CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 Characteristics of wastewater and soil properties

The ranges and average values of several characteristics of wastewater were shown in Table 3 and the results of the study were shown in Appendix B. Some physical, chemical and biological properties of soils were shown in Table 4.

Table 3 Characteristics of domestic wastewater from Huaykwang sewage treatment plant.

Characteristics	Range	Mean value
pH	7.1-7.5	7.4
COD (mg/l)	306-504	393
NH_4-N (mgN/l)	30-40	35
Total nitrogen (mgN/l)	34-43	39
NO_3-N (mgN/l)	immeasurable low value	-
Orthophosphate (mgP/l)	6.2-7.5	6.8
Total phosphate (mgP/l)	8.2-7.5	8.9
Total bacteria (col/ml)	$10x10^7$-$8.0x10^7$	$2.5x10^7$
Fecal caliform (col/ml)	$8x10^5$-$4.8x10^6$	$2.3x10^6$

Table 4 The properties of soils used in this experiment.

Soil series	Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	Moisture content (%)	pH in $CaCl_2$	CEC (meq/100 g soil)	Organic carbon (%)	Total bacteria ($\times 10^6$ col/g soil)	Fecal coliform (col/g soil)
Sattahip	25	64.6	29.9	5.5	SL	9.6	4.6	6.5	1.8	1.0	-
	50	72.7	22.4	4.9	SL	7.8	4.7	4.7	1.3	0.8	-
	75	75.3	20.3	4.4	LS	8.0	4.6	2.9	0.9	140.0	-
	100	79.5	15.1	5.4	LS	7.5	4.5	2.1	0.4	30.0	-
Muak Lek	25	62.5	21.5	16.0	SL	15.9	7.4	12.6	3.8	1.5	-
	50	60.5	23.5	16.0	SL	13.9	7.4	10.7	1.5	1.7	-
	75	56.7	26.7	16.6	SL	14.0	7.5	9.4	1.1	6.4	-
	100	57.1	28.4	14.5	SL	14.3	7.6	9.1	0.7	1.9	-
Ban Bung	25	69.5	26.5	4.0	SL	11.9	5.6	3.8	1.8	3.0	-
	50	83.1	15.9	1.0	LS	9.3	6.1	4.3	0.5	3.0	-
	75	83.3	16.3	1.4	LS	8.2	5.3	1.3	0.2	0.9	-
	100	83.0	15.6	1.4	LS	6.7	6.0	1.1	0.2	0.6	-
Chon Buri	25	75.7	19.3	6.0	SL	13.6	5.0	4.7	1.1	14.0	-
	50	71.4	19.2	9.4	SL	11.7	5.0	3.3	0.4	0.4	-
	75	73.1	23.0	3.9	SL	9.2	5.2	2.0	0.2	0.24	-
	100	63.9	21.2	14.9	SL	11.7	4.7	5.4	0.3	0.21	-
Klaeng	25	79.1	20.5	0.4	LS	7.3	5.6	3.0	0.9	5.2	-
	50	80.1	19.0	0.9	LS	6.6	6.1	1.5	0.2	0.61	-
	75	72.9	17.7	9.4	SL	5.1	5.6	3.9	0.1	1.1	-
	100	62.2	20.5	17.3	SL	8.4	6.6	7.7	0.1	0.88	-
Kampaeng Saen	25	4.0	50.7	45.3	SiC	18.7	5.5	19.9	1.6	6.6	-
	50	2.4	50.9	46.7	SiC	18.5	5.5	19.1	0.9	1.2	-
	75	1.0	55.9	43.1	SiC	17.6	5.9	17.9	0.6	0.8	-
	100	9.0	50.7	40.3	SiC	15.4	5.9	16.7	0.5	2.0	-
Thon Buri	25	4.6	48.2	47.2	SiC	17.5	6.1	33.9	3.2	1.5	-
	50	5.6	44.3	50.1	SiC	16.0	6.5	34.0	2.5	0.9	-
	75	6.2	43.1	50.7	SiC	11.2	7.1	35.4	1.4	7.7	-
	100	4.4	40.2	55.4	SiC-C	9.1	7.3	31.3	0.4	0.5	-

4.2 Soil Permeability

In this study, permeability of soil to domestic wastewater was roughly, measured by using the volume of water that remained on surface soil column as an index, the lesser the volume of water, the better the permeability.

When wastewater was added to some soil columns, two soil depths of the Kampaeng Saen, Thon Buri and the one at 50-100 cm depth of Klaeng soil series, no water came out. From the method mentioned above, these soils were not permeable to domestic wastewater. In fact, these soils have been used for septic tank soil adsorption system and they work. The results obtained may due to many factors. Firstly, the soils might be more compact than in natural condition because of the method of sampling. Secondly, wastewater passed through soil was limited mostly to one direction, the vertical flow. Thirdly, from their properties, it was shown that they contained more clay size particles than the other 4 series, therefore, the permeability of the latter should be better. Furthermore, permeability of any soil to water is greatly affected by chemistry of the soil-water system. Both the exchangeable cations of the soil and the concentration and composition of salts in water, Reeve (1965). In addition, kind of clay minerals in soils are also affected the permeability, especially at saturation.

The results obtained from soil at 0-50 cm depth of the remaining 5 soil series showed that these soils were different in their permeability. When first applied 1.5 liter of waste water to soil columns, there were no surface water left from 3 soil series, the Ban Bung, Muak Lek and Sattahip when recorded after 24 hours of applications. Eventhough, wastewater was applied to the same soil columns everyday to the initial level, there were no water left at the surface for 6, 9 and 10 days of the Ban Bung, Muak Lek and Sattahip soil series, respectively. There were about 600 and 1100 ml of water remained at the surface of soil columns of the Chon Buri and Klaeng series, on the first day of applications. After sometimes, see Figure 2, 3, 4, 5, 6, wastewater on the surface of soil columns remained constant for each soil when recorded everyday. The average values were 1204, 1216, 1370, 1331, 1384 ml/day for Sattahip, Muak Lek, Ban Bung, Chon Buri and Klaeng series, respectively. According to the author's method of measuring soil permeability to domestic wastewater, the percolation rate of soils in the study could be compared, Figures 2, 3, 4, 5, 6 as followed : Sattahip > Muak Lek > Ban Bung > Chon Buri, Klaeng > Kampaeng Saen and Thon Buri series. The decrease in permeability results from swelling, slaking, deflocculation, dispersion and other structure-disrupting processes (Reeve, 1965).

The majority of water added to soil column, at 50-100 cm depth remained on the surface on the first day of application were 1300, 1100, 1100 and 950 ml from Ban Bung, Muak Lek, Sattahip and Chon Buri series, respectively. Not more than 10 days, the volume of wastewater remained were about the same levels. The average values, from Ban Bung, Muak Lek, Sattahip and Chon Buri series, were 1394, 1383, 1382 and 1331 ml, respectively.

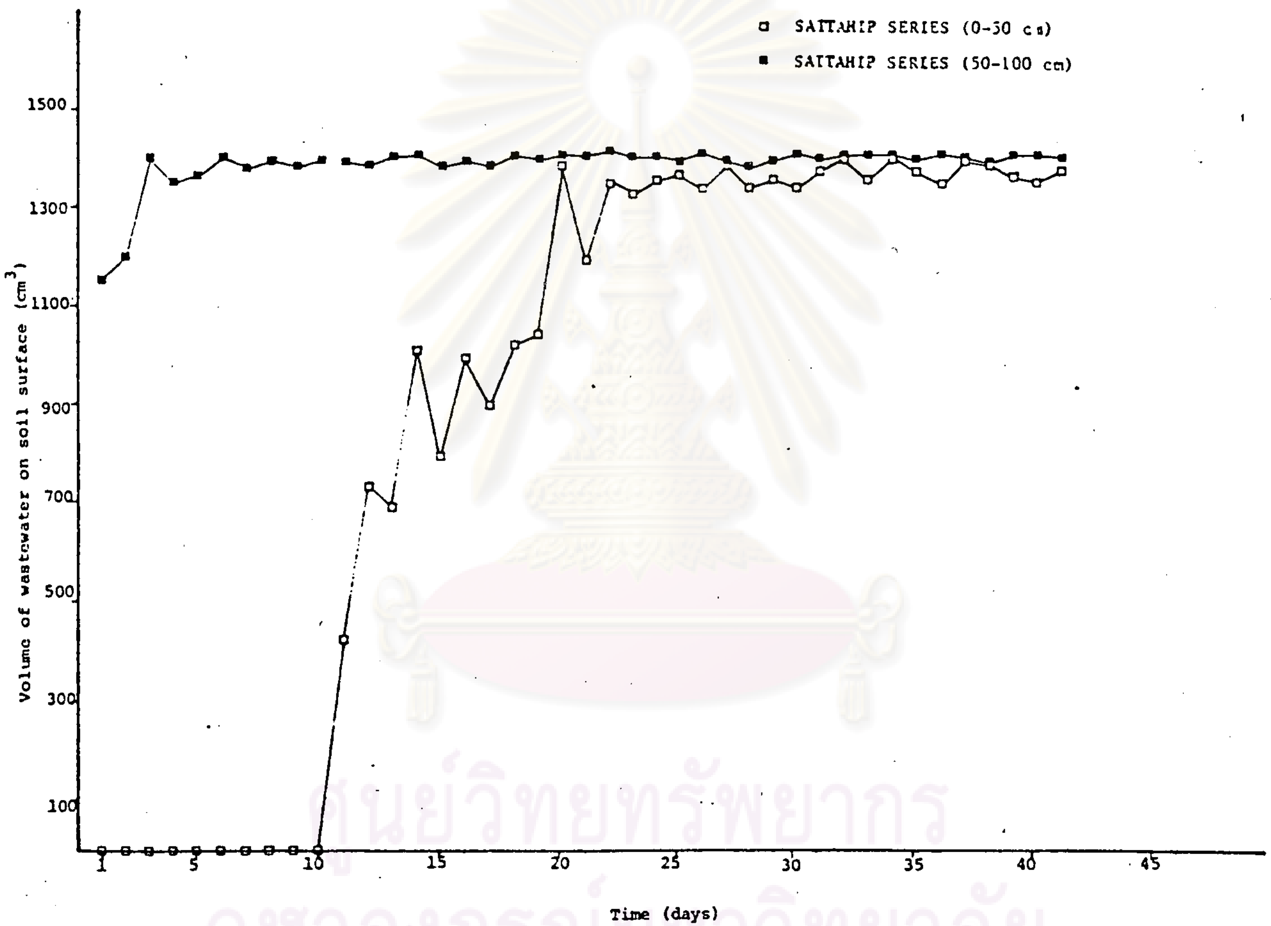

Figure 2 The volume of wastewater on upper and lower soil of Sattahip series.

