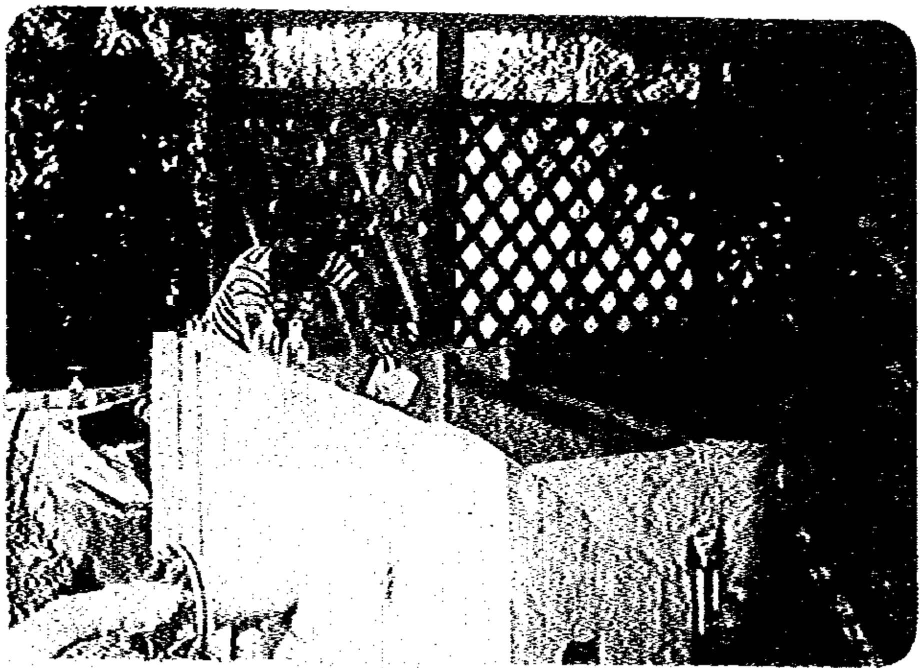

Fig. 2.6(a) - Sewage Holding Pond

Fig. 2.6(b) - Effluent Disposal by Lawn Spraying

Fig. 2.6 - Sewage Holding Pond and Effluent Discharge at Holiday Inn

5. Hotel Siam Bayshore - This hotel has a septic tank for the treatment of the wastewater. Samples were collected from the septic tank and analysed. The results of the wastewater characteristics are presented in Table 2.6 (station No. 5) and reveal that the septic tank is not working properly. Added to this, the septic tank effluent is directly discharged into a nearby canal, the Pattaya Canal, which turns black due to the prevailing anaerobic conditions in the canal. The concentration of BOD_5 (257 mg/l) is higher compared to Asia Pattaya. The zero concentration of DO confirms existence of anaerobic conditions.

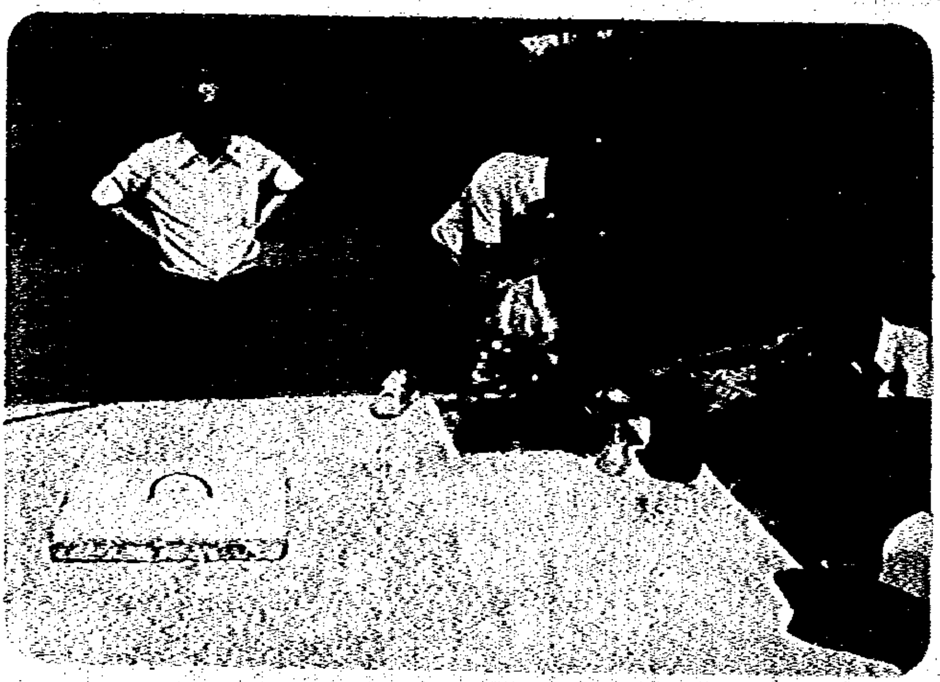

Fig. 2.7 - Septic Tank at Siam Bayshore Hotel

6. Royal Cliff Hotel - This hotel possesses an activated sludge plant, as shown in Fig. 2.8. However, the clarifier was under designed, being ineffective in removing the solids which were washed out in the effluent. The influent and effluent wastewater characteristics are presented in Table 2.6 under the code 6-1 and 6-2. The BOD_5 and COD values of 100 mg/l and 144 mg/l in the effluent is higher than the standards set by the Ministry of Industry. A better effluent, perhaps meeting the standards, could be achieved by improving the settling conditions in the clarifier.

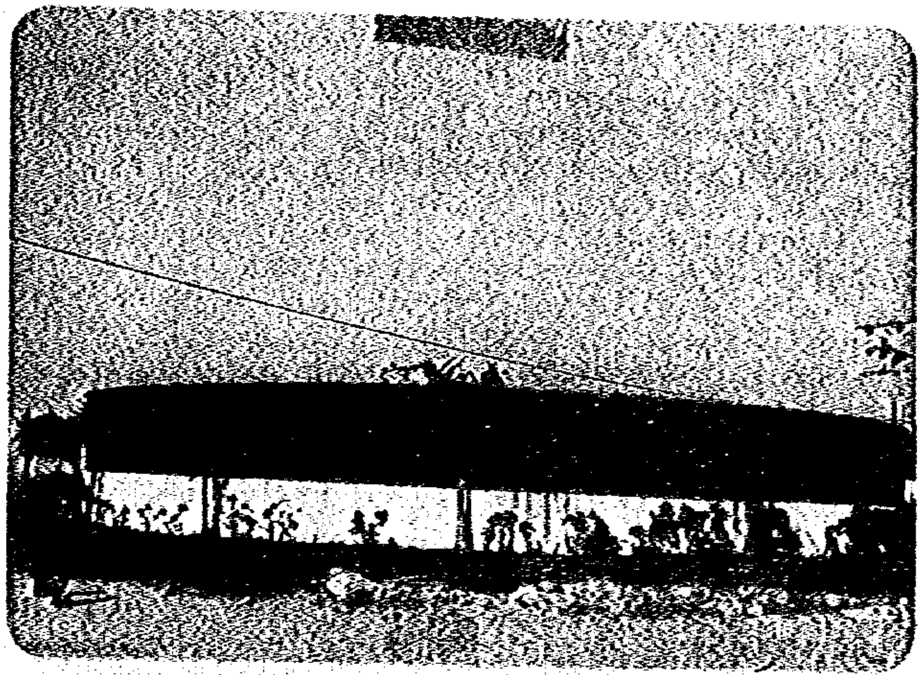

Fig. 2.8(a) - Covered Activated Sludge Plant

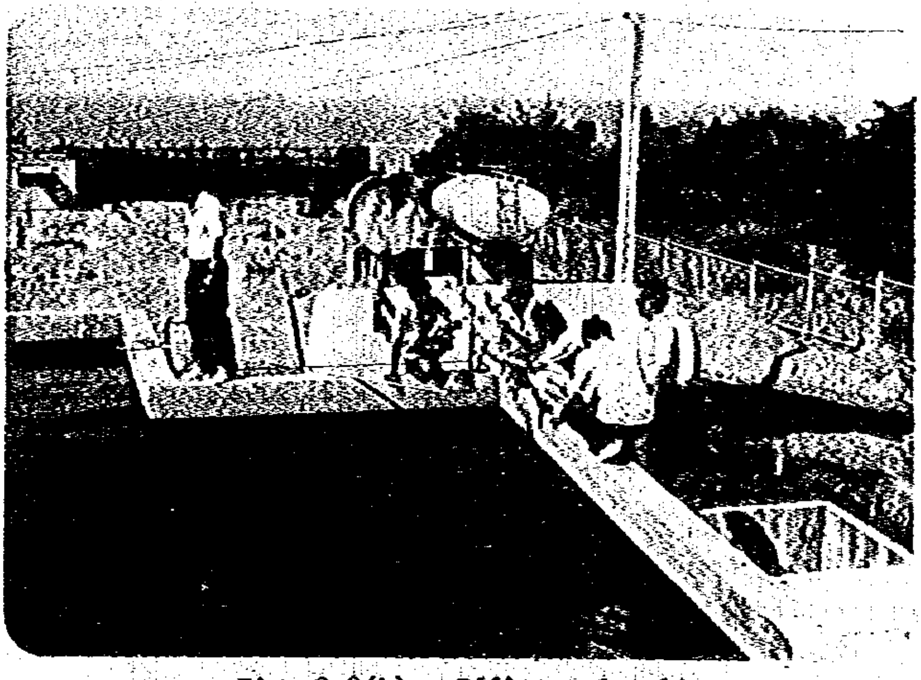

Fig. 2.8(b) - Effluent Sampling

Fig. 2.8 - Activated Sludge Plant at Royal Cliff Hotel

7. Hotel Asia Pattaya - This hotel has an aerated lagoon system as shown in Fig. 2.9. On the day of sampling, it was reported that some $KMnO_4$ was added in the lagoon to prevent the development of odor. The lagoon looked pink and all the biological system was disturbed due to the addition of $KMnO_4$ which could be toxic to the microorganisms. The influent and effluent wastewater characteristics are shown in Table 2.6 under the code 7-1 and 7-2. The BOD_5 and COD values of 85 mg/l and 236 mg/l in the effluent do not meet the standards set by Ministry of Thailand. With the better operation of the lagoon system, better effluent could be produced.

