CHAPTER VI

DISCUSSION

From experimental data and results presented previously, the combined effects of lead and zinc concentration and mean cell residence time on such indicators as COD removal efficiency, biokinetic coefficients, total reactor microorganism concentration, specific utilization rate, observed yield, sludge production, nitrification, synergistic and antagonistic effects, and lead and zinc distribution could be ascertained. Each of these indicators is discussed separately below.

COD Removal Efficiency

The effect of influent lead and zinc concentration on the soluble COD removal efficiency at various mean cell residence time is shown in Figure 6. As can be seen from the graphs, the soluble COD removal efficiency in the lead and zinc combination fed reactors decreased so slightly that it almost acheived at the same level as compared to the control reactor, receiving no lead and zinc concentration. At high mean cell residence time, the concentration of lead and zinc in feed solution has no effect on the soluble COD removal efficiency. However, the difference in soluble COD removal efficiency was not significant for the lead and zinc concentrations.

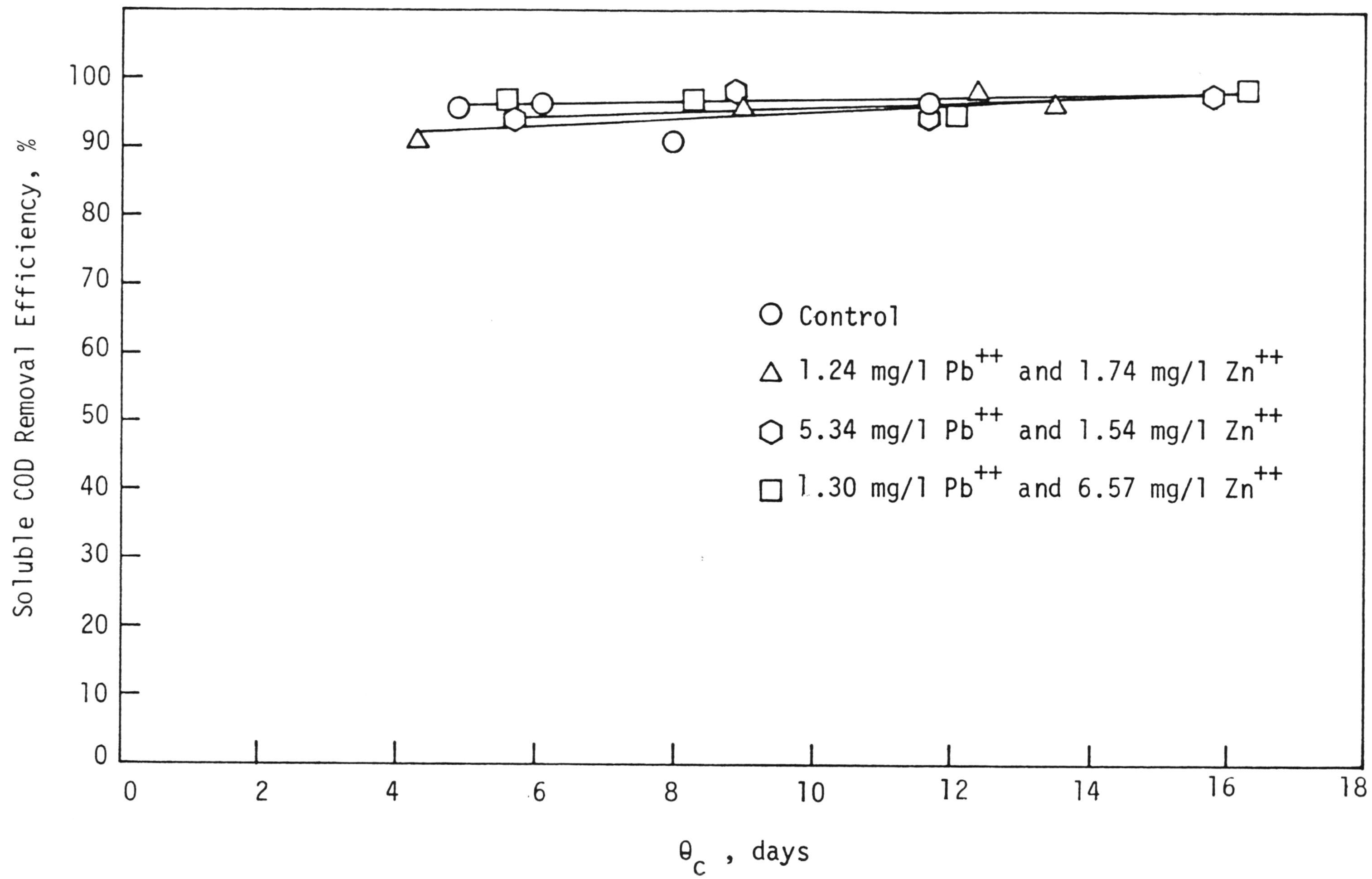

Figure 6. Soluble COD Removal Efficiency as a Function of Mean Cell Residence Time.

This is attributed to the heterotrophic population is un-severely inhibited and slightly decrease the ability to satisfy to stabilize the organic metters introduced into the system. In addition the increase in mixed liquor suspended solids concentration would cause the reduction in ratio of the total influent metal to total reactor solids and thereby increase COD removal efficiency.

Biokinetic Coefficients

The microorganism growth rate and maintenance energy coefficient for each of reactors were obtained according to the expression :

$$\frac{1}{\theta_c} = Y_{max} U - k_d$$

By plotting $\frac{1}{\theta_c}$, the specific growth rate, versus U, the specific utilization rate, the slope of the straight line represented Y_{max}, maximum microorganism cell yield coefficient, and the intercept represented k_d, maintenance energy coefficient. The list square method was utilized to make the linear graph.

Shown in Figure 7 are the linearlized relation plots of the specific growth rate and the specific utilization rate for each of the metal laden reactors and control reactor. The values of Y_{max} and k_d obtained are also depicted in the Table 17.