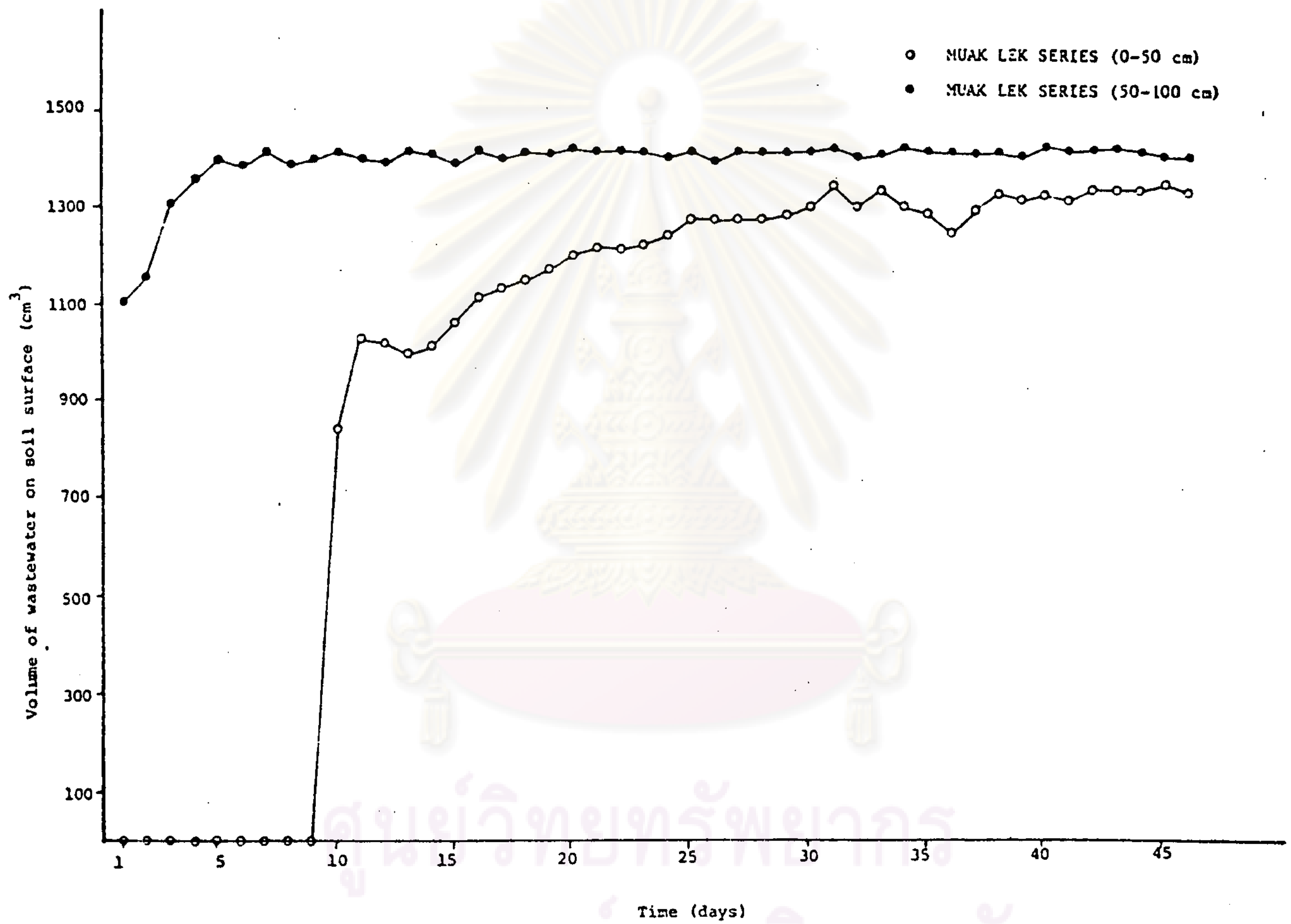

Figure 3 The volume of wastewater on upper and lower soil of Muak Lek series.

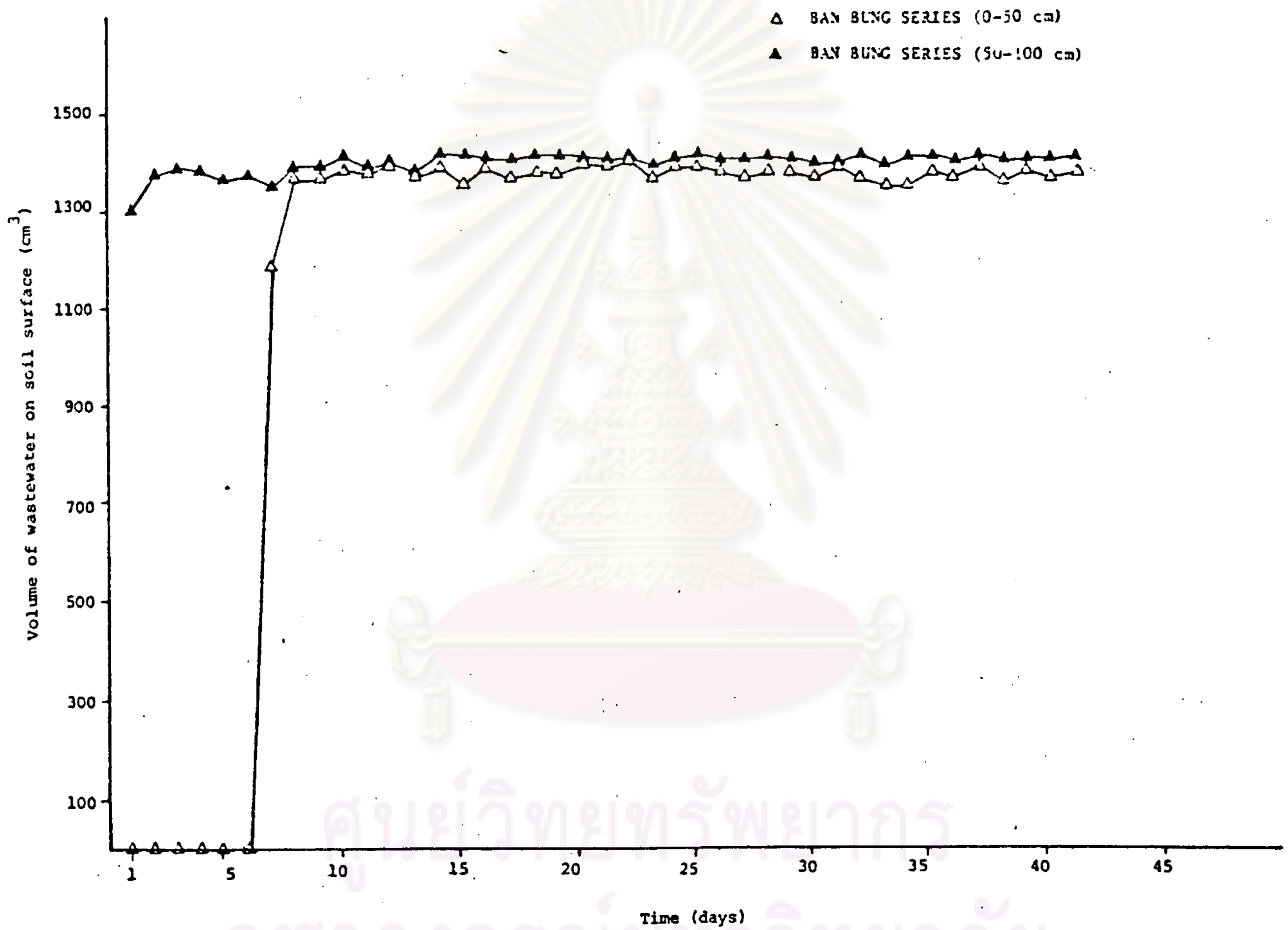

Figure 4 The volume of wastewater on upper and lower soil of Ban Bung series.