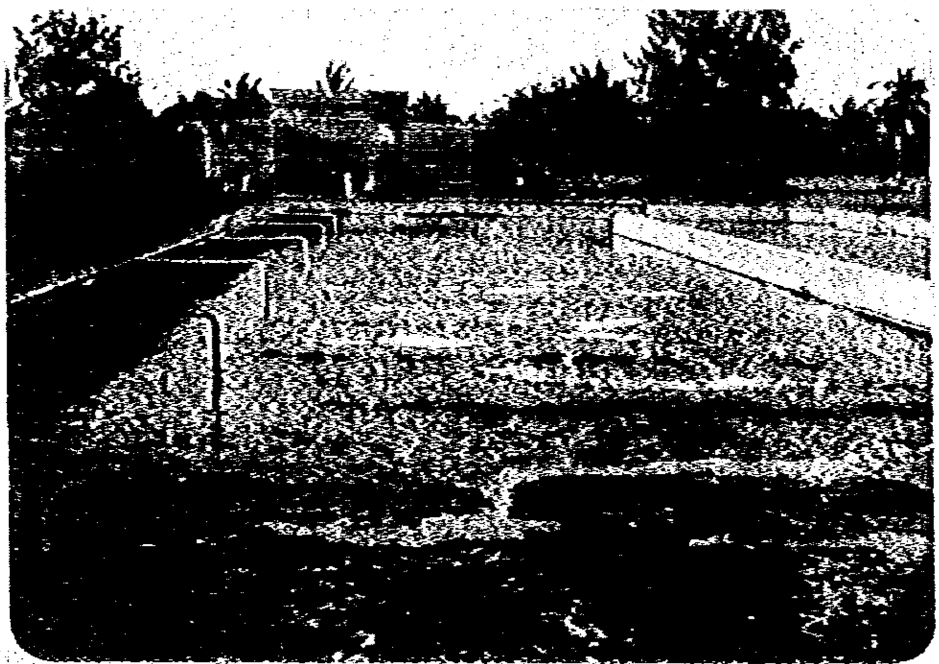

Fig. 2.9 - Aerated Lagoon at Asia Pattaya Hotel

8. Nang Nual Restaurant - This is one of the best sea food restaurant in Pattaya and at present discharges all the wastewater directly into the sea. Samples near the outfall could not be taken due to high tide period. Samples were, however, taken from the kitchen. The characteristics of the wastewater from the kitchen is presented in Table 2.6 under station 4. It may be observed that the levels of BOD_5, COD, SS, N and P (2070, 2280, 1360, 62.7 and 44 mg/l, respectively) were all quite high. This was expected as the waste consisted of mostly waste meat pieces. Due to the presence of high BOD_5, COD and suspended solids it is unacceptable to discharge this waste directly into the sea, and some form of treatment seems necessary.

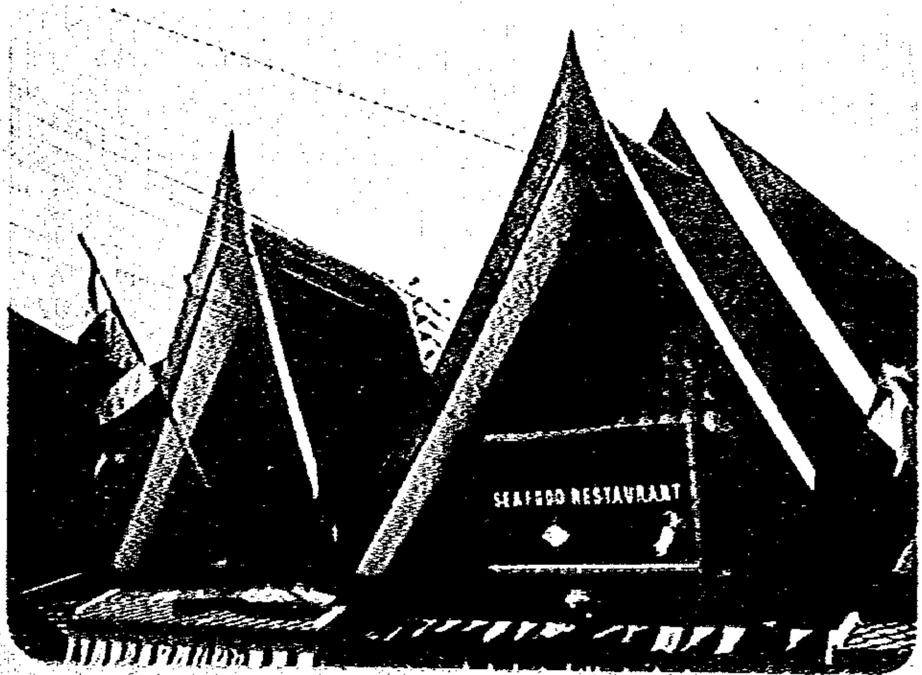

Fig. 2.10(a) - The Restaurant

Fig. 2.10(b) - DO Determination

Fig. 2.10 - Nang Nual Restaurant

CHAPTER III WATER QUALITY IN WELLS, WATER SUPPLY TAPS AND SWAMPS

Samples from five wells, one public water supply tap and one swamp were analysed in view to assessing the quality of water. All the four wells were shallow and presently used for domestic water uses including drinking. The photograph of one of the wells in the Naklua Residential area (station 22) is shown in Fig. 3.1. Table 3.1 presents the results of the analysis which will be compared with the standards adopted for drinking water. World Health Organization (WHO) has proposed such standards which are presented in Table 3.2.

Exception to some situations, most of the water quality parameters are within the allowable limits. The concentration of iron (Fe), ranges from 0.08 to 3.36 mg/l with the highest concentration in the water sample from public water supply tap (station 23). Iron in excess of 1.0 mg/l will cause unpleasant taste and reddish brown colour which produces staining of laundry,

Fig. 3.1 Well in the Naklua Residential Area (Station 22)

fountains and plumbing fixtures. The level of iron (Fe) should normally be kept at about 0.3 mg/l. In view of this, it appears that the water from all the wells and the public water supply tap except at stations 15 and 16 need some form of aeration which will convert iron into its insoluble forms.

The level of suspended solids is quite low with the highest concentration of 175 mg/l at station 23 i.e. the public tap water. Manganese (Mn) is also quite low and in many samples Mn is not present. Nitrogen concentration as nitrate is high at station 15 having a concentration of 28.4 mg/l which may be due to the presence of organic matter of animal or vegetable origin. The presence of more than 45 mg/l as nitrates (or

Table 3.1 Water Quality in the Wells, Water Supply Taps and Swamp (Sampling Date : January 8, 197[illegible])

Stations	Description	Time of sample collection	BOD_5 mg/l	COD mg/l	DO mg/l	SS mg/l	Total-N mg/l	NO_3-N mg/l	Total P	Mn mg/l	Fe mg/l	Turbidity FTN	Alkalinity mg/l as $CaCO_3$	Hardness as $CaCO_3$ mg/l	PH	MPN per 100 ml	Air Temp °C	Water Temp °C
12	Well (Proposed site for stabilization pond)	13.10	5	2	4.1	12	0.4	0.7	0	0	2.40	17	72	[illegible]	6.6	-	18	27
13	(do)	15.25	5	4	3.8	11	0.4	0.3	0	0.04	2.30	34	30	50	5.7	-	24	26
15	Village Water Supply Well	14.25	5	20	1.9	9	0	28.4	0	0.04	0.08	3	40	110	5.7	-	25.3	[illegible]
16	Village Water Supply Well	14.35	5	0	2.9	10	0.1	1.1	0.12	0	0.16	16	20	18	5.6	-	26.3	27
22	Well Offshore of Nakluo	18.10	5	35	2.0	12	1.1	0.3	0	0	1.60	87	30	32	6.3	1100	30	28
23	Tap Water	18.00	5	28	5.9	175	0.8	0.2	0.05	0	3.36	161	60	72	8.0	28	29	32
24	Swamp	10.25	5	20	5.9	10	0.4		0.03	-	-	-	-	-	6.6	-	29	[illegible]

10 mg/l N) is reported to be the cause of methemoglobinemia or "blue babies". With this regard, the nitrate concentrations at all the stations are within the acceptable level, except at station 15 which shows a comparatively high concentration of nitrates (28.4 mg/l)

Table 3.2 - WHO Standards for Potable Water

Constituent	Criterion	
Lead (as Pb)	0.1 mg/l	Maximum Allowable Concentration
Selenium (as Se)	0.05 mg/l	
Arsenic (as As)	0.02 mg/l	
Chromium (as Cr^{+6})	0.05 mg/l	
Cyanide (as CN)	0.01 mg/l	
	Permissible	Excessive
Total Solids	500 mg/l	1,500 mg/l
Color	5 units	50 units
Turbidity	5 units	25 units
Taste	Unobjectionable	- - - - - -
Odor	Unobjectionable	- - - - - -
Iron (Fe)	0.3 mg/l	1.0 mg/l
Manganese (Mn)	0.1 mg/l	0.5 mg/l
Copper (Cu)	1.0 mg/l	1.5 mg/l
Zinc (Zn)	5.0 mg/l	15 mg/l
Calcium (Ca)	75 mg/l	200 mg/l
Magnesium (Mg)	50 mg/l	150 mg/l
Sulphate (SO_4)	200 mg/l	400 mg/l
Chloride (cl)	200 mg/l	600 mg/l
pH	7.0 - 8.5	(6.5 or) 9.2
(Mg + Na) So_4	500 mg/l	1,000 mg/l
Phenolics	0.001 mg/l	0.002 mg/l

In general, hardness in the water samples from the wells and the public tap was found to be satisfactory. Normally water softer than 50 mg/l, as $CaCO_3$, is corrosive and samples at stations 16 and 22 showed respectively 18 and 32 mg/l as $CaCO_3$. This is however considered not a serious problem because there are no water supply distribution lines and the residents in the areas normally store the water in earthen bins. The hardness values in station 12, 13 and 23 are within the desirable values which are generally taken between 50 to 80 mg/l as $CaCO_3$. Water with hardness of 80 to 150 mg/l as $CaCO_3$ is considered moderately hard and the value of 110 mg/l in station 15 falls in this category.

