CHAPTER V

EXPERIMENTAL RESULTS AND DISCUSSIONS

5.1 Introduction

At the beginning of the research, a laboratory scale contact stabilization process was started up with the diluted tapioca wastewater. The treatment of diluted raw wastewater was firstly studied at a period of 69 days. During this period, the process efficiency was normally more than 85%, under the nutrient controlled condition. However, the problem of sludge bulking due to filamentous microorganism was encountered throughout this period of nutrient controlled condition.

The following results, the partial degradable of tapioca wastewater from waste stabilization ponds was used as feeding substrate to the laboratory scale contact stabilization unit throughout the study. The results of 9 sets from 49 sets of experimental test-run were out off considered (for various kinetic coefficient determination) due to the fluctuation of the influent COD and/or the failure of power supply. These are No. 1-1, 3-2, 4-2, 6-1, 6-2, 14-1, 16-1, 20-2 and 22-2.

The process performance the kinetic coefficients determination are presented and discussed in the following paragraphs.

5.2 Process Performance

5.2.1 Variation of pH

Fig. 5.1 shows the average pH of the influent, contact and stabilization tanks at various sludge ages. Fig. 5.2, 5.3,

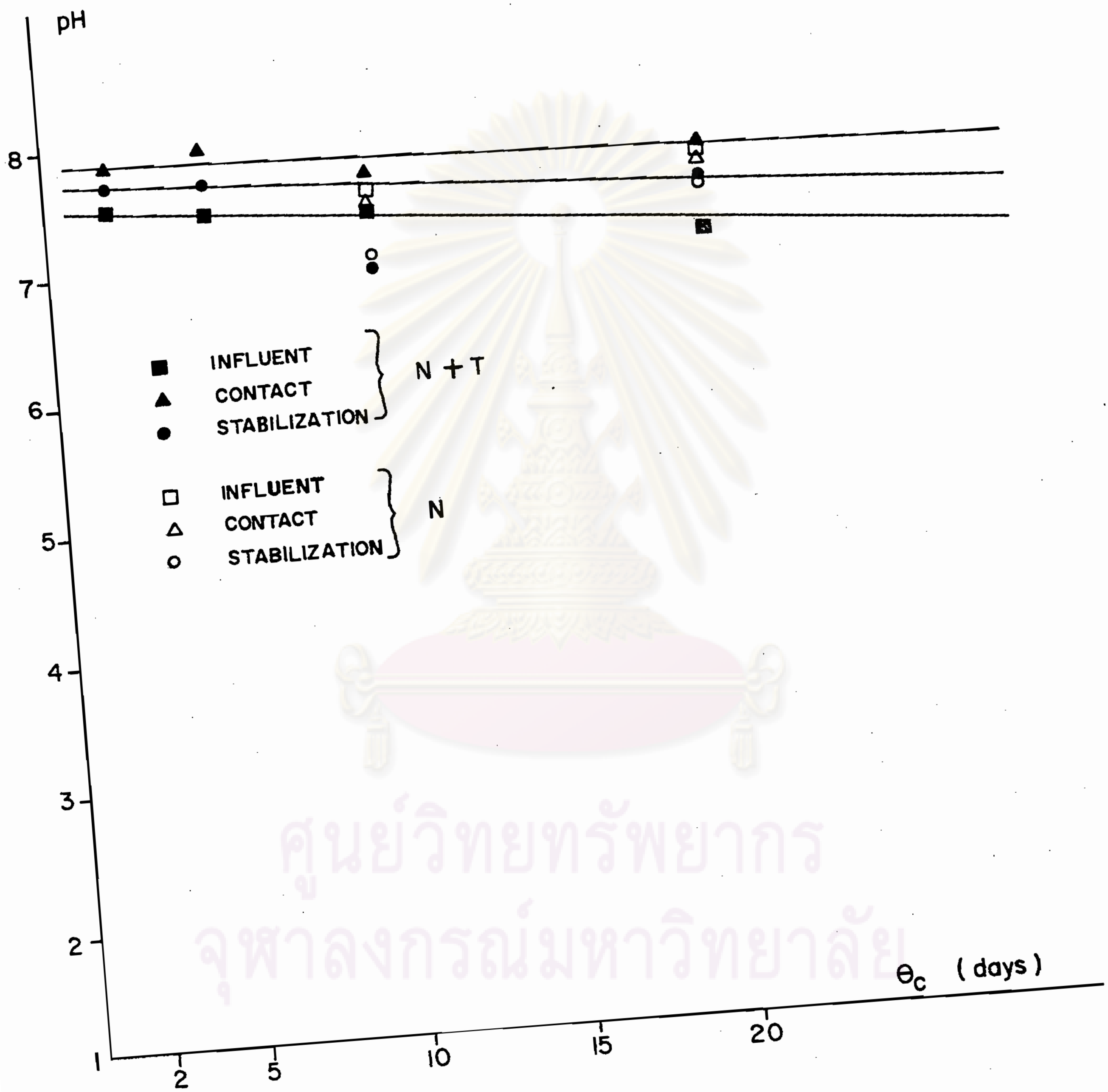


Fig. 5.1 Average pH at Various Sludge Ages

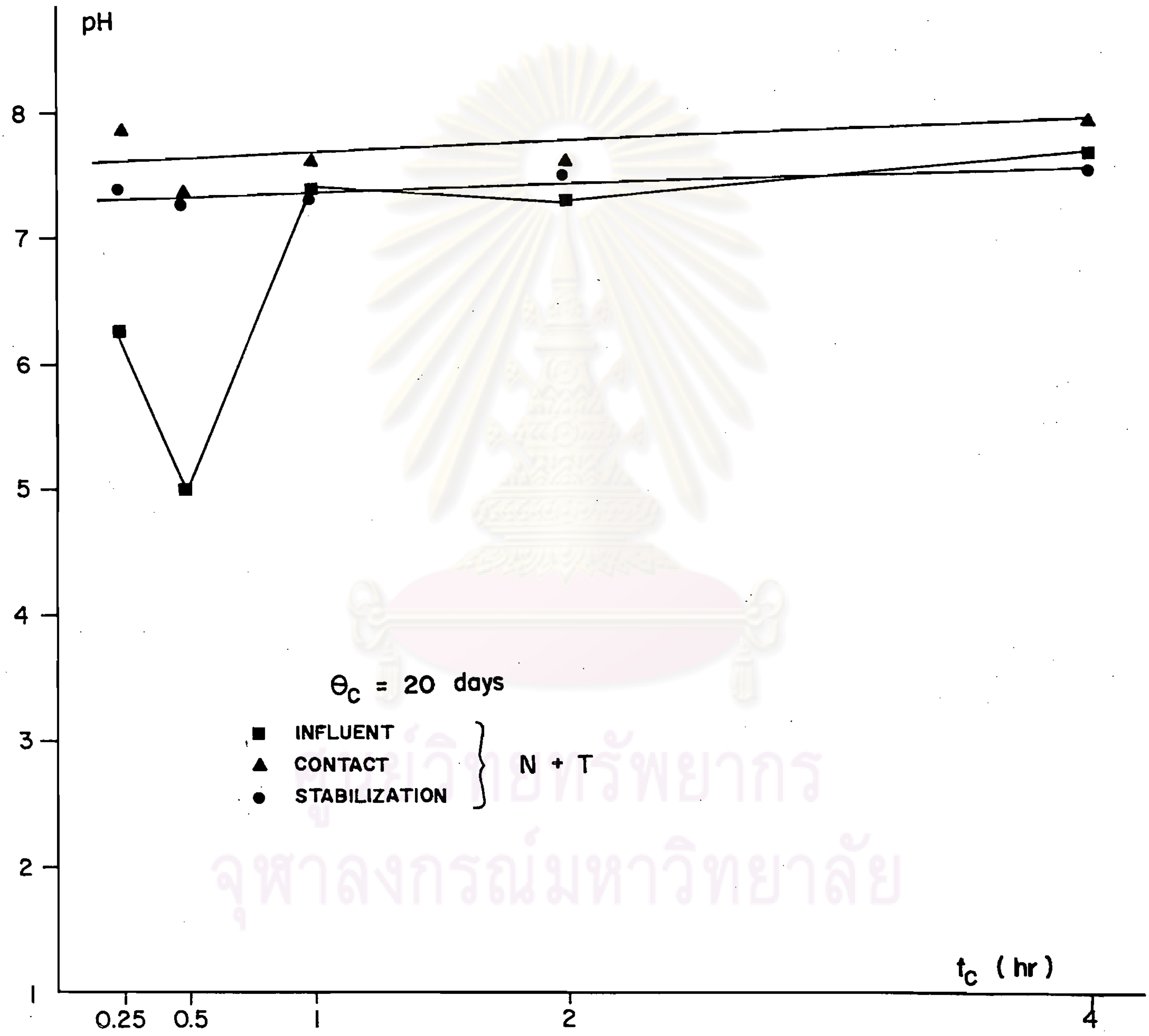


Fig. 5.2 Variation of pH at Sludge Age 20 days

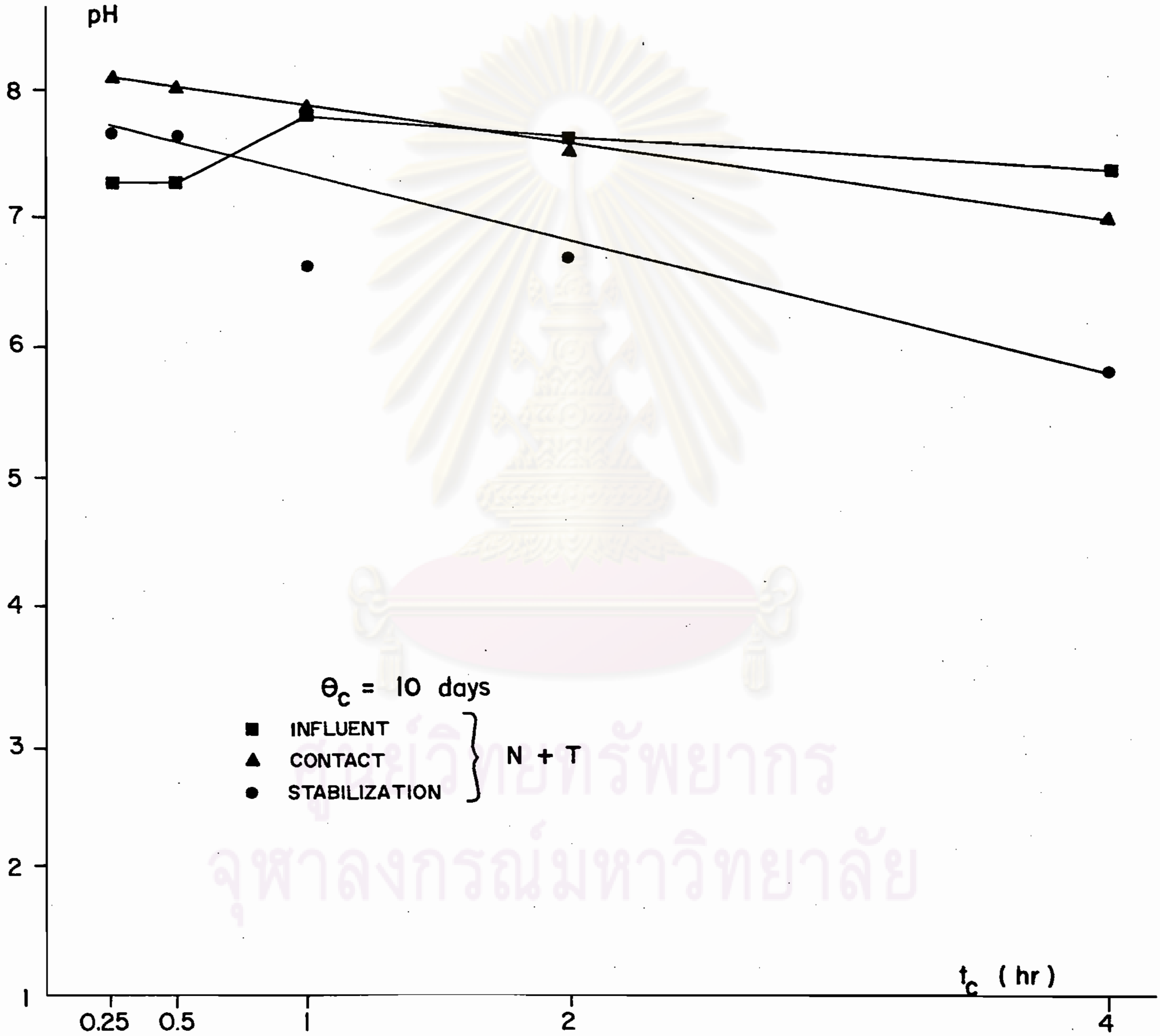


Fig. 5.3 Variation of pH at Sludge Age 10 days

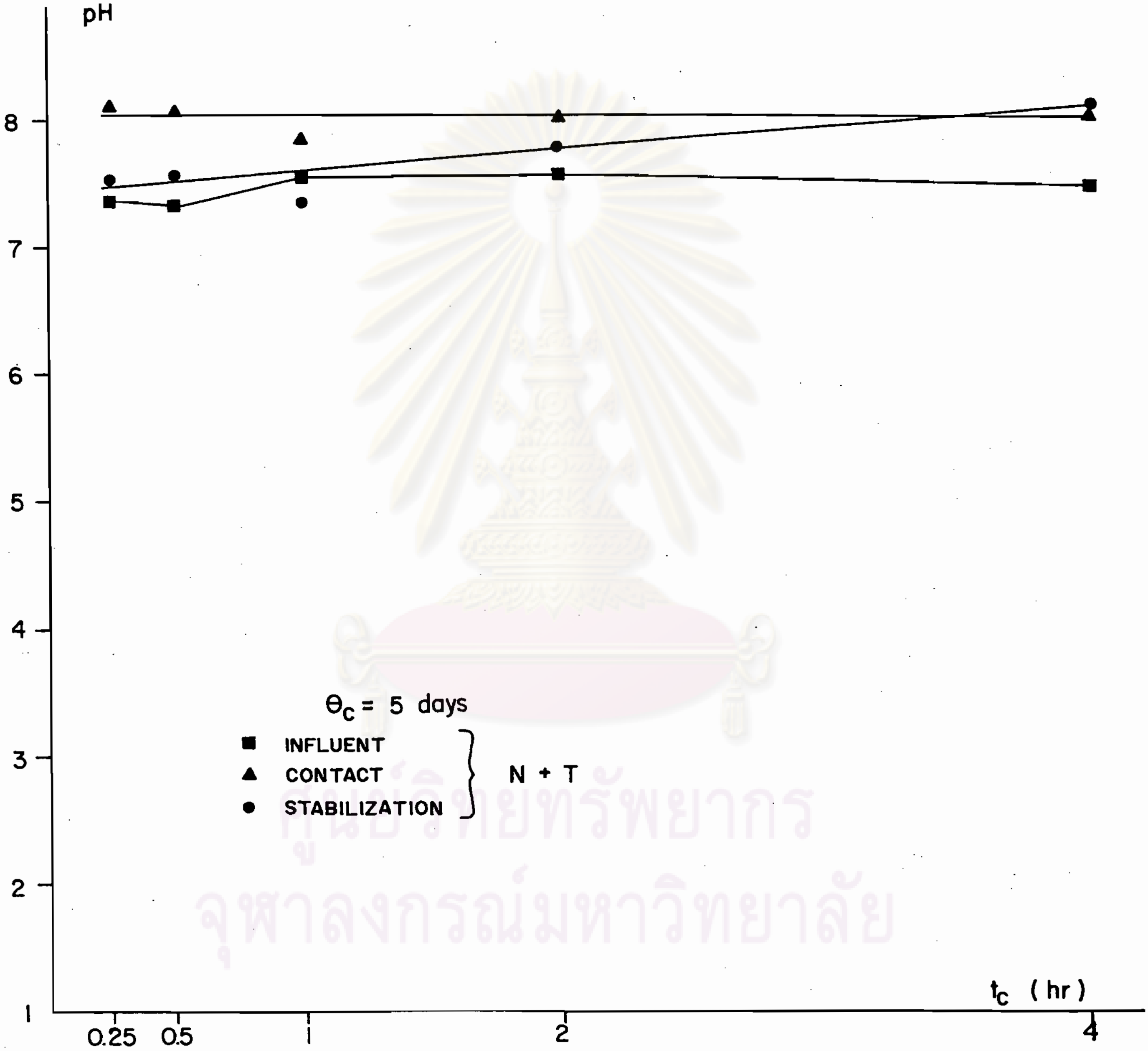


Fig. 5.4 Variation of pH at Sludge Age 5 days

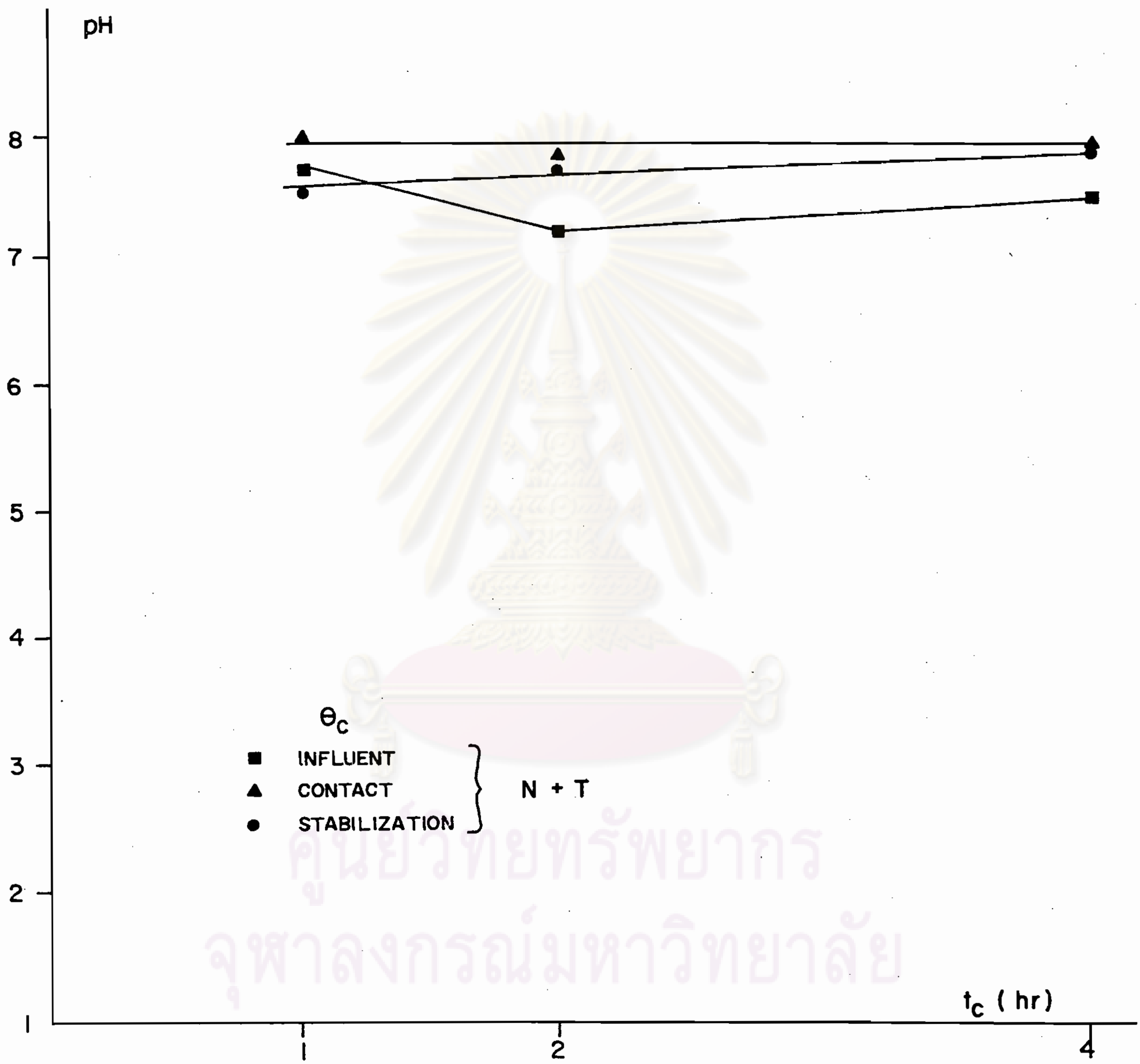


Fig. 5.5 Variation of pH at Sludge Age 2 days

5.4 and 5.5 show the variation of pH of the influent, contact and stabilization tank at sludge age 20, 10, 5 and 2 days respectively.

During each periods of sludge age, the pH in contact and stabilization tanks at various contact time ranged from 6 to 8 and did not vary so much. At sludge age 20 days, pH of the influent droped to 5.00 due to the fluctuation of influent characteristics. The average pH values at various sludge ages of the influent, contact tank and stabilization tank ranged from 7.10 to 7.53, 7.67 to 7.97 and 6.90 to 7.72 respectively. These results show that the pH of the contact and stabilization tank are slightly greater than the influent. The pH of the contact tank is also slightly greater than the stabilization tank. These average pH values of influent, contact and stabilization tanks are within the optimum range for the growth of microorganisms. METCALF & EDDY (1972) stated that most organisms could not tolerate pH levels above 9.5 or below 4.0. Generally, the optimum pH for the growth of microorganisms should be between 6.5 to 7.5.

5.2.2 Biomass Concentration

It is obvious from equation (3.37) that the total biomass in the system is constant during each various sludge ages. However, in the case of the system efficiency decreases, the total biomass decreases slightly simultaneously. From experimental result shows that the total biomass of the system decreases about 7-12% as the contact time decreases from 4 hr to 0.25

hr and the process efficiency decreases about 4-6%. The total biomass of the system also decreases as the sludge age decreases.

Fig. 5.6, 5.7, 5.8 and 5.9 shows the biomass concentrations in contact and stabilization tank in term of MLSS and MLVSS. The MLSS in the contact tank is about 5,000, 3,000, 1,500, and 800 mg/ℓ at sludge age 20, 10, 5 and 2 days respectively. The MLSS in the stabilization tank is about 10,000, 5,000, 2,500 and 1,100 mg/ℓ, at sludge age 20, 10, 5 and 2 days respectively. The biomass concentrations in both tanks increase as the contact time decreases due to the decrease of contact tank volume. The ratio of biomass concentration in contact tank to stabilization tank is about 0.5, this can be insisted from equation (3.4) if term $k_C t_C$ is negligible.

5.2.3 Distribution of Biomass

The factors affecting the distribution of biomass in the system are the volume of contact, stabilization and sedimentation tank as well as the recycle ratio.

As the system was operated at constant recycle ratio, constant stabilization and sedimentation tanks volume, the changing of contact tank volume (contact time) would affect directly to fraction of the biomass in the contact tank or distribution of biomass as well as the efficiency of the system.

Figs. 5.10, 5.11, 5.12 and 5.13 show the distribution of biomass of contact, stabilization and sedimentation tank in term of MLVSS at sludge age 20, 10, 5 and 2 days, respectively.

