CHAPTER IV

EXPERIMENTAL INVESTIGATION

4.1 Experimental Apparatus

A complete set of laboratory-scale contact stabilization unit which received from INSA - TOULOUSE, FRANCE was installed at Department of Sanitary Engineering, Faculty of Engineering, Chulalongkorn University and used for this study.

This set consists of contact tank, stabilization tank, sedimentation tank with sludge scraper, feeding pump, recycle pump, air compressor, refrigeration tank, thermostat control system and electrical control board. The details of these equipments are as following:

- Contact and stabilization tank are made of plexiglass, double walls for temperature control by thermostat control system without disturbing the aeration of both tanks. The contact tank has inside diameter of 10 cm, height 120 cm, maximum volume 9.4 ℓ and stabilization tank of 15 cm inside diameter, 120 cm height with maximum volume of 21.2 ℓ. A smaller contact tank of 7.5 cm inside diameter, height 90 cm, maximum volume 3.9 ℓ is constructed in order to use when the lower contact time values are investigated.
- Sedimentation tank has 6 ℓ in volume, hopper bottom and incorporated with mechanical sludge scraper of 1 rpm speed.
- Feeding and recycle pump are peristaltic type.

- Constant temperature tank is designed to recirculate the controlled temperature water around the outer layer of contact and stabilization tank.

- Air compressor generates the compressed air using for the contact and stabilization tank. The air flows through each flowmeters before passing through the porous PVC plates at the bottom of both tanks which allow the air bubble to mix the MLSS in suspension.

- Refrigeration tank is of ALFA-LAVA, capacity 200 ℓ, refrigerating temperature $4^{\circ}C \pm 2^{\circ}C$ and incorporated with continuous agitator.

- Electrical control board is provided to operate the equipment units.

The schematic diagram and general point of view of laboratory-scale contact stabilization unit are illustrated in Fig. 4.1 and Fig. 4.2 respectively.

4.2 Experimental Schedule

In this research work, the sludge age was utilized as the main parameter to control the system. The system was operated in four values of sludge age; 20, 10, 5 and 2 days respectively. During each periods of sludge age, the total biomass of the system was calculated and the volume of sludge wastage from the system (included with the samples for laboratory analysis) was determined. The influent flow rate and recycle ratio were kept constant of 36 ℓ/day and 100% respectively through out the study.