Turbidity values ranged from 3 to 161 FTU with the highest unit at public water tap. It can be said that all these waters, except at station 15, are considered inacceptable as far as turbidity is concerned. Normally, the permissible level of turbidity is 5 units and more than 25 units would justify the treatment of water.

The pH values of the water samples ranged from 5.6 at station 16 to 8.0 at station 23 and is within the acceptable level, from 5.0 to 8.5, when viewed from the standpoint of corrosion. However in comparison to the WHO standards, pH values at station 13, 15 and 16 are slightly on the lower side.

Although many attractive well waters could be devoid of oxygen, the dissolved oxygen (DO) levels in the wells varied from 1.9 to 4.1 mg/l whereas the DO level of 5.9 mg/l was observed at the public tap water. In general, it is preferable for the DO level to exceed 2.5 to 3.0 mg/l to avoid secondary tastes and odor from developing. The low DO level of 1.9 mg/l at station 13 is counter supported by high level of nitrates and could be due to presence of organic matter of animal or vegetable origin. In general, the DO levels in all the wells and the public tap water are satisfactory.

The alkalinity of water in the wells and tap water varied from 20 to 72 mg/l as $CaCO_3$. Normally, alkalinity value upto 500 mg/l is acceptable although this factor must be appraised from the standpoint of other parameters like pH, hardness, carbon dioxide and dissolved oxygen content. In view of all the above parameters, the alkalinity levels are well acceptable.

To detect an indication of faecal pollution, MPN values per 100 ml were determined. Due to the limiting sterilized bottles at site, samples could be taken only at station 22 i.e. the well located offshore of Na Klua River and at station 23 i.e. the tap for public water supply. The MPN value of 1100 at the well at station 22 is very high and should be considered as a sure indication of faecal pollution. The tap water sample showed MPN value of 28 per 100 ml which is still higher than the standard set by WHO which states that no sample should contain more than 10 coliform organism per 100 ml for water in the distribution system. Although not analysed, the MPN values for water in the wells at stations 12 and 13 could be expected quite high due to the activities of the people living around the area. The wastewaters are not properly disposed off and thus get into the wells.

Summary:- In general, except for the MPN values, turbidity and the concentration of iron (Fe) in the water samples, the water constituents are within the satisfactory levels. It is recommended that the water in the wells and the public tap water should be filtered and disinfected properly so that the water quality is acceptable for drinking and before disinfecting, iron (Fe) level will be reduced to a lower level making it satisfactory for domestic uses.

As per the ranges of promulgated standards for water sources of domestic water supply, shown in Table 3.3, reported by McKee and Wolf (1971)1/, the wells may, in general be classified as good source of water supply requiring usual treatment such as filtration and disinfection.

1/ McKee and Wolf (1971), Water Quality Criteria, California Water Resources Control Board, Second Edition.

Table 3.3 - Ranges of Promulgated Standards for Raw Water Sources of Domestic Water Supply

Constituent	Excellent source of water supply, requiring disinfection only, as treatment	Good source of water supply, requiring usual treatment such as filtration and disinfection	Poor source of water supply, requiring special or auxiliary treatment and disinfection
BOD (5-day) mg/l			
Monthly average:	0.75-1.5	1.5-2.5	Over 2.5
Maximum day, or sample:	1.0-3.0	3.0-4.0	Over 4.0
Coliform MPN per 100 ml			
Monthly average:	50-100	50-5,000	Over 5,000
Maximum day, or sample:	Less than 5% over 100	Less than 20% over 5,000	Less than 5% over 20,000
Dissolved Oxygen			
mg/l average:	4.0-7.5	4.0-6.5	4.0
% saturation:	75% or better	60% or better	--
pH			
Average:	6.0-8.5	5.0-9.0	3.8-10.5
Chlorides, max. mg/l	50 or less	50-250	Over 250
Fluorides, mg/l	Less than 1.5	1.5-3.0	Over 3.0
Phenolic compounds, max. mg/l	None	0.005	Over 0.005
Color, units	0-20	20-150	Over 150
Turbidity, units	0-10	10-250	Over 250

CHAPER IV WATER QUALITY IN RIVERS AND CANALS

Water quality conditions in two rivers, Na Chom Tiem and Na Klua, and one canal were studied. Two grab samples, one at the river mouth and the other down below the river underneath the bridge of Sukhumvit Highway, for each river and one grab sample for the canal were collected and analysed for the various water quality parameters, one additional sample on Na Klua River near the tapioca factory was also collected. Table 4.1 present the results of the water quality analysis. The results are briefly explained below.

1. Na Chom Tiem River - The dissolved oxygen levels, at the river mouth and down below the Sukhumvit Highway underneath the bridge i.e. at stations 10 and 9 respectively, were 8.5 mg/l and 7.2 mg/l which denote the healthy condition of the river. The BOD_5, SS, N, P and pH are all within the allowable limits stated in stream standards. As expected, the chloride concentration at the river mouth (to the sea) is quite high and is 17,150 mg/l, slightly lower than the chloride concentration at sea. However, the MPN values of 940 and 2400 per 100 ml at stations 9 and 10 indicate the presence of fecal pollution. Comparing with the stream standards based on stream classification and wastewater treatment given in Table 4.2, the river could be classified as B class and thus suitable for fishing but not suitable for bathing and drinking due to the presence of high density of coliform bacteria.

2. Na Klua River - Three samples collected at the river mouth, underneath the Sukhumvit Highway bridge and near a tapioca starch factory i.e. at stations 21, 20 and 17 respectively, were analysed for water quality parameters and the results are presented in Table 4.1. The dissolved oxygen level at station 20 underneath the bridge is 0 mg/l and was in septic condition. The hydrogen sulphide gas could be smelled during sampling. The BOD_5 concentration at station 20 is too high for a river and is of the order of 1620 mg/l indicating high concentration of organic matter. Due to the fact that this river is in the vicinity of a number of tapioca starch factories, it is to be expected that some wastewater discharges into the water course take place. pH being near 4.3 is the same as pH in tapioca starch wastewater, as will be discussed later in chapter VI. The coliform level of 1,100 MPN per 100 ml is also high. Again comparing with the stream standards in Table 4.2, the river portion near station 20 could be considered as worse and lower than the quality of water specified for class D streams.

The water quality at the mouth of the Na Klua River i.e. at station 21 is better than the water quality at station 20. The BOD_5 level is less than 5 mg/l and pH value of 7.0 is acceptable. The dissolved oxygen level is 3.2 mg/l which is just about sufficient for fishes. This is due to stream self-purification and algal growth. However, the coliform bacteria is 1,400 MPN/100 ml and is quite high making it unsuitable for bathing and recreational uses. As per the classification in Table 4.2, the river portion near station 21 may be considered as class C.

Table 4.1 - Water Quality in Rivers (Sampling Date : January 8, 1978)

Station No.	Description of Location	Time of Sampling	BOD_5 mg/l	Chloride mg/l	DO mg/l	SS mg/l	Total N mg/l	Total P mg/l	pH	MPN	Air Temp °C	Water Temp °C
6	Pattaya Canal	11:55	45	-	0	47	13.4	2.7	6.9	240×10^4	25.5	28.5
9	Na Chom Tiem River (underneath the Sukhumvit Bridge)	16:05	<5	-	8.5	61	1.3	0	7.0	930	27.5	28.5
10	Na Chom Tiem River (River Mouth)	15:45	<5	17,150	7.2	40	0.3	0	7.1	Greater than 2,400	31	29
17	Na Klua River (Near Tapioca Factory)	14:50	10	-	1.4	25	5.7	0.6	6.7	-	28	31
20	Na Klua River (Underneath the Sukhumvit Bridge)	14:10	1620	-	0	171	45.7	5.2	4.3	1,100	34.5	29.5
21	Na Klua River (Mouth of River)	13:45	<5	18,500	3.2	106	0.6	0	6.3	1,400	26	28

Table 4.2 - Stream Standards Based on Stream Classification and Waste Water Treatment

Class	Use	Standards of quality at low-water stage	Required treatment of sewage	Emergency treatment
D (Bad)	For rough industrial uses and for irrigation	Absence of nuisance, odors and unsightly suspended or floating matters; dissolved oxygen present	Sedimentation, except in large receiving waters	Chlorination: ferric chloride treatment to remove hydrogen sulphide; addition of nitrate to supply oxygen
C	For fishing	D.O. content not less than 3 and preferably 5 ppm; CO_2 not more than 40 and preferably 20 ppm*	Sedimentation; chemical or biological treatment where necessary	Aeration; addition of diluting waters
B	For bathing, recreation, and shellfish culture	No visible sewage matters; a bacterial standard such as coliform density less than 100 per 100 ml	As in class C; chlorination if necessary	Chlorination
A (Good)	For drinking water after chlorination	In the absence of filtration, † a bacterial standard such as coliform density less than 50 per 100 ml. Chemical standards for substances not removable by common treatment methods	As in class B; removal of certain taste-producing substances such as phenols	Treatment of drinking water with heavy doses of chlorine and activated carbon

*At high temperatures the tolerance of fish to low D.O. and high CO_2 is decreased; high temperatures are also objectionable in themselves. † With complete purification in modern filtration works, a bacterial standard such as 5,000 coliform density per 100 ml. will normally permit production of a safe drinking water.

SOURCE: Imhoff and Fair (4). Reproduced by permission of the publisher.

Fig. 4.1(a) - Underneath the Bridge on Sukhumvit Highway (Station No. 9)

Fig. 4.1(b) - At the River Mouth (Station No. 10)

Fig. 4.1 - Na Chom Tiem River.