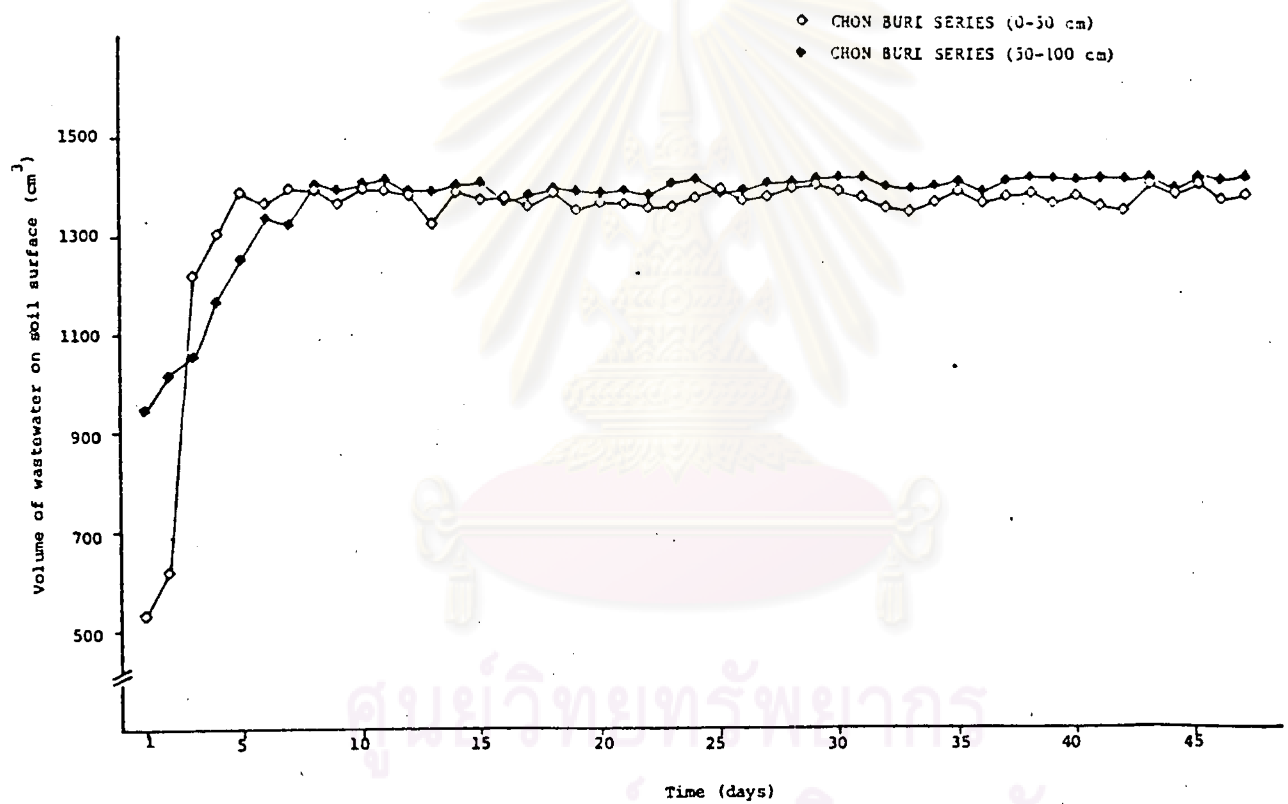

Figure 5 The volume of wastewater on upper and lower soil of Chon Buri series.

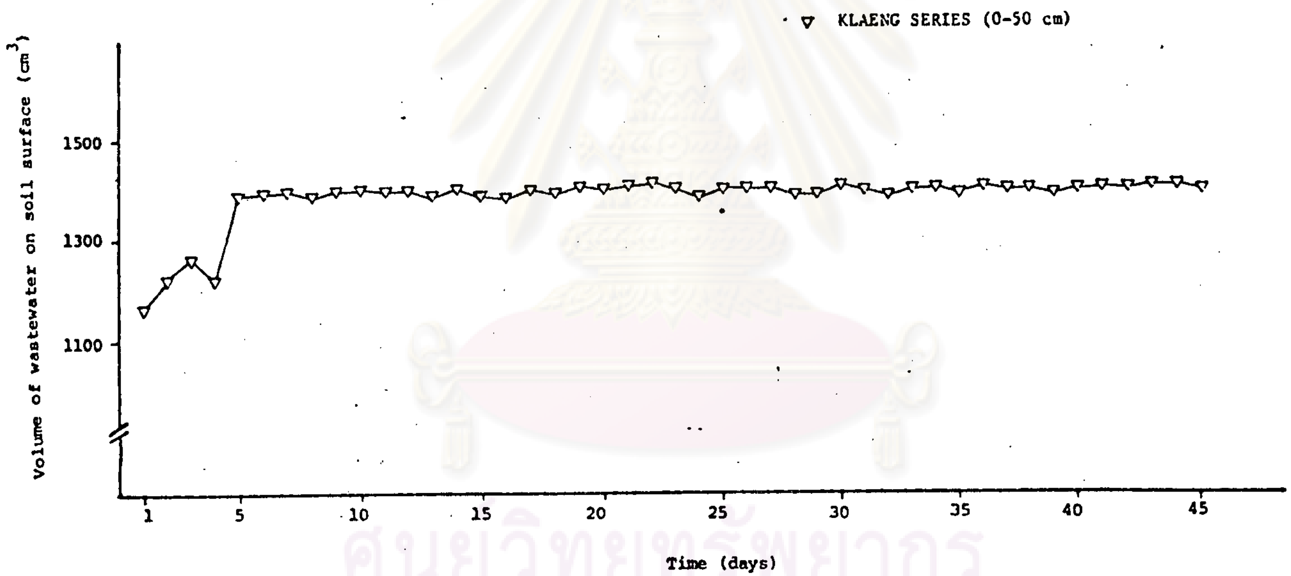

Figure 6 The volume of wastewater on upper soil of Klaeng series.

In general, each soil exhibited the same trend, soil at the surface was more permeable than soil at the lower depth at the beginning of application for sometimes. Later on the permeabilities of the same soil were almost the same, the different was not very significant for some soils.

4.3 pH

From Figures 7, 8 the pH of influent and effluents from soil series were plotted against time of application. The pH of domestic wastewater determined everyday of sampling, they varied between 7.1-7.5, neutral to slightly alkaline, with the average of 7.4.

The pH ranges of the effluents from Sattahip, Muak Lek, Ban Bung, Chon Buri and Klaeng soil series at 0-50 cm depth, were 5.7-8.3, 7.0-7.9, 6.6-8.2, 4.9-6.0, 5.6-6.2 with the average of 7.52, 7.5, 7.6,5.3 and 5.9, respectively. From Figur 7, most pH of the effluents from Sattahip, Muak Lek and Ban Bung soil series increased to the initial pH of wastewater eventhough the soil pH were 4.75, 7.4, 5.8 respectively. The pH of the effluents from Chon Buri and Klaeng series were rather acid and decreased from the influent pH, obviously.

The effluents obtained from soil column at the 50-100 cm depth were in the ranges of 4.9-8.1, 7.6-8.0, 6.4-78 and 4.8-6.1 with the average of 7.1, 7.8, 7.3 and 5.4 respectively. The pH from the effluents of the Sattahip, Muak Lek and the Ban Bung soil series were higher and slightly alkaline than the Chon Buri series.

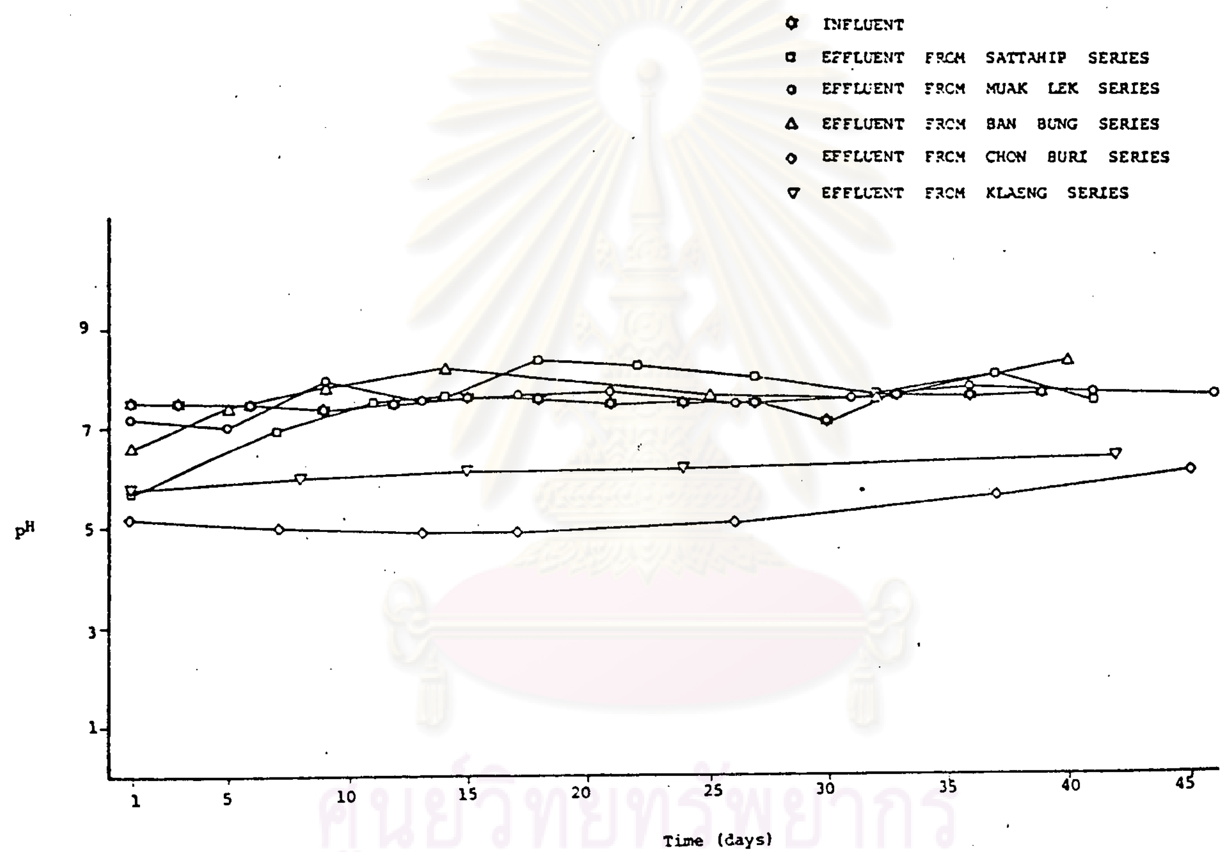

Figure 7 pH of the influent and effluent from upper soils (0-50 cm).