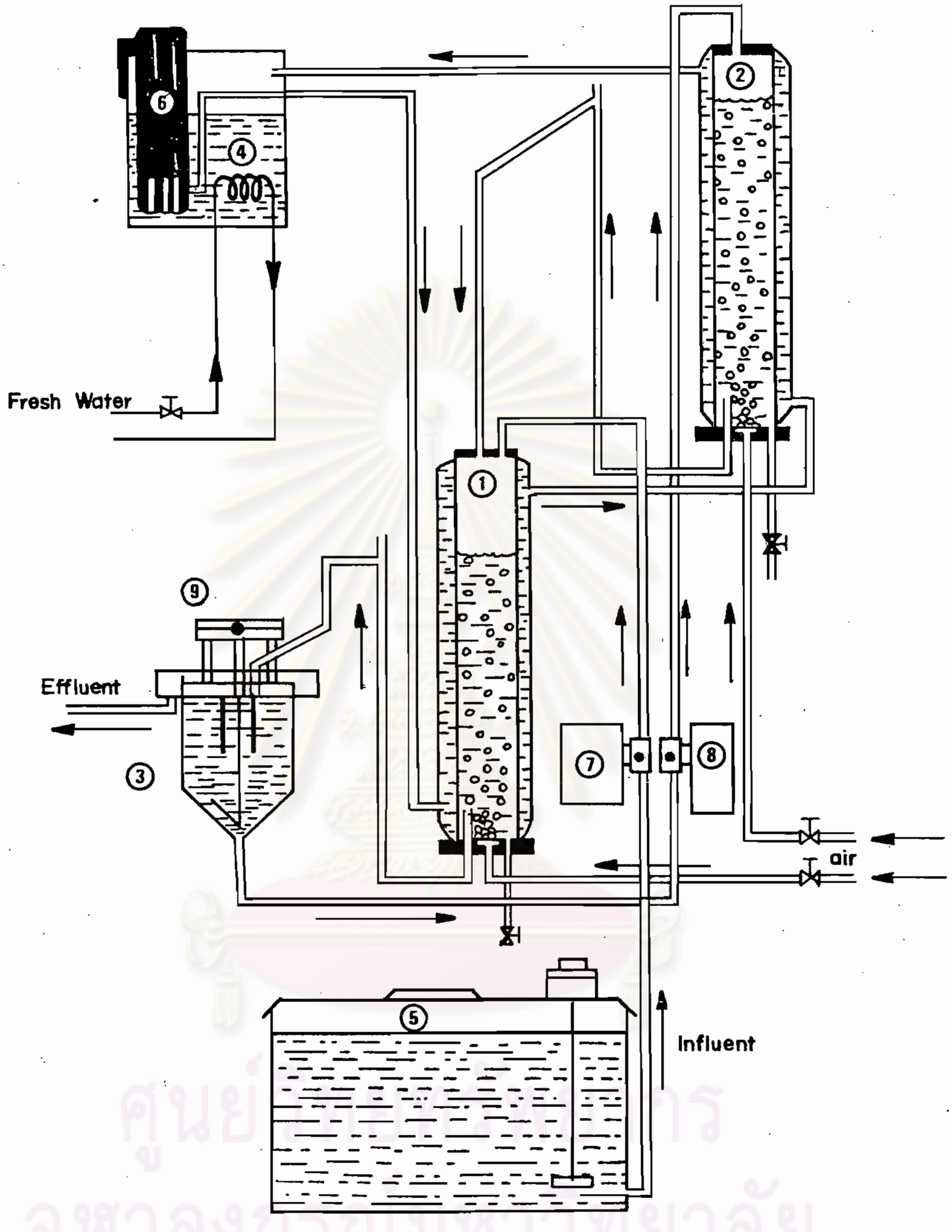

Fig. 4.1 - Schematic Diagram of the Laboratory-Scale Contact Stabilization Unit.

1. Contact tank
2. Stabilization tank
3. Sedimentation tank
4. Constant temperature tank
5. Refrigeration tank
6. Recirculating pump
7. Peristaltic feeding pump
8. Peristaltic recycle pump
9. Sludge scraper

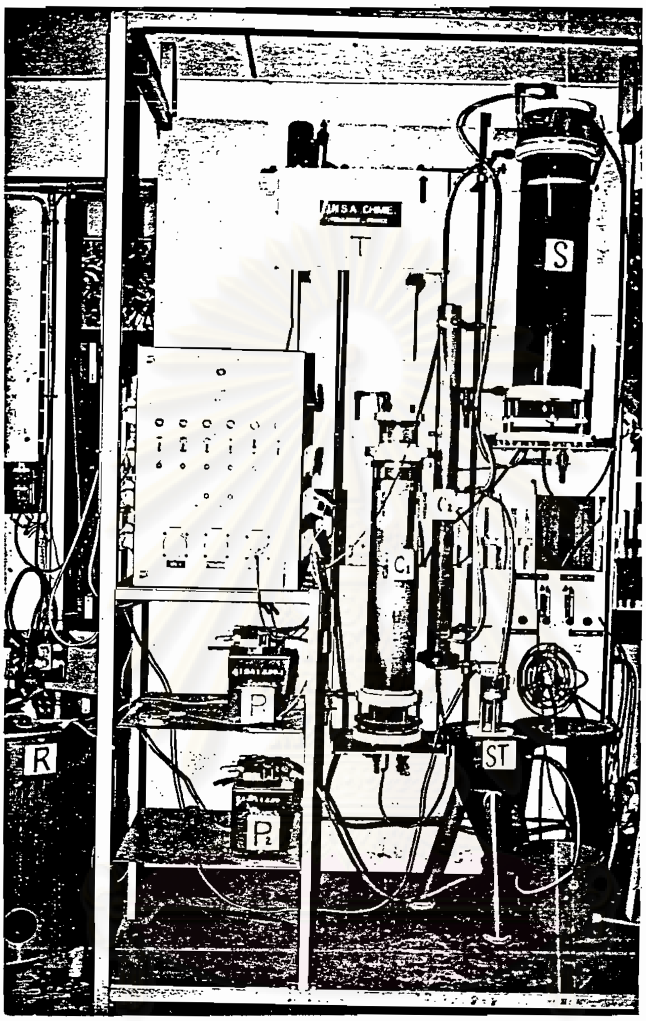

Fig. 4.2 - General Point of View of the Laboratory-Scale Contact Stabilization Unit