The obtained results of Y_{max} and k_d for reactor receiving lead and zinc concentration in feed solution were lower than that for control reactor. These are attributed to a shift in microorganism species and the inhibition of biological activities in synthesizing the cellular structure in the metal laden reactors and thereby decreased Y_{max}. At the same time, decreasing value of k_d obtained may be resulted

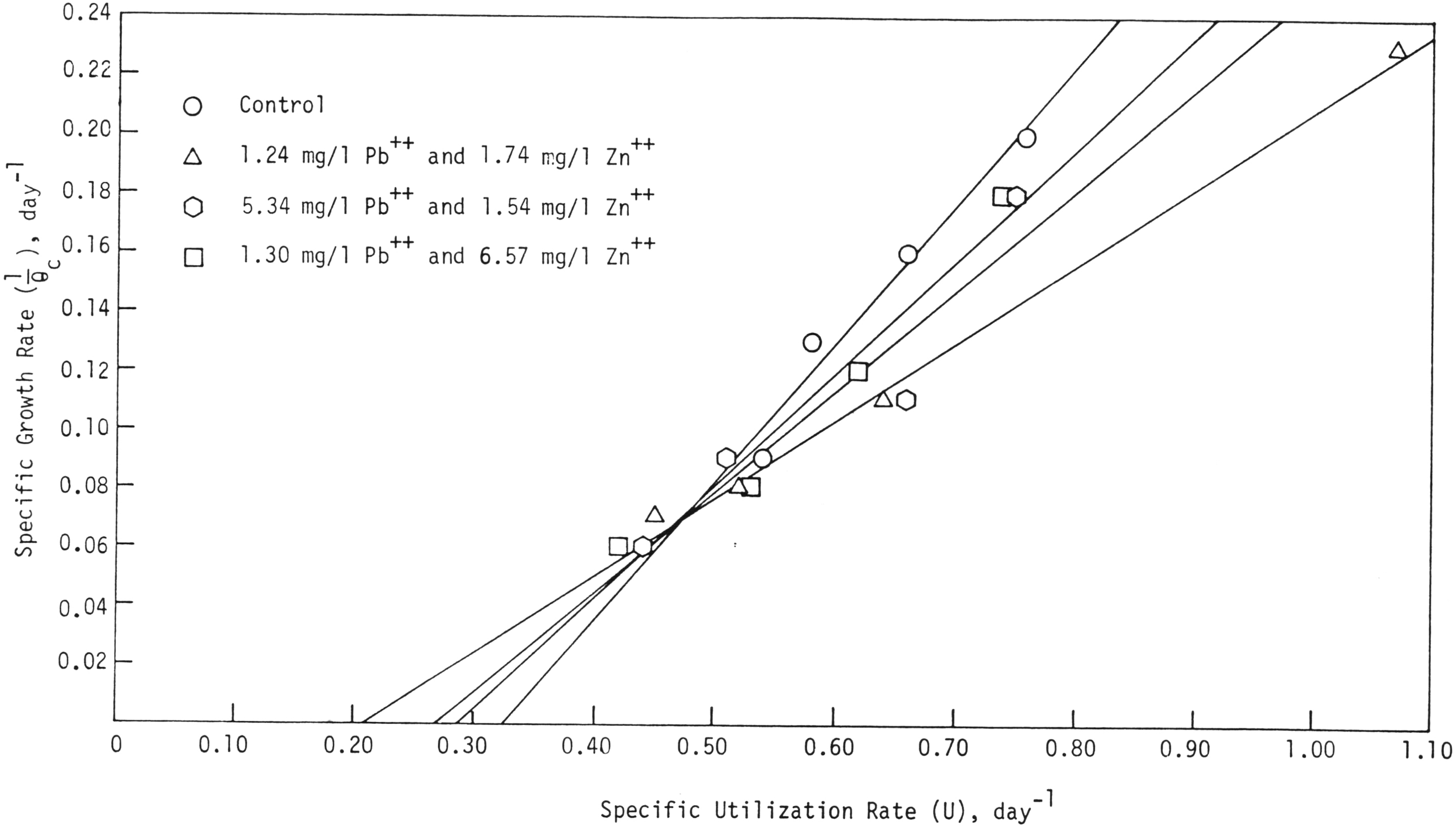

Figure 7 Specific Growth Rate versus Specific Utilization Rate.

TABLE 17

BIOKINETIC COEFFICIENTS AND LINEAR EQUATIONS

Reactor	Biokinetic Coefficient		Linear equation	Coefficient of determination (r^2)
	Y_{max}	k_d (day^{-1})		
Control	0.470	0.153	$\frac{1}{\theta_c} = 0.470\ U - 0.153$	0.962
1.24 mg/l Pb^{++} and 1.74 mg/l Zn^{++}	0.264	0.055	$\frac{1}{\theta_c} = 0.264\ U - 0.055$	0.996
5.34 mg/l Pb^{++} and 1.54 mg/l Zn^{++}	0.342	0.092	$\frac{1}{\theta_c} = 0.342\ U - 0.092$	0.889
1.30 mg/l Pb^{++} and 6.57 mg/l Zn^{++}	0.382	0.110	$\frac{1}{\theta_c} = 0.382\ U - 0.110$	0.959

from the fact that the microorganisms being stimulated to their activities by the combined effects of lead and zinc to requiring lower maintenance energy.

Of three metal laden reactors, the value of Y_{max} and k_d could be respectively ranged as follows : the reactor fed with solution having concentration of 1.30 mg/l Pb^{++} and 6.57 mg/l Zn^{++} and that of 5.34 mg/l Pb^{++} and 1.54 mg/l Zn^{++} and that of 1.24 mg/l Pb^{++} and 1.74 mg/l Zn^{++}.

These results indicate that the inhibited effects on microbial activities of 1.24 mg/l Pb^{++} and 1.74 mg/l Zn^{++} fed reactor is higher than that of 5.34 mg/l Pb^{++} and 1.54 mg/l Zn^{++} fed reactor which is likewise higher than that of 1.30 mg/l Pb^{++} and 6.57 mg/l Zn^{++} fed reactor. In addition the maintenance energy requirement for biological activities of 1.24 mg/l Pb^{++} and 1.74 mg/l Zn^{++} fed reactor is lower than that of the others metal laden reactors.