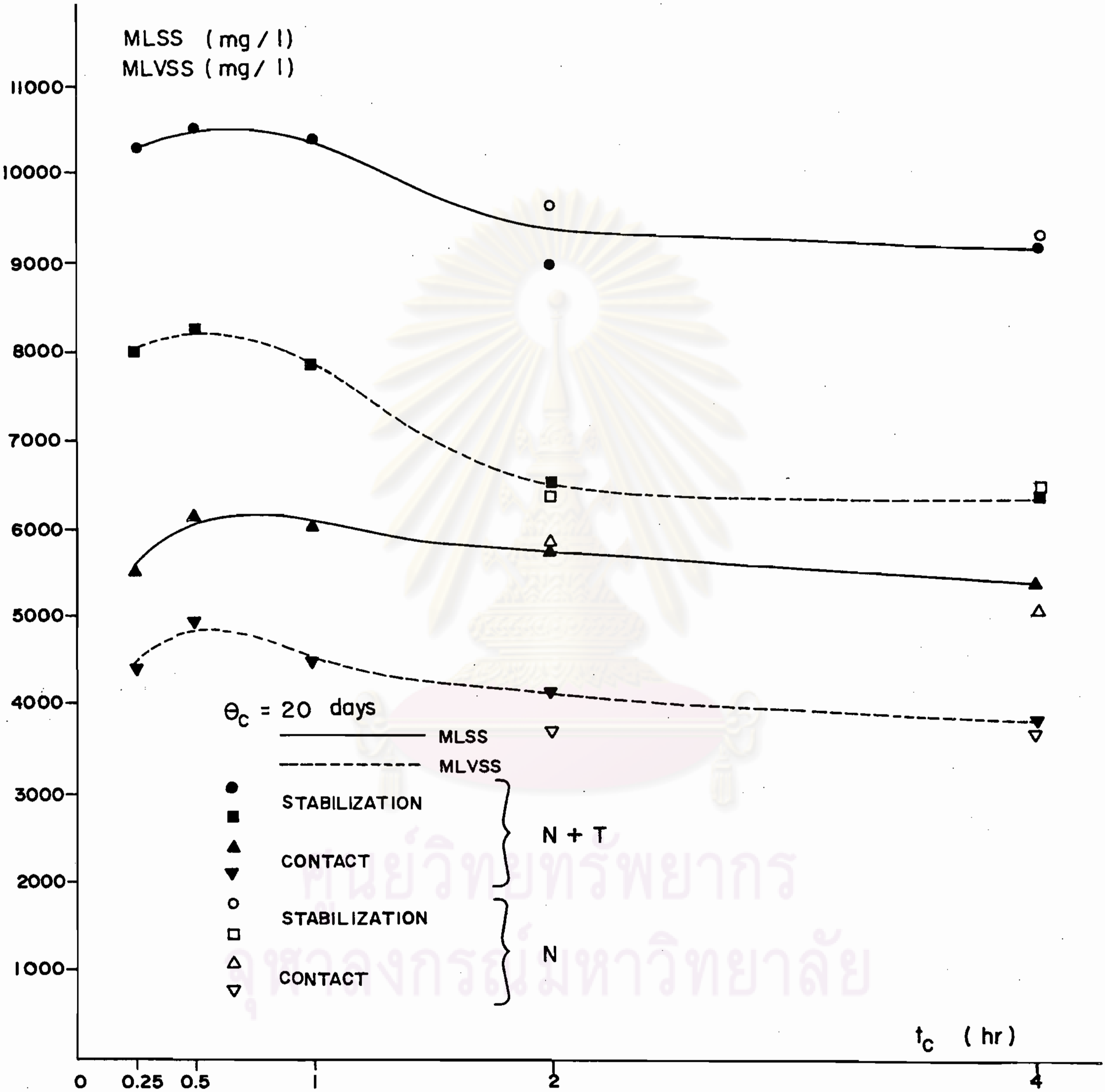


Fig. 5.6 MLSS and MLVSS Concentration at Sludge Age 20 days

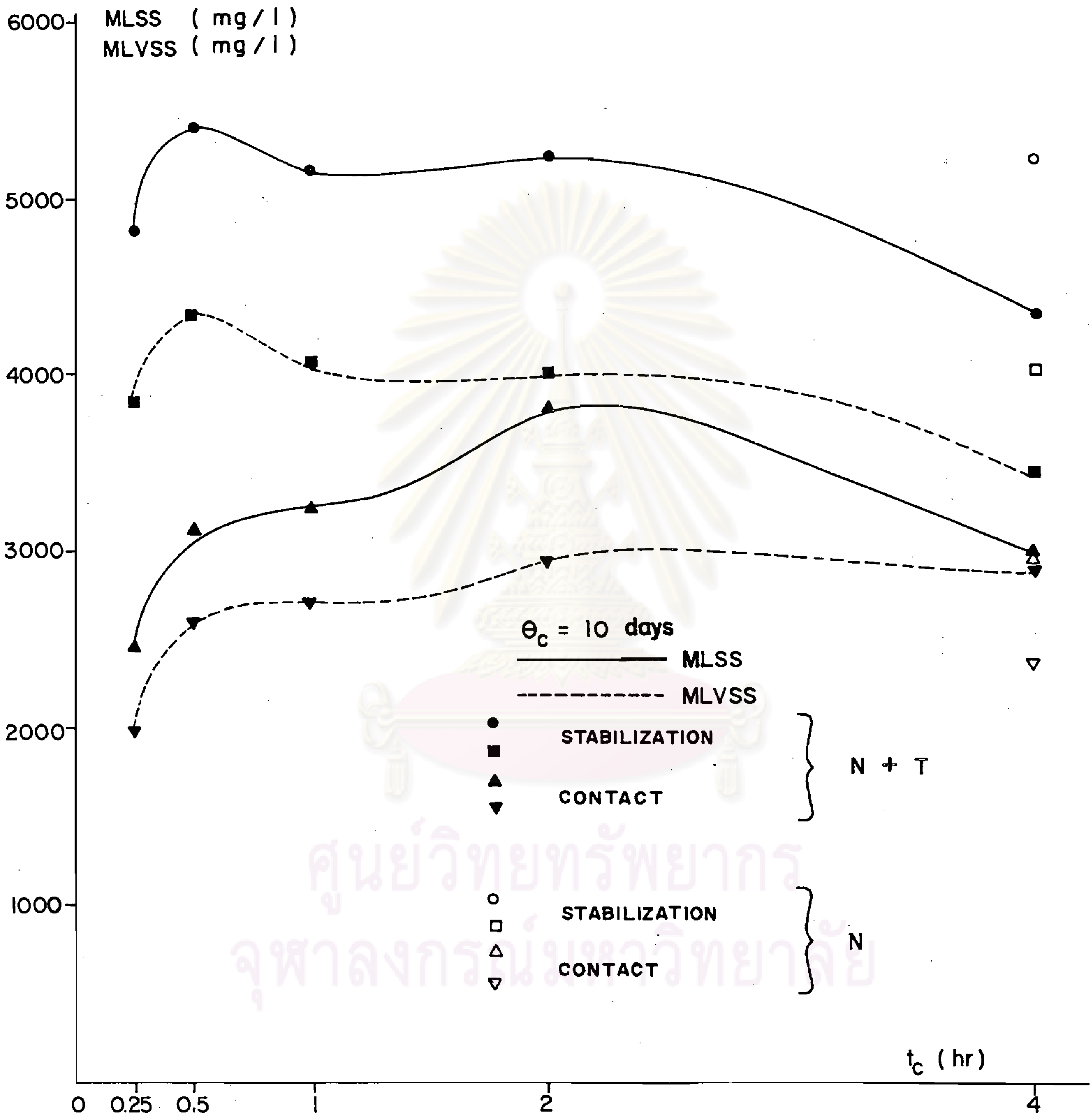


Fig. 5.7 MLSS and MLVSS Concentration at Sludge Age 10 days

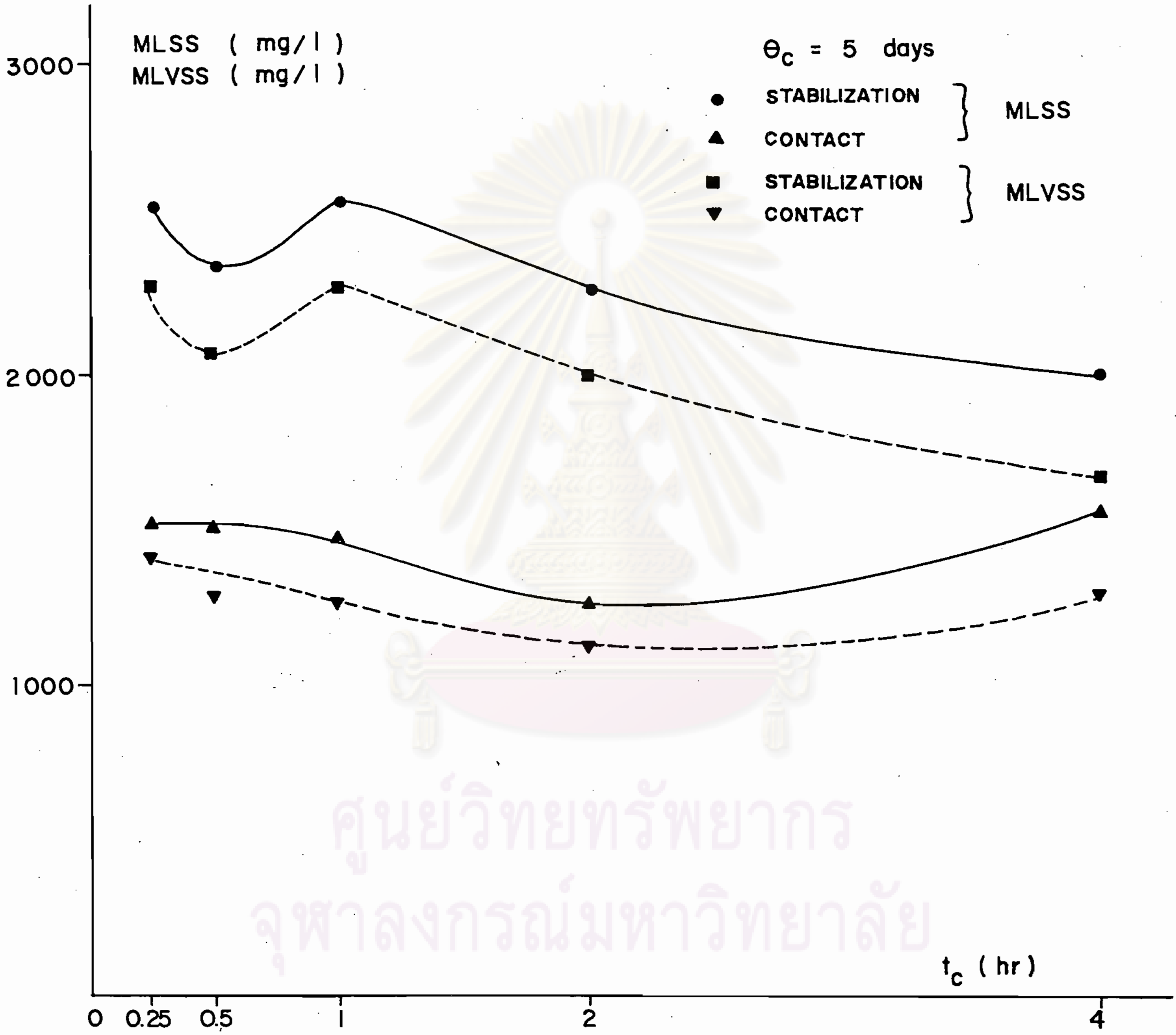


Fig. 5.8 MLSS and MLVSS Concentration at Sludge Age 5 days

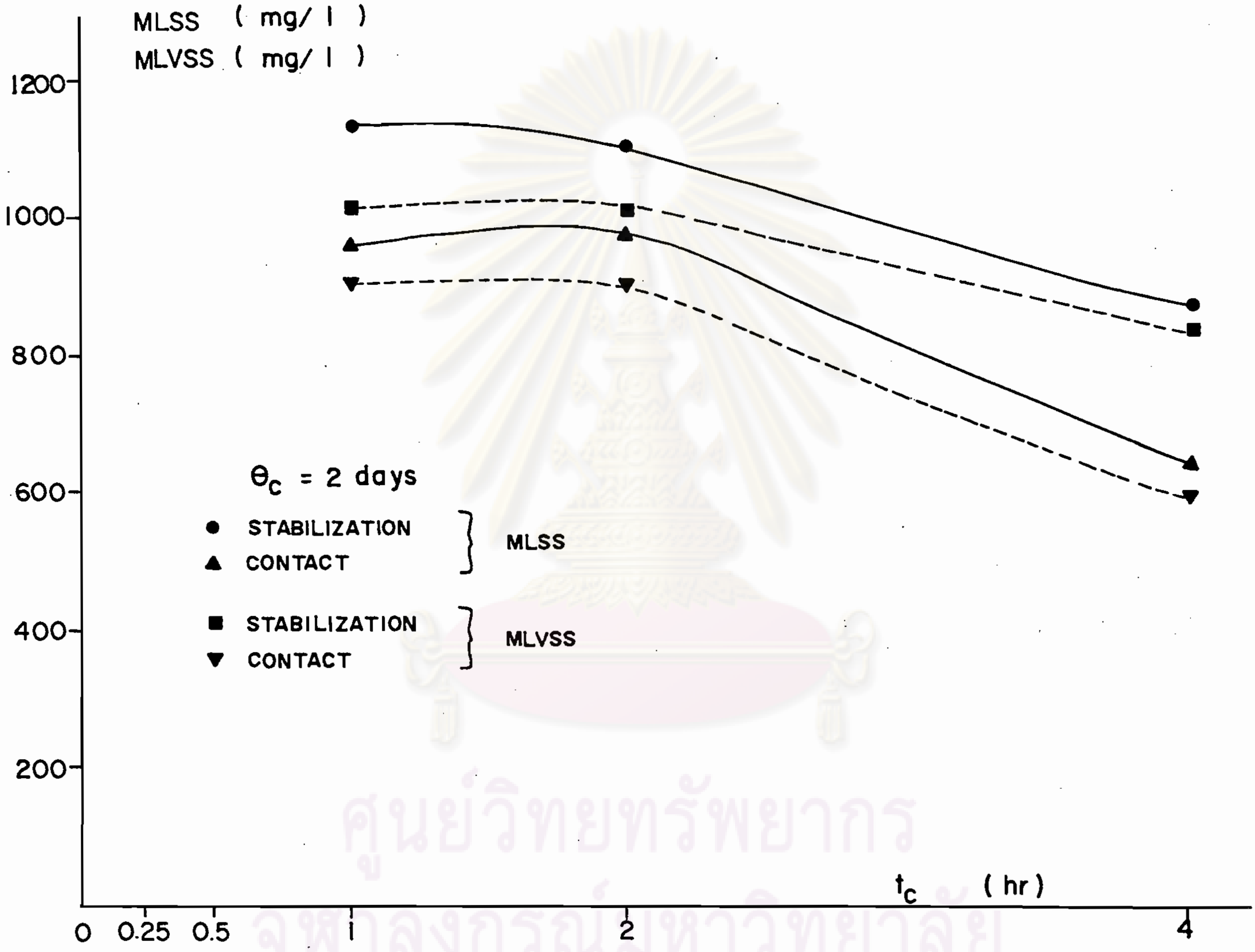


Fig. 5.9 MLSS and MLVSS Concentration at Sludge Age 2 days

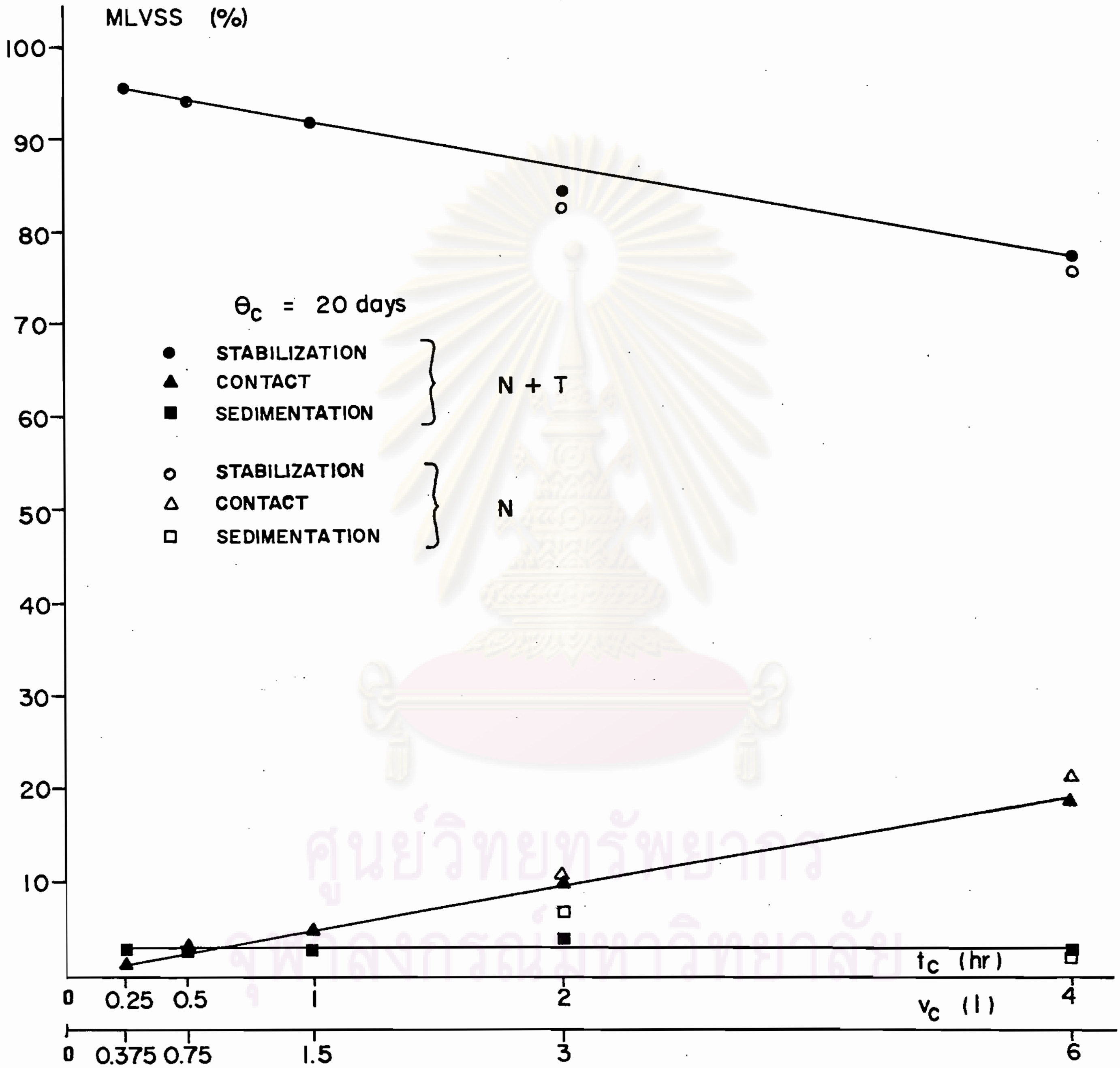


Fig.5.10 Distribution of MLVSS(%) at Sludge Age 20 days

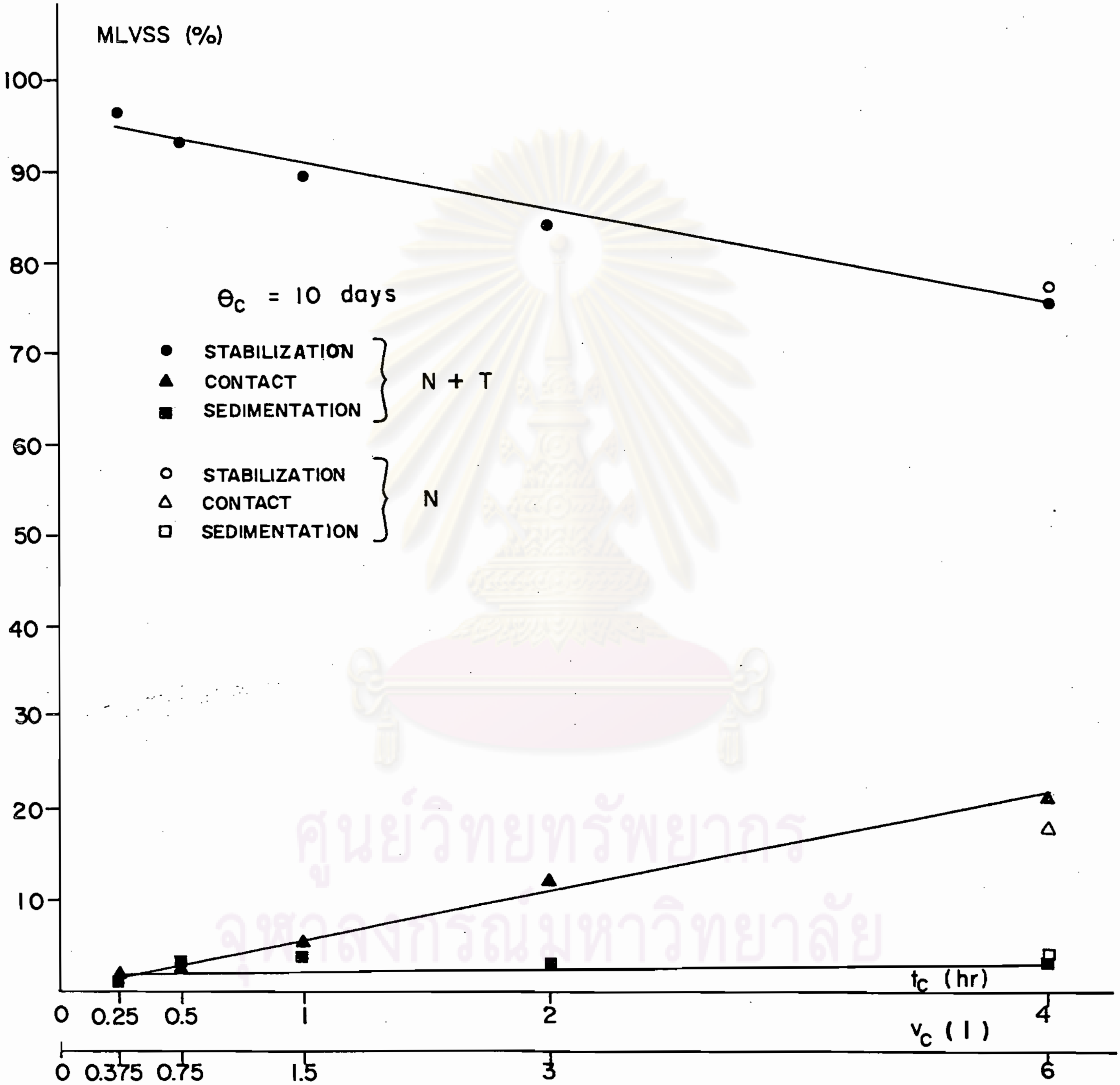


Fig. 5.11 Distribution of MLVSS(%) at Sludge Age 10 days

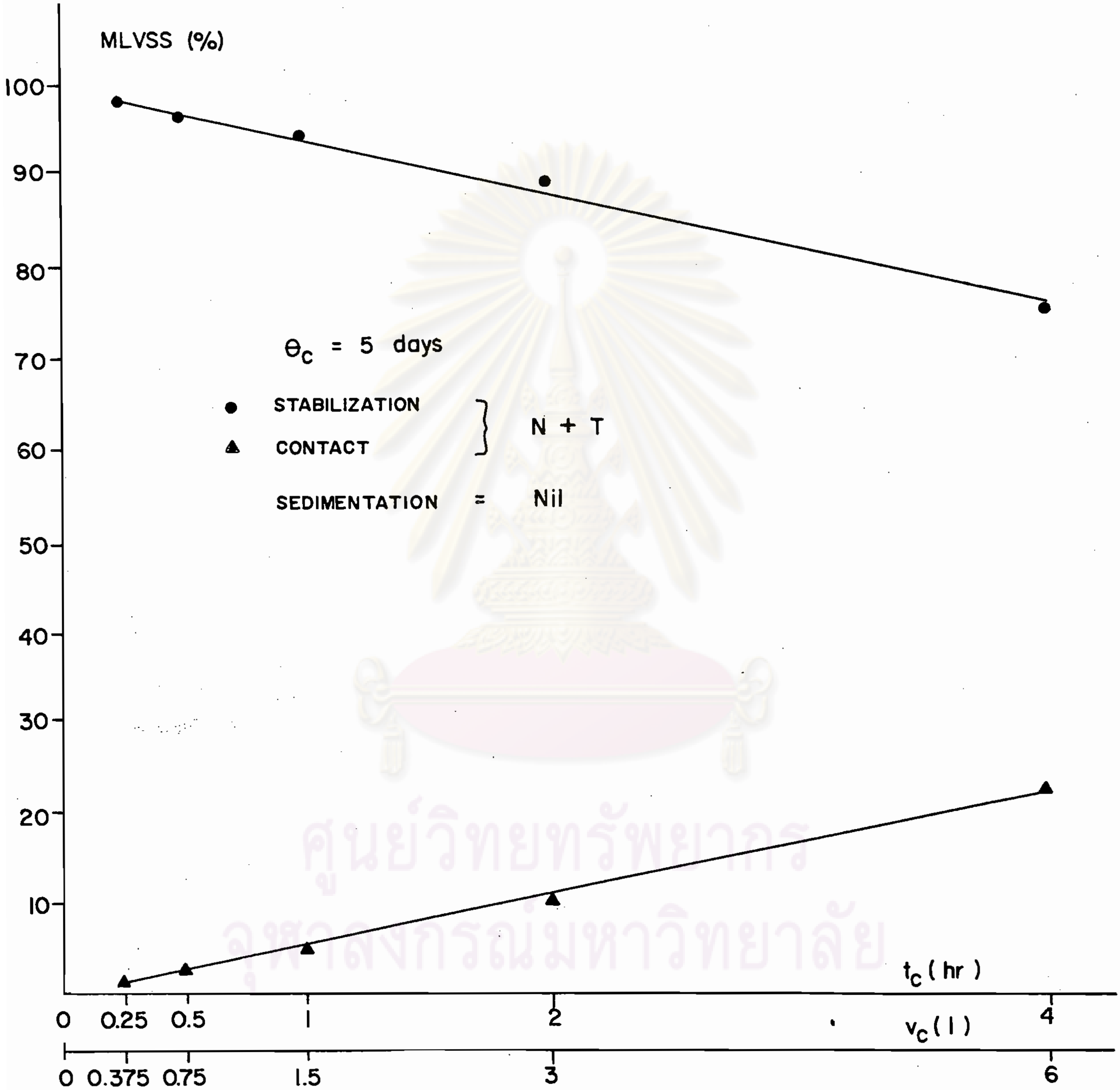


Fig. 5.12 Distribution of MLVSS(%) at Sludge Age 5 days

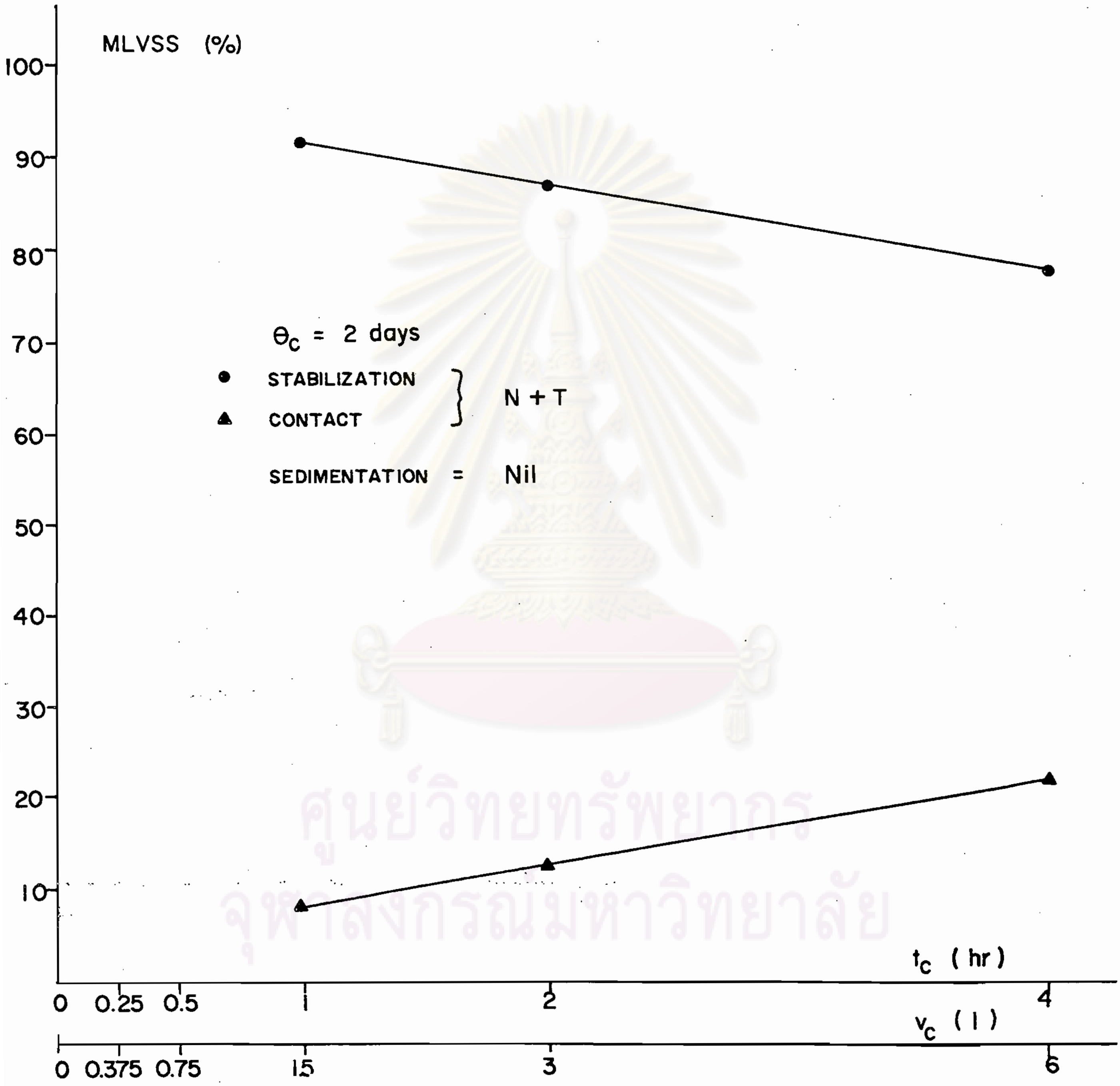


Fig.5.13 Distribution of MLVSS(%) at Sludge Age 2 days

The distribution range of biomass in contact and stabilization tanks at various sludge ages are about 20-5% and 80-95% respectively. The percentage of biomass in sedimentation tank is about 3% of the total biomass at sludge age 20 and 10 days but at sludge age 5 and 2 days this value is nil.

5.2.4 Variation of VSS/SS Ratio

During each periods of sludge age 20, 10, 5 and 2 days, the ratio of total biomass in the system in term of VSS and SS was evaluated as shown in Table 5.1.

Table 5.1 - VSS/SS Ratio at Various Sludge Age

θ_c (day)	No. of Tests	VSS/SS			
		Avg.	Min.	Max.	S.d.
2	7	0.919	0.835	0.949	0.040
5	9	0.874	0.818	0.929	0.033
10	16	0.789	0.750	0.816	0.019
20	17	0.716	0.646	0.780	0.042
Total System	49	0.798	0.646	0.949	0.081

The variation of VSS/SS ratio at various sludge ages is also shown in Fig. 5.14. The result indicates that the VSS/SS ratio ranges from 0.72 to 0.92 according to sludge age 20 days to 2 days. The average VSS/SS ratio of the total system is 0.80. The VSS/SS ratio increases directly as the sludge age decreases. This correlation can be expressed as following equation, at which correlation coefficient equal to 0.957.