C_1 = Contact tank (No. I)

C_2 = Contact tank (No. II)

E = Electrical control board

P_1 = Peristaltic feeding pump

P_2 = Peristaltic recycle pump

S = Stabilization tank

ST = Sedimentation tank (with scraper)

T = Constant temperature tank

R = Refrigeration tank

At sludge age 20 days, the system was operated in two conditions; nutrient controlled condition (N) and both of nutrient and trace element controlled condition (N+T). The contact tank volume varied from 6 ℓ to 3 ℓ, 1.5 ℓ, 0.75 ℓ and 0.375 ℓ which corresponding to the contact time 4 hr, 2 hr, 1 hr, 30 min and 15 min respectively. Stabilization tank volume kept at 12 ℓ and 15 ℓ which corresponding to stabilization time 8 hr and 10 hr respectively. The sedimentation tank volume was normally kept constant at 6 ℓ through out the study.

At sludge age 10 days, the system was also operated in two conditions and the same variation of contact time as in sludge age 20 days. We spent one run to study the process performance at contact time approached zero.

At sludge age 5 days and 2 days, the system was studied only in nutrient and trace element controlled condition. The stabilization tank volume was kept constant at 15 ℓ or stabilization time 10 hrs through out sludge age 10, 5 and 2 days. The temperature of the system was controlled at $29.5 \pm 2.5^{\circ}C$

Each experimental schedule for corresponding sludge age is summarized in Table 4.1, Table 4.2, Table 4.3 and Table 4.4.

Through out the research, 49 sets of experimental were carried out. There were 17, 16, 9 and 7 sets of experimental for sludge age 20, 10, 5 and 2 days respectively. Table 4.1, 4.2, 4.3 and 4.4 showed the running number with respected to serial manipulation which varied according to the varying of contact time.

Table 4.1 - Experimental Schedule at Sludge Age 20 Days

θ_c = 20 days, R = 100 %, Q_i = 36 ℓ/day						
RUN No.	CONTACT			STABILIZATION		COND.
	V_C (ℓ)	t_C (hr)	t_{CR} (hr)	V_S (ℓ)	t_S (hr)	
1-1	6	4	2	12	8	N
1-2	6	4	2	12	8	N
1-3	6	4	2	12	8	N
2-1	3	2	1	12	8	N
2-2	3	2	1	12	8	N
3-1	3	2	1	15	10	N
3-2	3	2	1	15	10	N
4-1	6	4	2	15	10	N+T
4-2	6	4	2	15	10	N+T
5-1	3	2	1	15	10	N+T
5-2	3	2	1	15	10	N+T
6-1	1.5	1	30*	15	10	N+T
6-2	1.5	1	30*	15	10	N+T
6-3	1.5	1	30*	15	10	N+T
6-4	1.5	1	30*	15	10	N+T
7-1	0.75	30*	15*	15	10	N+T
8-1	0.375	15*	7.5*	15	10	N+T

* : Values in minutes

N : Nutrient controlled condition

N+T : Nutrient and trace element controlled condition

Table 4.2 - Experimental Schedule at Sludge Age 10 Days

θ_c = 10 days, R = 100 %, Q_i = 36 ℓ/day						
RUN No.	CONTACT			STABILIZATION		COND.
	V_C (ℓ)	t_C (hr)	t_{CR} (hr)	V_S (ℓ)	t_S (hr)	
9-1	6	4	2	15	10	N
9-2	6	4	2	15	10	N
9-3	6	4	2	15	10	N
9-4	6	4	2	15	10	N
9-5	6	4	2	15	10	N
9-6	6	4	2	15	10	N
9-7	6	4	2	15	10	N+T
9-8	6	4	2	15	10	N+T
10-1	3	2	1	15	10	N+T
10-2	3	2	1	15	10	N+T
11-1	1.5	1	30*	15	10	N+T
11-2	1.5	1	30*	15	10	N+T
12-1	0.75	30*	15*	15	10	N+T
12-2	0.75	30*	15*	15	10	N+T
13-1	0.375	15*	7.5*	15	10	N+T
14-1	0	0	0	15	10	N+T