Total Reactor Microorganism Concentration

Figure 8 and 9 illustrate the effect of lead and zinc concentration on the total reactor microorganism concentration at various mean cell residence time. Graphs of mixed liquor volatile suspended solids concentration as a function of mean cell residence time is shown in Figure 8. The mixed liquor volatile suspended solids concentration observed for the metal laden reactors was lower than those for the control reactor. This is attributed to the influences of lead and zinc present in the feed solution on the decreasing microorganism cell yield, Y_{max}, as aforediscussed in biokinetic coefficients.

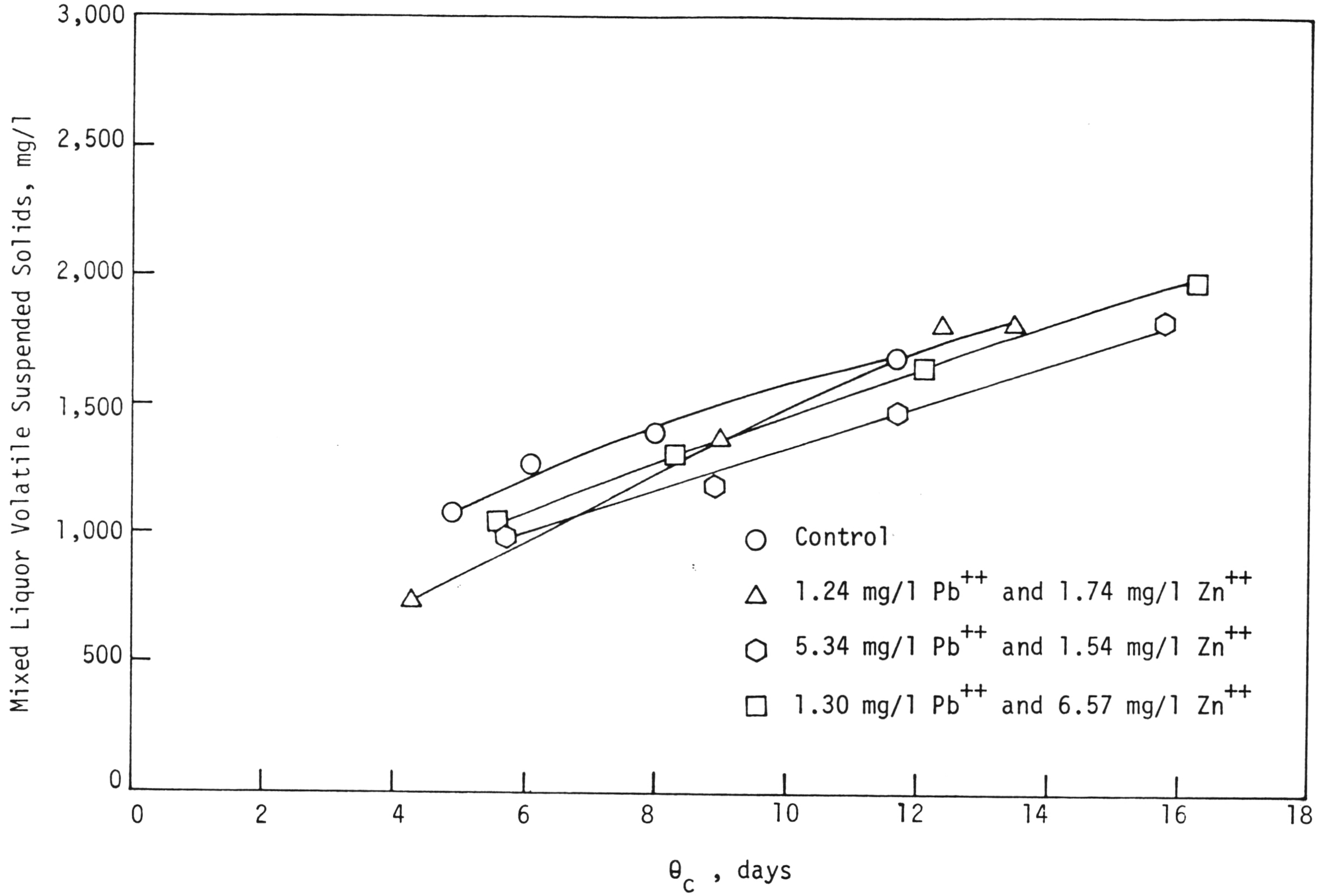

Figure 8. Mixed Liquor Volatile Suspended Solids as a Function of Mean Cell Residence Time.