The water quality at station 17 i.e. near the tapioca factory showed lower levels of BOD_5, COD, N and P, indicating less organic pollution. MPN values could not be measured due to limited sterilized bottles at site. It is, however expected that MPN values might be high also making it unsuitable for bathing and recreational uses because of the expected fecal pollution the resident living near the sampling station.

3. Pattaya Canal - Previously flowing towards the sea, the canal is now blocked at both its ends making it a stagnant body of water and making "canal" as an unsuitable name at present. The water quality characteristics of the canal is shown in Table 4.1. Significantly noted is the value of coliform bacteria which 240 x 10^4 MPN per 100 ml and is very high. This is due to the fact that the canal receives the effluent from the septic tank located at Siam Bayshore Hotel and the canal has no exit. Also seen is the dissolved oxygen level of 0 mg/l indicating anaerobic condition in the canal producing odor around the area. The canal at present is just like a stagnant sewer.

Fig. 4.2(a) - View of Pattaya Canal

Fig. 4.2 - The Pattaya Canal

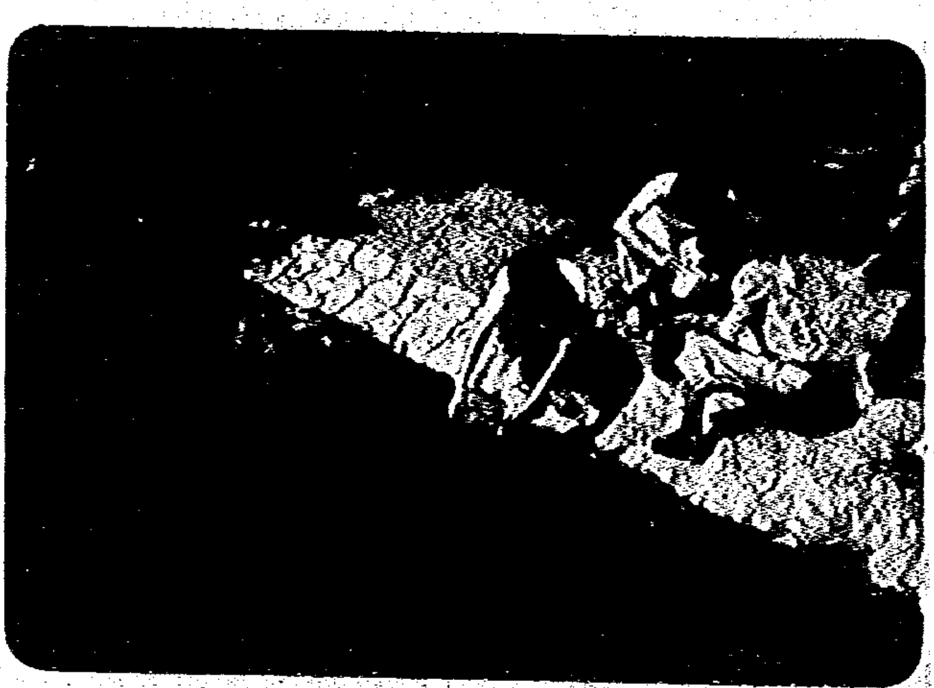

Fig. 4.2(b) - Sample Collection

Fig. 4.2 (Cont'd) - The Pattaya Canal

CHAPTER V QUALITY OF SEA WATER

Three sampling locations each about 200 metres offshore from the beach were chosen and the water quality analysed. Table 5.1 shows the parameters analysed for the sea water samples.

As the sea water around the beach is principally used for swimming, boating and other recreational uses, it is therefore logical to interprate the sea water quality in terms of its uses. To be acceptable to the public and the regulatory authorities, waters that are used for swimming and bathing must conform to three general conditions: (a) they must be aesthetically enjoyable i.e. free from obnoxious floating or suspended substances, objectionable color, and foul odors (b) they must contain no substances that are toxic upon ingestion or irritating to the skin of human being; (c) they must be reasonably free from pathogenic organisms.

Thailand does not have standards for recreational uses and therefore it might be worthwhile to compare with the standards guidelines available in other countries.

Bathing beach water quality standards in U.S.A. vary throughout the country. They range from no standard to a permissible total coliform count of 50/100 ml to 2400/100 ml or higher. A recommended standard for water used for wading, swimming, water skiing and surfing states:1/

"Fecal coliform should be used as indicator organism for evaluating the microbiological suitability of recreation waters. As determined by the multiple-tube fermentation or membrane filter procedures, the fecal coliform content of recreation water shall not exceed a log mean of 200/100 ml, and "..... the pH should be within the range of 6.5-8.3 except when due to natural causes and in no case shall be less than 5.0 nor more than 9.0.

McKee and Wolf (1971)2/ has presented a possible series of standards for recreational waters and is given in Table 5.2. The wide range specified put emphasis on the uncertainty concerning limiting factors.

Considering the above standards and guidelines, it may be observed from Table 5.1 that the sea water quality at stations 26 and 27 are quite good. The area between station 26 and station 27 is the most crowded portion and popular among the beach bathers. No objectionable and undesirable objects or odor were observed in the sea water between these two stations. The DO levels of 5.8 and 6.1 mg/l, MPN counts of 460 and <3 per 100 ml, pH values of 7.6 and 7.1 and suspended solid concentrations at stations 26 and 27, respectively, are quite low, therefore indicating acceptable areas for re-

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1/ Report of the Committee on Water Quality Criteria (1968), Federal Water Pollution Control Administration, U.S. Dept. of Interior, Washington, D.C.

2/ McKee and Wolf (1971), Water Quality Criteria, California Water Resources Control Board, Second Edition.

creation. However, the sea water quality at station 25 which is located offshore of Na Klua pier is not acceptable for sea swimming or bathing purposes, as far as coliform content is concerned. Some undesirable and objectionable objects were seen floating around the area and bad odor could be smelled. The DO level of 1.7 mg/l is quite low and MPN count of 7,500 per 100 ml indicates the presence of fecal contamination. In this present condition, the area around station 25 should be avoided for recreational purposes. In general, the BOD_5 concentration in sea water is low at three stations.

<u>Summary</u>: Sea water quality in the popular area i.e. between station 26 and 27 is at present in excellent condition and should be protected from future pollution hazards. The area around station 25 should be improved and care should be taken to stop organic fecal pollution around the area.

Fig. C.1 Sample Collection (Station No. 25)
Offshore of Na Klua Village

Table 5.1 - Quality of Sea Water (Sampling Date : 9th January, 1978)

Station No.	Location	Time of Sampling	BOD_5 mg/l	Chloride mg/l	DO mg/l	SS mg/l	Total N mg/l	Total P mg/l	pH	MPN/100 ml	Air Temp °C	Water Temp °C
25	Sea (offshore of Na Klua Pier) ≃ 200 m	10:15	<5	20,000	1.7	50	0.3	0	7.7	7500	27.5	25
26	Sea (offshore of Pattaya beach, Nang Nual Res-taurant) ≃ 200 m	9:55	<5	19,250	5.8	46	0	0	7.6	460	24.5	26
27	Sea (offshore of South Pattaya hill, sea view villa) ≃ 200 m	9:35	<5	19,000	6.1	38	0	0.15	7.1	<3	25	26.5

Table 5.2 - Tentative Guides for Evaluating Recreational Waters.

Determination	Water contact		Boating and aesthetic	
	Noticeable threshold	Limiting threshold	Noticeable threshold	Limiting threshold
Coliforms, MPN per 100 ml	1000*	†		
Visible solids of sewage origin	None	None	None	None
ABS (detergent), mg/liter	1*	2	1*	5
Suspended solids, mg/liter	20*	100	20*	100
Flotable oil and grease, mg/liter	0	5	0	10
Emulisified oil and grease, mg/l	10*	20	20*	50
Turbidity, silica scale units	10*	50	20*	‡
Color, standard cobalt scale units	15*	100	15*	100
Threshold odor number	32*	256	32*	256
Range of pH	6.5-9.0	6.0-10.0	6.5-9.0	6.0-10.0
Temperature, maximum °C	30	50	30	50
Transparency, Secchi disk, ft	...	...	20*	‡

*Value not to be exceeded in more than 20 percent of 20 consecutive samples, nor in any 3 consecutive samples.

†No limiting concentration can be specified on the basis of epidemiological evidence, provided no fecal pollution is evident. (Note: Noticeable threshold represents the level at which people begin to notice and perhaps to complain. Limiting threshold is the level at which recreational use of water is prohitited or seriously impaired.

‡No concentrations likely to be found in surface waters would impede use.
SOURCE: McKee and Wolf(p.33). Reproduced by permission of the California State Water Quality Control Board.

CHAPTER VI A SURVEY OF WASTEWATER FROM TAPIOCA STARCH INDUSTRY

1. Tapioca Plant - Tapioca, Manihot esculenta crantz, also called cassava or manioc, is a starch-producing tropical shrubby perennial root crop. The plant propagates vegetatively by means of stem cuttings and adventitious roots, or tubers, radiate from the base of these cuttings. Optimum yield can be achieved by having 3,000 - 10,000 plants per hectare. The yield varies from region to region and strain to strain, with 2-3 kg of root per plant being common, but improved strains now yield more than 10 kg of root per plant. As a crop, tapioca's popularity with farmers is due to several attributes: it is easily planted and requires little attention; it can stand drought and short periods of flood fairly well; it grows in relatively poor soils; and it is high yielding compared with many other crops.

2. Pollution from Tapioca Starch Industry - Tapioca starch production is a significant agro-industry in Thailand. In areas where tapioca is grown and processed, tapioca starch wastes contribute significantly to stream pollution. The process to extract starch from tapioca roots (or tubers) requires large quantities of water, both for root washing and for the extraction of starch from rasped roots, and significant amounts of wastewaters are released. Heavy pollution of land and streams by these wastes gives rise to obnoxious odours in the neighbourhood of factories and aquatic flora and fauna are seriously affected. In Thailand, tapioca starch factory wastewaters are, and will continue to be, a serious threat to the environment and quality of life in rural areas. As an example of the magnitude of the problem in comparison with other waste sources, it was estimated that in 1972 more than 80 percent of the suspended solids and more than 95 percent of BOD_5 finding their way into the Gulf of Thailand from the Province of Cholburi were from tapioca starch processing[1/] (McCARRY, et al. 1973).