$$VSS/SS = 0.928 - 0.011\ \theta_c \qquad (5.1)$$

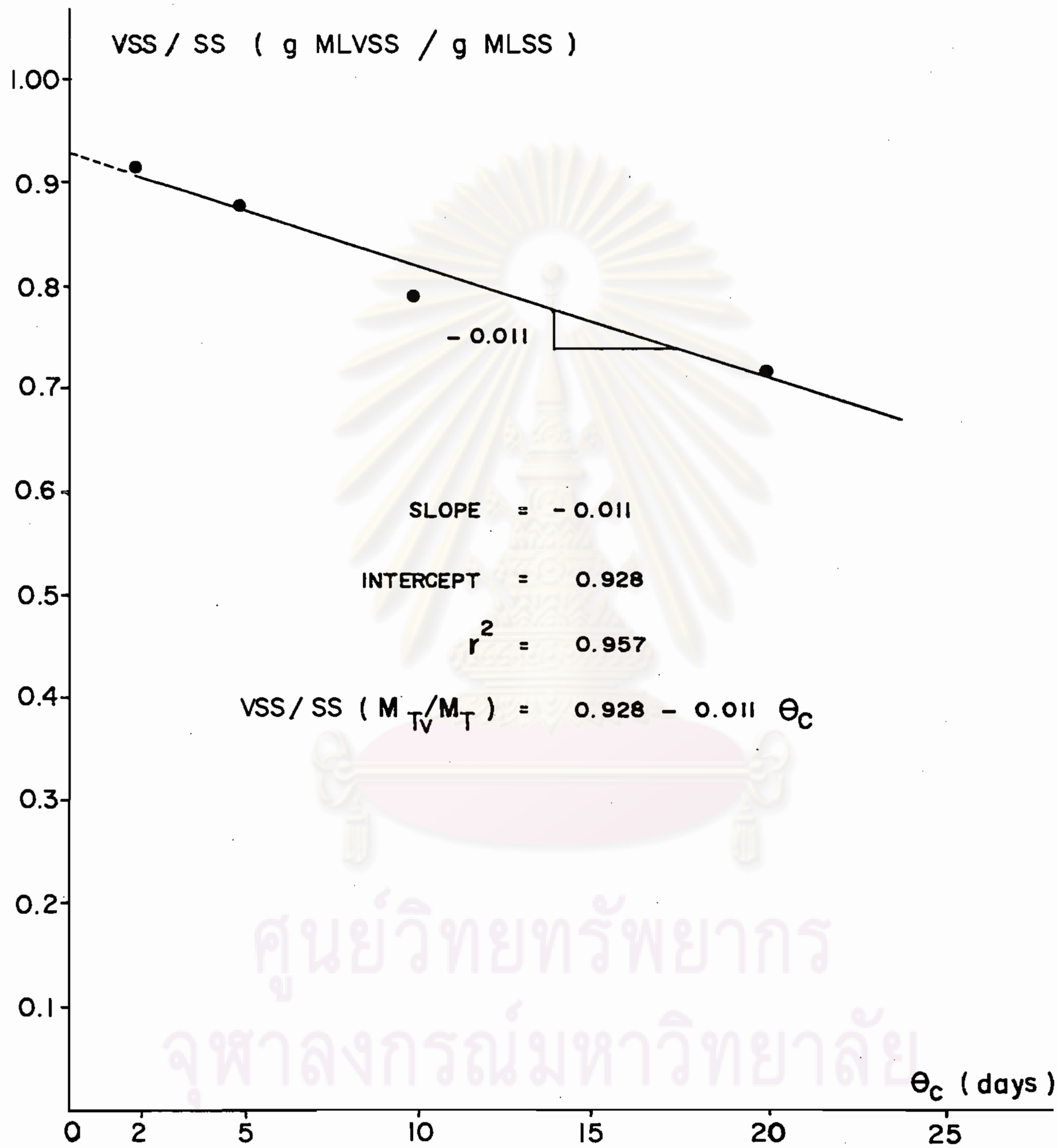


Fig. 5.14 Ratio of VSS/SS at Various Sludge Ages

This phenomenon occurs due to the higher the sludge age the lower the net specific growth rate of microorganisms which affects to increase the inert and non biodegradable part of the biomass. This affect is similar to the investigation of JENKINS and ORHON (1972) which stated that viability increased as sludge growth rate increased. They also pointed out that in contact and stabilization tank sludge viable fractions were constant at 90-95 per cent and 85-90 per cent of VSS respectively at contact tank removal rates > 3 g COD removed/g VSS-day but below this the viability decreased shaply.

The variation of VSS/SS ratio at various sludge ages is also affected the determination of microorganisms decay coefficient (k_2) of the process which based upon MLSS and MLVSS

5.2.5 Influent and Effluent Suspended Solids

During the performance of the process, the values of influent suspended solids (X_i) were depend upon the characteristics of partial degradable tapioca wastewater picked up from the waste stabilization ponds. These values ranged from 100-400 mg/ℓ.

The effluent suspended solids (X_e) ranged from 10-100 mg/ℓ throughout the experiments. It is obvious that the effluent suspended solids increases when the contact time decreases less than 2 hr, see Figs. 5.15, 5.16, 5.17, and 5.18.

5.2.6 Substrate Concentration and Process Efficiency

Principally, the influent COD concentration picked up from the waste stabilization ponds was aimed to be nearly 1,000