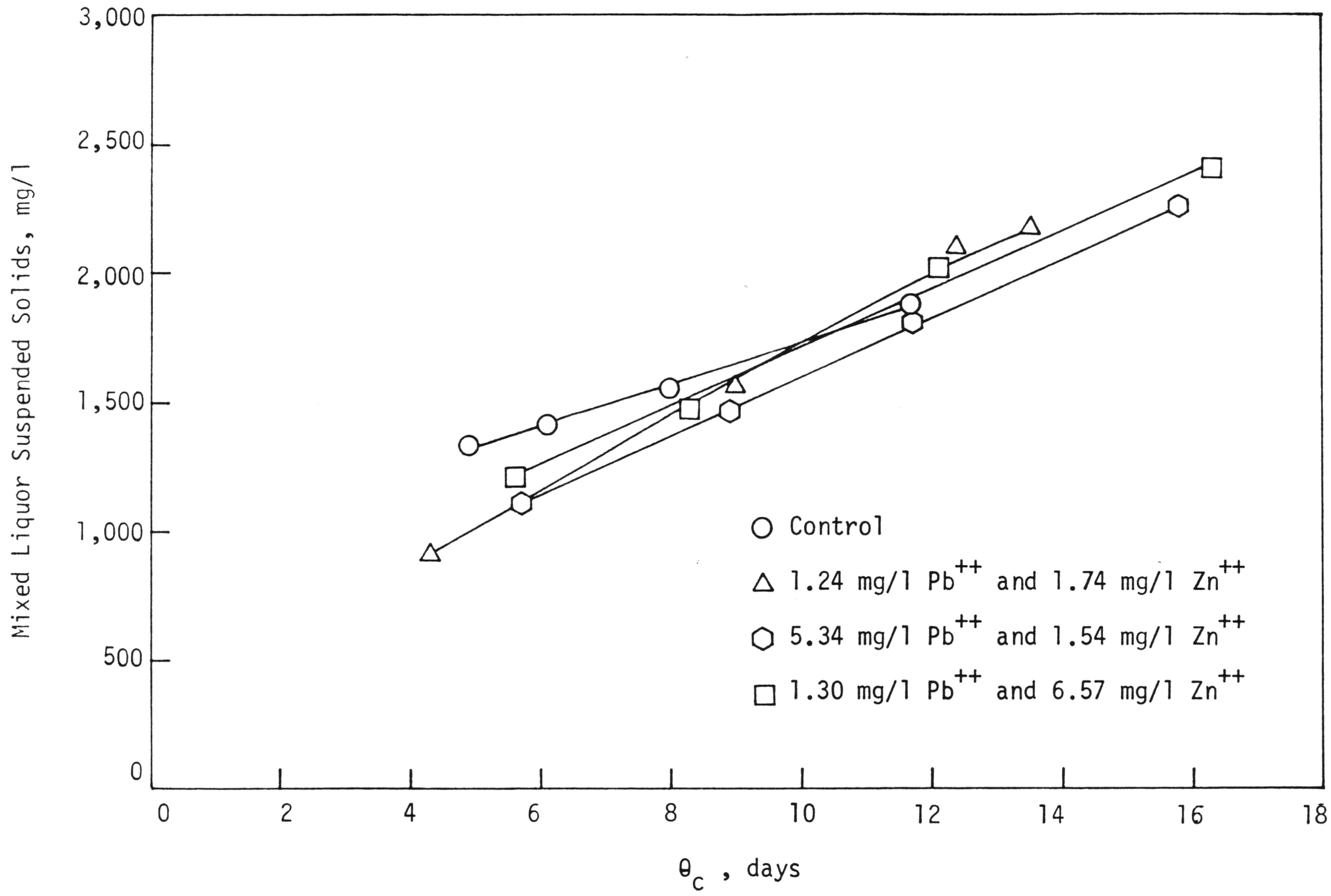

Figure 9. Mixed Liquor Suspended Solids as a Function of Mean Cell Residence Time.

Figure 9 serves to further demonstrate the ralationship between total mixed liquor suspended solids concentration and sludge age. As being shown, the total mixed liquor suspended solids concentration for the control reactor was higher than those for the reactor receiving metal concentration at low mean cell residence time, but on the contrary, the total mixed liquor suspended solids concentration at high mean cell residence time for control reactor was lower than those for the metal laden reactors. From these graphs, it is evident that there is high concentration of fixed solids in the metal laden reactors at high sludge age.

Specific Utilization Rate

The effect of lead and zinc in feed solution on specific utilization rate at various mean cell residence time is shown in Figure 10. According to the comparison between the graph generated for the control reactor and those obtained for the metal laden reactors, the effect of lead and zinc caused the increase in specific utilization rate. This may be attributed to less cellular synthesis of microorganisms in the reactors receiving lead and zinc in feed solution.

Observed Yield

As illustrated in Figure 11, low observed yield could be seen in the metal laden reactors when conpared to the control reactor. The observed yield is the parameter that indicates the cellular synthesis based on the same amount of substrate utilization. The low observed yield for these metal fed reactors was the result of lower cellular and higher substrate utilization. This indicates that cellular