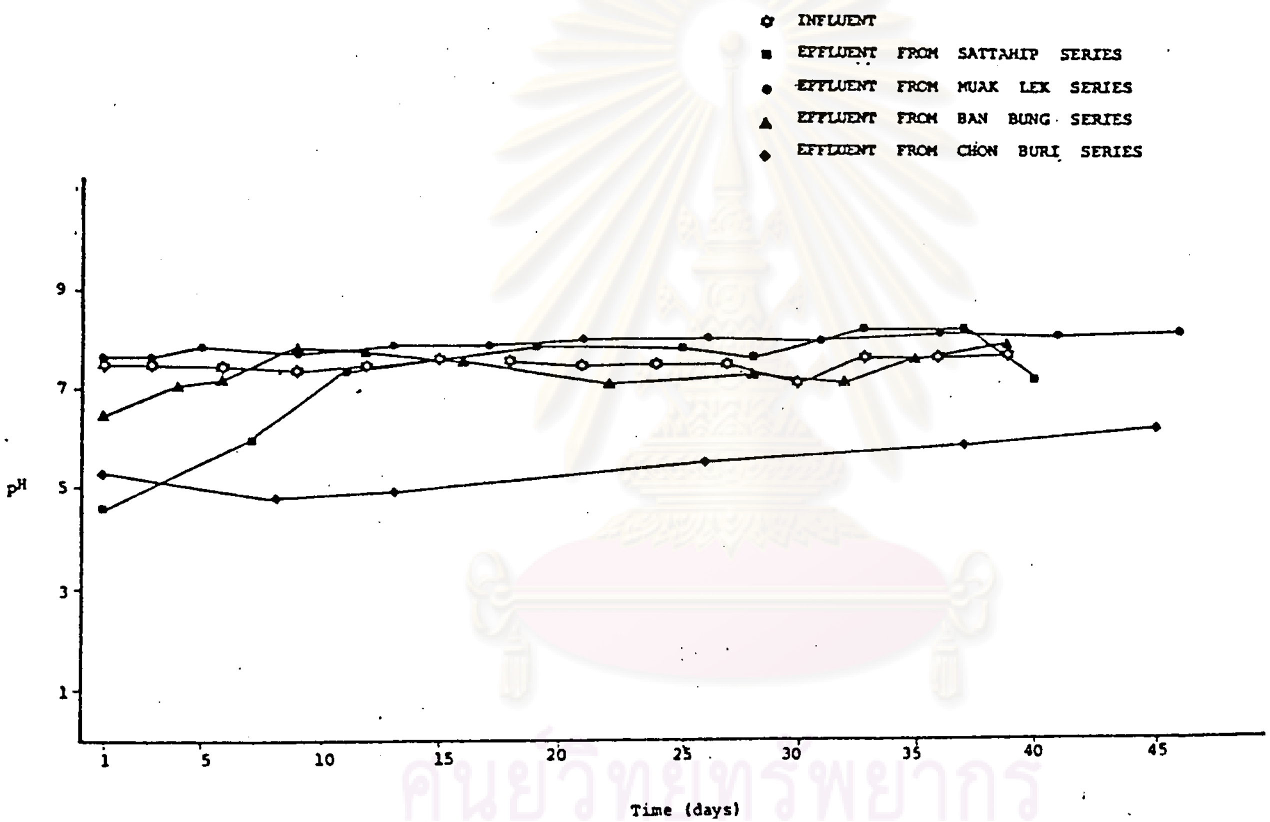

Figure 8 pH of the influent and effluent from lower soils (50-100 cm)

Almost the same trend was shown as mentioned above except the Muak Lek series exhibited average higher pH than the Sattahip series. The different in pH of the effluents probably due to the fact that soils with good permeability could not remove bases from the influent, therefore, they exhibited alkaline reaction.

4.4 Chemical Oxygen Demand (COD)

The COD concentration of domestic wastewater varied between 306-504 mg/1 with the average value of 393 mg/1. When passing water through soil columns the COD concentration decreased in every soils.

The COD of wastewater passing through the soils at 0-50 cm depth of 5 soil series, Sattahip, Muak Lek, Ban Bung, Chon Buri and Klaeng series, varied within the series in the ranges 24-102, 30-108, 84-176, 16-60 and 80-108 mg/1 and the average values were 80, 50, 113, 33 and 96 mg/1, respectively. From the average value and range of COD in wastewater, the author calculated the COD concentration in the influent reduced to 87, 80, 71, 92 and 76 % by Sattahip, Muak Lek, Ban Bung, Chon Buri and Klaeng series, respectively.

The COD concentration in wastewater was removed by the soil at 50-100 cm depth in the range of 8-100, 16-64, 18-100, 20-48 by Sattahip, Muak Lek, Ban Bung and Chon Buri series with the aveage values of 57, 32, 60 and 33 mg/1, respectively. The percentage reduced were 86, 92, 85 and 92% respectively.

From Figures 9 and 10, it could be easily seen that all soils had high capacities for reducing the COD concentration in domestic wastewater, the Chon Buri series showed the highest

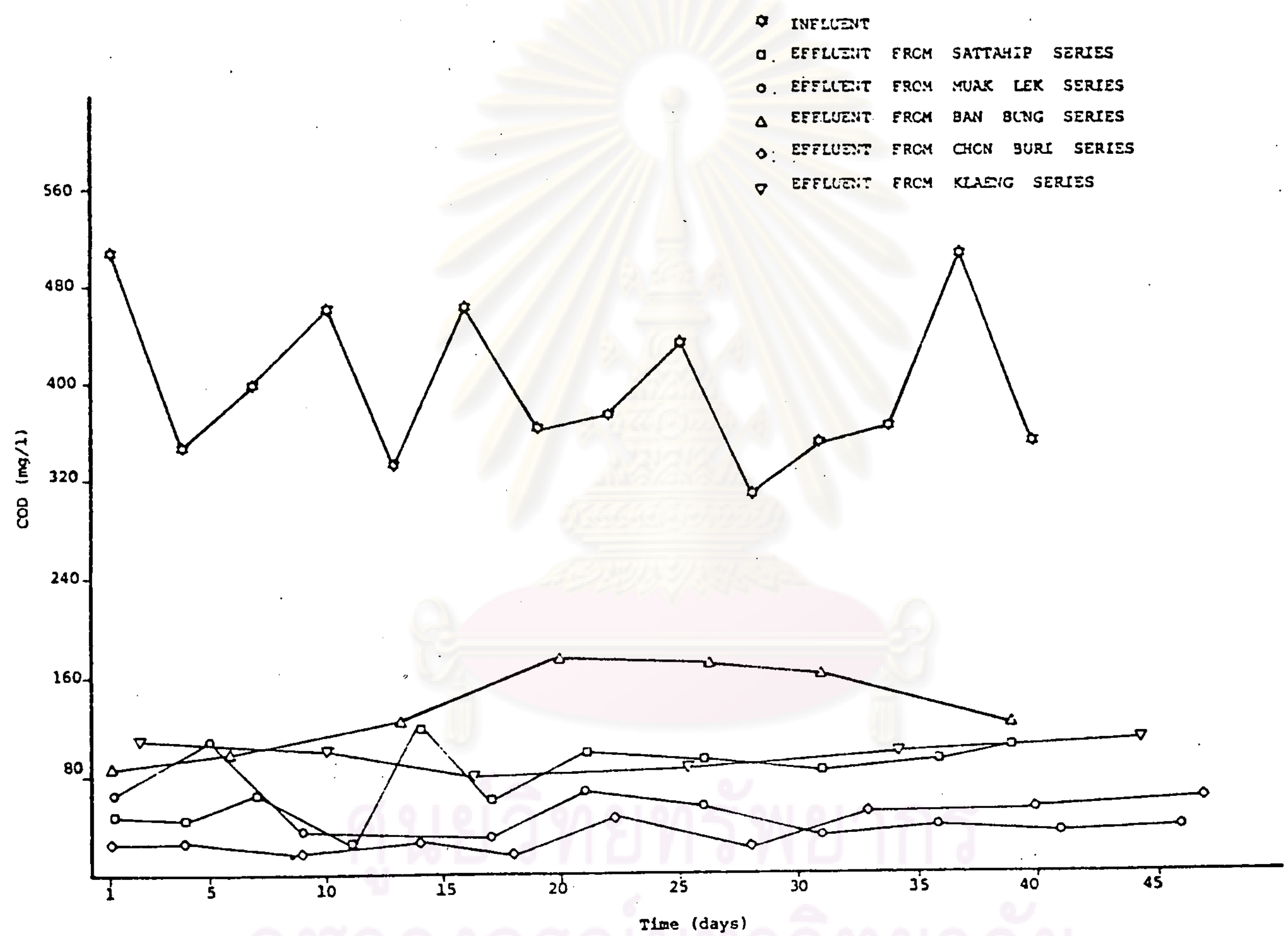

Figure 9 COD concentration of influent and effluent from upper soils (0–50 cm)