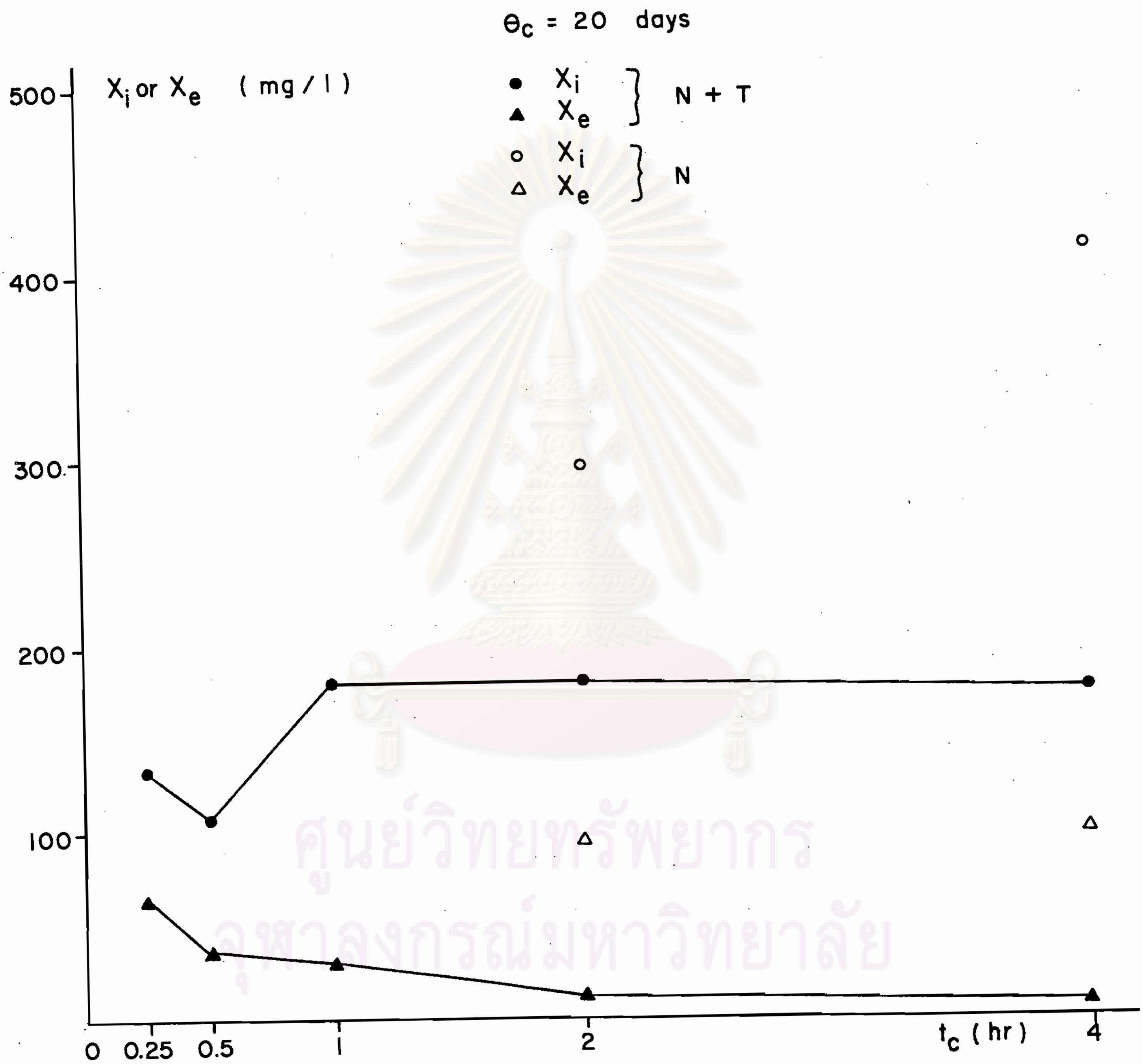


Fig. 5.15 Influent and Effluent SS at Sludge Age 20 days

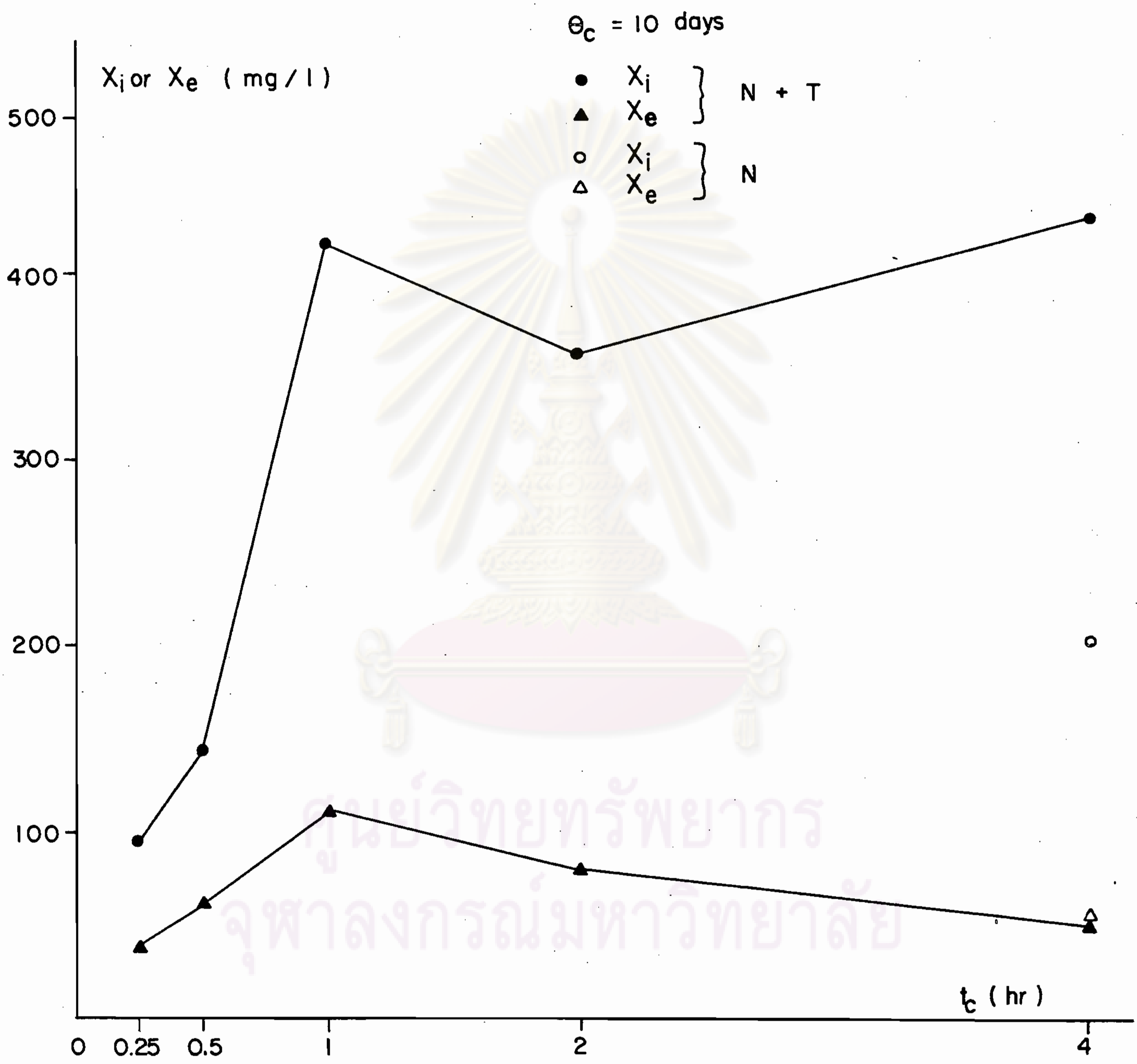


Fig. 5.16 Influent and Effluend SS at Sludge Age 10 days

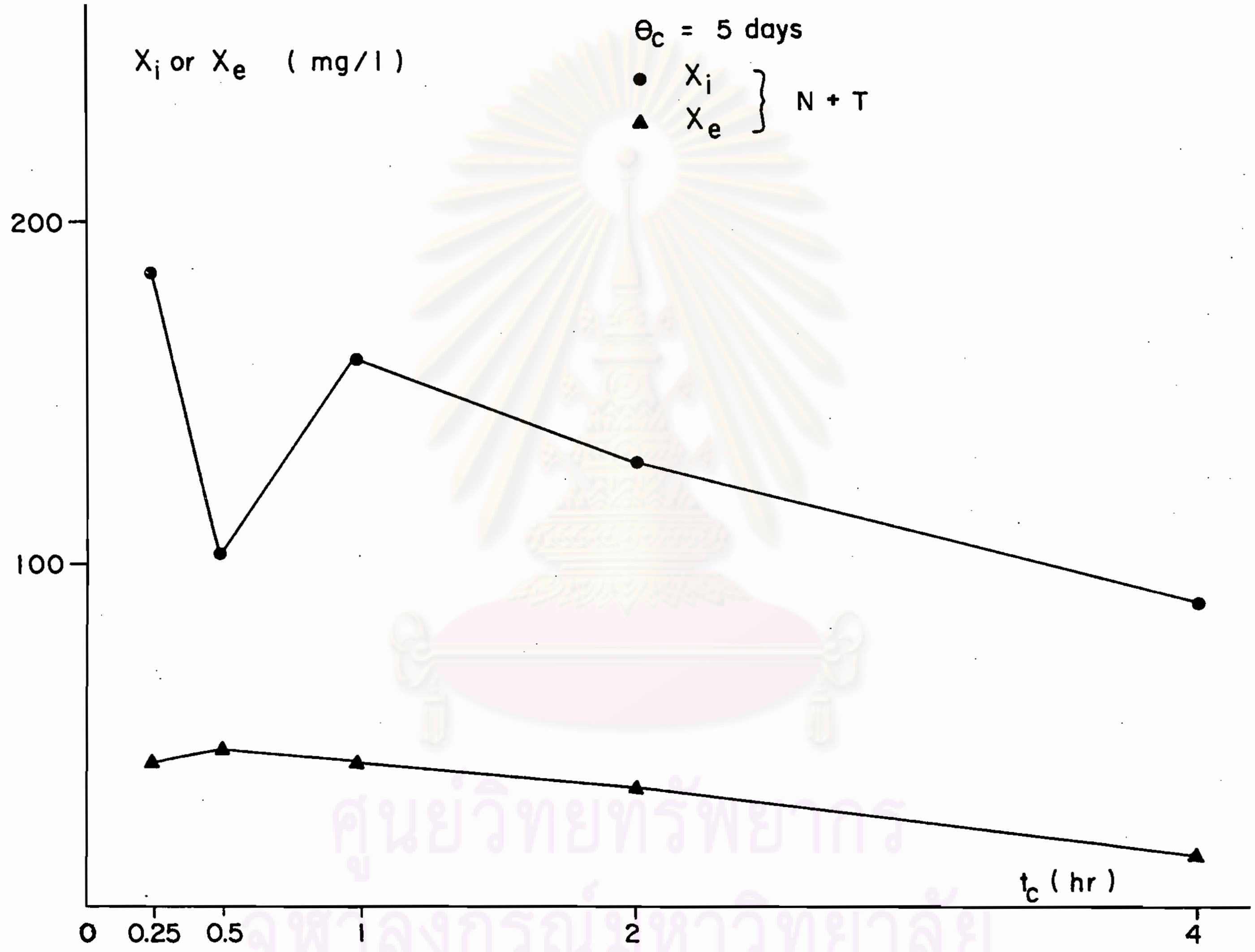


Fig. 5.17 Influent and Effluent SS at Sludge Age 5 days

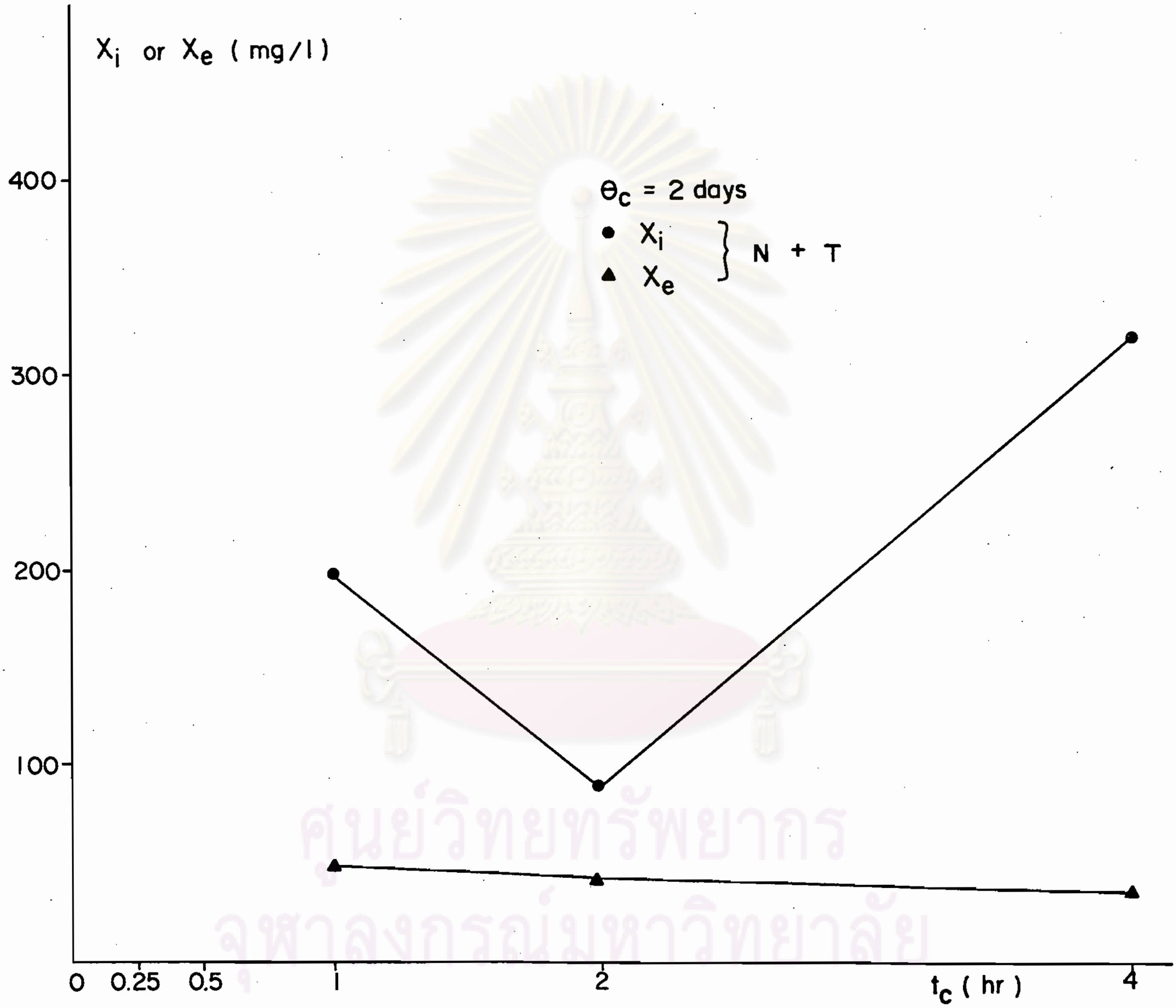


Fig. 5.18 Influent and Effluent SS at Sludge Age 2 days

mg/ℓ. Since the COD concentration could not be analysed on the site of the factory. Therefore the average influent COD concentration of the system was fluctuated.

Tables 5.2, 5.3, 5.4 and 5.5 show the COD concentration of the influent, contact, stabilization and sedimentation tanks as well as the process efficiency. If assume that biochemical reaction in the sedimentation tank is negligible, the soluble COD concentration of the effluent will be equal to the soluble COD concentration in the contact tank. In these tables, the terms INF_T and ST_T are expressed in total COD concentrations but INF_S, C and S are expressed in soluble COD concentrations.

Soluble (based on effluent) efficiency is defined by:

$$\eta_{TT} = \frac{INF_T - C}{INF_T} \times 100\% \qquad (5.2)$$

The term η_{TT} is employed in the evaluation of other parameters through out the study. The another term of total efficiency is calculated based upon INF_T and ST_T.

The variation of average influent COD and BOD concentration and effluent COD concentration at various sludge ages are shown in Figs. 5.19, 5.20, 5.21 and 5.22.

The average influent COD and BOD ranges about 800-1,000 mg/ℓ and 600-650 mg/ℓ respectively. The effluent COD concentration is between 20 and 140 mg/ℓ and also increases when the contact time decreases less than 2 hr. The average effluent BOD concentrations range between 20 and 60 mg/ℓ and are within the

Table 5.2 - Substrate Concentration and Efficiency at Sludge Age 20 Days.

θ_c = 20 days, R = 100 %, Q_i = 36 ℓ/day							
RUN No.	Substrate Concentration in COD (mg/ℓ)					η in COD (%)	
	INF_T	INF_S	C	S	ST_T	Soluble	Total
1-1	1117	674	55	31	82	95.32	93.03
1-2	1016	550	42	32	111	95.86	89.07
1-3	830	368	45	41	71	94.57	91.45
2-1	870	571	46	23	75	94.71	91.38
2-2	909	554	47	20	76	94.83	91.64
3-1	862	431	74	47	74	91.41	91.41
3-2	692	287	51	44	63	92.63	90.87
4-1	1016	730	29	32	44	97.14	95.67
4-2	607	392	19	19	21	96.87	96.54
5-1	827	630	16	22	41	98.06	95.04
5-2	762	482	25	16	44	96.72	94.22
6-1	446	273	15	15	41	96.63	90.80
6-2	717	448	60	23	100	91.63	86.05
6-3	1153	808	71	28	95	93.84	91.76
6-4	1068	725	73	33	94	93.16	91.20
7-1	945	763	81	35	101	91.43	89.31
8-1	934	747	83	120	163	91.11	82.55

Table 5.3 - Substrate Concentration and Efficiency at Sludge Age 10 Days.

θ_c = 10 days, R = 100 %, Q_i = 36 ℓ/day							
RUN No.	Substrate Concentration in COD (mg/ℓ)					η in COD (%)	
	INF_T	INF_S	C	S	ST_T	Soluble	Total
9-1	1340	613	21	31	31	98.43	97.68
9-2	1273	767	33	25	42	97.40	96.70
9-3	950	753	66	27	84	93.05	91.16
9-4	861	618	69	30	108	91.98	87.45
9-5	833	452	93	68	216	88.83	74.07
9-6	717	319	57	51	111	92.05	84.52
9-7	664	260	64	40	116	90.36	82.53
9-8	846	314	100	63	154	88.18	81.79
10-1	896	341	92	53	207	89.73	76.89
10-2	763	317	103	54	265	86.50	65.26
11-1	998	376	134	37	290	86.57	70.94
11-2	888	318	148	44	297	83.33	66.55
12-1	950	699	82	21	146	91.36	84.63
12-2	928	500	83	33	157	91.05	83.08
13-1	910	642	112	26	173	87.69	80.93
14-1	1061	943	398	20	498	62.49	53.06

Table 5.4 - Substrate Concentration and Efficiency at Sludge Age 5 Days.

θ_c = 5 days, R = 100 %, Q_i = 36 ℓ/day							
RUN No.	Substrate Concentration in COD (mg/ℓ)					η in COD (%)	
	INF_T	INF_S	C	S	ST_T	Soluble	Total
15-1	890	716	56	28	62	93.70	93.03
15-2	624	461	60	38	67	90.38	89.26
16-1	1038	865	84	36	107	91.90	89.69
16-2	808	582	50	21	86	93.81	89.35
17-1	869	689	44	20	87	94.94	89.99
17-2	779	528	61	24	138	92.16	82.28
18-1	803	670	47	12	88	94.14	89.04
18-2	797	627	74	22	112	90.71	85.94
19-1	684	471	99	39	137	85.52	79.97

Table 5.5 - Substrate Concentration and Efficiency at Sludge Age 2 Days.

θ_c = 2 days, R = 100 %, Q_i = 36 ℓ/day							
RUN No.	Substrate Concentration in COD (mg/ℓ)					η in COD (%)	
	INF_T	INF_S	C	S	ST_T	Soluble	Total
20-1	759	483	187	76	169	75.36	77.73
20-2	1113	901	85	60	175	92.36	84.27
20-3	1020	837	70	53	139	93.13	86.37
21-1	883	740	47	28	102	94.35	87.75
21-2	900	-	39	26	86	95.66	90.44
22-1	770	487	97	33	130	87.40	83.12
22-2	538	312	185	59	273	65.61	49.25

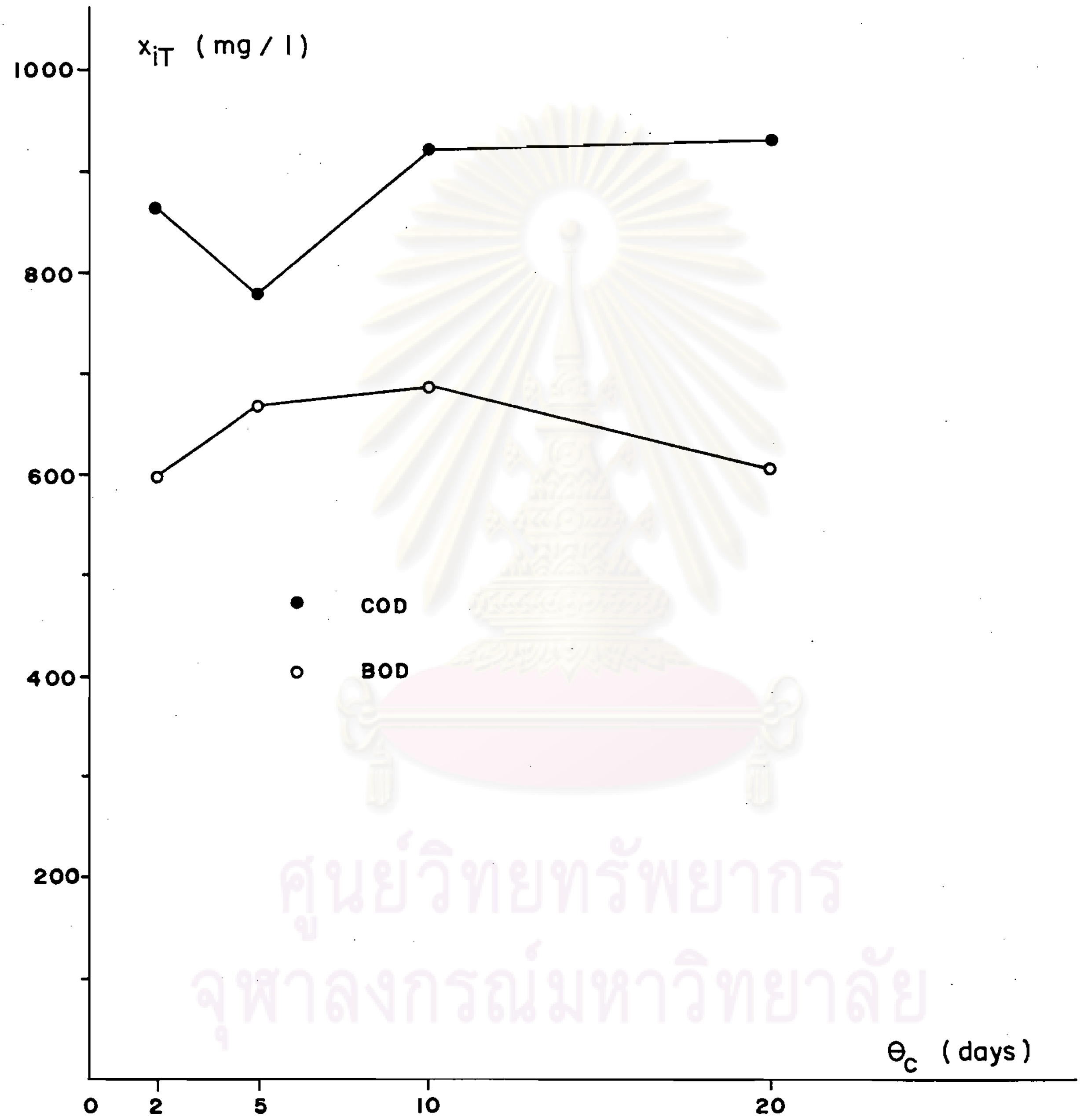


Fig. 5.19 Average Influent COD Concentration at Various Sludge Ages

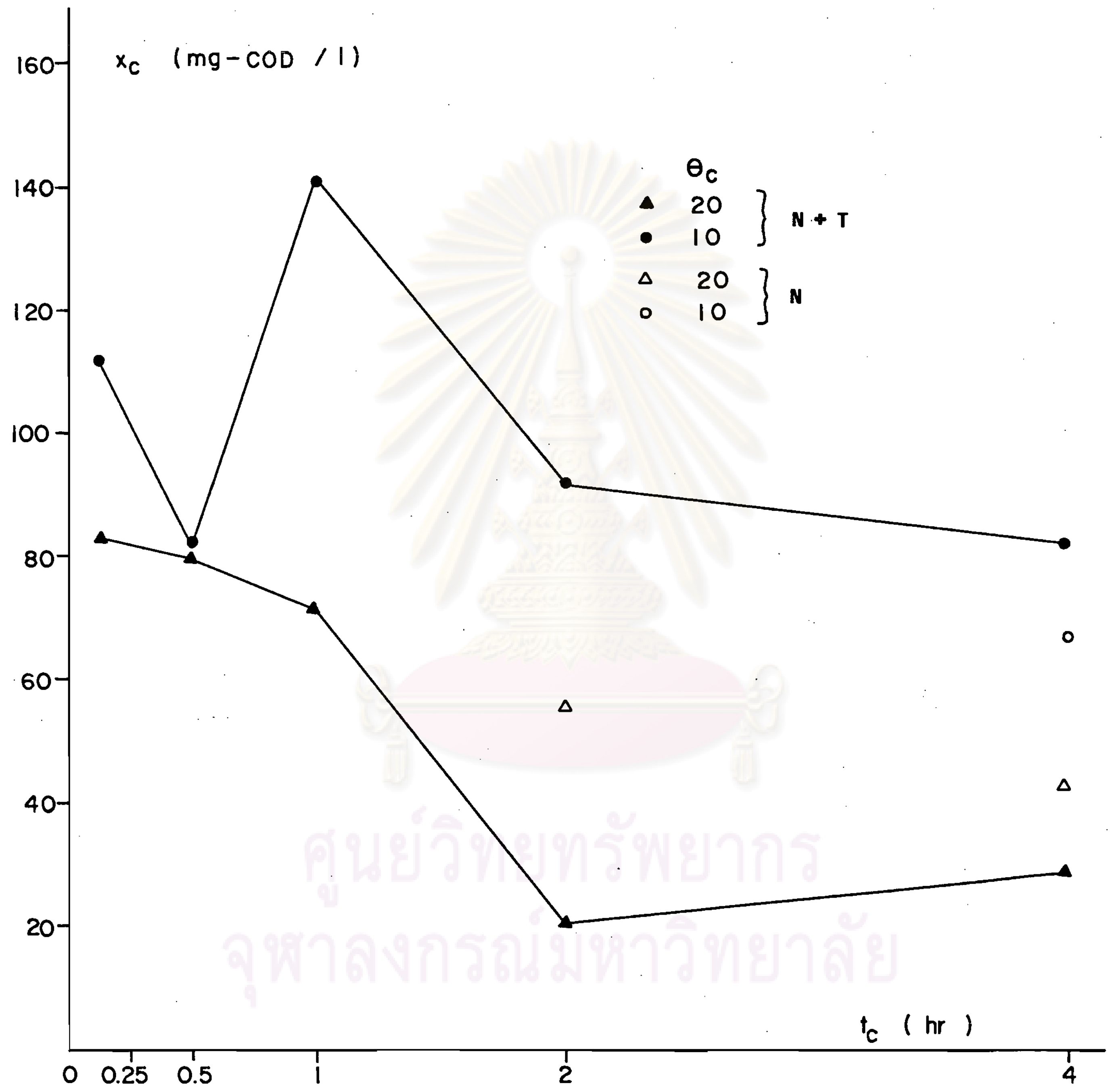


Fig. 5.20 Soluble COD in Contact Tank at Sludge Age 20 and 10days

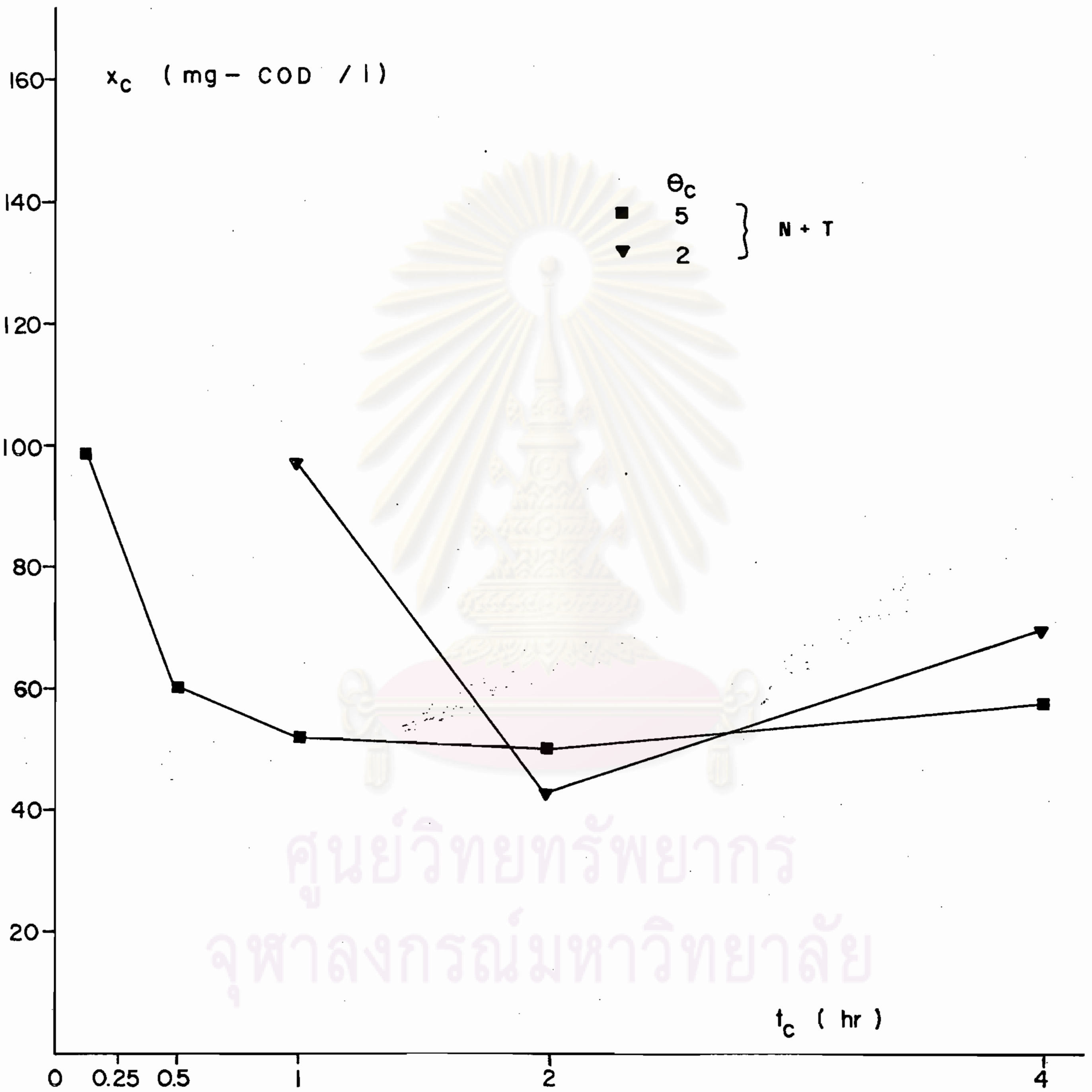


Fig. 5.21 Soluble COD in Contact Tank at Sludge Age 5 and 2days

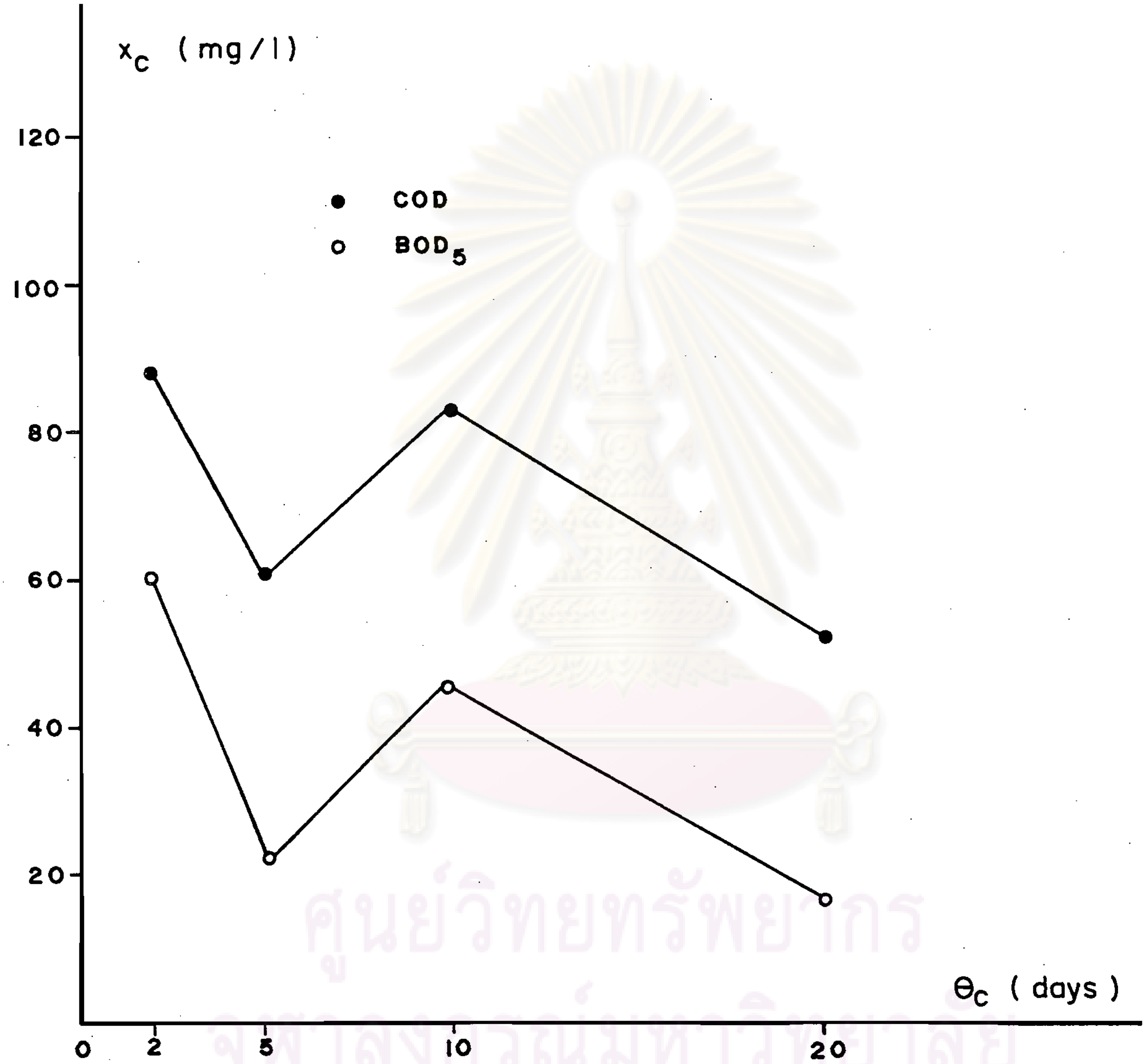


Fig. 5.22 Average Soluble COD in Contact Tank at Various Sludge Ages

effluent standard of Ministry of Industry (see Appendix, Table B-1).