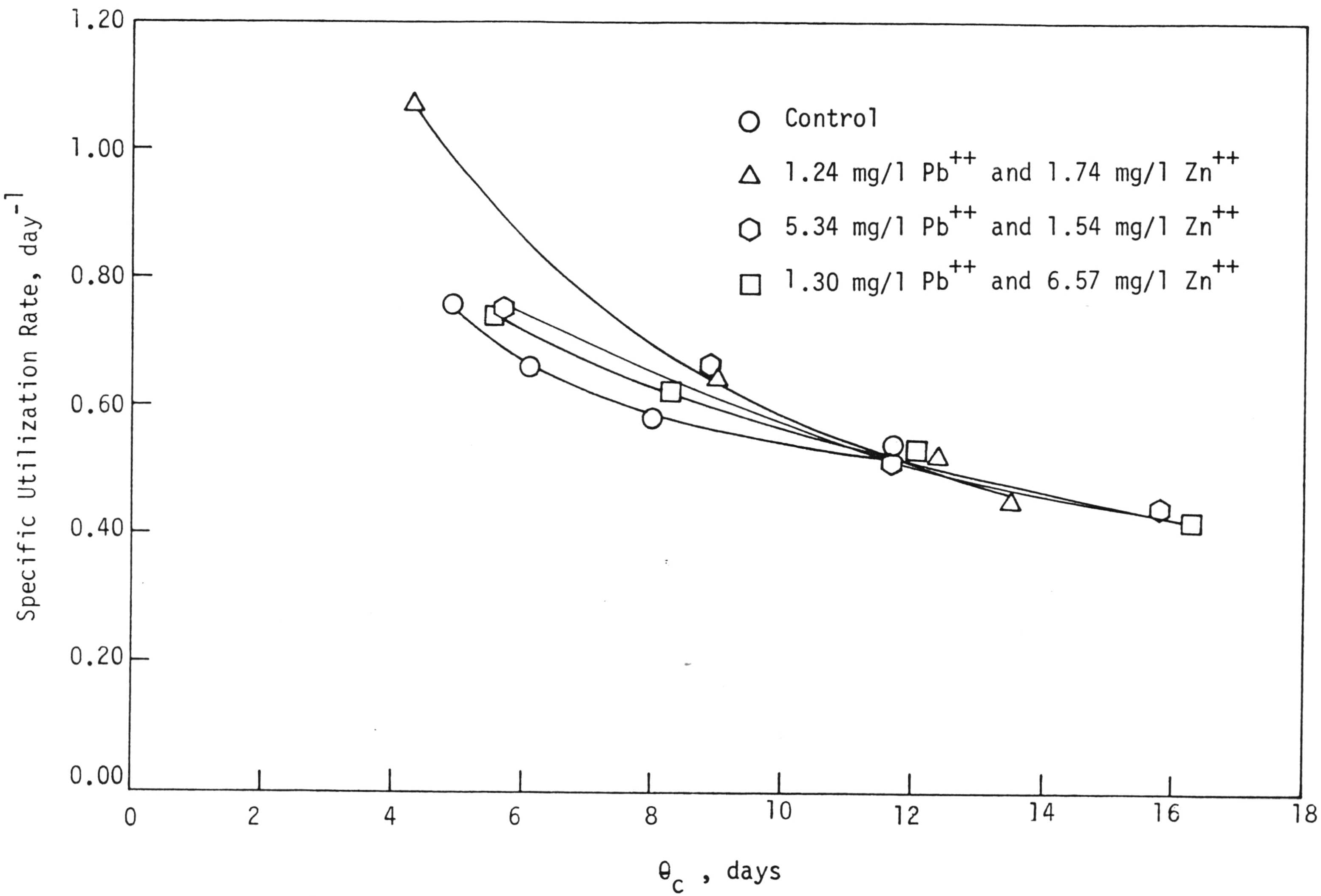

Figure 10. Specific Utilization Rate as a Function of Mean Cell Residence Time.

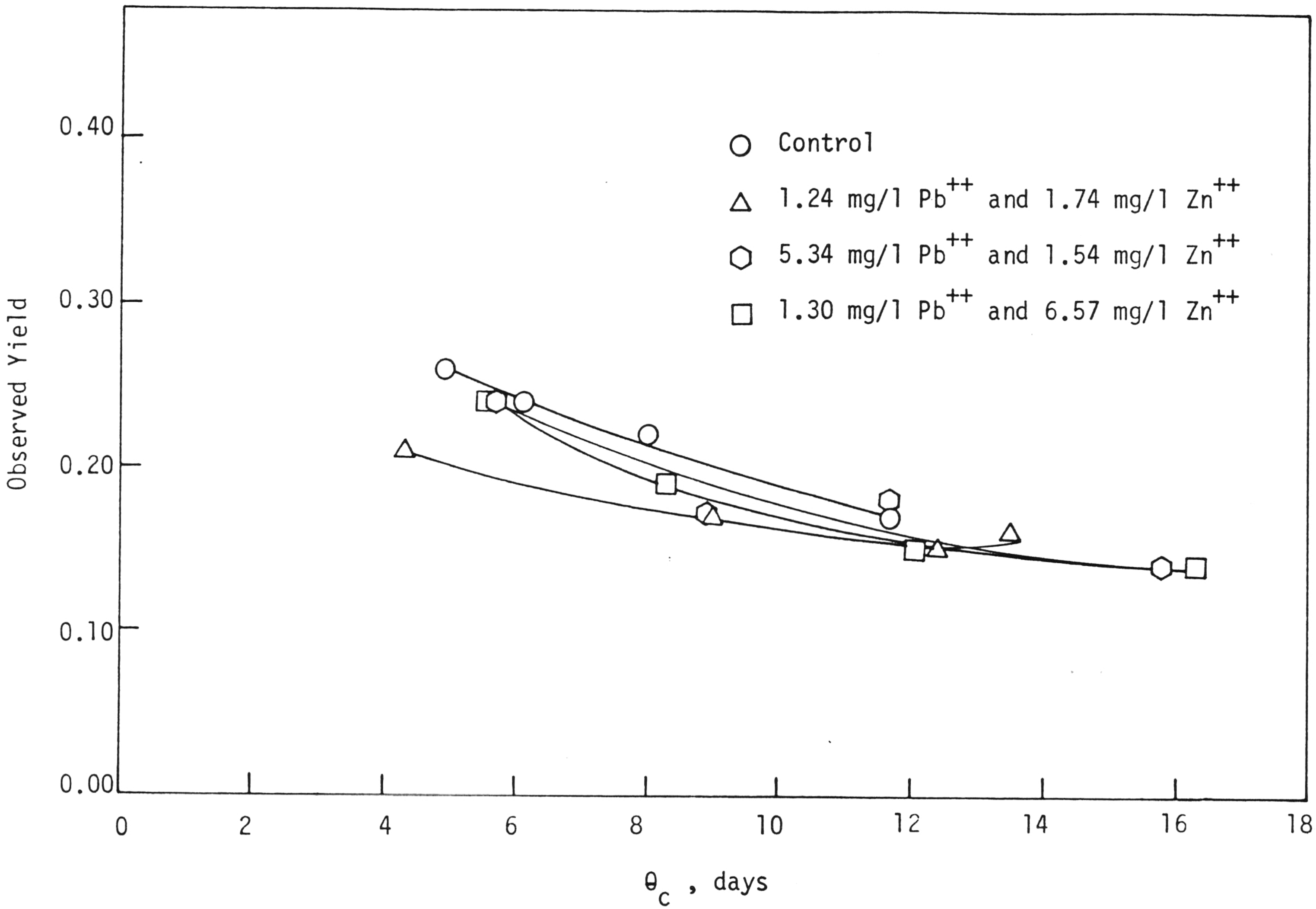

Figure 11. Observed Yield as a Function of Mean Cell Residence Time.

synthesis of microorganisms can be depressed by the presence of lead and zinc in the feed solution.

Sludge Production

Figure 12 illustrates the effect of lead and zinc on sludge production at various mean cell residence time. The conclusion may be made by the graph generated. The higher sludge production for the control reactor was obtained as compared to those for the metal laden reactors. This is attributed to the fact that the total reactor microorganism concentration, the microorganism cell yield coefficient and the observed yield for the control reactor were higher than those for the metal laden reactor.