* : Values in minutes

N : Nutrient controlled condition

N+T : Nutrient and trace element controlled condition

Table 4.3 - Experimental Schedule at Sludge Age 5 DAys

θ_c = 5 days, R = 100 %, Q_i = 36 ℓ/day						
RUN No.	CONTACT			STABILIZATION		COND.
	V_C (ℓ)	t_C (hr)	t_{CR}(hr)	V_S (ℓ)	t_S(hr)	
15-1	6	4	2	15	10	N+T
15-2	6	4	2	15	10	N+T
16-1	3	2	1	15	10	N+T
16-2	3	2	1	15	10	N+T
17-1	1.5	1	30*	15	10	N+T
17-2	1.5	1	30*	15	10	N+T
18-1	0.75	30*	15*	15	10	N+T
18-2	0.75	30*	15*	15	10	N+T
19-1	0.375	15*	7.5*	15	10	N+T

Table 4.4 - Experimental Schedule at Sludge Age 5 Days

θ_c = 2 days, R = 100 %, Q_i = 36 ℓ/day						
RUN No.	CONTACT			STABILIZATION		COND.
	V_C (ℓ)	t_C(hr)	t_{CR} (hr)	V_S (ℓ)	t_S (hr)	
20-1	6	4	2	15	10	N+T
20-2	6	4	2	15	10	N+T
20-3	6	4	2	15	10	N+T
21-1	3	2	1	15	10	N+T
21-2	3	2	1	15	10	N+T
22-1	1.5	1	30*	15	10	N+T
22-2	1.5	1	30*	15	10	N+T

The data were collected at the steady state condition for each serial manipulations which was greater than one week. The samples were picked up from the influent, contact tank, stabilization tank and sedimentation tank. These samples were immediately analysed in the laboratory analysis for various characteristics of pH, SS, VSS, COD, BOD, TKN, NH_3-N, NO_2^--N, NO_3^--N and $PO_4^{\equiv}$-P. The sludge volume index (SVI) and microscopic observation were also determined. The dissolved oxygen concentration in the system was scarcely measured.

4.3 Wastewater Used in the Study

During the start-up period of the contact stabilization laboratory apparatus, the diluted tapioca starch raw wastewater was used to build up the biomass in the system. The characteristics of tapioca raw wastewater are illustrated in Table 4.5 and 4.6. The treatment of tapioca raw wastewater was firstly studied for 69 days.

After that the partial degradable wastewater from waste stabilization ponds of Khow Chang Eah Tapioca Starch Factory (shown in Fig. 4.3) was used through out the study for the period of 331 days. Table 4.7 showed the characteristics of the wastewater and Fig. 4.4 showed the BOD_5 and SS removal in each ponds. Based on Fig. 4.4, the samples were picked up from the waste stabilization ponds at required influent COD concentration nearly 1,000 mg/ℓ. However, the characteristics of wastewater in the stabilization ponds changed during each times we picked up. Therefore the tap water was normally used to dilute the wastewater to about 1,000 mg/ℓ COD before filling in the refrigeration storage tank. At this concentration of the wastewater the COD:N:P ratio was greater than 150:5:1.

Table 4.5 - First Grade Tapioca Wastewater Characteristics

Item	Unit	Raw Wastewater		After 2-hr Settle	
		Separator	Root Washer	Separator	Root Washer
Temperature	°C	28-29.5	27-29.5	-	-
pH	-	5-6	6-6.5	-	-
Suspended Solids	mg/ℓ	1,110-2,060	1,270-7,280	985-1,250	380-420
VSS	mg/ℓ	1,010-1,990	980-6,040	970-1,200	360-370
Total Solids	mg/ℓ	5,540-7,940	1,770-8,850	4,105-6,960	4,105-6,965
TVS	mg/ℓ	4,850-7,020	1,270-7,110	3,810-5,800	1,106-1,440
Settleable Solids	ml/ℓ	15-90	19-50	0	0
Volatile Acid	mg/ℓ as Hac	265-1,080	255-500	290-960	225-430
COD	mg/ℓ	7,460-13,250	2,700-12,780	6,900-10,000	1,970-2,200
BOD	mg/ℓ	4,800-11,660	1,600-3,750	4,630-7,500	1,550-1,100
TKN	mg/ℓ	118-154	40-50	101-103	18-39
Ammonia - N	mg/ℓ	17-29	8-10	11-32	2-10
Organic - N	mg/ℓ	101-125	32-40	71-90	16-29
Phosphate - P	mg/ℓ	8-31	6-24	8-31	4-6