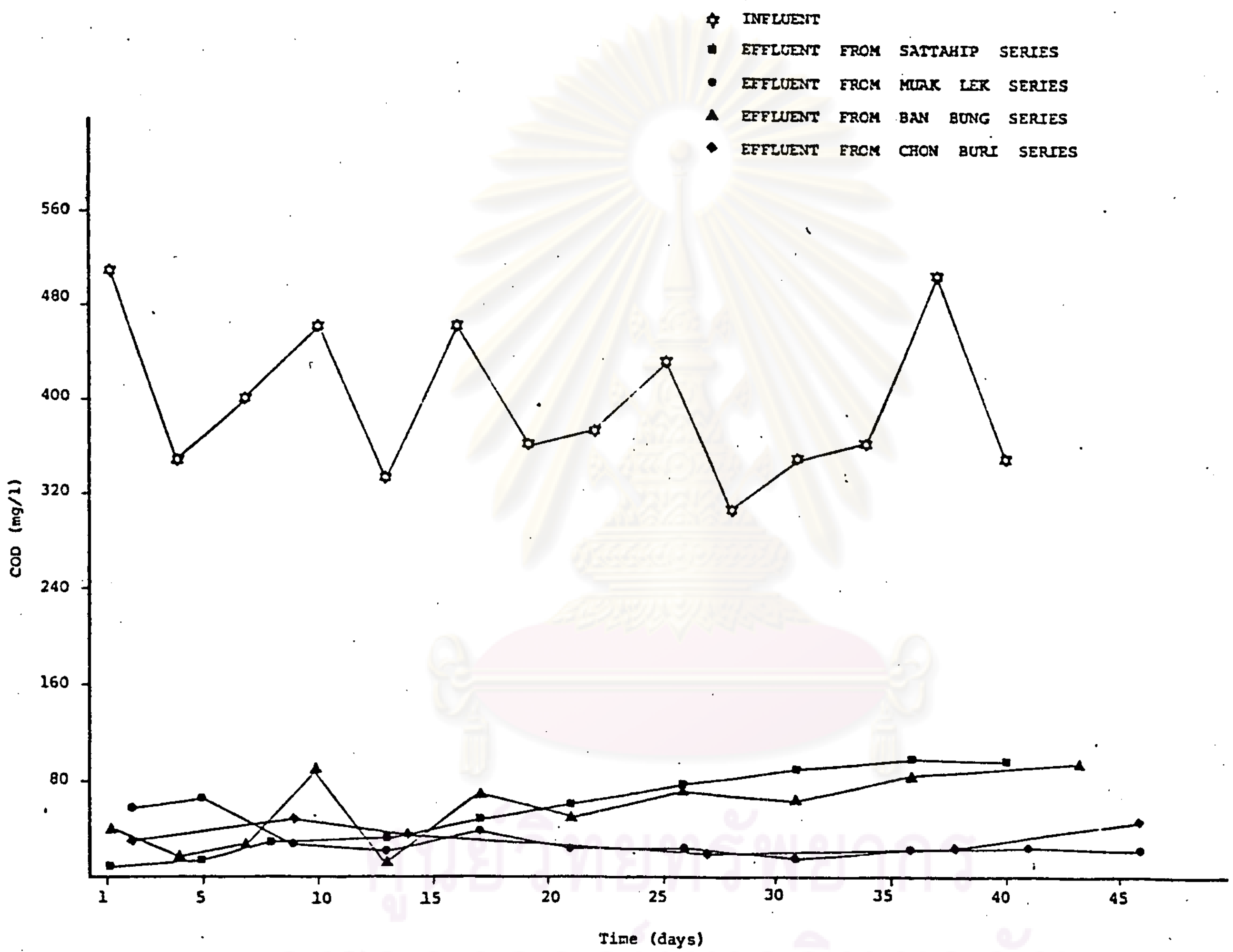

Figure 10 COD concentration of influent and effluent from lower soils (50-100 cm)

efficiency in both soil depths, the others reduced COD concentration better in the soils at 50-100 cm depth. This may due to the fact that at lower level, the soil was more compacted and could screen organic material.

4.5 Nitrogen Content

Total nitrogen and NH_4-N contents of wastewater from table 3, were 34-43 and 30-40 mg N/1 with the average of 39 and 35 mg N/1, respectively. No NO_3-N could be found from the influent. According to Kristiansen, 1981, who collects in formation from other investigators, the N in septic tank effluent originates mainly from fecal material which accounts for 90% of total nitrogen. Septic tank effluent N is usually composed of about 80% NH_4-N and 20% organic N. Concentration of total N are typically 40-80 mg N/1 Therefore, it could be assumed that organic-N of wastewater in the study would be about 4 mg N/1

From Figure 11, NH_4-N contents of the effluents from 3 soil columns of the Sattahip, Muak Lek and Ban Bung soil series at 0-50 cm depth were lower than the content found in the wastewater indicated that NH_4-N that NH_4-N may be bound to negatively charged colloids of the soil particles and thus removed from percolating waste water. Nitrate-N was not detected in these soil columns for the first 15 days indicated that there was no aerobic zone in the columns. After that the redox conditions changed from anaerobic to aerobic started first in the Ban Bung followed by the Sattahip and the Muak Lek soil columns respectively. The NO_3-N contents from nitrification process

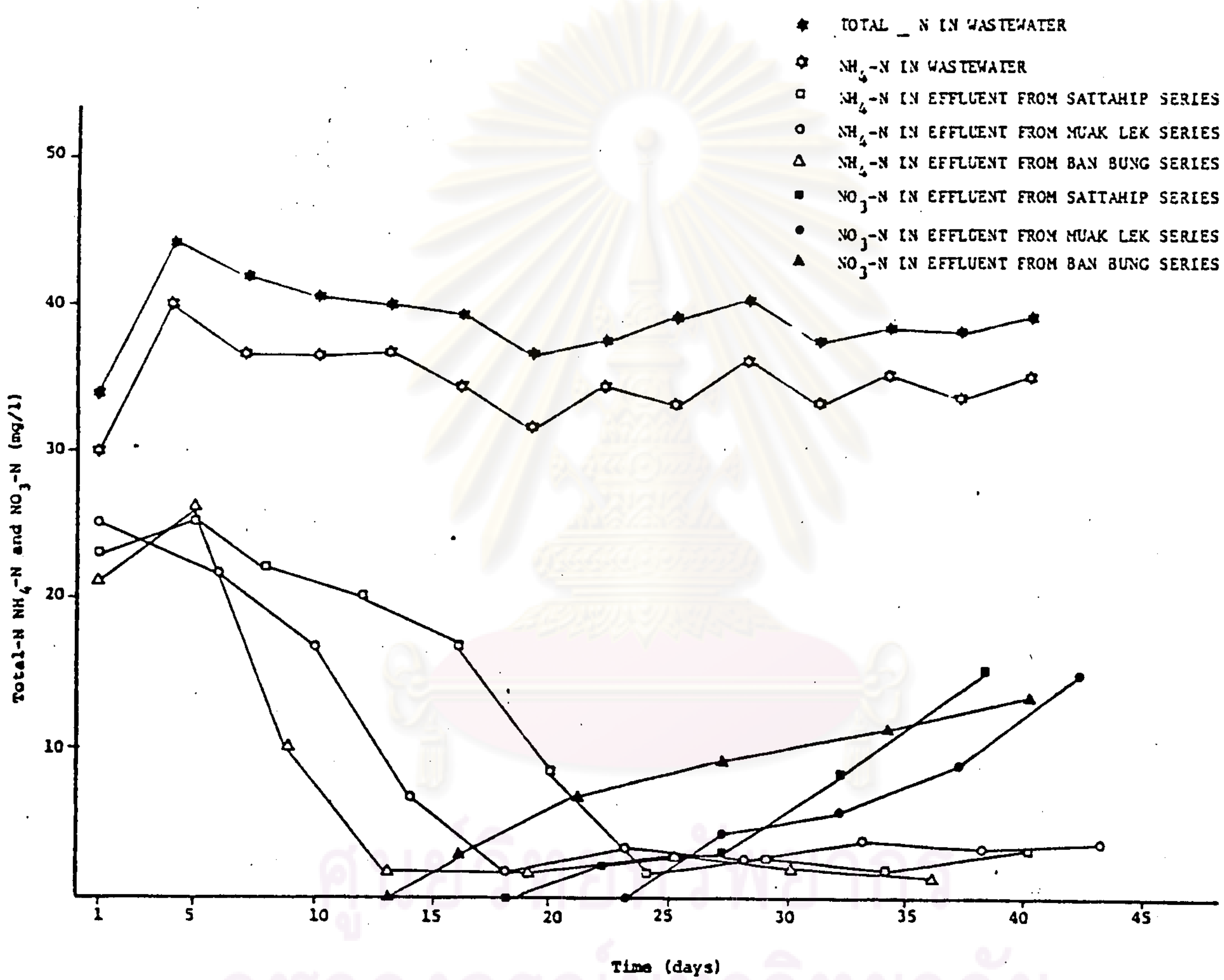

Figure 11 Total-N, NH_4-N and NO_3-N in the influent and effluent from upper soils (0-50 cm)

in those soil columns increased to more than 10 mg N/liter in every effluents. At the same period that NO_3-N was found, NH_4-N was also found. The content was less than 5 mg N/liter from every effluents. The effluents from Chon Buri and Klaeng soil series Figure 12, showed different trend. Only, NH_4-N could be found average of less than 5 mg N/liter. No NO_3-N could be found indicated the system were anaerobic and the low contents of NH_4-N indicated NH_4-N was removed by soil particles.