At the present time, few factories have any control over their waste discharges and those do attempt any form of treatment are guided by expediency alone and have usually limited their wastewater processing to inadequate holding in ponds. Few studies have been carried out to arrive at rational and effective waste treatment process.

3. Tapioca Starch Production - In Thailand tapioca starch is produced in two grades by two types of processes, although the quality of final product is similar in both cases. Initially, the tapioca roots pass through the same processing in both grades of factory, namely dry removal of sand and clay, root washing and rasping. Thereafter, first-grade starch is produced using centrifugation, filtration, and spray drying as the basic unit processes; this process is capital intensive and uses less labour and more water than the other process. By contrast, very little mechanization is

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1/ McCARRY, M.G., SHUTO, N., WHITAKER T. and CHAVANICH, L. (1973), Coastal Water Pollution Survey of Cholburi Province, Research Report, AIT, Bangkok.

utilized by second-grade starch factories, which are usually small private-enterpirse plants; these installations are not capital intensive but use very simple methods of separation by cloth filtration, gravity settling, decanting and drying on heated concrete slabs. Flow diagrams for both types of process are given in Fig. 6.1 and wastewater streams are shown.

4. Wastewater Emission Rates - The combined wastewater from tapioca starch production is mainly composed of two kinds of wastes, the root wash-water and either the starch supernatant decanted from sedimentation basins or the separator wastewater, depending upon whether a second-grade or first-grade starch factory is being considered. First-grade factories process in the order of 200 metric tons of tapioca root per day while second-grade factories commonly process about 30 tons per day. Unit emission rates (UMER Values) for the characteristics of wastewater from first and second-grade factories are shown in Table 6.1. Designations A, B, C and D refer to waste sources shown in Fig. 6.1.

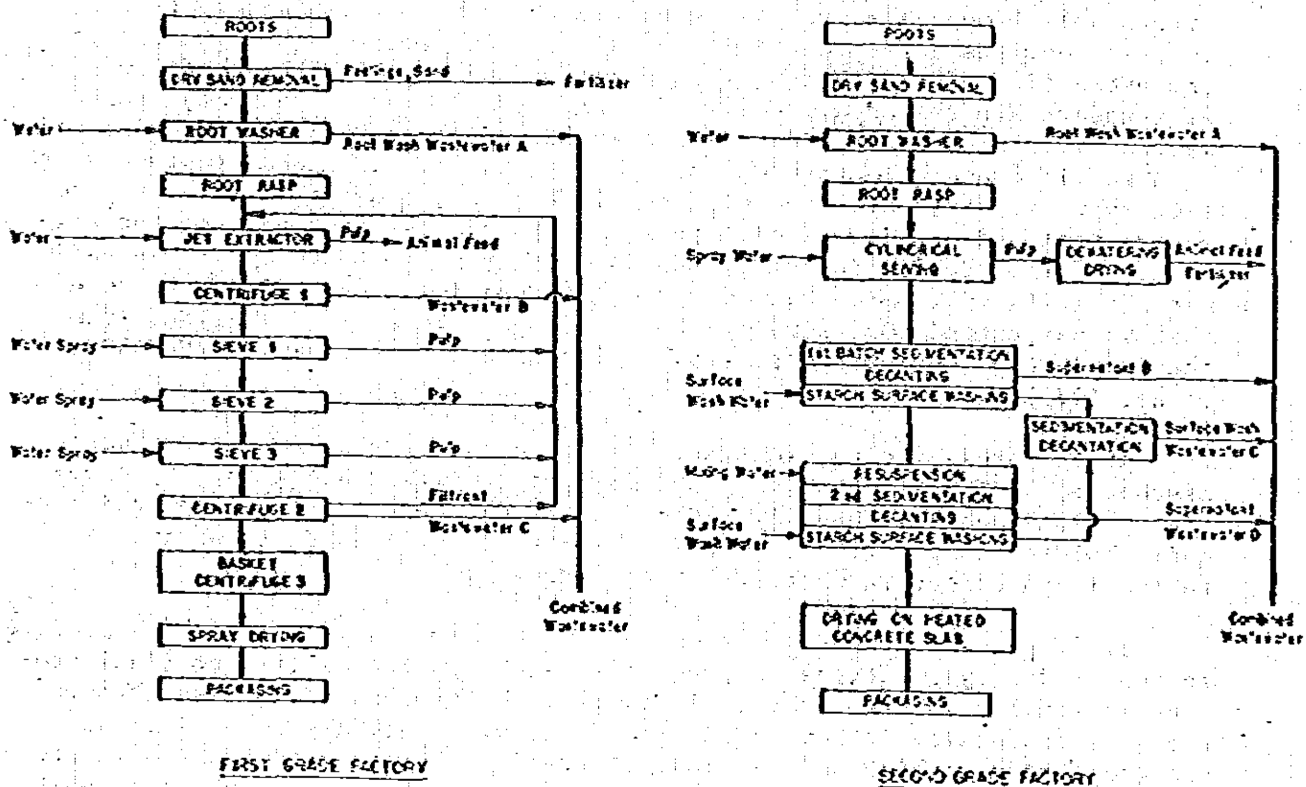

Fig.6.1 -Tapioca Starch Processing In Thailand

Table 6.1 - UMER Values of Tapioca Starch Wastewaters in k/kg Root

Characteristic	Wastewater				
	A	B	C	D	Combined
		1st-Grade Factory			
COD	0.69	55.2	6.0		62.0
BOD_5	0.33	26.5	2.9		29.8
Suspended Solids	0.54	10.5	3.7		15.7
Dissolved Solids	4.91	46.3	9.6		60.8
	2nd-Grade Factory (Average of 2 Plants)				
BOD_5	0.8	28.5	1.5		30.4
Total Solids	2.2	45.2	1.9		49.5
Suspended Solids	0.8	11.3	1.3		13.4
		2nd-Grade Factory (One Plant)			
BOD_5	1.8	44.8		2.1	48.7
Total Solids	3.1	102.8		2.2	109.2
Suspended Solids	3.1	83.5		0.6	87.2

5. Present Survey of Wastewater from Tapioca Starch Factory - In this survey, wastewater samples at various process points from a first-grade mills, namely CHO CHAIWAT mill and KOH CHANG HEA mill, and from a second-grade mill, CHAROEN ROONG RUENG and TONG HENG, were collected and their characterics analyzed. The results of analyses are prexented in Table 6.2

The tapioca mill CHO CHAIWAT (Fig. 6.2), designated as station No. 11 does not possess any wastewater treatment device. Wastewater is directly discharged into the field behind the factory without any treatment. Root wash wastewater and separator wastewater are channelled into two separate streams, as indicated in Fig. 6.3. Sampling was carried out on various points designated as 11-1, 11-2, 11-3, 11-4 and 11-5. Sampling points 11-1 and 11-2 represent root wash and separator wastewaters, respectively. These two wastewater streams were then combined in proportion of 50:50, which is at 11-3. The combined wastewater is then allowed to flow freely in the back-yard field where buffaloes are living (sampling point 11-4). The marked difference in BOD_5 and COD concentrations between the 50:50 combined waste and the total combined waste is due to the fact that the 50:50 combination did not respect the flow proportionality of the two waste streams. Point 11-5 represents wastewater emanating from jet extraction process.

The second first-grade tapioca starch factory investigated is the KHOW CHANG EAH LIMITED PARTNERSHIP, station No. 14 (Fig. 6.4). This plant is characterized by an immense waste treatment system consisted of a series of statilization ponds some of which were unnecessarily designed. Root wash wastewater and separator wastewater are conducted in two separate streams channelling to a series of holding ponds as indicated in Fig. 6.5, and finally combined in one channel (Fig. 6.6) to be further treated in statilization ponds. The arrangement of ponds and sampling points is

Table 6.2 - Characteristics of Tapioca Starch Wastewater

Station No.	Location	Time	BOD_5	COD	Chloride	DO	SS	Total N	Total P	pH	Air Temp °C	Water Temp °C	Remarks
11-1	CHO CHAIWAT (1st grade)	17:45	1300	2,530	10.0	0	2332	23.1	3.3	4.7	26	28	Root wash wastewater
11-2		17:55	2100	4,193	25.0	0	3235	0.5	5.4	3.6	26	28	Separator wastewater
11-3		18:30	1680	3,520	125.0	0	2760	0.9	2.8	5.5	26	28	Combined wastewater (50:50)
11-4		18:15	3000	5,364	10.0	0	2442	3.6	10.4	4.3	24	29	Combined wastewater after
11-5	(Jet extraction wastewater)	18:35	2000	5,035	10.0	0	3000	2.5	3.9	5.0	26	27	discharged into the field
14-1	KOH CHANG EAH (1st grade)	10:40	3500	6,151	-	0	2462	96.4	13.3	5.5	33	27	Root wash wastewater
14-2		10:50	7800	12,688	-	0	1978	138.1	28.6	5.5	33	29	Separator wastewater
14-3		11:00	4500	8,036	25.0	0	2138	4.4	10.5	4.3	36	29	Combined wastewater
14-4	Stabilization pond	11:30	2500	3,793	-	0	648	2.7	18.1	5.1	36	28	4th pond after combined waste holding pond
14-5	Stabilization pond	11:35	2040	2,923	-	0	274	2.9	11.6	5.3	38	28	5th pond after combined waste holding pond
14-6	Stabilization pond	11:40	1065	1,822	-	0	134	.0	9.0	6.4	35	30	8th pond
14-7	Stabilization pond	12:00	420	725	-	0	229	54.6	8.8	7.3	34	30	Influent of last pond
14-7F		-	340	229	-	-	-	-	-	-	-	-	Filtrate BOD_5 and COD
14-8	Stabilization pond	11:50	400	804	-	0	162	53.7	10.9	7.2	35	30	Last pond
14-8F		-	330	502	-	-	-	-	-	-	-	-	Filtrate BOD_5 and COD
18-1	Tapioca Factory CHAROEN RO-ONG (2nd grade)	14:22	1500	3,900	10.0	3.5	1995	0.7	2.4	4.6	29	30	Root wash wastewater
18-2		14:25	8700	17,257	-	0	7175	1.8	20.0	5.4	31	27	Supernatant
19-1	Tapioca Factory TONG HENG (2nd grade)	14:57	1050	1,616	10.0	2.6	988	3.0	0.6	4.3	31	30	Root wash wastewater
19-2		15:02	2940	4,637	-	0	340	99.0	10.2	4.5	28.5	27	Supernatant
19-3		15:16	3000	4,778	-	0	313	116.3	8.6	5.2	32	33	Holding pond