Nitrification

Figure 13 and 14 illustrate the influence of mean cell residence time and influent lead and zinc concentration on the percentage of NH_3-N net change, and the effluent NO_3-N concentration. The results obtained indicated that nitrification in each reactor is dependent on operating mean cell residence time. As mean cell residence time increased, the percentage of NH_3-N net change and the effluent NO_3-N concentration would also increase.

Another relationship obtained for nitrification is illustrated in Figure 15 which is the plots between the net change of alkalinity in percentage and mean cell residence time. Being indicated by these graphs, the percentage of alkalinity net change would increase when mean cell residence time increased. This result is also supported by the above conclusion on ground that alkalinity would be destroyed by

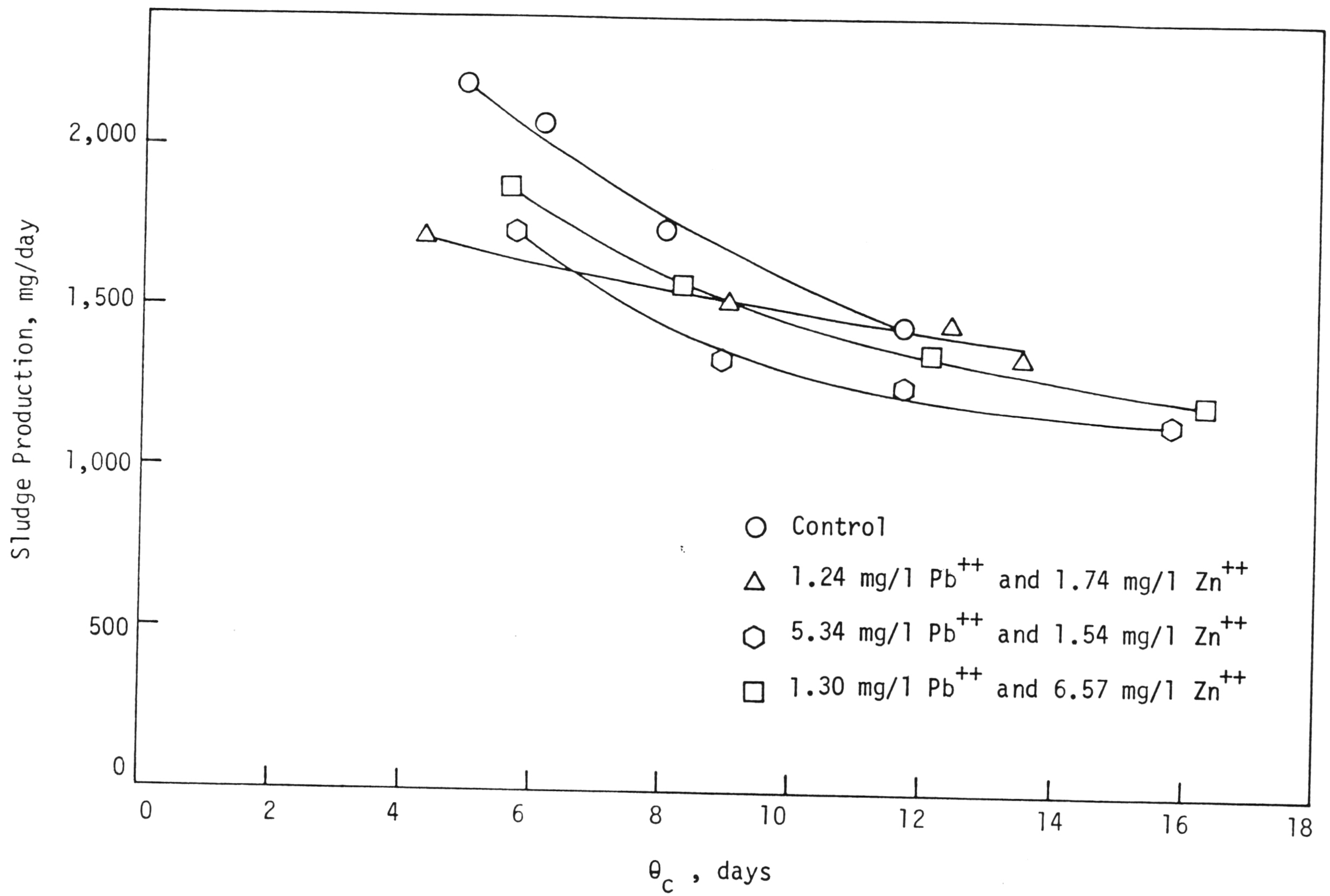

Figure 12. Sludge Production as a Function of Mean Cell Residence Time.