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Table 4.6 - Second Grade Tapioca Wastewater Characteristics

Item	Unit	Raw Waste			After 2 hr Settle
		1st-Sed. Tank	2nd-Sed. Tank	Root Washer	Root Washer
Temperature	°C	26.5-28	26.5-28	28-31	-
pH	-	5.5-6	4-6	6-6.5	-
Suspended Solids	mg/ℓ	540-710	47-316	3,960-6,050	340-350
VSS	mg/ℓ	496-696	41-266	3,080-3,365	247-334
Total Solids	mg/ℓ	6,700-12,220	2,650-6,535	7,640-26,850	1,440-2,260
TVS	mg/ℓ	4,790-9,940	2,150-4,910	2,050-4,550	900-1,800
Settleable Solids	ml/ℓ	0	0	-	-
Volatile Acid	mg/ℓ as Hac	1,475-2,800	770-1,300	315-500	300-490
COD	mg/ℓ	7,980-14,635	3,875-4,155	7,600-16,200	1,575-2,720
BOD	mg/ℓ	6,200-11,250	2,600-3,710	2,600-3,330	900-1,600
TKN	mg/ℓ	86-165	33-53	58-67	16-27
Ammonia - N	mg/ℓ	11-20	9-12	6-10	2-5
Organic - N	mg/ℓ	75-145	24-41	52-57	14-22
Phosphate - P	mg/ℓ	14-28	7-10	5-10	3-11

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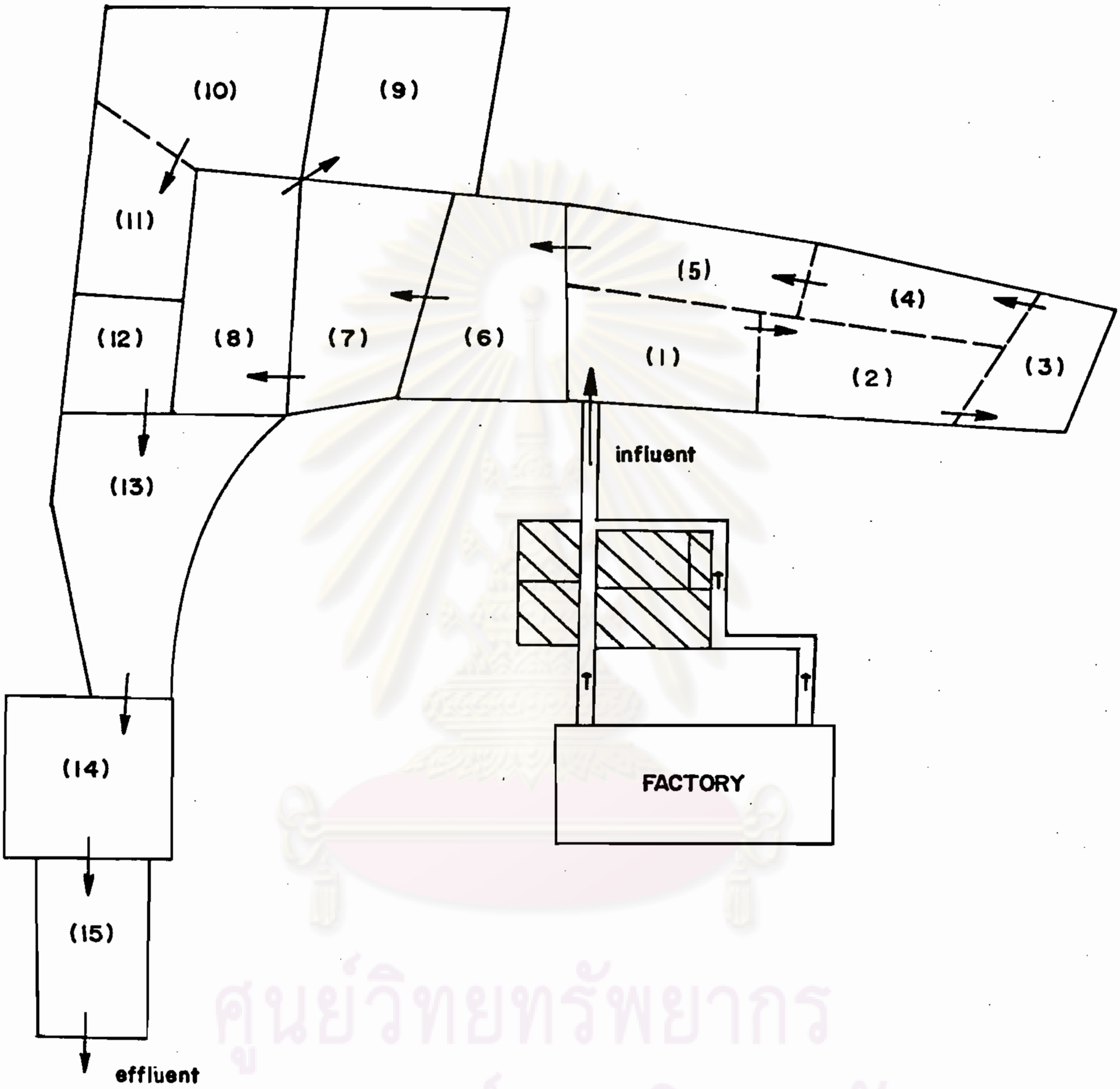