Figure 13 exhibited NH_4-N contents of the effluents from Sattahip, Muak Lek, Ban Bung and Chon Buri series at 50-100 depth. Ammonium contents found were less than 10 mg N/liter with the average value around 5 mg N/liter. There was no NO_3-N detected indicated redox condition and no nitrification. About 80-90% of NH_4-N was removed from wastewater by each soil.

4.6 Phosphate Content

Phosphate were determined in wastewater as orthophosphate and total phosphate which could be found in the range of 6.2-7.5 and 8.2-10.5 mg/l and the average values were 6.8-8.9 mgP/l, respectively. The contents were within the range found elsewhere, Viraraghavan and Warnock, 1976. Figure 14 shows the orthophosphate could be detected from the effluents of 3 soils series, the Sattahip, Muak Lek and Ban Bung soil series, on the first day as 4.7, 5.0 and 3.6 mgP/l, respectively. On the fifth day of the experiment the effluents, orthophosphates detected from the Sattahip and Muak Lek series were 2.1 and 2.9 mgP/l, respectively. After that orthophosphate could not be detected or could be found less than 0.2 mg/l. Orthophosphate

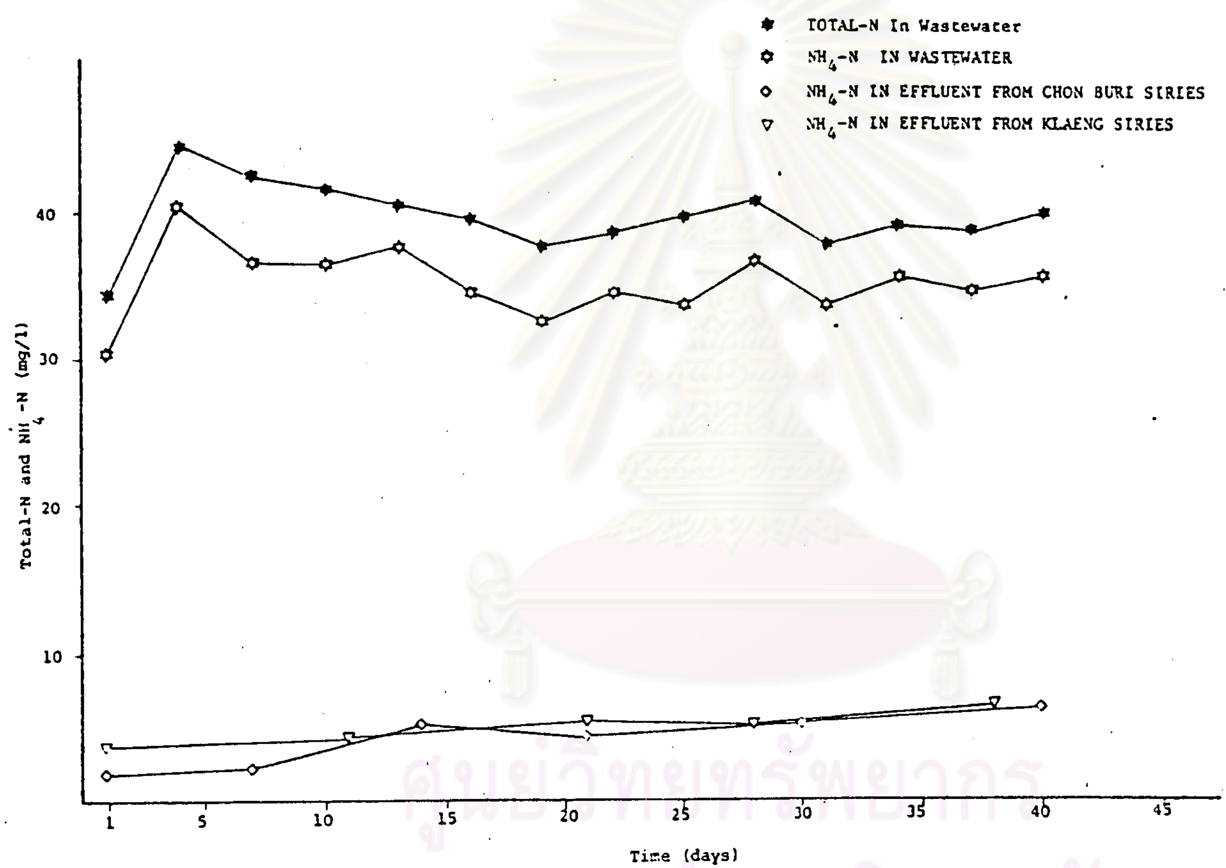

Figure 12 Total-N and NH_4-N in the influent and effluent from upper soils (0-50 cm)

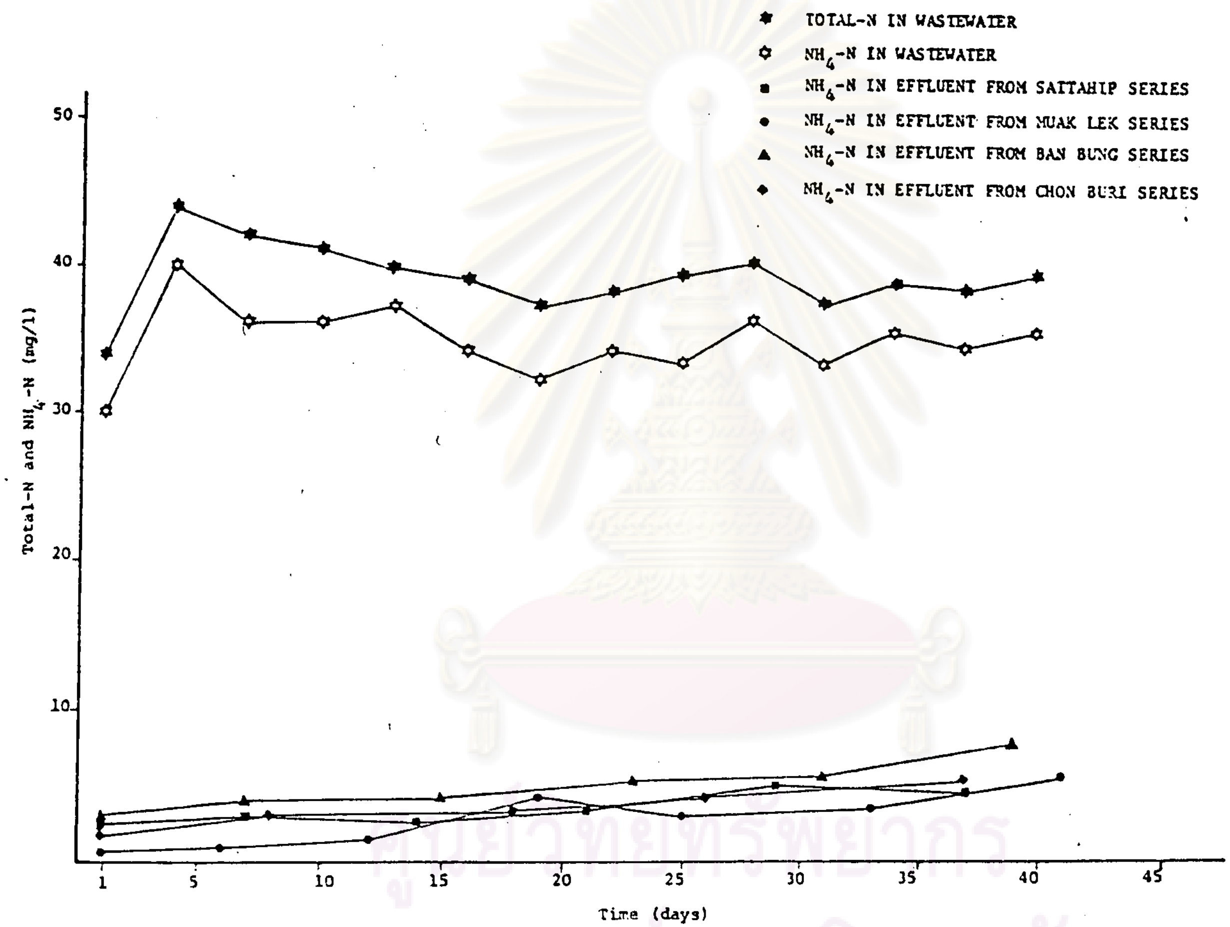

Figure 13 Total-N and NH_4-N in the influent and effluent from lower soils (50-100 cm)