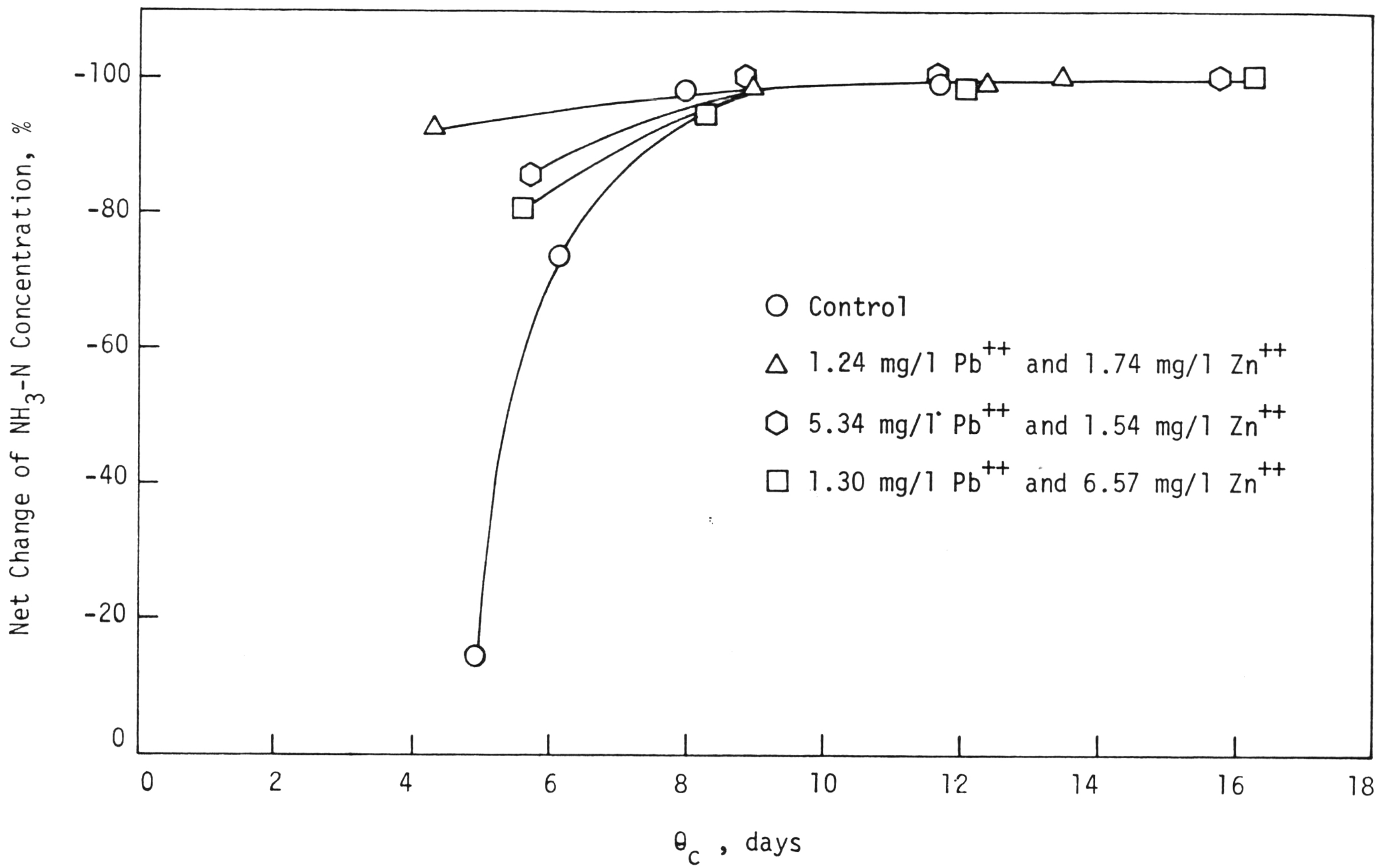

Figure 13. Net Change of NH_3-N Concentration as a Function of Mean Cell Residence Time.

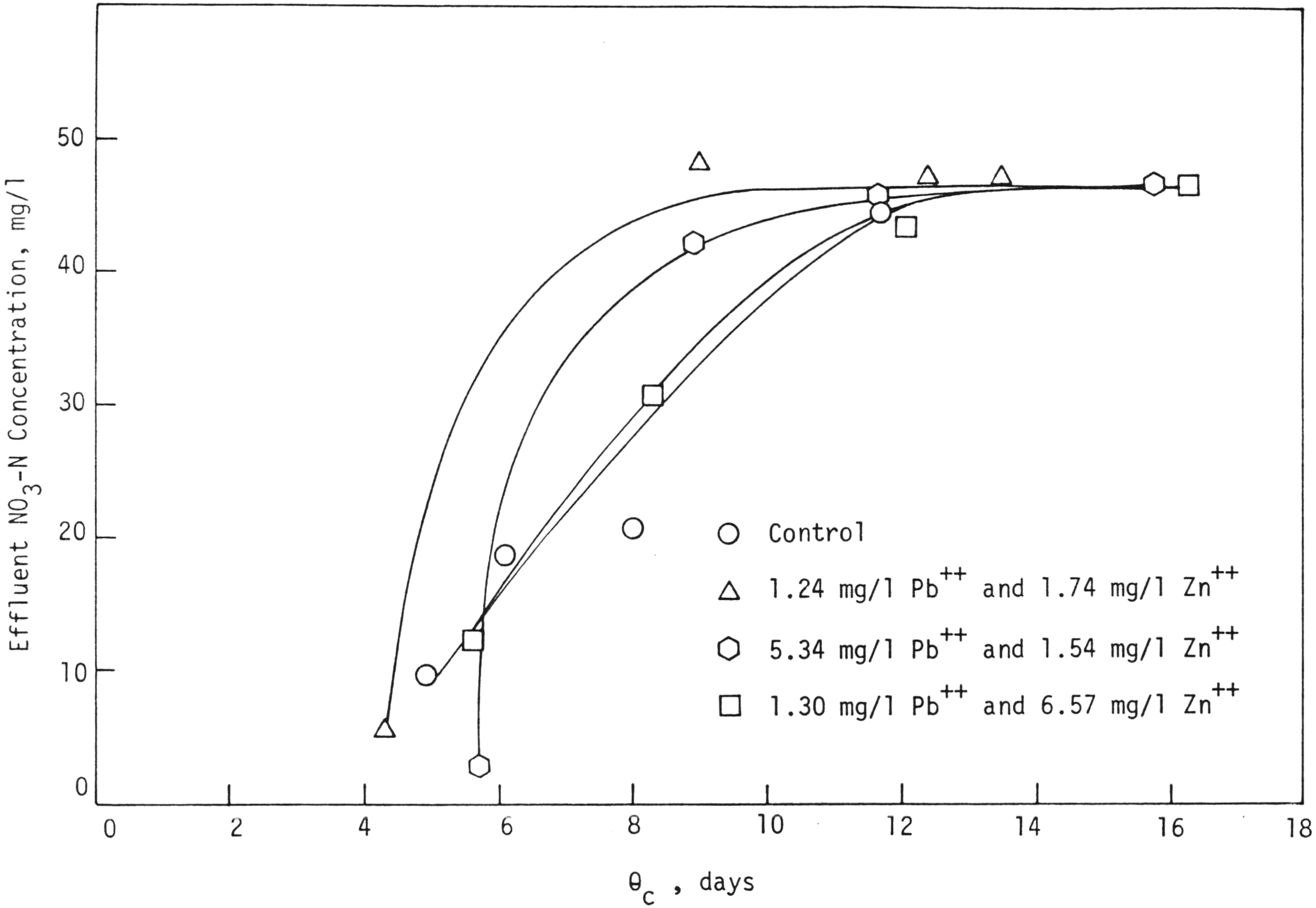

Figure 14. Effluent NO_3-N Concentration as a Function of Mean Cell Residence Time.