5.2.7 Effect of Trace Elements on Sludge Volume Index (SVI)

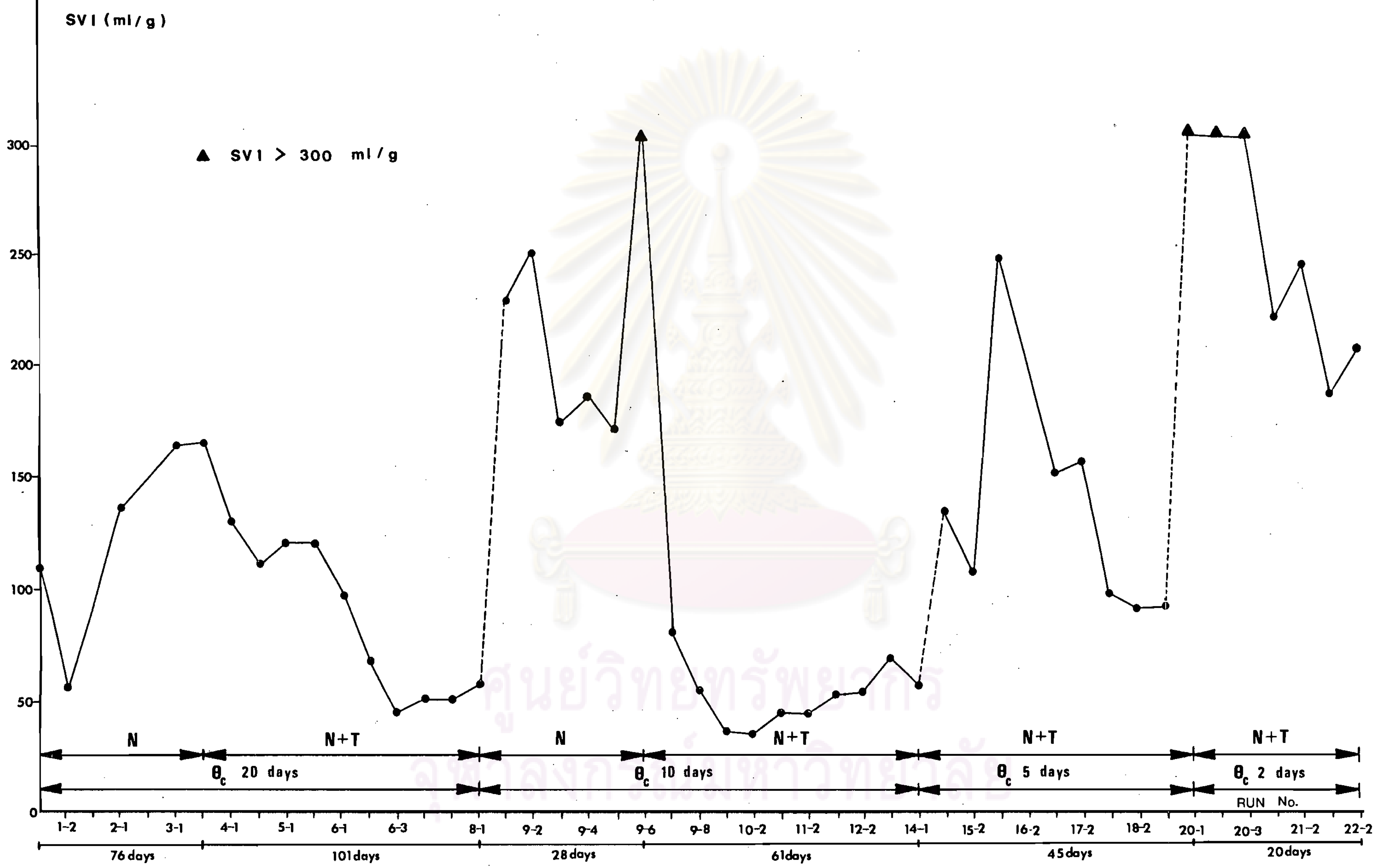
The sludge volume index (SVI) and microscopic observation corresponding to each sets of experimental test-run were determined through out this research as shown in Figs. 5.23, 5.24, and Table 5.6, respectively.

The obtained data indicated that during 76 days of N-condition and sludge age 20 days, the SVI values were rather high given average SVI value about 150 mℓ/g and the filamentous bacteria were abundant through out this period which normally caused the problem of sludge bulking. At N+T condition, sludge age 20 days, it was obvious that within 37 days (RUN No. 4-1 to 4-2) after the trace elements shown in Table 4.8 were added into the system, the population of filamentous bacteria decreased to low level and SVI value also decreased to around 120 mℓ/g and continued to decreased to the value about 50 mℓ/gm without the problem of sludge bulking through out the period.

This effect of trace elements which had ability to control the population of filamentous bacteria was also investigated again at the beginning of sludge age 10 days.

The system was operated without addition of trace elements. During 28 days (RUN No. 9-1 to 9-6) of this only nutrient controlled condition (N-condition), sludge age 10 days, the population of filamentous bacteria increased. The SVI also increased

Fig. 5.23 Variation of SVI in Contact Tank



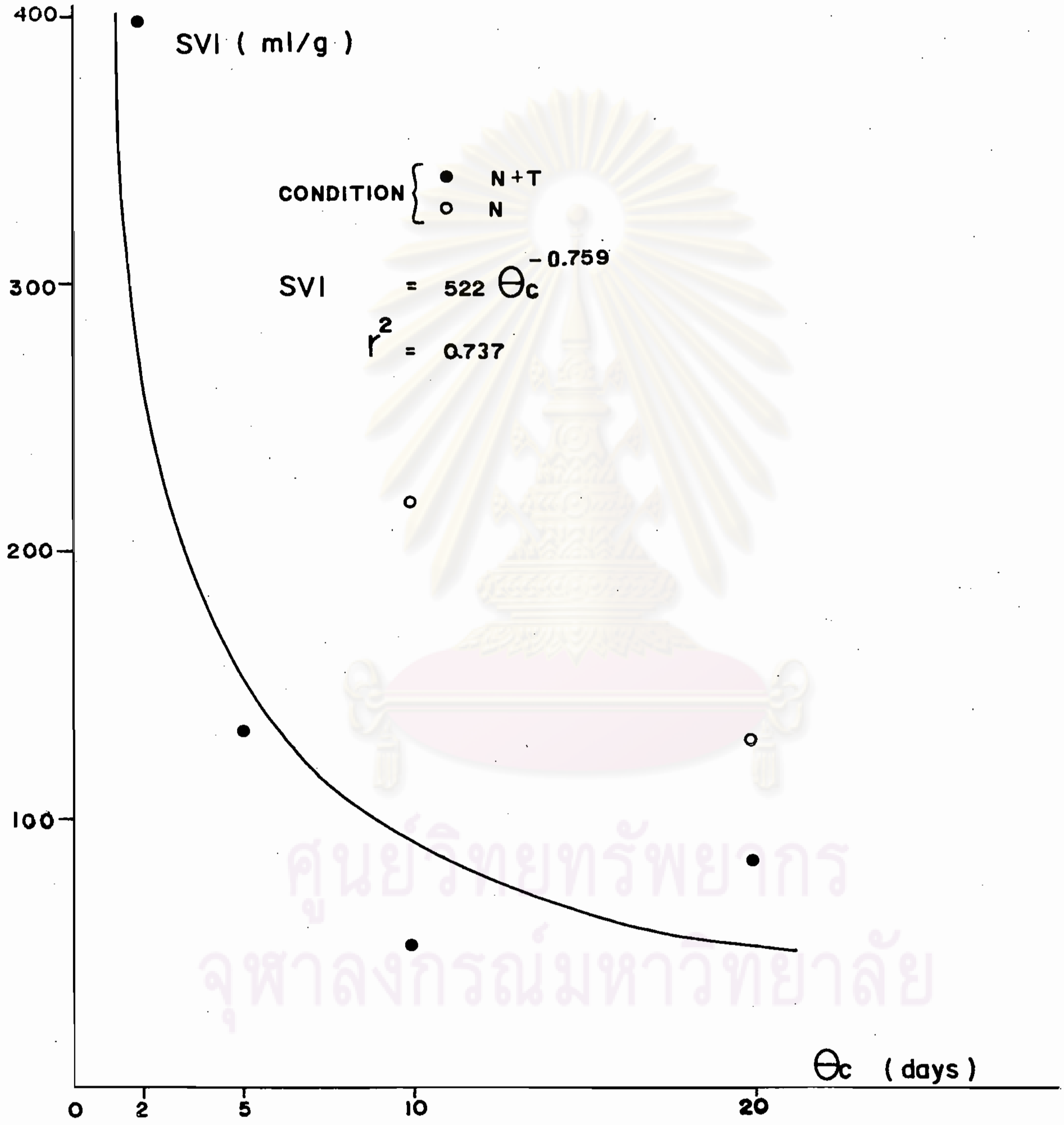
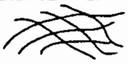


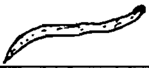
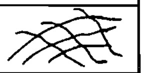
Fig. 5.24 Variation of SVI at Various Sludge Ages

Table 5.6 - Microscopic Observation

RUN No.	Type of Microorganisms					
						
	Rotifer	Stalked Ciliate	Free-Swimming	Round Worm	Flagel-late	Filamen-tous bact.
1-1	ooo	ooo	o	oo	x	ooo
1-2	ooo	ooo	o	ooo	x	ooo
1-3	oo	oo	o	o	x	ooo
2-1	o	o	x	o	x	ooo
2-2	o	oo	x	x	x	ooo
3-1	o	o	o	o	oo	ooo
3-2	o	oo	o	o	x	ooo
4-1	ooo	ooo	oo	oo	x	o
4-2	ooo	oo	x	o	x	o
5-1	ooo	ooo	x	o	x	o
5-2	ooo	ooo	x	o	x	o
6-1	ooo	ooo	x	o	x	o
6-2	ooo	ooo	x	o	x	o
6-3	ooo	oo	x	o	x	o
6-4	ooo	ooo	x	x	x	oo
7-1	ooo	ooo	o	x	x	oo
8-1	o	ooo	x	x	ooo	oo
9-1	o	ooo	o	o	x	ooo
9-2	o	ooo	o	o	x	ooo
9-3	oo	ooo	x	o	x	ooo
9-4	ooo	ooo	x	o	x	ooo
9-5	ooo	ooo	oo	oo	x	ooo
9-6	ooo	ooo	oo	oo	x	ooo
9-7	ooo	ooo	ooo	x	x	oo
9-8	ooo	ooo	ooo	x	x	o

ooo = abundant, oo = moderate, o = low, x = not detectable

Table 5.6 - (Cont'd)

RUN No.	Type of Microorganisms					
						
	Rotifer	Stalked Ciliate	Free-Swimming	Round Worm	Flagel-late	Filamen-tous bact
10-1	ooo	ooo	o	x	x	o
10-2	ooo	ooo	oo	x	x	o
11-1	ooo	ooo	oo	x	ooo	x
11-2	ooo	ooo	ooo	x	ooo	x
12-1	ooo	ooo	o	x	ooo	x
12-2	ooo	ooo	x	x	ooo	o
13-1	ooo	ooo	x	x	ooo	o
14-1	oo	ooo	x	o	-	o
15-1	ooo	ooo	oo	x	oo	oo
15-2	ooo	ooo	oo	x	oo	oo
16-1	o	oo	o	o	ooo	ooo
16-2	o	oo	x	x	ooo	oo
17-1	o	oo	x	x	ooo	oo
17-2	oo	ooo	oo	x	ooo	oo
18-1	o	o	o	x	ooo	o
18-2	o	o	o	o	ooo	o
19-1	oo	o	x	x	ooo	x
20-1	o	o	o	x	x	ooo
20-2	o	o	oo	x	x	ooo
20-3	o	o	oo	x	x	ooo
21-1	o	o	ooo	x	ooo	oo
21-2	o	o	ooo	x	ooo	oo
22-1	o	x	ooo	x	ooo	ooo
22-2	o	x	ooo	x	ooo	ooo

from 60 mℓ/g to about 300 mℓ/g at the last sets of experimental test-run (RUN No. 9-6) of this period. Therefore, the system could not continue to operate at this condition.

After the same amount of trace elements shown in Table 4.8 were put into the system again, the population of filamentous bacteria decreased and the SVI value also decreased to about 50 mℓ/g within 14 days (RUN No. 9-7 to 9-8).

At the period of sludge age 5 days, the system was operated only within N+T condition. The population of filamentous bacteria were moderate and the average SVI value was about 130 mℓ/g without sludge bulking through out this period.

During sludge age 2 days, although the system was operated within N+T condition, the population of filamentous bacteria were abundant given high SVI value about 250-400 mℓ/g. The phenomenon that SVI increased when sludge age was between 5 and 2 days was due to the specific substrate utilization rate increased from 0.7 to 1.6 day^{-1} which had ease tendency to induce sludge bulking.

The average SVI values decreased exponentially as the sludge age increased and could be expressed as following equation (only N+T condition) with correlation coefficient r^2 equal to 0.737.

$$SVI = 522\ \theta_c^{-0.759} \qquad (5.3)$$

Based on these various results, it should be pointed out that the trace elements have ability to restrict the population of filamentous bacteria which resulted to get rid of the sludge bulking problem when the system is operated at sludge age equal or greater than 5 days. These phenomina could be explained that trace elements are necessary to promote the growth of other microorganisms more rapid than filamentous bacteria which result to restrict the population of filamentous bacteria. However, at sludge age 2 days, N+T condition, the system was lack of its stability due to high organic loading. The biomass was spongy and slimable of very high population of filamentous bacteria. Therefore the N+T operating condition of sludge age equal or greater than 5 days is recommended.

The effect of trace elements have been postulated by some investigators as following: PFEFFER (1967) cited by CARTER and McKINNEY (1973) found that iron was not only essential for good biological growth but that it could improve the SVI of filamentous sludge and a lack of trace inorganic elements may also induce bulking conditions in activated sludge system. CARTER and McKINNEY (1973) have also shown that supplying adequate iron could reduce sludge bulking problems.

The population of rotifers, stalked ciliates, free-swimming ciliates and flagellates shown in Table 5.6 also indicated the degree of substrate stabilization as described by McKINNEY (1962). It is obvious that the higher the sludge age and/or the contact time the better the degree of substrate stabilization. This is because while the sludge age is high the organic loading is low (see Fig. 5.28) and the lower the contact time the lower the fraction of biomass in the contact tank (M_C) which increases organic loading of contact tank as well.

5.2.8 <u>Efficiency of the Process</u> (η_{TT})

The efficiency of the process (as defined in 5.2.6) at sludge age 20, 10 and 5 days slightly decreased as the contact time decreased which ranged from 91-97%, 85-90% and 85-93%, respectively. The process still had capability for treatment efficiency of 62% at sludge age 10 days when the contact time approached zero.

At sludge age 2 days, the process efficiency fluctuated due to the unstability and unrealiability of the system and have not recommended for the design calculation and operating.

The process efficiency at each sludge ages was shown in Figs. 5.26 and 5.27. Fig. 5.25 showed the average of process efficiency at various sludge ages. The average process efficiency decreased directly as the sludge age decreased which could be expressed as the following equation.

$$\eta_{TT} = 86.60 + 0.36\theta_C \qquad (5.4)$$

5.2.9 <u>Process Organic Loading</u> (C_{TT})

The process organic loading is correlated to sludge age (θ_C), other parameters also affected of the process organic loading. Based on the experimental data, the process organic loading decreased exponentially from about 1.8 day^{-1} to 0.3 day^{-1} as the sludge age increased from 2 to 20 days (see Fig. 5.28). The cor-