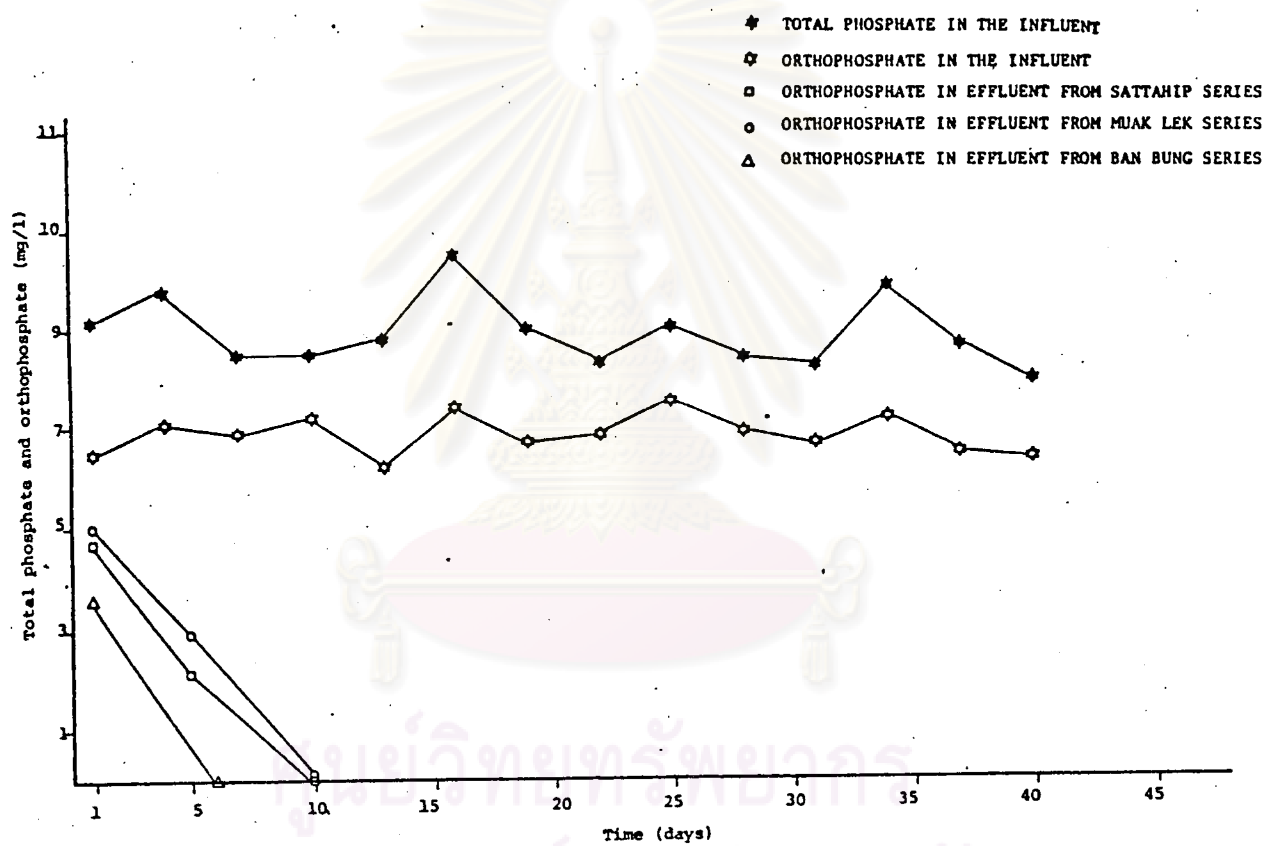

Figure 14 Total phosphate and orthophosphate in the influent and effluent from upper soils (0-50 cm)

was not found in the effluent from Chon Buri and Klaeng series indicated that phosphorus could be, totally, removed from wastewater by soil under saturated flow in soil column before the adsorption site was saturated. However, Hilland and Sawhney, 1981, showed that phosphorus added to soils in waste water moved extremely slowly. Sawhney and Hill, 1975, from their experiments illustrated that movement of wastewater around drainfields is three dimensional and analysis of sample from operating drainfield and from wastewater renovation study indicate that most P in wastewater is sorbed within a shorted distance from the point of application than simple laboratory experiment would indicate.

4.7 Total Bacteria and fecal coliform counts.

Total bacteria counts from the influent during the experiment were in the range of $1.0 \times 10^7 - 8.0 \times 10^7$ col/ml and the average was 2.5×10^7 col/ml. The fecal coliform, E. coli, counts were $8 \times 10^5 - 4.8 \times 10^6$ col/ml with the average of 2.3×10^6 col/ml.

Total bacteria counts from the influent and effluents from 5 soil series at 0-50 cm depth were shown in Figure 15 There were $1 \times 10^5 - 7 \times 10^7$, $1.1 \times 10^3 - 7.9 \times 10^6$, $2.9 \times 10^4 - 8 \times 10^6$, $1 \times 10^3 - 1.7 \times 10^5$ and $1.2 \times 10^5 - 5 \times 10^5$ col/ml in the effluents from the Sattahip, Muak Lek, Ban Bung, Chon Buri soil series, respectively. This data indicated that part of total bacteria was removed from each soils. From the curves, it appeared that Chon Buri soil removed more total bacteria and Sattahip removed lesser total bacteria than other soils although they have the same texture. Fecal coliform, E. coli,

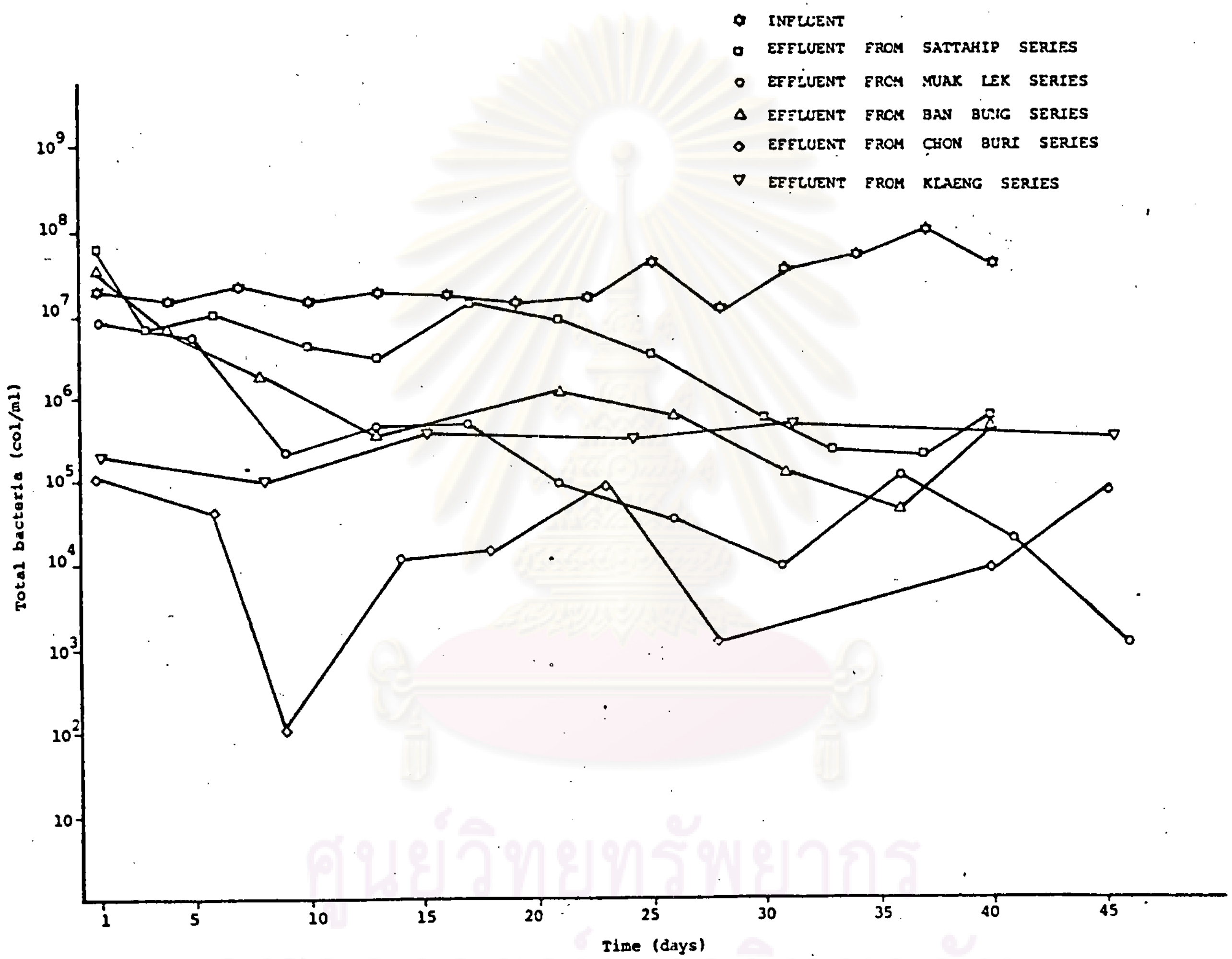

Figure 15 Total bacteria in the influent and effluent from upper soils (0-50 cm)

could be detected from 3 soil series the Sattahip, Muak Lek and Ban Bung. There were immeasurable low value-5 x 10^4, - 14 x 10^5 and - 6 x 10^5 col/ml, respectively. And, the fecal coliform counts could be measured from the first day and decreased to immeasurable low value at 21, 22 and 27th day. Then, no E. coli could be measured which could mean that the water may be free from pathogenic bacteria Figure 16. This condition could be achieved by the process of soil filtering and adsorption or the die-off of bacteria (Reddy et al, 1981).