Fig. 4.3 Waste Stabilization Ponds of Khow Chang Eah Tapioca Starch Factory

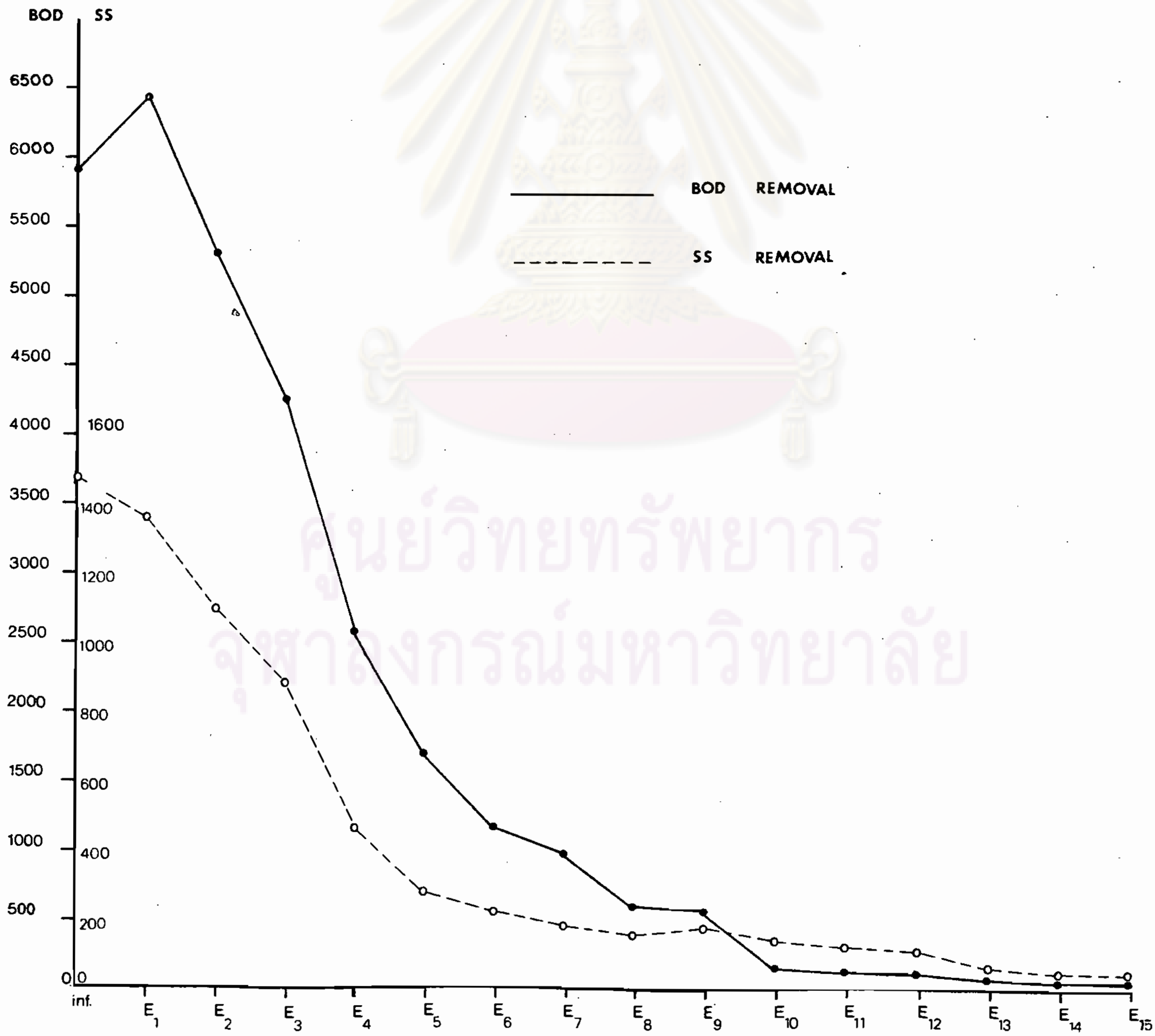
Table 4.7 - Characteristics of Wastewater in Waste Stabilization Ponds of Khow Chang Eah Tapioca Starch Factory*