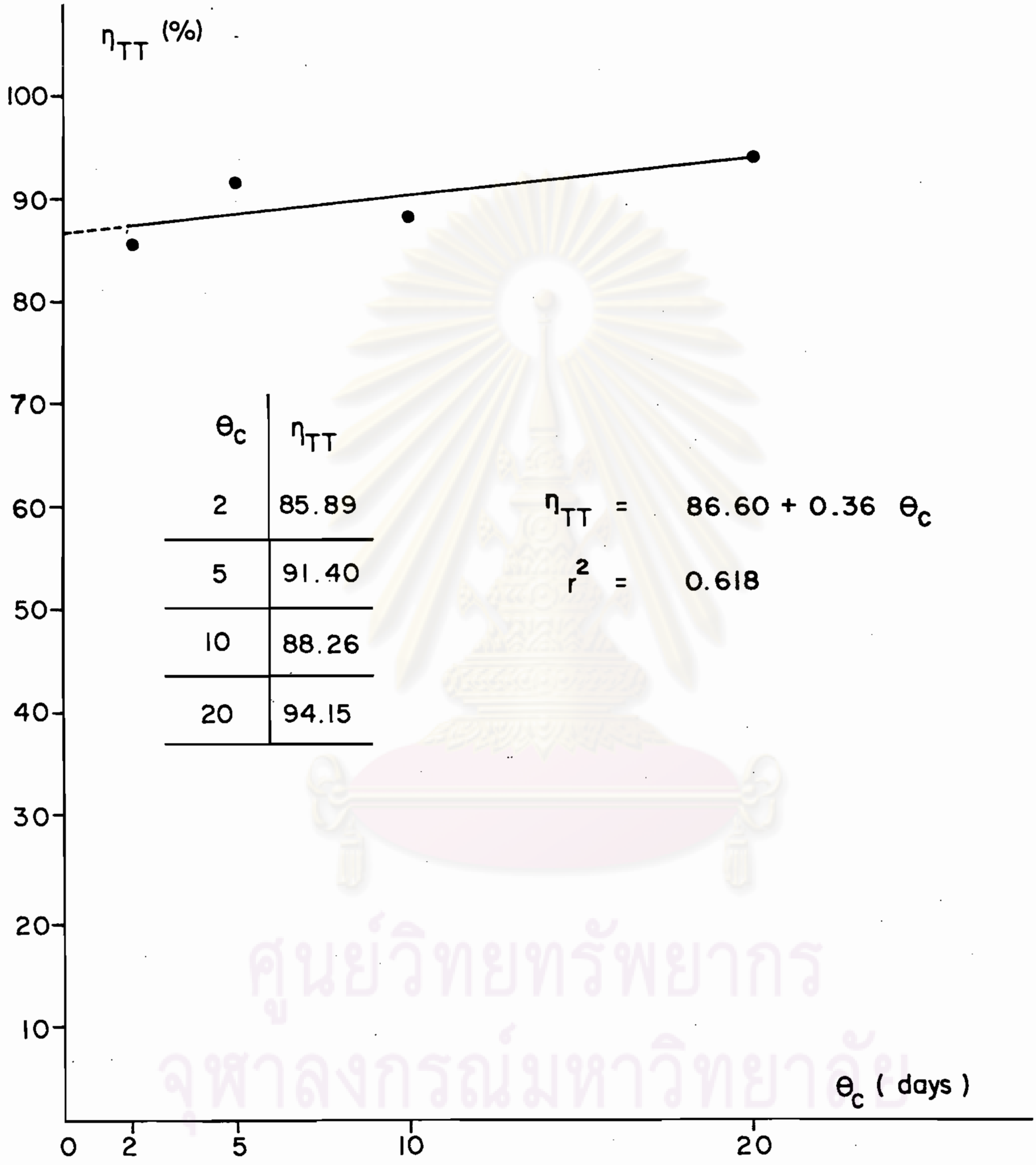


Fig. 5.25 Average of Process Efficiency at Various Sludge Ages

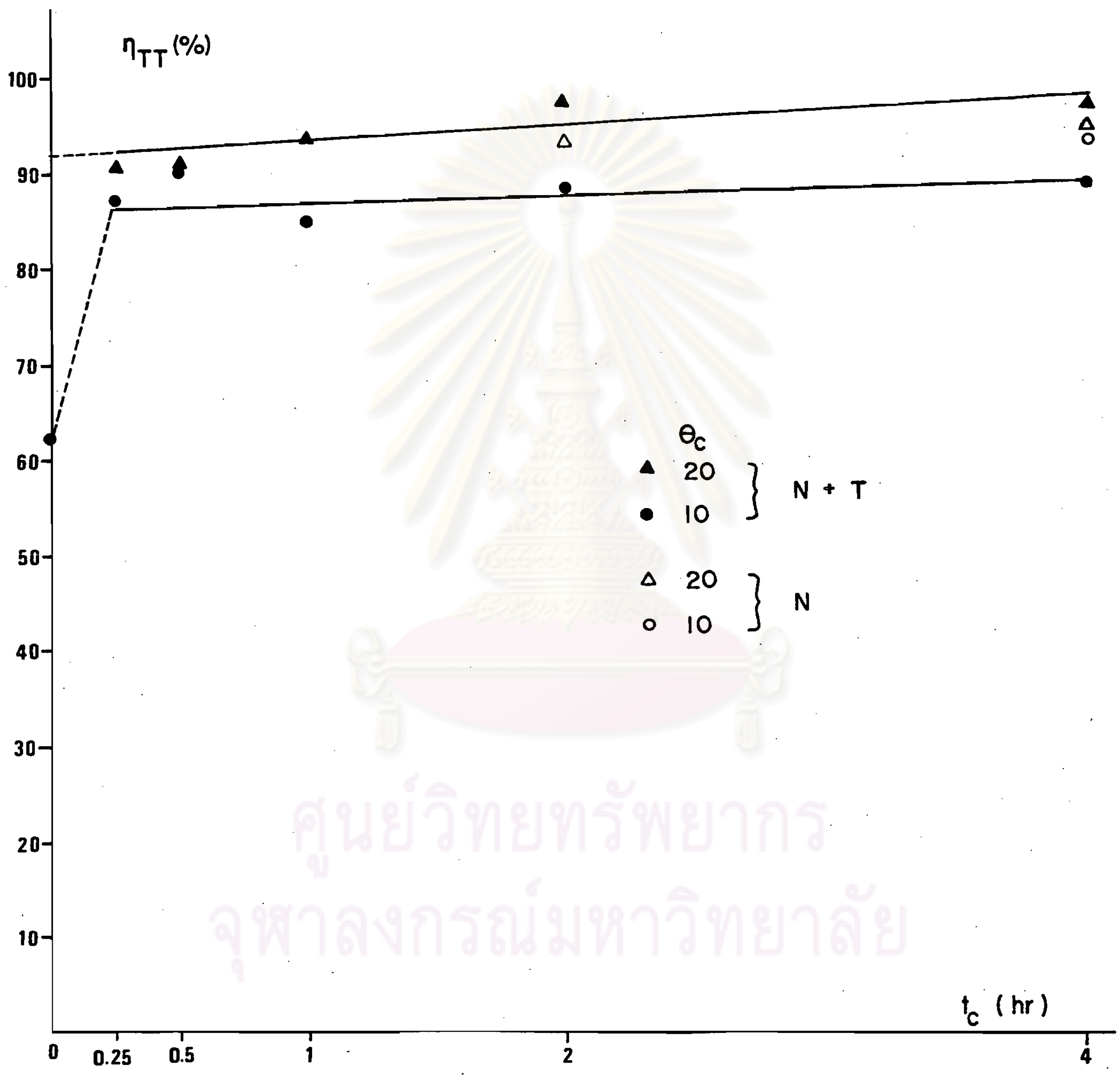


Fig. 5.26 Process Efficiency at Sludge Age 20 and 10 days

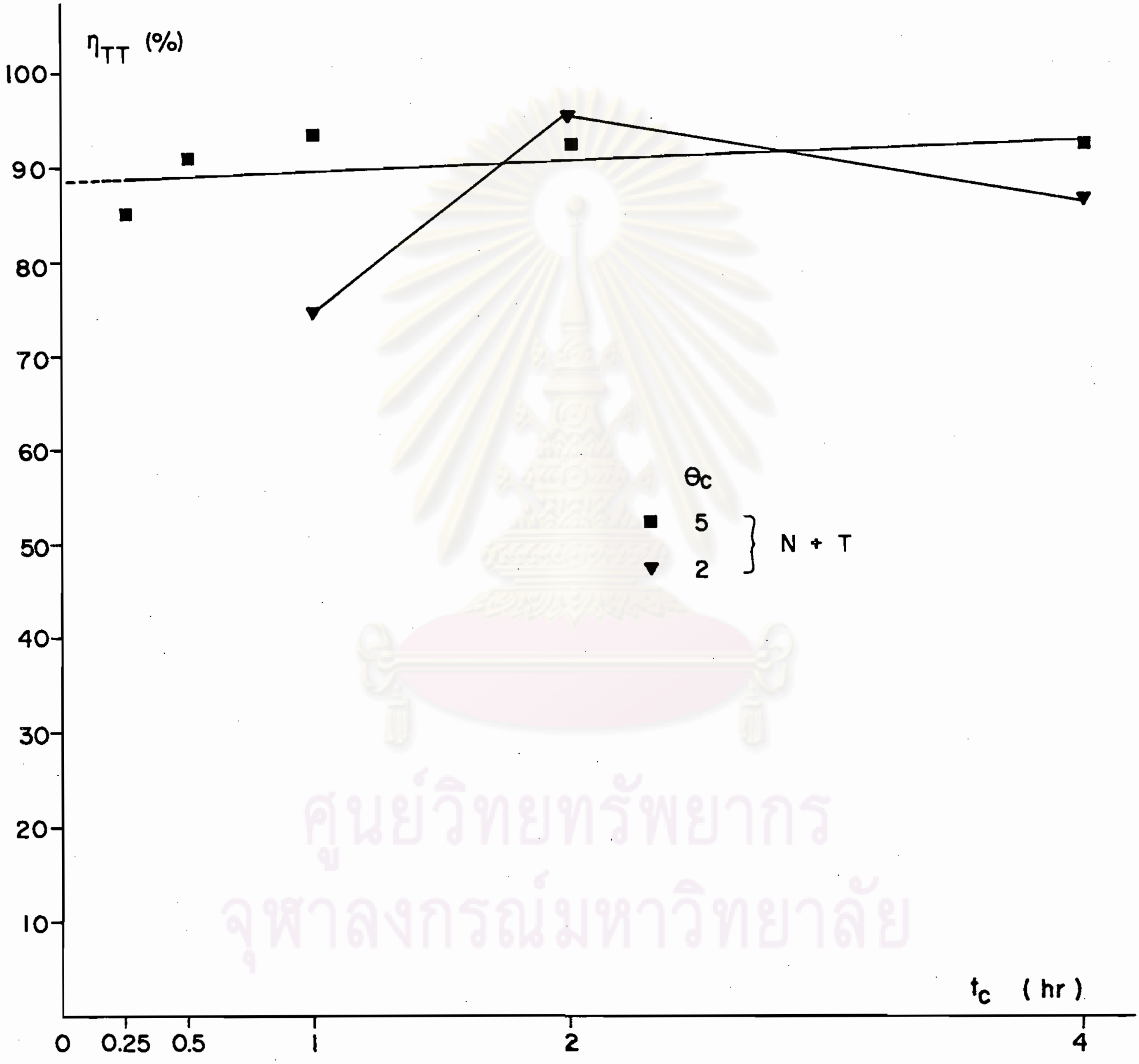


Fig. 5.27 Process Efficiency at Sludge Age 5 and 2 days

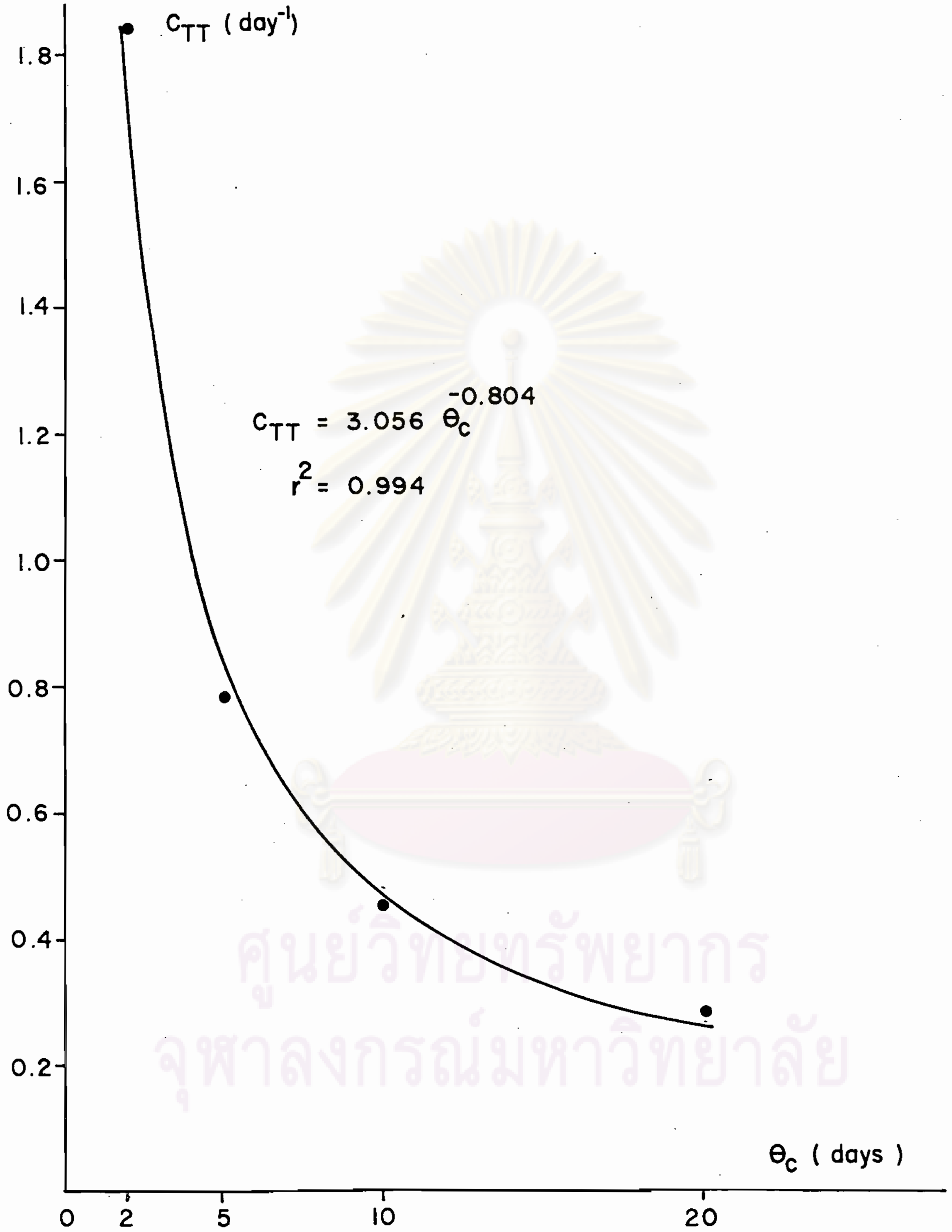


Fig. 5.28 Process Organic Loading at Various Sludge Ages

relation could be expressed as following:

$$C_{TT} = 3.056\ \theta_C^{-0.804} \tag{5.5}$$

5.3 Kinetic Coefficient Determination

5.3.1 Growth Yield (a) and Microorganisms Decay Coefficient (k_2) Determination of the System

The determination of "a" and k_2 of the system are based on equation (3.17).

$$k_T = \frac{1}{\theta_c} = a\ U_T - k_2$$

The average values of specific substrate utilization rate (U_T) based on MLSS and MLVSS at various sludge ages as shown in Table 5.7 and 5.8 are plotted corresponding to $\frac{1}{\theta_c}$ or k_T values. The slope is "a" and the Y- intercept is k_2 as shown in Fig. 5.29.

Table 5.7 - Specific Substrate Utilization Rate (based on MLSS) at Various Sludge Ages.

θ_c Day	k_T Day^{-1}	No. of Tests	U_T (day^{-1})			
			Avg.	min.	max.	s.d.
2	0.50	5	1.528	1.200	1.925	0.247
5	0.20	8	0.667	0.541	0.769	0.077
10	0.10	15	0.327	0.250	0.411	0.049
20	0.05	12	0.197	0.157	0.239	0.022

From Fig. 5.29 the values of "a" and "k_2" (U_T based on MLSS) are equal to 0.336 g SS/g COD and 0.016 day^{-1} respectively. The values of "a" and k_2 where U_T based on MLVSS are 0.327 g VSS/ g COD and 0.041 day^{-1} respectively. These values of "a" and k_2

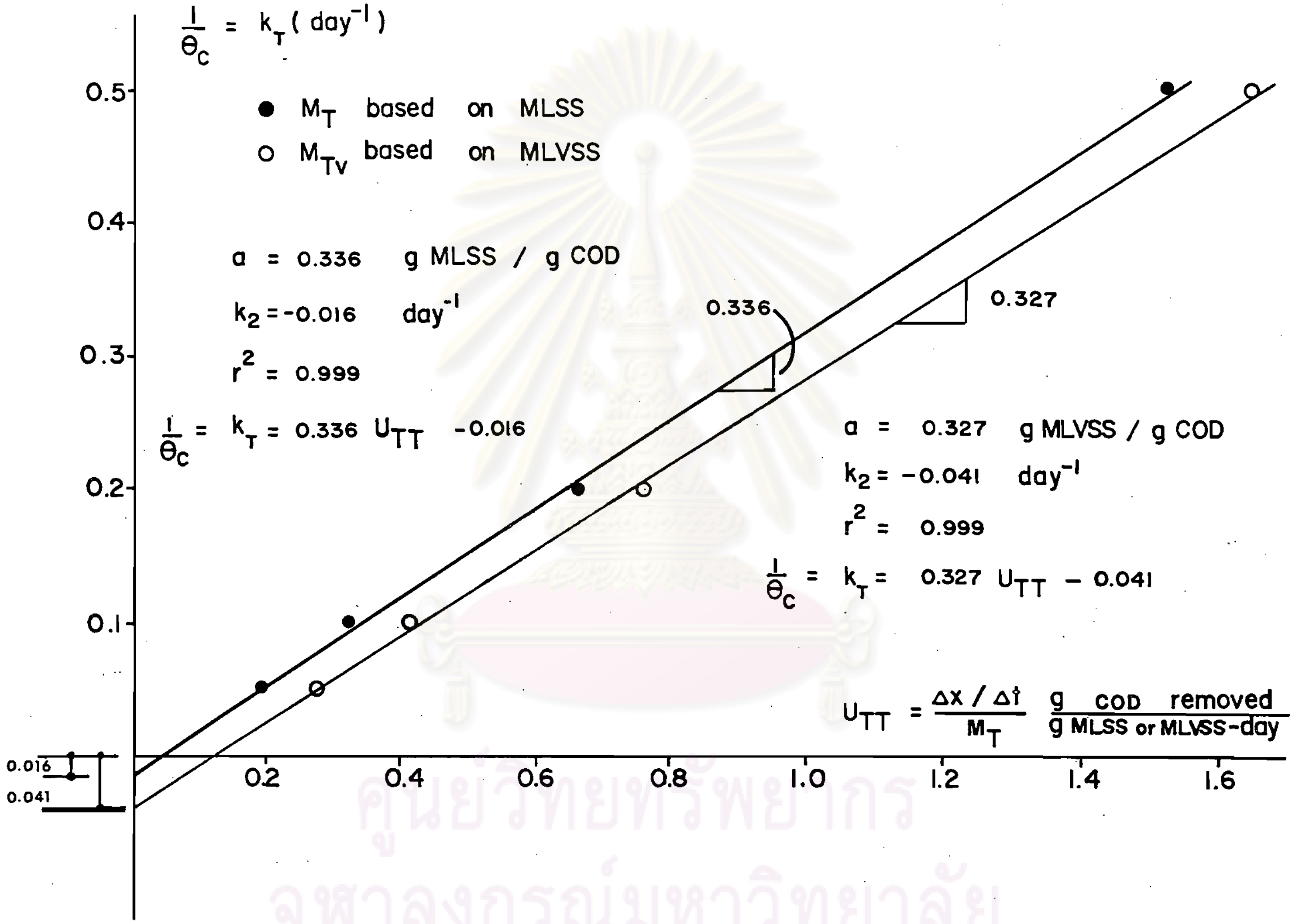


Fig. 5.29 Growth Yield and Microorganisms Decay Coefficient Determination

Table 5.8 - Specific Substrate Utilization Rate (based on MLVSS) at Various Sludge Ages.

θ_c Day	k_T Day^{-1}	No. of Tests	U_T (day^{-1})			
			avg.	min.	max.	s.d.
2	0.50	5	1.648	1.292	2.138	0.293
5	0.20	8	0.760	0.604	0.879	0.090
10	0.10	15	0.415	0.325	0.515	0.058
20	0.05	12	0.276	0.238	0.347	0.037

are nearly to previous investigators as following.

GUJER and JINKINS (1975 a) studied on contact stabilization process employed domestic waste. The results pointed out that k_2 was independent of temperature, while "a" was temperature dependent. The values of "a" equal to 0.48 g VSS/g COD at 11^{o}C and 0.38 g VSS/g COD at 21^{o}C, k_2 equal to 0.07 day^{-1}.

SAIPHANICH (1978) showed that "a" and k_2 of domestic wastewater in contact stabilization process were 0.371 g VSS/g COD and 0.053 day^{-1} respectively.

The difference of k_2 which based upon MLSS and MLVSS is affected from the variation of VSS/SS ratio at various sludge ages (see also equation 3.17) as mentioned in 5.2.4. It means that k_2 should be constant if the VSS/SS ratio is constant through out various sludge ages, only for "a" must be changed with respect to the VSS/SS ratio.

It is obvious that $\frac{1}{\theta_c}$ or k_T vary directly with the U_T, furthermore, the U_T decreases exponentially as the θ_c increases (see Fig. 5.30) which can be written as following:

$$U_{TT} = 2.818\ \theta_c^{-0.904} \quad (U_{TT} \text{ based on MLSS}) \tag{5.6}$$

$$U_{TT} = 2.750\ \theta_c^{-0.788} \quad (U_{TT} \text{ based on MLVSS}) \tag{5.7}$$

5.3.2 The "a_C" and "$(k_2)_C$" Determination

The coefficients a_C and $(k_2)_C$ can be determined, based on the contact tank, the equation (3.17) can be written as:

$$k_C = a_C U_C - (k_2)_C \tag{5.8}$$

The specific substrate utilization rate of the contact tank (U_C) can be written based on Fig. 3.5 as:

$$U_C = \frac{Q\left\{x_i + Rx_S - (1 + R)x_C\right\}}{M_C}$$

From equation (3.3):

$$k_C = \frac{(1 + R)X_C - \bar{R}X_S}{X_C t_C}$$

The values of U_C and k_C at sludge age 20, 10, 5 day were calculated as shown in Figs. 5.31, 5.32 and 5.33 respectively. Obviously, the slope is a_C and the Y-intercept is $(k_2)_C$. These values of a_C and $(k_2)_C$ at various sludge age are shown in Table 5.9.

The value "a" is not equal to a_C because of the values a_C and $(k_2)_C$ vary as the sludge age (θ_c) varies. This can be explained that k_C and U_C vary due to the varying of t_C at each sludge ages but k_T and U_T are constant at each sludge ages which

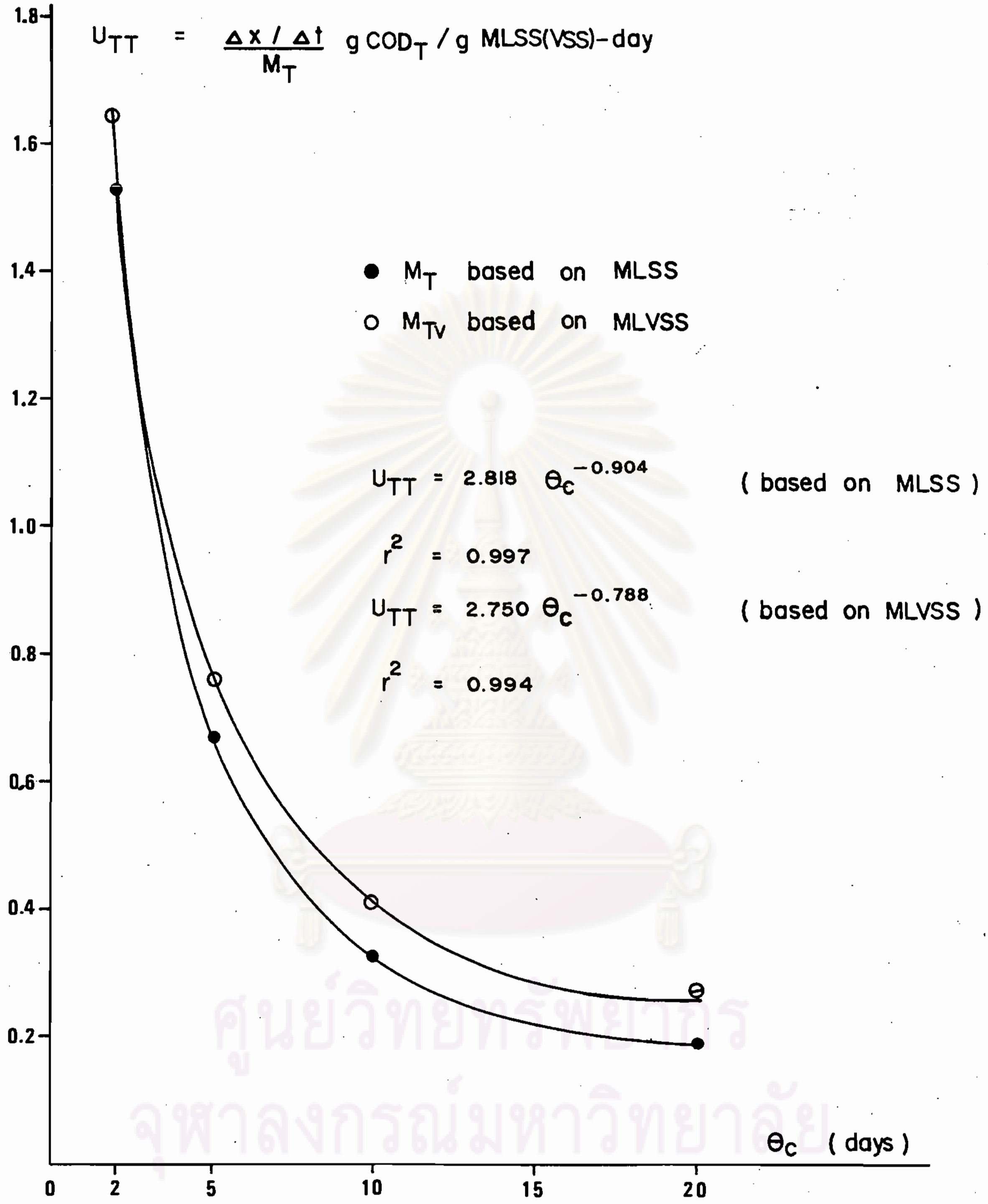


Fig. 5.30 Process Specific Substrate Utilization Rate at Various Sludge Ages

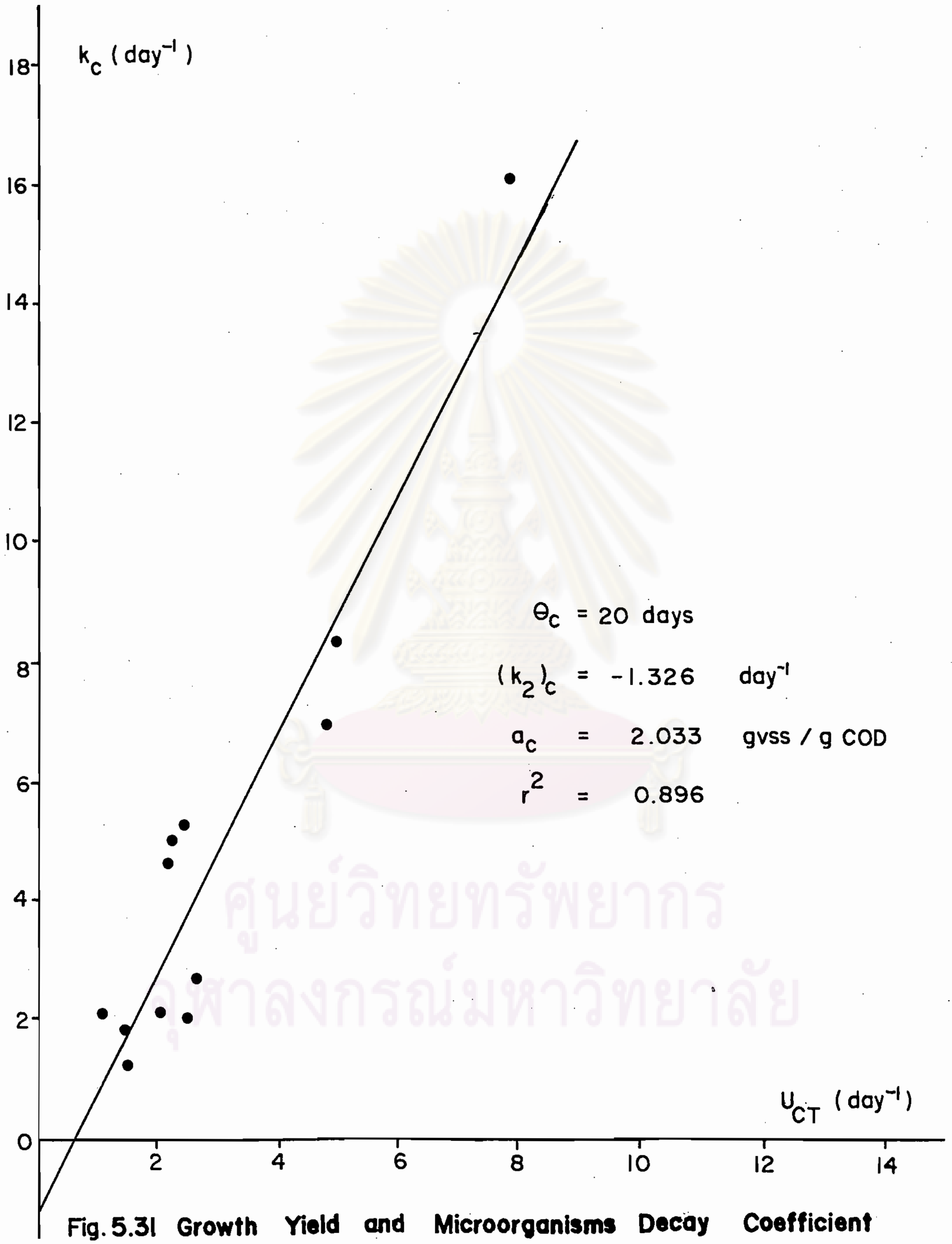


Fig. 5.31 Growth Yield and Microorganisms Decay Coefficient Determination of Contact Tank at Sludge Age 20 days