The effluents from the 4 soil series, the Sattahip Muak Lek, Ban Bung and Chon Buri, exhibited total bacteria counts as 4 x 10^3 - 1.6 x 10^6, 1 x 10^3 - 4.8 x 10^5, 7 x 10^4 - 1.5 x 10^6 and 5 x 10^2 - 3.6 x 10^5 col/ml, respectively. The variation in bacteria counts were found through the period of experiment, Figure 17. No E. coli could be found in those soils probably the soils about the depth used were more compact and water could pass slowly, therefore the bacteria was filter or die off. Hagedorn et al.(1981) concluded that variations in the results obtained could be ascertained from the information : I quote (i) coliforms and other microorganisms move only a few dozen centimeters with the percolating water in unsaturated soil layers although much greater distances are possible under saturated flow conditions ; (ii) with all soil water conditions, the degree of bacterial retention by soil is inversely proportional to the size of the component particles in the unstructured matriz ; (iii) the physical straining or filtration of organisms by soil particles are the main limitation to travel through soils, and sedimentation of bacterial cluster occurs through out the zone of saturated flow ; (iv) adsorption is a factor

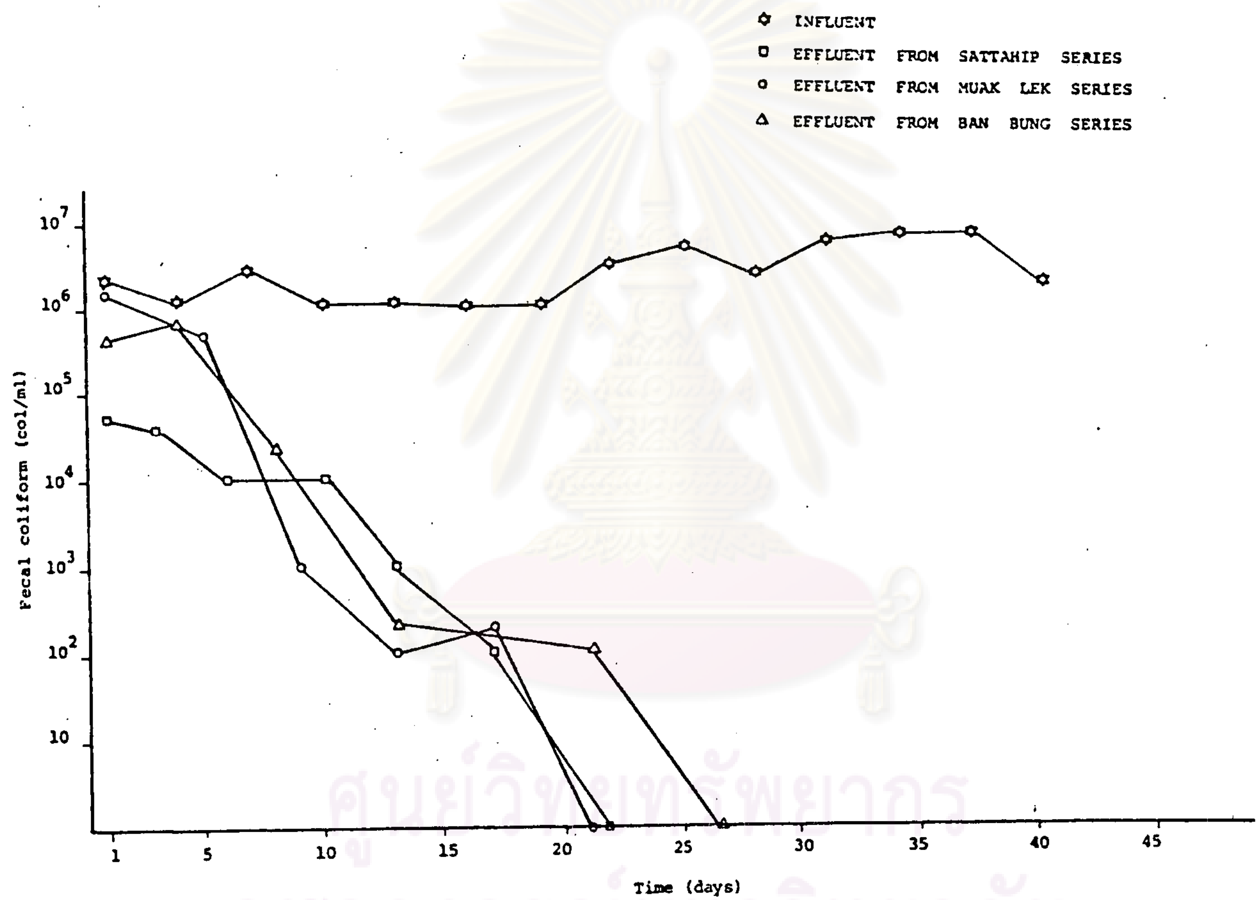

Figure 16 Fecal coliform in the influent and effluent from upper soils (0-50 cm).

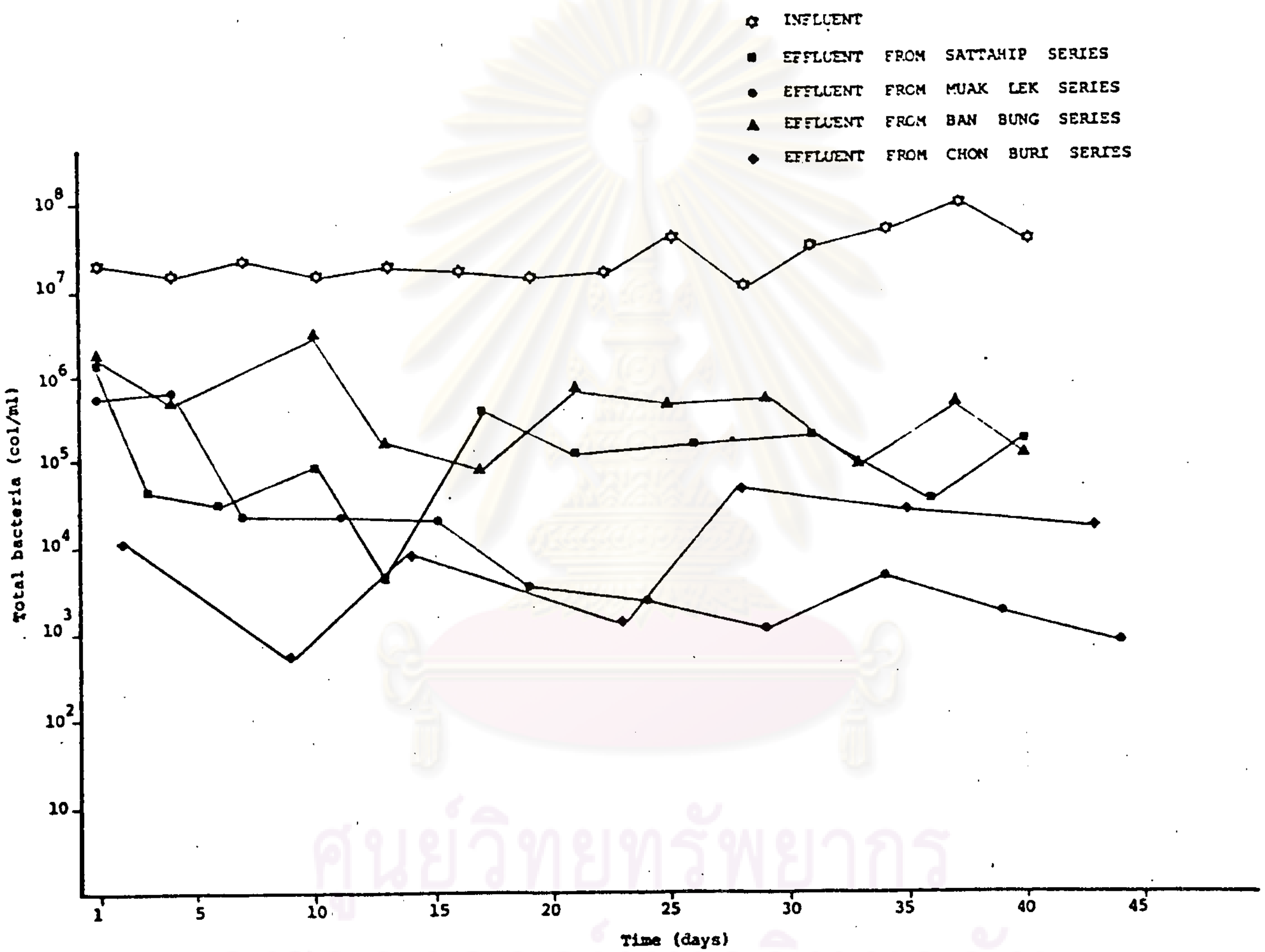

Figure 17 Total bacteria in the influent and effluent from lower soils (50-100 cm)

in the retention of bacteria by soil and becomes more effective in soils with increasing clay content ; and (v) death of microorganism plays an important role during the longer retention periods or unsaturated flow conditions. Thus, both physical removal and inactivation influence the change in the bacteriological quality of wastewater percolating through the soil.