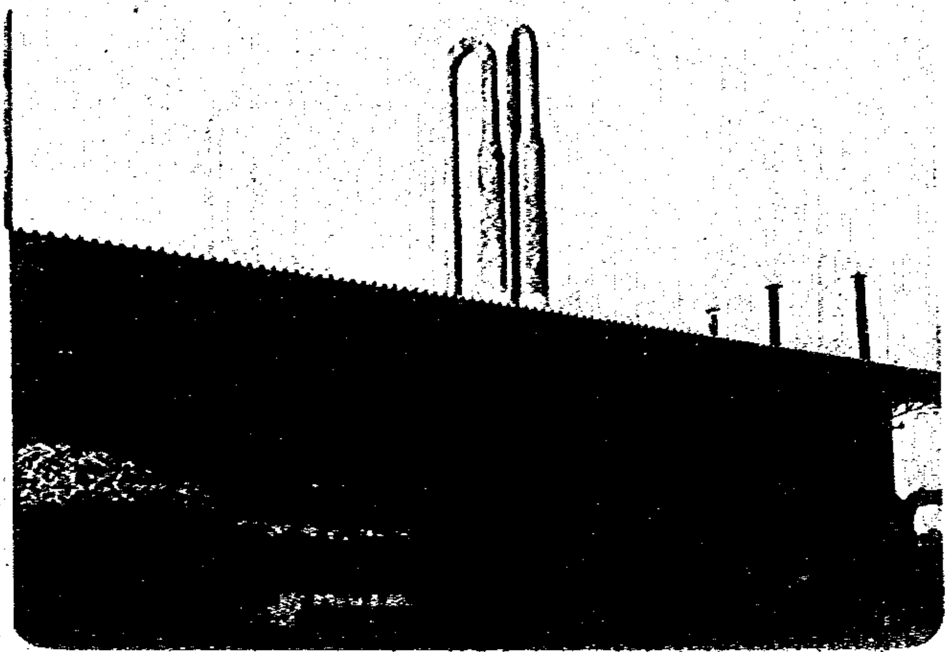

Fig. 6.2 - Cho Chaiwat (First-Grade Tapioca Mill)

Fig. 6.3 - Streams of Root Wash Wastewater (Right) and Supernatant Wastewater (Left) at CHO CHAIWAT.

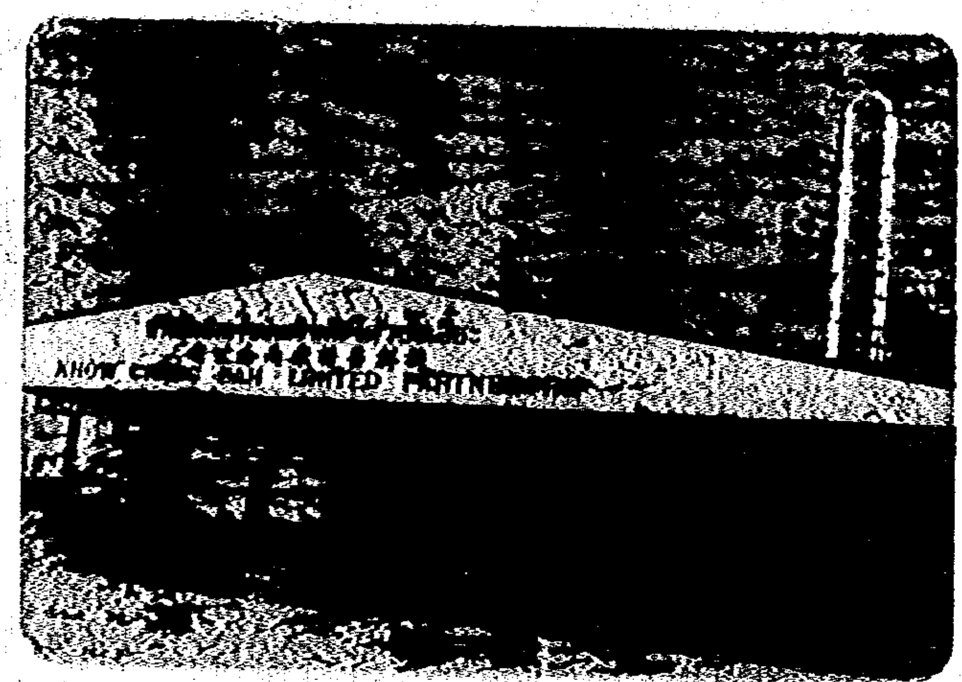

Fig. 6.4 - Khow Chang Eah - First-Grade Tapioca Starch Mill

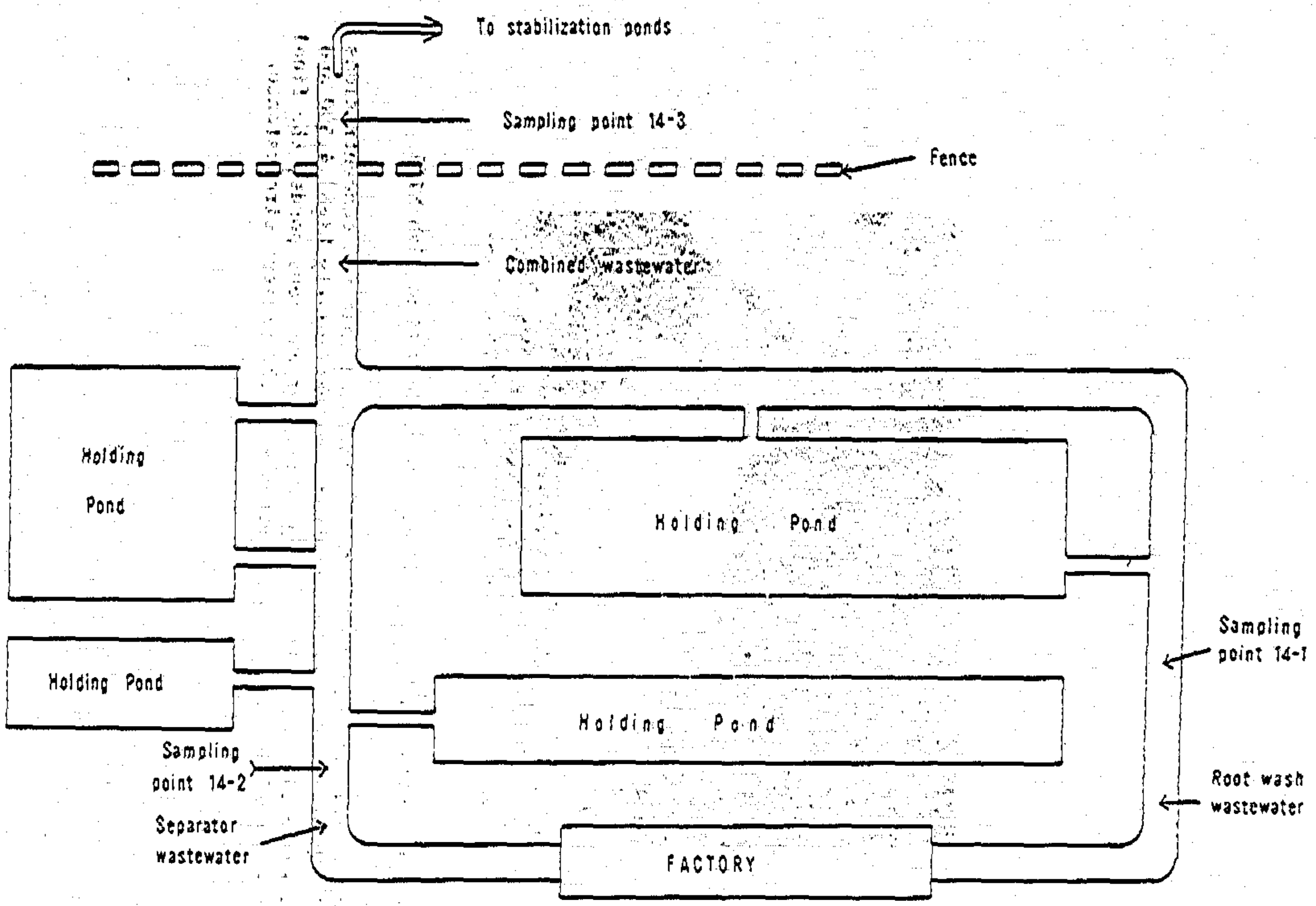

Fig. 6.5 Flow Pattern of wastewater at KHOW CHANG EAH MILL

Fig. 6.6 - Combined Wastewater Stream at Khow Chang Eah Mill

represented in Fig. 6.5, 6.7, and 6.8. It is noted that the concentrations of BOD_5 and COD of the combined wastewater are particularly high, 4,500 and 8,036 mg/l, respectively. With the concurrence of numerous ponds, the final effluent of 400 mg/l is considered acceptable in the present circumstance.