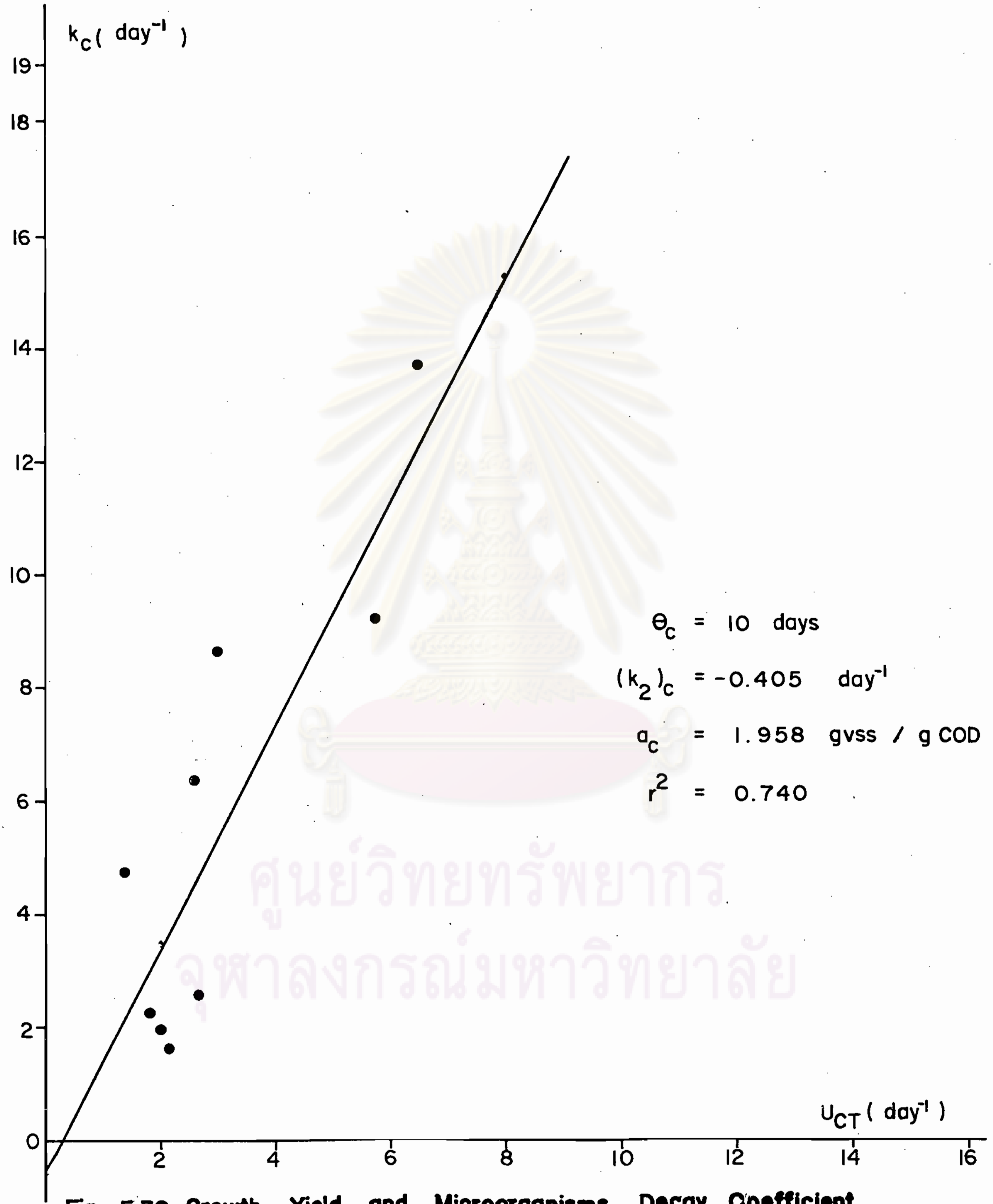


Fig. 5.32 Growth Yield and Microorganisms Decay Coefficient Determination of Contact Tank at Sludge Age 10 days

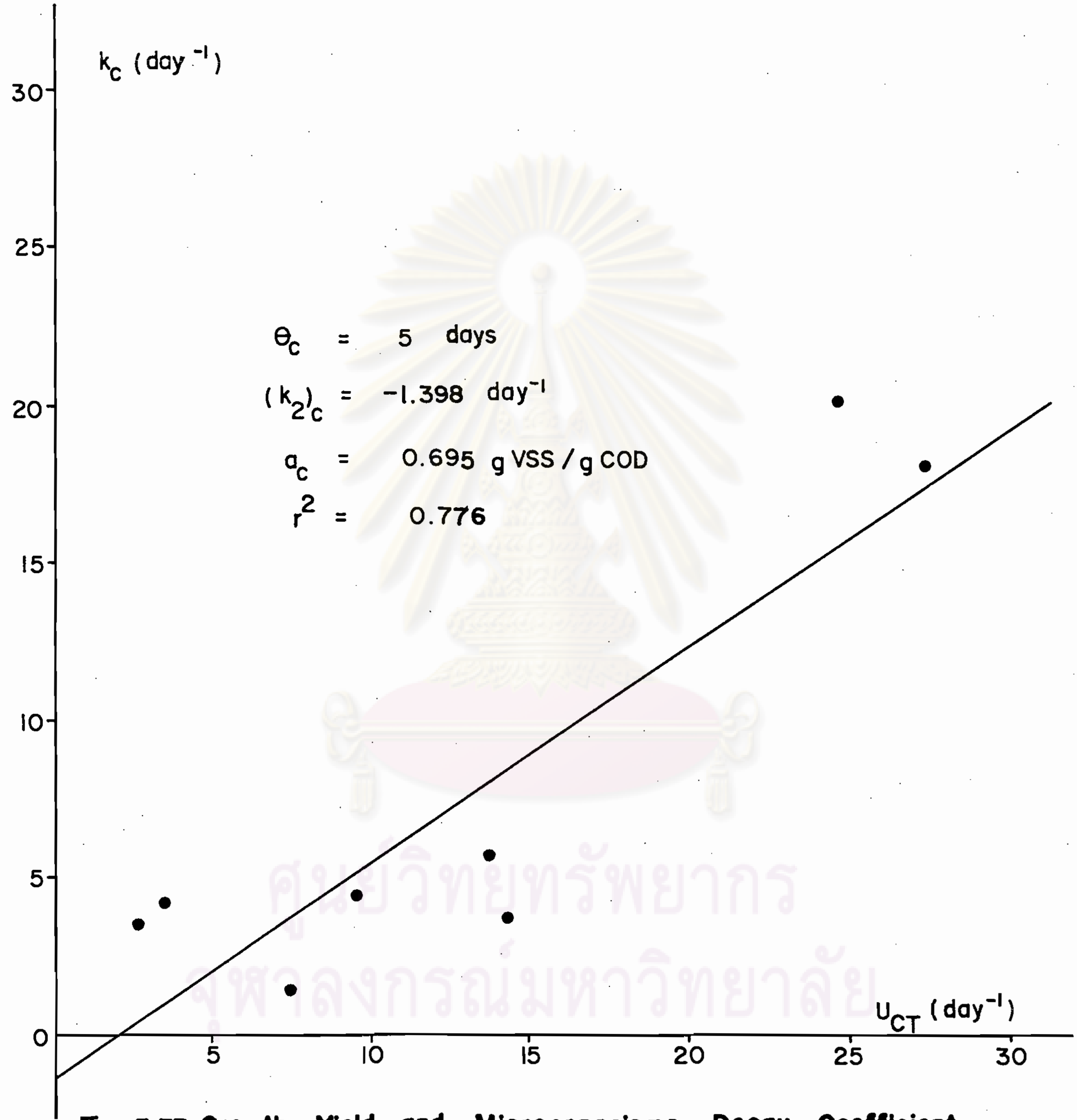


Fig. 5.33 Growth Yield and Microorganisms Decay Coefficient Determination of Contact Tank at Sludge Age 5 days

Table 5.9 - Values of a_C and $(k_2)_C$ at Various Sludge Ages

θ_C	a_C (g VSS/g COD)	$(k_2)_C$ (day^{-1})	r^2
5	0.695	-1.398	0.776
10	1.958	-0.405	0.740
20	2.033	-1.326	0.896

are given unique value of "a" and k_2 with respected to the total system.

The values of a_C and $(k_2)_C$ at sludge age 2 days are not determined due to inadequate of data.

5.3.3 Determination of $(K_o)_{TT}$ and γ_{TT}

Based on equation (3.44), it could be rewritten with respected to the total system and total substrate as following:

$$U_{TT} = \frac{(K_o)_{TT} \cdot C_{TT}}{\gamma_{TT} + C_{TT}}$$

If γ_{TT} is supposed to be constant, this equation could be partitioned into inverted form as:

$$\frac{1}{U_{TT}} = \frac{1}{(K_o)_{TT}} + \frac{\gamma_{TT}}{(K_o)_{TT}} \cdot \frac{1}{C_{TT}}$$

Therefore $1/U_{TT}$ is function of $1/C_{TT}$ and these two terms are plotted through out the values of sludge ages 20, 10, 5 and 2 days from 40 sets of experimental test run as shown in Fig. 5.34. The result is pointed out that $1/U_{TT}$ is linear function of $1/C_{TT}$ with the correlation coefficient (r^2) equals to 0.997. The slope of the graph is $\gamma_{TT}/(K_o)_{TT}$ and Y-intercept is $1/(K_o)_{TT}$. Then,

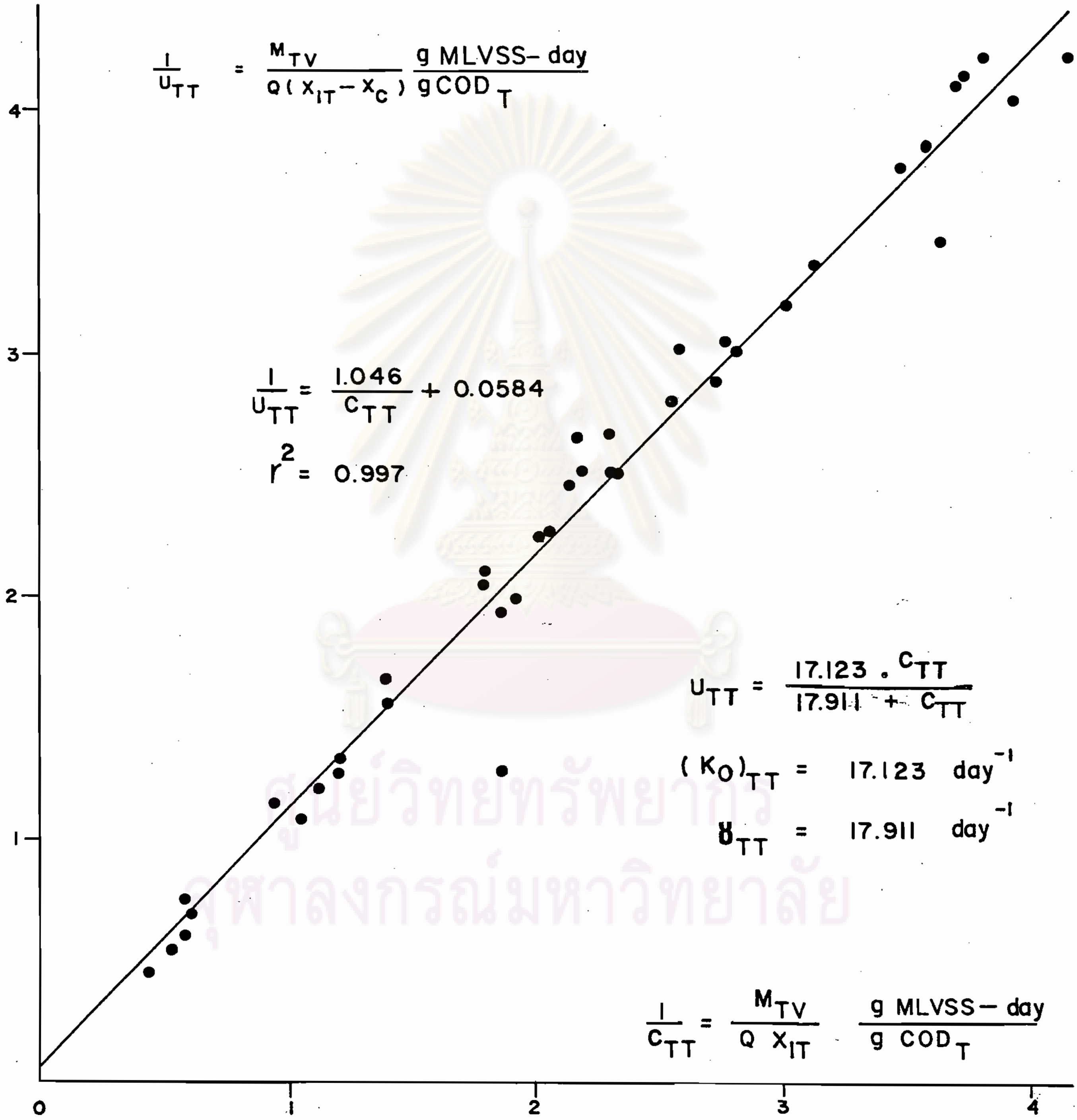


Fig. 5.34 Determination of $(K_o)_{TT}$ and ϑ_{TT}

the values of $(K_o)_{TT}$ and γ_{TT} are evaluated and postulated to be constant values. The comparison of these values between the obtained values and based on SAIPHANICH (1978) are shown in Table 5.10. The correlation of U_{TT} and C_{TT} are shown in Fig. 5.35.

Table 5.10 - The Comparison of $(K_o)_{TT}$ and γ_{TT} between the Obtained Values and SAIPHANICH (1978)

Comparison	No. of Tests	$(K_o)_{TT}$	γ_{TT}	r^2
		Day^{-1}	Day^{-1}	
Obtained Values*	40	17.12	17.911	0.997
SAIPHANICH (1978)**	68	5.13	5.65	0.994

*Based on tapioca wastewater

**Based on domestic wastewater

The obtained value of $(K_o)_{TT}$ is about 3 times greater than the value of $(K_o)_{TT}$ of the domestic wastewater. This can be indicated that, although the influent substrate concentration of tapioca wastewater is also about 3 times greater than the domestic wastewater the contact stabilization process still has ability to increase maximum rate of process substrate utilization per unit weight of microorganisms $(K_o)_{TT}$, without affecting the growth yield coefficient (a) and microorganism decay coefficient of the process (see also 5.3.1).

5.3.4 Determination of $(K_o)_{CT}$ and γ_{CT}

The equation (3.45) can be transformed to:

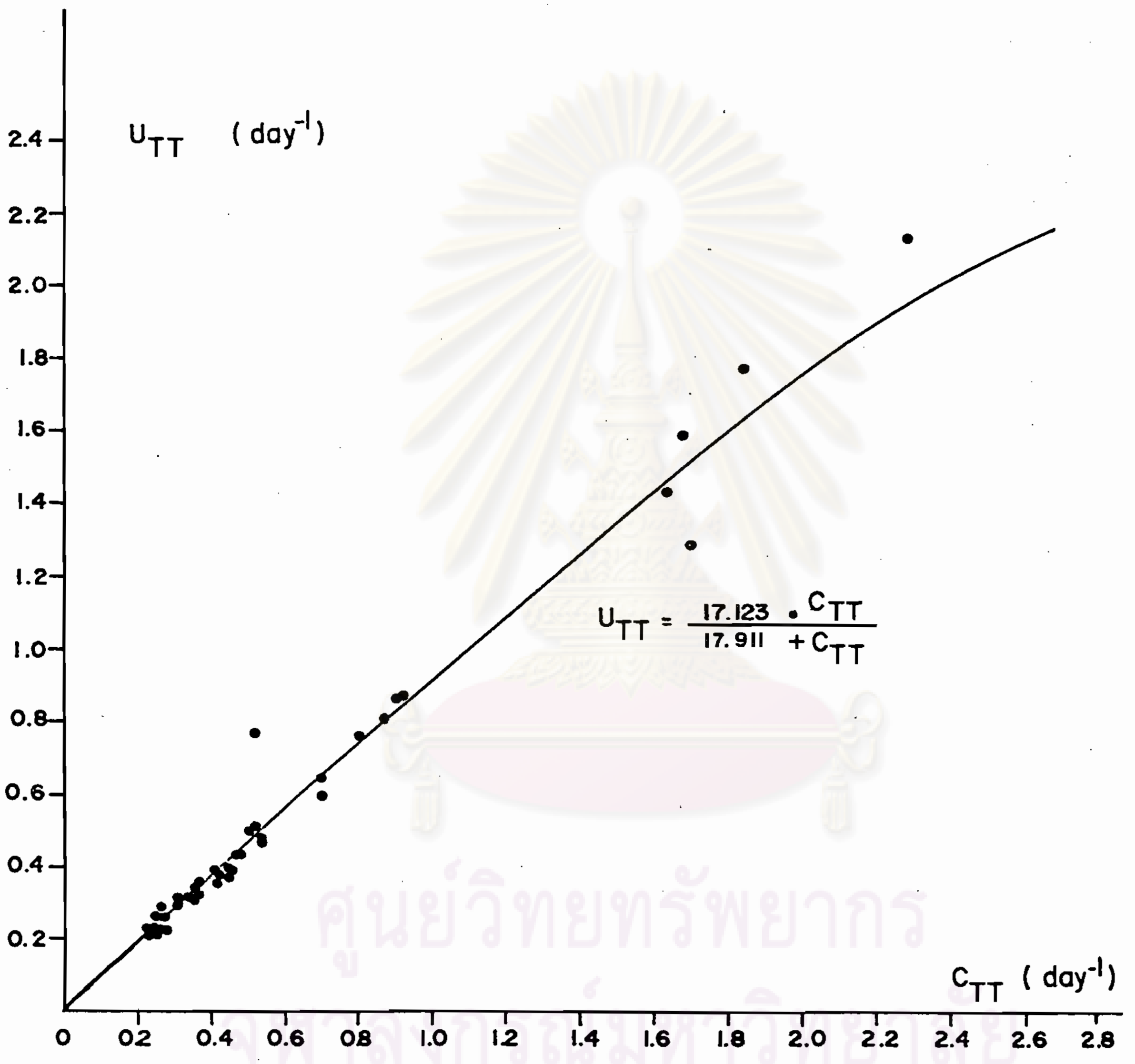


Fig. 5.35 Correlation between Process Spceific Substrate Utilization Rate and Process Organic Loading

$$\frac{1}{U_{CT}} = \frac{1}{(K_o)_{CT}} + \frac{\gamma_{CT}}{(K_o)_{CT}} \cdot \frac{1}{C_{CT}}$$

where:

$$U_{CT} = \frac{Q\left\{x_i + Rx_S - (1 + R)x_C\right\}}{M_C}$$

$$C_{CT} = \frac{Q(x_i + Rx_S)}{M_C}$$

The values of $(K_o)_{CT}$ and γ_{CT} can be evaluated by the same method of $(K_o)_{TT}$ and γ_{TT} determination as shown in Fig. 5.36. It could be pointed out that $(K_o)_{CT}$ and γ_{CT} are also constant. The comparison of these values between the obtained values and based on SAIPHANICH (1978) are shown in Table 5.11. The correlation of U_{CT} and C_{CT} are shown in Fig. 5.37.