	2 MAR.78			30 MAR.78			11 APR.78			26 APR.78			10 MAY.78			29 JUN.78			12 JUL.78			27 JUL.78			10 AUG.78			AVERAGE			** area
	BOD	PH	SS	BOD	PH	SS	BOD	PH	SS	BOD	PH	SS	BOD	PH	SS	BOD	PH	SS	BOD	PH	SS	BOD	PH	SS	BOD	PH	SS	BOD	PH	SS	
Inf.	5892	4.7	1300	7559	4.9	2100	6616	4.5	1750	4891	4.6	4060	6498	4.6	1528	7704	4.9	2100	3210	5.6	530	2447	4.8	360	4900	5.4	1945	5908	4.9	1471	m^2
E_1	7342	4.6	1086	4915	4.6	2900	6218	4.5	1325	6238	4.5	1620	7785	4.6	1200	9309	4.8	1857	6206	4.6	867	3781	5.2	520	6541	4.6	900	6482	4.7	1364	1247
E_2	2872	4.7	570	4756	4.7	2000	5958	4.6	666	5045	4.6	1140	5274	4.7	675	5735	4.8	1240	6848	4.9	1560	5323	4.9	1100	5860	4.8	857	5297	4.7	1090	1131
E_3	4792	4.9	614	3278	4.9	1466	5324	5.0	640	4082	4.7	616	4177	4.9	640	4222	4.8	553	4334	5.0	1292	4150	5.2	1127	3940	5.0	984	4255	4.9	881	3616
E_4	1504	5.0	500	2604	6.1	488	3697	5.9	380	1779	5.3	510	2820	5.2	556	2639	4.9	422	3959	4.9	490	2010	6.2	356	2133	5.7	466	2572	5.5	463	2750
E_5	2748	5.3	420	1721	7.1	440	1115	6.8	125	825	6.6	245	879	6.7	160	2173	5.0	354	3237	5.0	418	1406	6.5	110	1100	6.4	217	1689	6.2	277	3213
E_6	766	6.5	433	746	7.3	250	950	7.8	110	556	6.9	200	696	7.0	81	1270	5.2	307	2981	5.0	204	1688	6.0	117	665	6.7	252	1146	6.5	217	3225
E_7	1036	7.1	137	453	7.8	200	798	7.4	80	229	7.2	40	320	7.3	16	923	5.3	250	2020	5.1	200	2064	6.0	165	733	70	213	953	6.7	178	4342
E_8	277	7.3	96	140	8.2	170	272	7.8	210	110	7.4	150	153	7.8	164	756	6.7	175	1598	5.3	160	1369	6.0	183	720	71	115	599	7.1	158	3750
E_9	234	7.5	64	118	8.2	160	159	8.3	200	59	7.8	156	64	8.1	154	250	7.2	230	774	6.0	196	745	7.0	200	414	74	142	564	7.5	167	7267
E_{10}	160	7.7	72	97	8.3	120	90	8.3	125	64	8.0	108	48	8.1	120	120	8.2	113	350	7.0	220	477	7.2	153	262	7.5	180	185	7.8	135	7150
E_{11}	149	7.9	100	91	8.2	96	82	8.3	60	60	8.1	80	52	8.3	80	84	8.3	54	229	7.3	188	216	7.5	314	143	7.7	100	121	8.0	117	3750
E_{12}	81	7.8	78	93	8.3	98	73	8.2	44	64	8.3	48	42	8.4	53	53	8.6	54	184	7.9	220	153	7.6	172	118	7.8	163	96	8.1	103	14300
E_{13}	46	8.1	70	89	8.7	23	79	8.5	28	59	8.7	30	55	8.7	30	30	8.9	38	101	8.7	122	73	8.0	103	47	7.9	180	64	8.4	56	10600
E_{14}	47	8.2	184	77	8.8	10	72	8.8	24	60	8.9	26	38	9.0	50	49	9.2	70	34	8.7	43	99	8.0	72	40	8.2	153	57	8.6	43	5607
E_{15}	20	8.7	64	133	9.2	22	72	9.1	20	56	9.1	26	31	9.2	30	79	9.5	136	82	93	55	–	9.3	72	48	86	125	55	9.1	42	3150