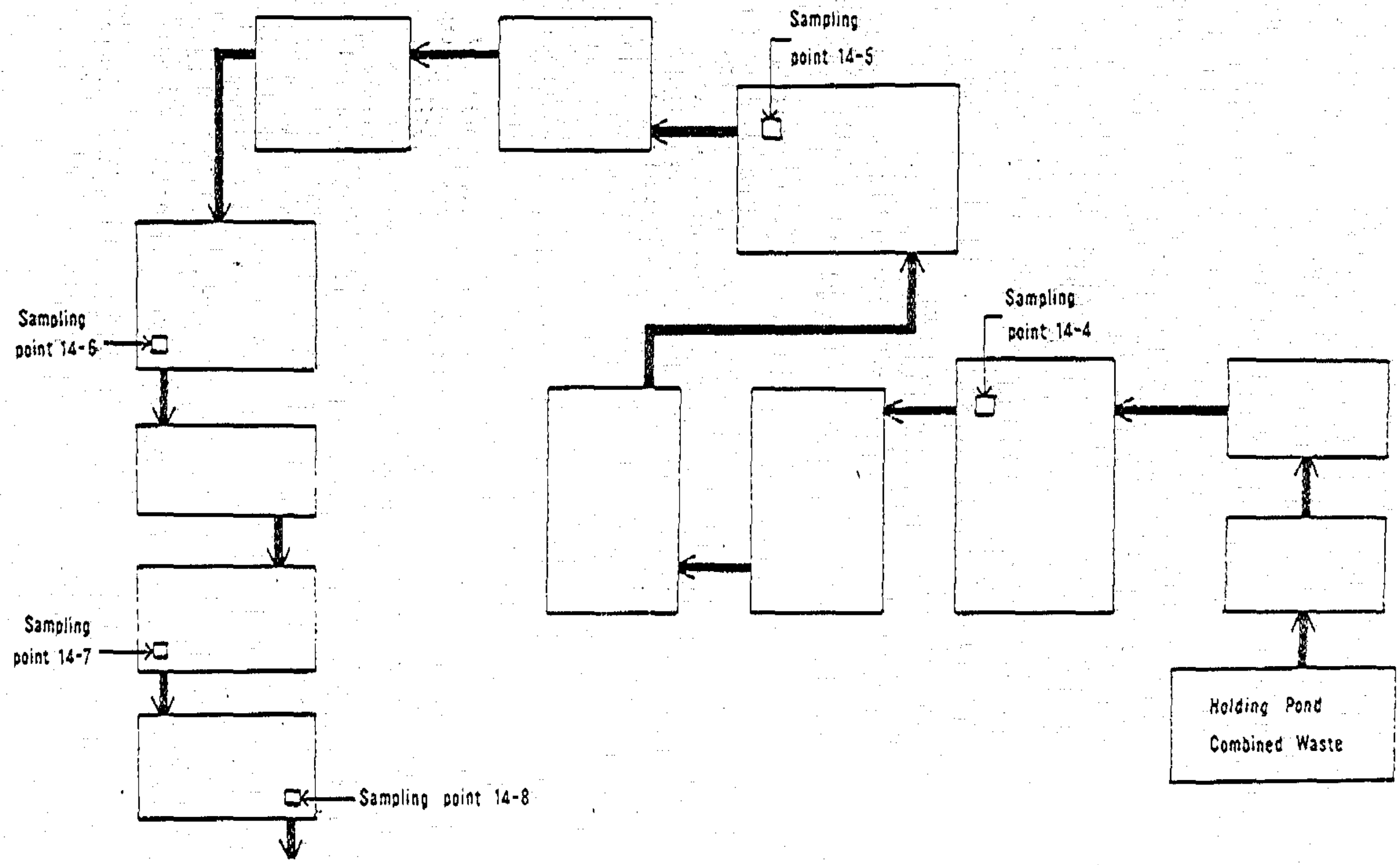

Fig. 6.7 Arrangement of Ponds at KHOW CHANG EAH MILL

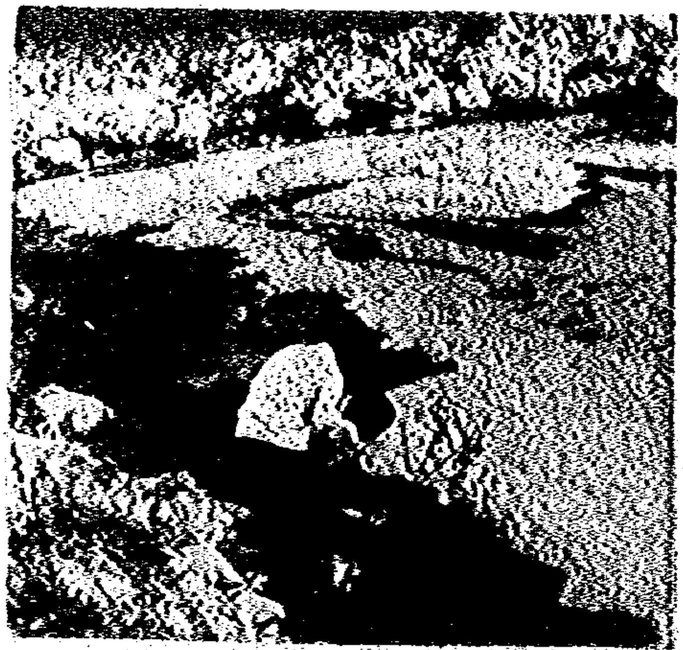

Fig. 6.8 - Final Effluent Sampling at Khow Chang Eah Mill

Both second-grade tapioca starch mills under survey, CHAROEN ROONG RUENG and TONG HENG, have batch processes. There is no wastewater treatment plant. In the case of CHAROEN ROONG RUENG, wastewater is directly discharged into the backyard field. TUNG HENG mill discharges wastewater into a large pond from which it is allowed to flow into a nearby canal. It is of common practice at second-grade tapioca starch mills to release the wastewater into the field early in the morning and to keep it in holding ponds at other times of the day.

In general, land is available at all factories visited and could be partially put aside for wastewater treatment purpose.

6. Characteristics of Tapioca Starch Wastewater - From Table 6.2 it can be seen that root wash wastewater contains a large amount of settleable solids which are mainly sand and clay particles from the raw roots. The BOD_5 and COD concentrations of the wastewater at different process points vary over a wide range. The combined waste is acidic in nature and the pH is about 4.3. This could be expected due to the addition of sulphuric and in the extraction process and also from the release of some prussic acid by the tapioca roots. The ratio of BOD_5 to COD of the combined waste, separator or supernatant and root wash wastewater are respectively 0.53-0.56, 0.48-0.6 and 0.4-0.57, indicating that the waste is biological degradable. Thanh and Wu (1975)[1/] also reported that the ratio BOD_5 to soluble COD in the settled separator waste is 0.6-0.8. The combined wastewater showed 3.6-4.4 mg/l of nitrogen and about 10.5 mg/l of phosphorous

[1/] Thanh, N.C. and Wu, J.S. (1975), Treatment of Tapioca Starch Wastewaters by Torula Yeast, Canadian Journal of Food Science Technology.

thus giving the ratio of BOD_5:N:P as 100:0.12:0.35 for CHAO CHAIWAT factory waste and 100:0.10:0.23 for KHOW CHANG EAH factory. Normally the ratio BOD:N:P of the order of 100:5:1 is considered as the minimum requirement for biological waste treatment. Therefore, additional nutrients, i.e. nitrogen and phosphorous, would be added for biological treatment. The temperature of the wastewater was found to range from 28 to 33°C, which is close to the ambient air temperature in Thailand, and this high temperature will be advantageous for biological waste treatment process. Due to the high BOD_5 and COD concentrations, it may be suggested that anaerobic biological processes would be effective.

The characteristics of tapioca starch wastewaters have also been reported by CHARIN (1965)[1/] and YOTHIN (1975)[2/] and are summarized in Table 6.3. Comparison of their results with the results in Table 6.2 shows that the BOD_5 and COD values for combined waste of first-grade factory are lightly lower than those reported by YOTHIN and CHARIN. However, the concentrations of suspended solids and pH fall within the reported ranges.

7. Recommended Approach to Treatment - Although tapioca starch is produced in two grades by two different types of processes, both first and second grade factories discharge two major wastewaters. These are washwater, from root washing (wastewater A in Figure 6.1), and separator waste, from jet extraction and channel separation in first-grade factories (wastewaters B and C in Fig. 6.1, 1st grade factory), or starch supernatant decanted from sedimentation basins in second-grade factories (wastewaters B, C, D in Fig. 6.1, 2nd grade factory).

Different factories use different amounts of water depending on plant capacity and type and on the availability of water. In general, however, second-grade factories use less water and release less wastewater than first-grade factories, 6.3 l/kg root processed compared with 7.6 l/kg (McGARRY et al., 1973)[3/], and process less root each day. Washwater makes up from 7 to 16 percentof the total combined waste flow in both types of tapioca starch plant.

In terms of quality, there is little difference between wastes from the two types of factory but there is a significant difference in quality between wastes from the different sources within a factory. Washwater usually contains easily settleable solids and much lower BOD_5 and COD levels than separator waste. Because of its lower organic strength and flow rate,

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1/ CHARIN, T. (1965), Anaerobic Treatment of Tapioca Starch Waste, M. Eng., Thesis No. 228, AIT, Bangkok.

2/ YOTHIN, U. (1975), Evaluation and Treatment of Wastes from the Tapioca Starch Industry, M. Eng., Thesis No. 836, AIT, Bangkok.

3/ McGARRY, M.G., SHUTO N., WHITAKER T. and CHAVANICH L. (1973), Coastal Water Pollution Survey of Chonburi Province Research Report, Asian Institute of Technology, Bangkok, Thailand.