Table 5.11 - The Comparison of $(K_o)_{CT}$ and γ_{CT} between The Obtained Values and SAIPHANICH (1978)

Comparison	No. of Tests	$(K_o)_{CT}$ Day^{-1}	γ_{CT} Day^{-1}	r^2
Obtained Values*	40	81.30	90.67	0.985
SAIPHANICH (1978)**	68	25.91	34.00	0.986

*Based on tapioca wastewater

**Based on domestic wastewater

5.3.5 <u>Determination of</u> $(K_s)_{CT}$

From equation (3.49):

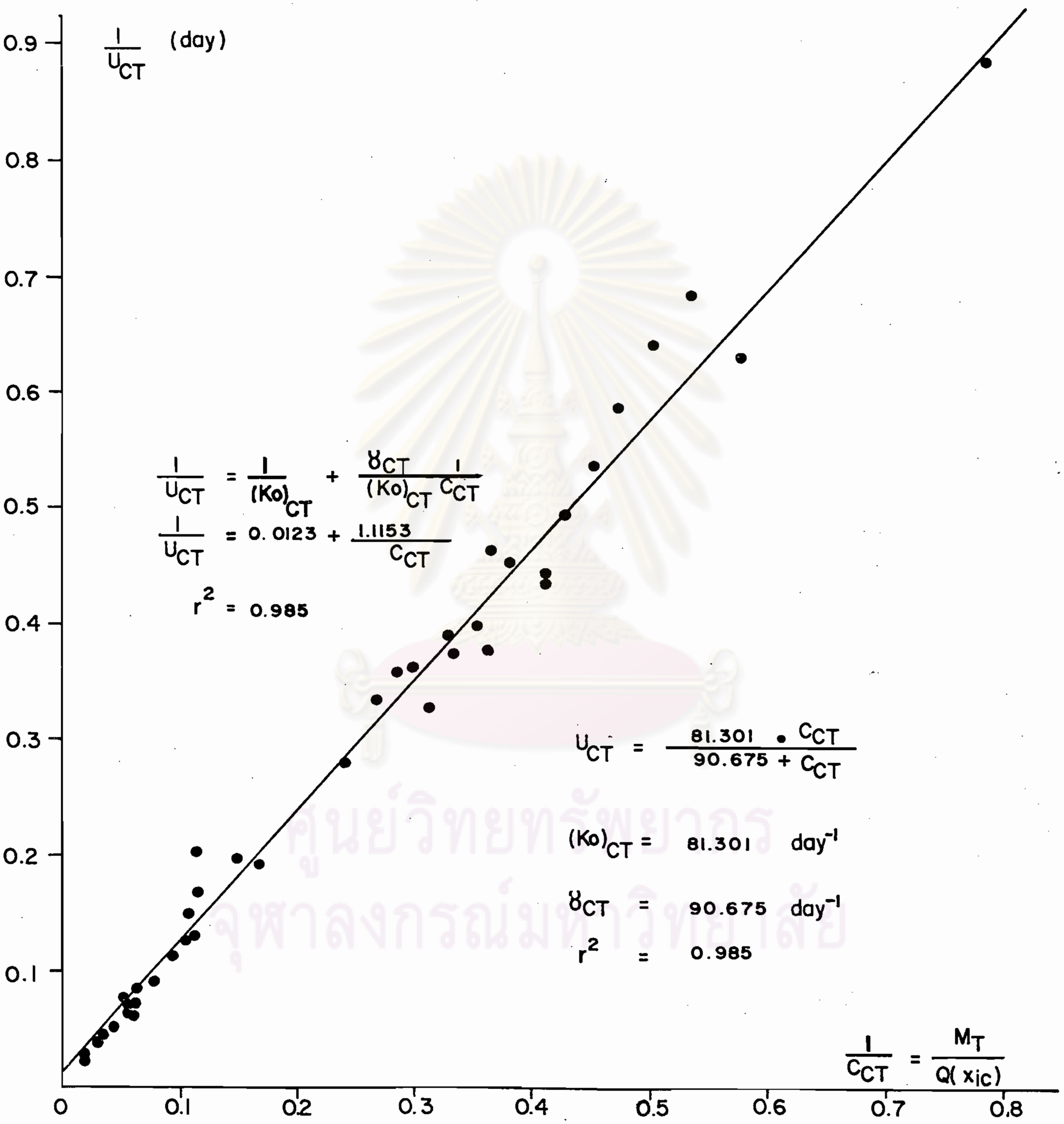


Fig. 5.36 Determination of $(K_o)_{CT}$ and ϑ_{CT}

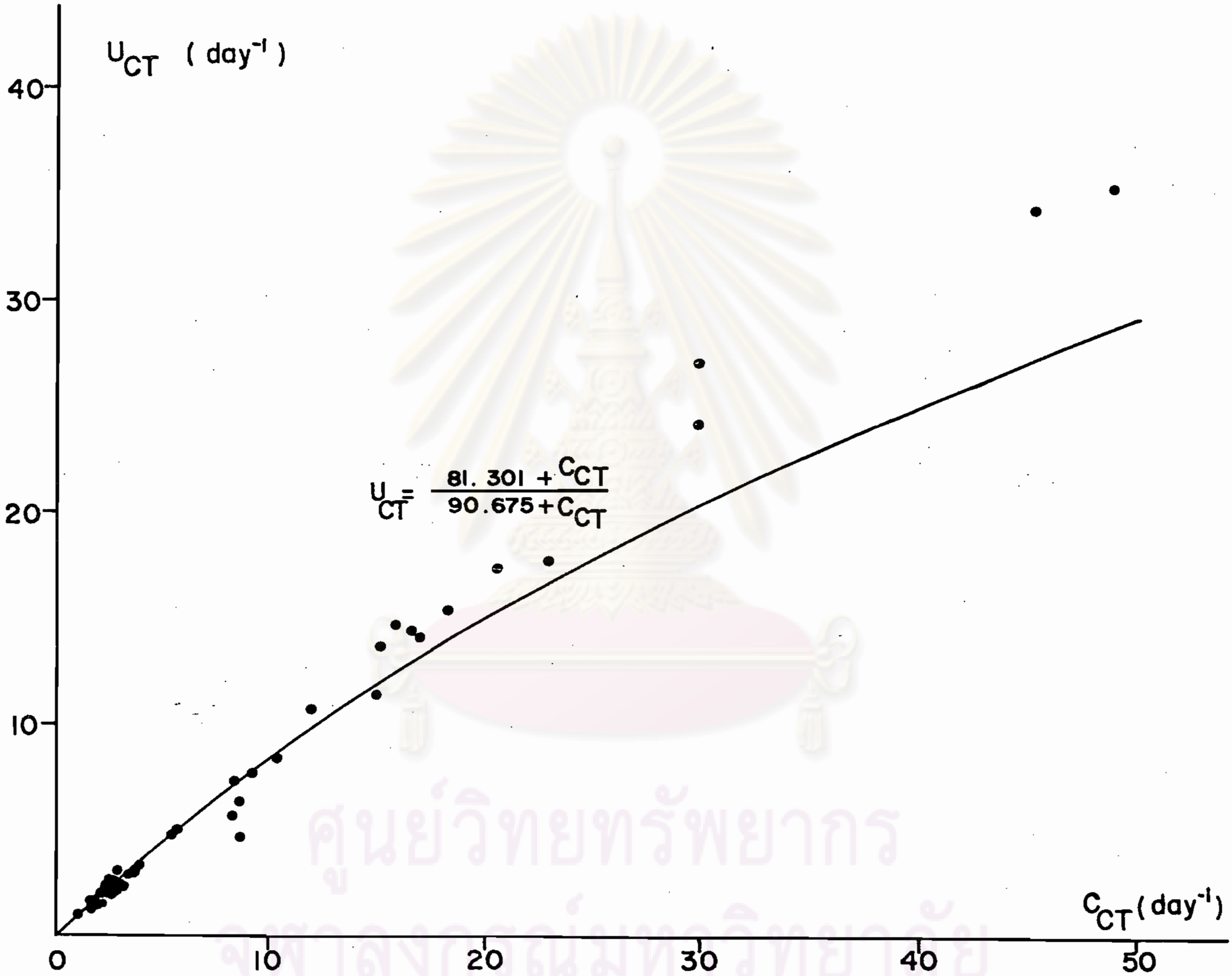


Fig. 5.37 Correlation between Specific Substrate Utilization Rate and Organic Loading of Contact Tank

$$(K_S)_{CT} = \gamma_{CT} \cdot \frac{1}{C_{CT}} \cdot x_C$$

It could be pointed out from the experimental data that $1/C_{CT}$ varied directly as fraction of biomass in the contact tank (α) at various sludge ages and the slopes of the graphs were also exponentially correlated with sludge age (θ_c) as shown in Fig. 5.38 and 5.39 respectively. Therefore the term $1/C_{CT}$ and the above equation could be written as following:

$$\frac{1}{C_{CT}} = 0.308\theta_c^{0.813} \cdot \alpha \qquad (5.9)$$

or in general form:

$$\frac{1}{C_{CT}} = a_1\theta_c^{a2} \cdot \alpha \qquad (5.10)$$

$$(K_S)_{CT} = 0.308\theta_c^{0.813} \cdot \gamma_{CT} \cdot \alpha \cdot x_c \qquad (5.11)$$

or in general form:

$$(K_S)_{CT} = a_1\theta_c^{a2} \cdot \gamma_{CT} \cdot \alpha \cdot x_c \qquad (5.12)$$

from equation (5.5):

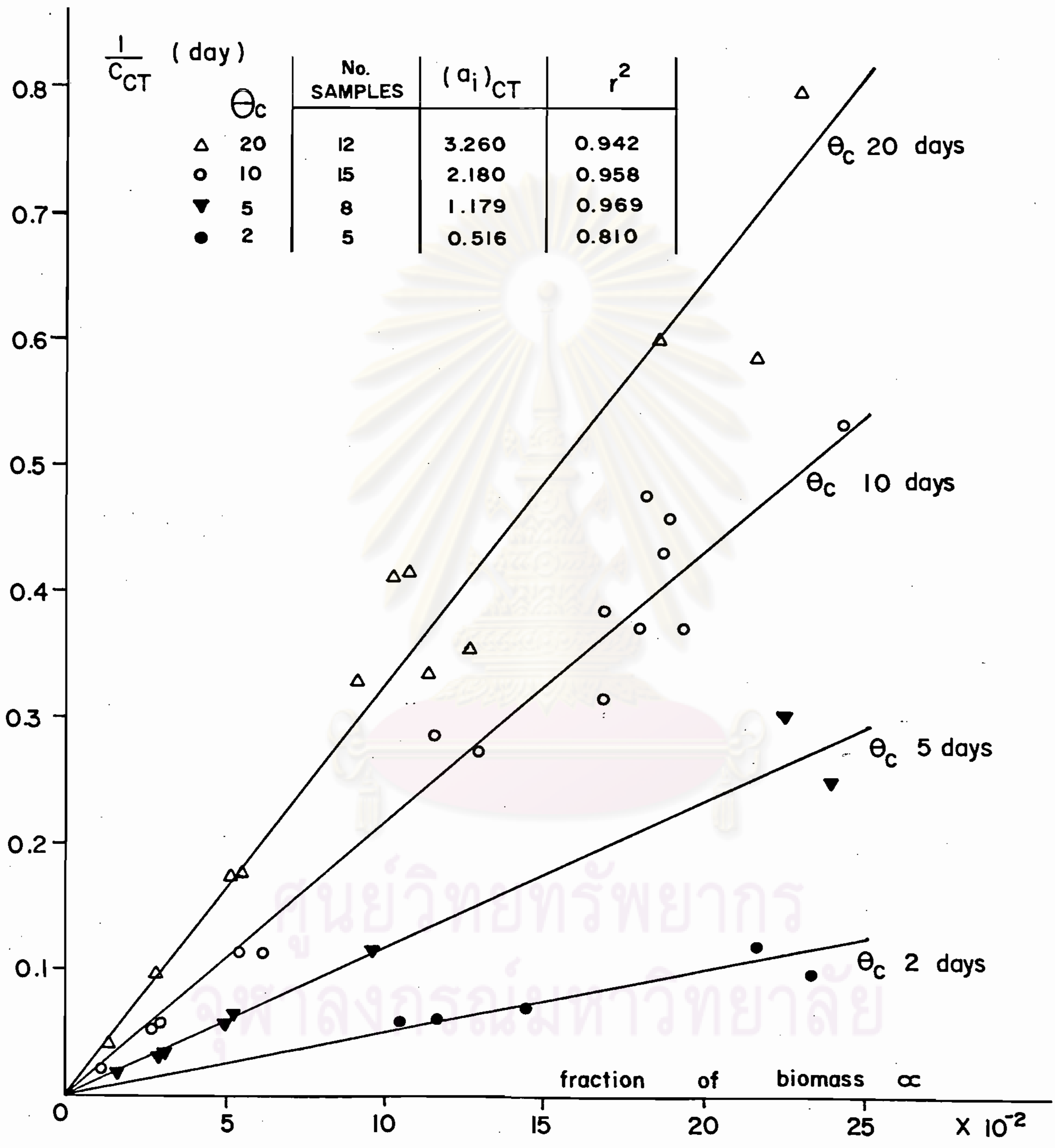
$$C_{TT} = 3.056\theta_c^{-0.804}$$

or in general form:

$$C_{TT} = a_1^* \, \theta_c^{a_2^*} \qquad (5.13)$$

substitute equation (5.9) and (5.12) into equation (3.54):

$$\eta_{CT} = 1 - a_1 a_1^* \, \theta_c^{a_2 + a_2^*} (1 - \eta_{TT})(1 + R) \qquad (5.14)$$



θ_c	No. SAMPLES	$(a_i)_{CT}$	r^2
△ 20	12	3.260	0.942
○ 10	15	2.180	0.958
▼ 5	8	1.179	0.969
● 2	5	0.516	0.810

Fig. 5.38 Correlation between $1/C_{CT}$ and Fraction of Biomass at Various Sludge Ages

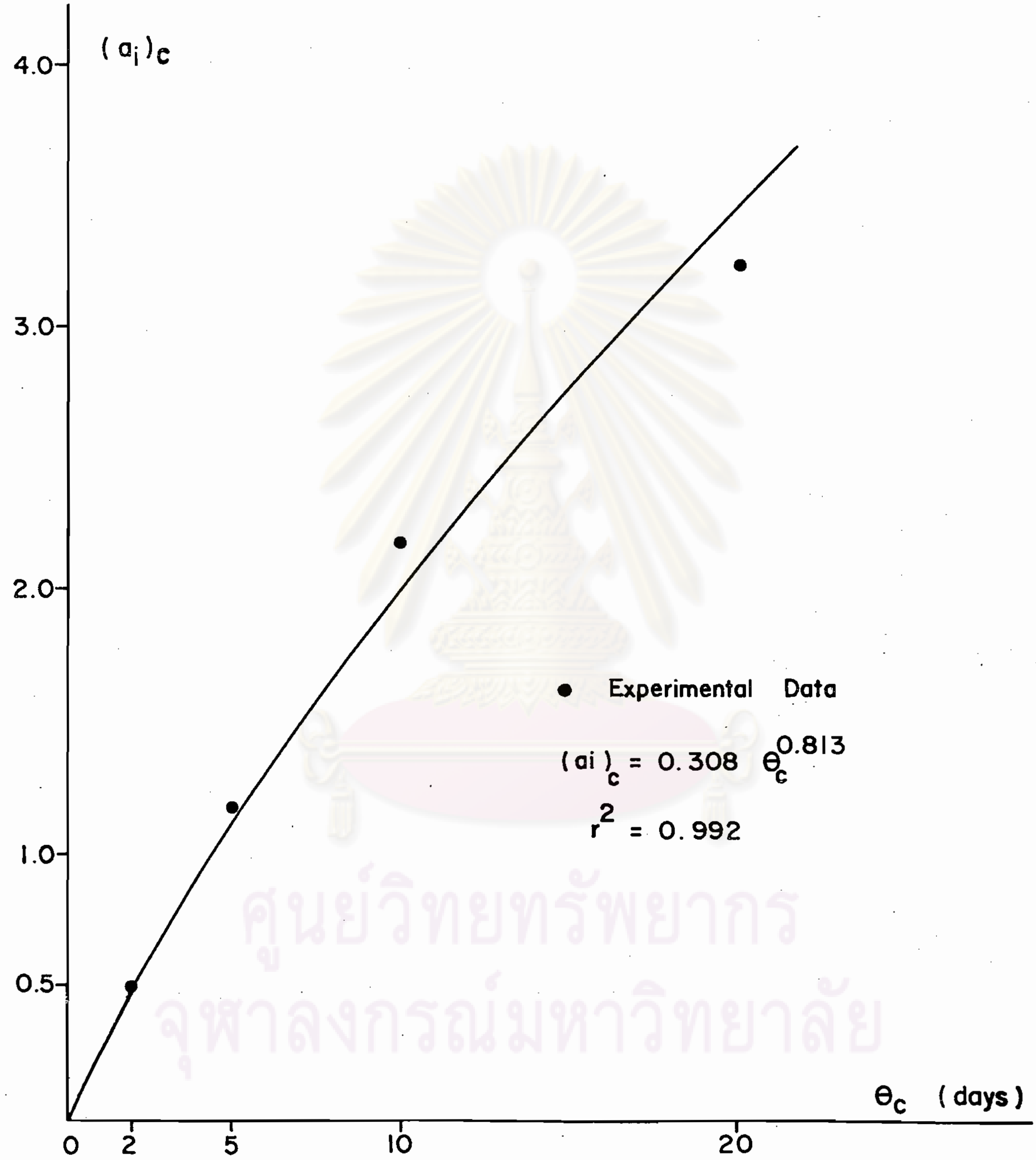


Fig. 5.39 Correlation between $(a_i)_c$ and Sludge Ages

from equation (3.48):

$$(K_S)_{TT} = \gamma_{TT} \cdot \frac{1}{C_{TT}} \cdot x_e \qquad (5.15)$$

substitute equation (5.12) into equation (5.14):

$$(K_S)_{TT} = a_1^* \, \theta_c^{a_2^*} \cdot \gamma_{TT} \cdot x_c \qquad (5.16)$$

where; $x_e = x_c$

It is obvious from equation (5.15) and (5.10) that $(K_S)_{TT}$ is functional of θ_c and x_c whereas $(K_S)_{CT}$ is functional of θ_c, x_c and α.

5.4 Determination of "U_S"

According to the flow diagram of contact stabilization process, Fig. 3.5, the substrate remained in the contact tank were continued to remove in the stabilization tank. The specific substrate utilization rate of the stabilization tank (U_S) should be calculated as following:

$$U_S = \frac{RQ(x_c - x_s)}{M_s} \qquad (5.17)$$

The obtained data showed that U_S decreases exponentially as the sludge age (θ_c) increases, as illustrated in Fig. 5.40. The represented equation could be written with correlation coefficient (r^2) equal to 0.969 as following:

$$U_S = 0.249 \, \theta_c^{-1.057} \qquad (5.18)$$

or in general form:

$$U_S = a_3 \theta_c^{a_4} \qquad (5.19)$$

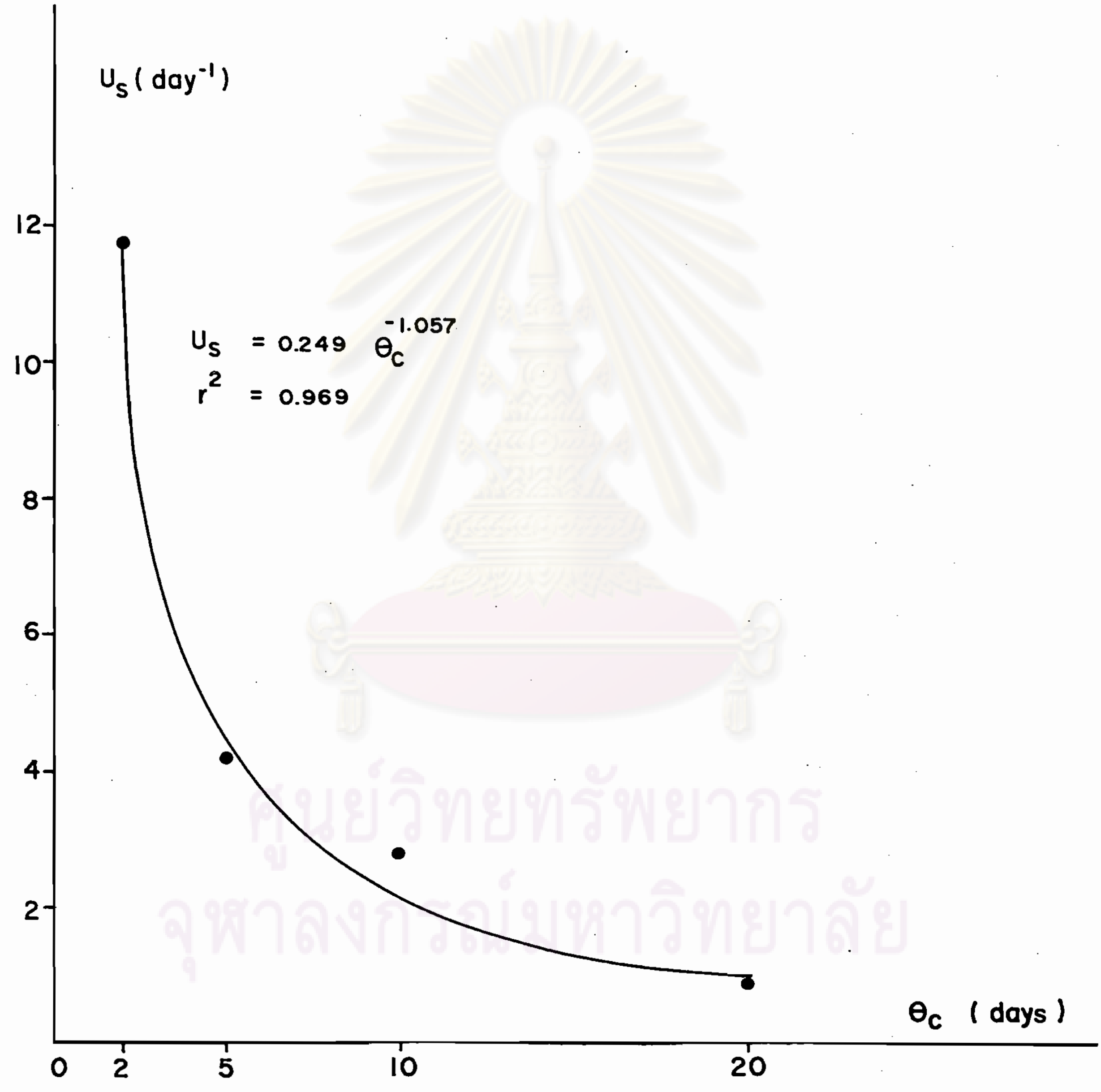


Fig. 5.40 Specific Substrate Utilization Rate of Stabilization Tank at Variouse Sludge Ages

5.5 Summarized of the Obtained Parameters and Kinetic Coefficients

In this research the obtained parameters and kinetic coefficients are summarized as shown in Table 5.12. The values of substrate and biomass are based on COD and MLVSS respectively.

Table 5.12 - Obtained Parameters and Kinetic Coefficients

Parameters or Kinetic Coefficients	Units	Equal to	r^2
VSS/SS ratio	non	$0.928-0.011\theta_c$	0.957
SVI	mℓ/g	$522\theta_c^{-0.759}$	0.737
η_{TT}	%	$86.60 + 0.36\theta_c$	0.618
C_{TT}	day^{-1}	$3.056\theta_c^{-0.804}$	0.994
a_1^*	non	3.056	0.994
a_2^*	non	-0.804	0.994
a	g VSS/g COD	0.327	0.999
k_2	day^{-1}	-0.041	0.999
U_{TT}	day^{-1}	$2.750\theta_c^{-0.788}$	0.994
$(K_o)_{TT}$	day^{-1}	17.123	0.997
γ_{TT}	day^{-1}	17.911	0.997
$(K_o)_{CT}$	day^{-1}	81.301	0.985
γ_{CT}	day^{-1}	90.675	0.985
$1/C_{CT}$	day	$0.308\theta_c^{0.813}\cdot\alpha$	0.992
U_S	day^{-1}	$0.249\theta_c^{-1.057}$	0.969
a_1	non	0.308	0.992
a_2	non	0.813	0.992
a_3	non	0.249	0.969
a_4	non	-1.057	0.969