* From Industrial Environmental Division Department of Industrial Works.

** Approximate net Area.

Fig. 4.4 BOD_5 and SS Removal in Waste Stabilization Ponds of Khow Chang Eah Tapioca Starch Factory



The system was operated into two conditions; nutrient controlled condition (N) and both of nutrient and trace element controlled condition (N+T). The "N" condition expressed the wastewater from the stabilization ponds (partial degradable) which had adequate nitrogen and phosphorus. Therefore the two main nutrients of nitrogen and phosphorus were not added. The "N+T" condition expressed the condition that all the trace elements showed in Table 4.8 were added into the influent wastewater used throughout this period.

Table 4.8 - Trace Elements Employed in the System

Trace Elements in Solution	Concentration (gm/ℓ[1])	Feeding (mℓ/ℓ[2])	Approximate Equivalent Ratio (mg/1,000-mg COD)
$MgSO_4.7H_2O$	22.50	1	22.5
$CaCl_2$	27.50	1	27.5
$FeCl_3.6H_2O$	0.25	1	0.25
KH_2PO_4	25.00	1	25.0

(1) of preparing solution

(2) of influent wastewater

The characteristics of influent wastewater of the system were shown in Chapter 5 and in Table A-1 to A-9.

4.4 Laboratory Analytical Techniques

The laboratory analytical techniques utilized in this research were summarized as following:

pH : by pH-meter, BECKMAN, ZEROMATIC IV.

SS : according to STANDARD METHODS, utilized the GF/C glass fibre paper, WATTMAN.

VSS : according to STANDARD METHODS.

COD : according to STANDARD METHODS.

BOD_5 : according to STANDARD METHODS.

TKN : by Kjeldahl Method, according to STANDARD METHODS.

NH_3-N : by distillation, according to STANDARD METHODS.

NO_2-N : by colour development according to Zambelli Method.

NO_3-N : by Phenoldisulphonic Acid Method, according to STANDARD METHODS.

PO_4-P : by Vanadomolybdophosphoric Acid Colorimetric Method, according to STANDARD METHODS.

DO : by temperature & DO-meter, DELTA SCIENTIFIC, ENVIRON-TECH, model 1010.

SVI : by sampling the MLSS in contact tank, let it settled 30 min in 100 mℓ graduated cylinder then the volume occuplied in 1,000 mℓ was calculated, the MLSS concentration known and the SVI value could be finally calculated.

Microscopic Observation : by binoxcular microscope, SEITZ WETZLAR HM-LUX.

Others Apparatus:

- Centrifugal Apparatus, DYNAC^{TM}-CENTRIFUGE BECTON CLAY ADAMS No. 211466

- Vacuum Pump, CENTRAL SCIENTIFIC CO.
- Hot air oven, CENTRAL SCIENTIFIC CO.
- Muffle furnace, GALENKAMP - HOTSPOT
- Spectrophotometers

  LANGE SPEKTRAL PHOTOMETER-LP_4 for NO_2-N and NO_3-N determination.

  FISHER ELECTROPHOTOMETER-II for PO_4-P determination
- Incubator $20^{o}C$, GENERAL ELECTRIC
- Refrigerator $4^{o}C$, WESTINGHOUSE
- Stirrer plate, THERMOLYNE
- Balance, METTLER - H31