Table 6.3 - Characteristics of Tapioca Starch Wastewaters (After CHARIN, 1968 and YOTHIN, 1975)

Characteristic, mg/l (except as indicated)	2nd-Grade Starch Wastewater				1st-Grade Starch Wastewater		
	Washwater		Supernatant		Plant A		Plant B
	Range	Mean	Range	Mean	Separater Waste	Washwater	Combined Wastewater
BOD_5	300 - 2,490	1,192	1,720 - 6,820	4,148	3,000 - 4,000	200 - 1,700	5,550 - 7,400
COD	613 - 6,110	2,696	4,704 - 10,010	7,584	3,100 - 13,900	2,000 - 4,850	13,300 - 19,500
Suspended Solids	290 - 4,240	1,880	470 - 1,710	855	1,480 - 8,400	400 - 6,100	1,970 - 3,850
NH_3-N	0 - 7.8	1.9	1.2 - 35.0	15.6	0 - 4.7	0 - 1.1	0
Org-N	0 - 67.2	32.1	4.3 - 109.2	68.8	19.0 - 38.9	14.5 - 18.2	86.0 - 115
Phosphorus	0 - 6.0	3.6	0 - 10.5	6.6	5.6 - 8.5	1.2 - 1.3	0
T.D.S.	32 - 6,956	2,749	3,892 - 16,392	9,388	-	-	-
pH	3 - 4.6	4.2	2.6 - 4.0	3.4	3.4 - 4.2	4.2 - 7.1	3.8 - 5.2
D.O.	0 - 4.9	2.7	0 - 2.7	1.0	0	0.6 - 5.3	0
Acidity	-	-	-	-	668 - 860	19 - 223	135 - 1,010
Settleable Solids, ml/l	-	--	-	-	60 - 200	10 - 100	48 - 115
Temperature, °C	-	-	-	-	28.5 - 33	28 - 31	30 - 31

washwater is much less a problem in treatment than separator or starch supernatant waste from a tapioca starch factory. It may, of course, be treated in combination with the separator of starch supernatant waste but normally it will be advantageous to treat them separately. If the combined factory waste is to be treated, the processes outlined herein for separator or starch supernatant waste will apply equally to the combined waste.

Root Washwater contains mainly cork cells, sand and clay particles which are derived from washing of the raw roots in the wash tank. During the dry season, when washwater BOD_5 values from a first-grade factory were found by Jesuitas (1966)[1/] to range from 200-500 mg/l, plain sedimentation was sufficient to produce an effluent suitable for reuse in root washing. However, during the wet season when the organic load of the waste increased to about 1700 mg/l BOD_5 in the same first-grade plant, Jesuitas suggested that chemical coagulation followed by sedimentation was a possible method of treatment which might produce a treated waste suitable for recycling in the process. If chemical treatment studies in any particular instance prove that an acceptable effluent cannot be produced using this treatment method, then the washwater must be treated in combination with separator waste. The same recommendations will be applicable to washwater from second-grade tapioca starch plants. Recycling of treated washwater is a desirable objective in any tapioca starch factory.

Separator Waste or Starch Supernatant, which are very similar in quality, pose the greatest problem in treatment. Plain sedimentation of these wastes can be used to remove gross suspended solids and reduce the levels of BOD_5 and COD. Settled separator or starch supernatant wastes, although high in BOD_5 and COD concentrations, are readily degradable using biological means. It is anticipated that the high BOD_5 and COD concentrations will result in anaerobic biological processes being effective. However, the effluent from anaerobic treatment will require aerobic biological treatment to produce an effluent of acceptable quality for discharge to a surface water. The need for simple low-cost treatment processes suggests that anaerobic ponds followed by facultative oxidation ponds will be appropriate for handling this waste in developing countries. Use of anaerobic ponds may eliminate the necessity for constructing primary sedimentation tanks, although the latter might well be economic if the settled solids are saleable for animal feed.

8. Primary Sedimentation - Separator wastewater from tapioca starch production contains large amounts of solids, of which over 80 percent will settle, as reported in previous works. This indicates that a large portion of the solids and significant amounts of organic matter present in the waste could be removed by primary sedimentation. Jesuitas (1966) carried out sedimentation studies on separator waste and reported that the solids in separator waste readily settle, with 91 and 96 percent of the suspended solids being deposited in 15 minutes and 1 hour respectively. Likewise after 15 minutes, considerable reductions in BOD_5 of 74 percent and in COD of 80 percent were observed. These removals were further increased to

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[1/] Jesuitas, E.P. (1966), An Investigation of Tapioca Wastes, M. Eng. Thesis No. 136, Asian Institute of Technology, Bangkok, Thailand.

83 percent for BOD_5 and 85 percent for COD after one hour of sedimentation. Insignificant additional removals of BOD_5, COD and SS resulted, when the detention time was prolonged to 2 hours under the conditions of this test. These results indicate that plain sedimentation is an essential first-grade process in treatment of this waste and will be highly efficient not only in solids removal but also in removing organic material, thereby reducing the load of an subsequent biological treatment process.

9. Biological Treatment - The effluent from primary sedimentation of tapioca starch wastewaters will still contain relatively high concentrations of BOD_5 and COD and some suspended solids. Its direct discharge to a stream would certainly give rise to pollution problems and some from of secondary treatment of the waste is necessary.

As a first-stage requirement, anaerobic ponds appear to be the best choice. These anaerobic ponds are most appropriate in view of the very high BOD_5 and COD concentrations, low costs of treatment and general availability of land.

As a second-stage requirement, several biological methods could be adopted and are mentioned below:

(i) Facultative Pond where land in large areas are available and cheap.

(ii) Aerated Lagoon where land is available to a limited degree and is costly; although not very costly.

(iii) Rotating Biological Drum Filter where land use must be minimized due to the high cost and availability.

(iv) Activated Sludge Process where limited land is available and is very costly.

Of the four appropriate technologies, the best choice for the tapioca starch industry in Thailand appears to be aerated lagoons. Survey of the industry indicates that land is relatively available, particularly to first grade mills, and is relatively inexpensive. Thus utilization of a rotating biological drum filter, which is a capital intensive treatment system, is not necessary to minimize land use. The estimated cost of activated sludge is too high. The work of Yothin (1975) compared the capital , operation and maintenance costs for a facultative oxidation pond and an aerated lagoon and found that both types of costs were greater for a facultative oxidation pond given land costs in the South of Thailand. The higher operation and maintenance costs were attributed to the monthly land rental, which accounted for 75 percent of these costs. In addition it is doubtful that ponds could achieve the same removal efficiencies as aerated lagoons. Thus utilization of an aerated lagoon rather than a facultative oxidation pond as the second stage requirement is preferable on the basis of cost minimization.

Removal Efficiencies

The recommended biological methods are capable of reducing the physical, chemical and biological parameters of tapioca starch wastes. Some of the more significant parameters affected are: BOD_5, COD, SS, pH.

In order to simplify this presentation, the removal efficiencies associated only with BOD and SS are given in Table 6.4. The removal efficiency of the first stage for BOD is 60 percent, which gives an effluent discharge from first grade plant of 1800 mg/l and from a second grade plant of 1400 mg/l. The removal efficiency of the second stage for BOD is 85 percent, which gives an effluent discharge from a first grade plant of 270 mg/l and from a second grade plant of 210 mg/l. The total removal efficiency is 94 percent. The removal efficiency of the first stage of SS is 82 percent, which gives an effluent discharge from a first grade plant of 360 mg/l and from a second grade plant of 180 mg/l. There is no additional removal of SS for the second stage. Thus, the total removal efficiency is 82 percent.

Table 6.4 - Raw Waste Load (RWL) Removal Efficiencies and Effluent Concentrations.

Type of mill	RWL	First Stage % Removal	Effluent Concentration from 1st-stage treatment	Second Stage % Removal	Final Effluent Concentration	Total % Removal
	(mg/l)	BOD_5	BOD_5 (mg/l)		BOD_5 (mg/l)	
First Grade	4,500	60	1,800	85	270	94
Second Grade	3,500	60	1,400	85	210	94
			SS			
First Grade	2,000	82	360	0	360	82
Second Grade	1,000	82	80	0	180	82

Source : Yothin (1975)

10. Economics of Pollution Control - Table 6.5, 6.6, and 6.7 summarize the cost for representative plants reported by Luken (1976)[1/] based on the cost of operations obtained from the industry survey and past works. Table 6.8 presents the annual treatment costs for the first-stage and second-stage treatments requirements which clearly show the economics of scale available to larger plants for the same type of treatment facilities.

It should be realized that treatment costs vary from plant to plant, from operation to operation, from one location to another. Nevertheless the costs data presented here should give sufficient informations for preliminary planning.

1/ Luken, R.A. (1976), Economic Analysis of Alternative Effluent Guidelines Report for NEB, Thailand.

Table 6.5 - Current Costs for Representative Plants

Segment	Land m^2	Cost of Land ฿	Excavation ฿	Operation ฿ / mo	Electricity ฿ / mo	Chemicals ฿ / mo
First Grade 60 T/day	136,000	467,000	400,000	800	none	none
Second Grade 8.4 T/day	3,200	30,000	70,000	none	none	none
Second Grade 2 T/day	1,600	15,000	none	none	none	none

Source : Field Investigations, April 1976 (Luken, 1976)

Table 6.6 - Summary of First Stage Costs Per Representative Plant

Segment	Land m^2	Cost of Land ฿	Excavation ฿	Operation ฿ / mo	Electricity ฿ / mo	Chemicals ฿ / mo
First Grade 60 T/day	3,800	13,000	125,000	800	-	-
Second Grade 8.4 T/day	530	5,000	17,500	400	-	-
Second Grade 2 T/day	152	1,500	4,200	200	-	-

Source : Yothin (1975)

Table 6.7 - Summary of Second Stage Costs (Incremental) Per Representative Plant

Segment	Land m	Cost of Land ฿	Excavation ฿	Aerators ฿	Concrete ฿	Operation ฿ / mo	Elec-tricity ฿ / mo	Chemical ฿ / mo
First Grade 60 T/day	3,800	13,000	84,000	600,000	50,000	800	25,000	27,000
Second Grade 8.4 T/day	530	5,000	12,000	110,000	20,000	800	2,700	2,800
Second Grade 2 T/day	152	1,500	3,400	50,000	10,000	800	900	880

Source : Yothin (1975)

Table 6.8 - Annual Treatment Costs Per Representative Plants

Segment	Annual Production Starch	Potential Incremental Pollution Control ฿ / ton		Incremental Pollution Control Cost As percent of Year End 1975 Starch Price	
		1977	1979	1977	1979
First Grade 60 T/day	18,000 T	2	40	<1 %	1.5 %
Second Grade 8.4 T/day	2,250 T	3	42	<1	1.7
Second Grade 2 T/day	600 T	5	66	<1	2.8

Includes capital recovery and operation and maintenance costs. Assumes no pollution control facilities are in place. Assumes a 20 year life of facilities, 12 % interest rate and 12 month operation.