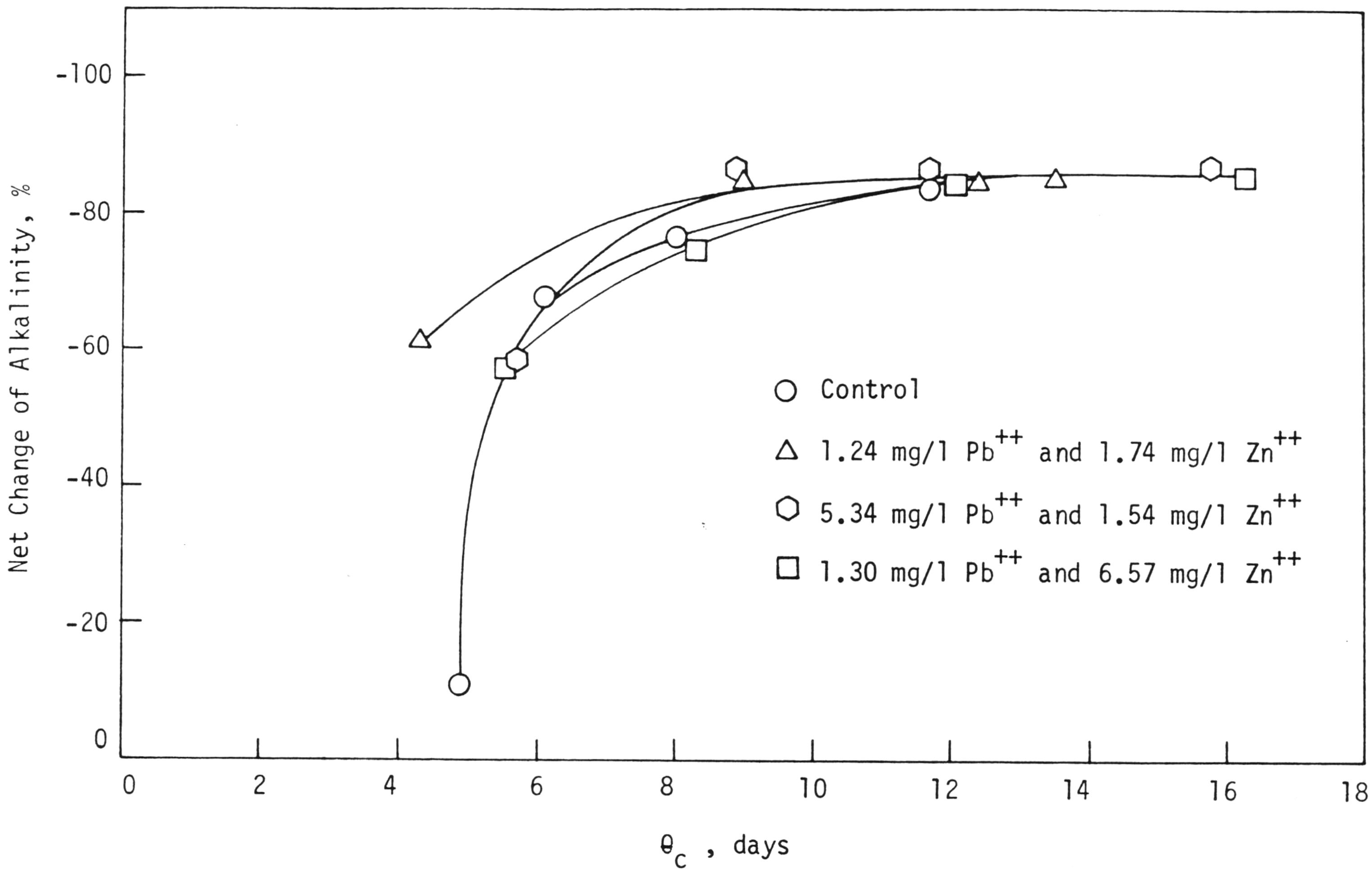

Figure 15 Net Change of Alkalinity as a Function of Mean Cell Residence Time.

the oxidation of NH_3-N to NO_3-N.

By comparing these graphs generated for the control reactor to those for the metal laden reactors, the influence of metal concentration and mean cell residence time on nitrifying organisms present in each reactor can be ascertained. The degree of nitrification for metal laden reactors was stimulated to be greater than that for the control reactor at low mean cell residence time. However, no effect on nitrification was observed at high sludge age. This can be attributed to the stimulation on larger quantity of autotrophic organisms responsible for oxidation of NH_3-N to NO_3-N in the metal laden reactors than that in the control reactor as at low mean cell residence time and thereby increase the degree of nitrification. The nitrifying organisms in all of reactors would become comparable while mean cell residence time stood at high level.

Results showing the influence of lead and zinc on organic nitrogen is presented in Figure 16. This indicated that the organic nitrogen net change percentage dependent on mean cell residence time for the reactors receiving metal concentration would be comparable to that obtained for the control reactors. It can be concluded that the metal concentration has no effect on the utilizing of organic nitrogen.

Synergistic and Antagonistic Effects

As can be seen from the graphs in Figure 6 to 16, effects of lead and zinc concentrations on the performance indicators for 1.24 mg/l Pb^{++} and 1.74 mg/l Zn^{++} fed reactor were higher than those for 5.34 mg/l Pb^{++} and 1.54 mg/l Zn^{++} fed reactor which is likewise higher than those for 1.30 mg/l Pb^{++} and 6.57 mg/l Zn^{++} fed reactor. This

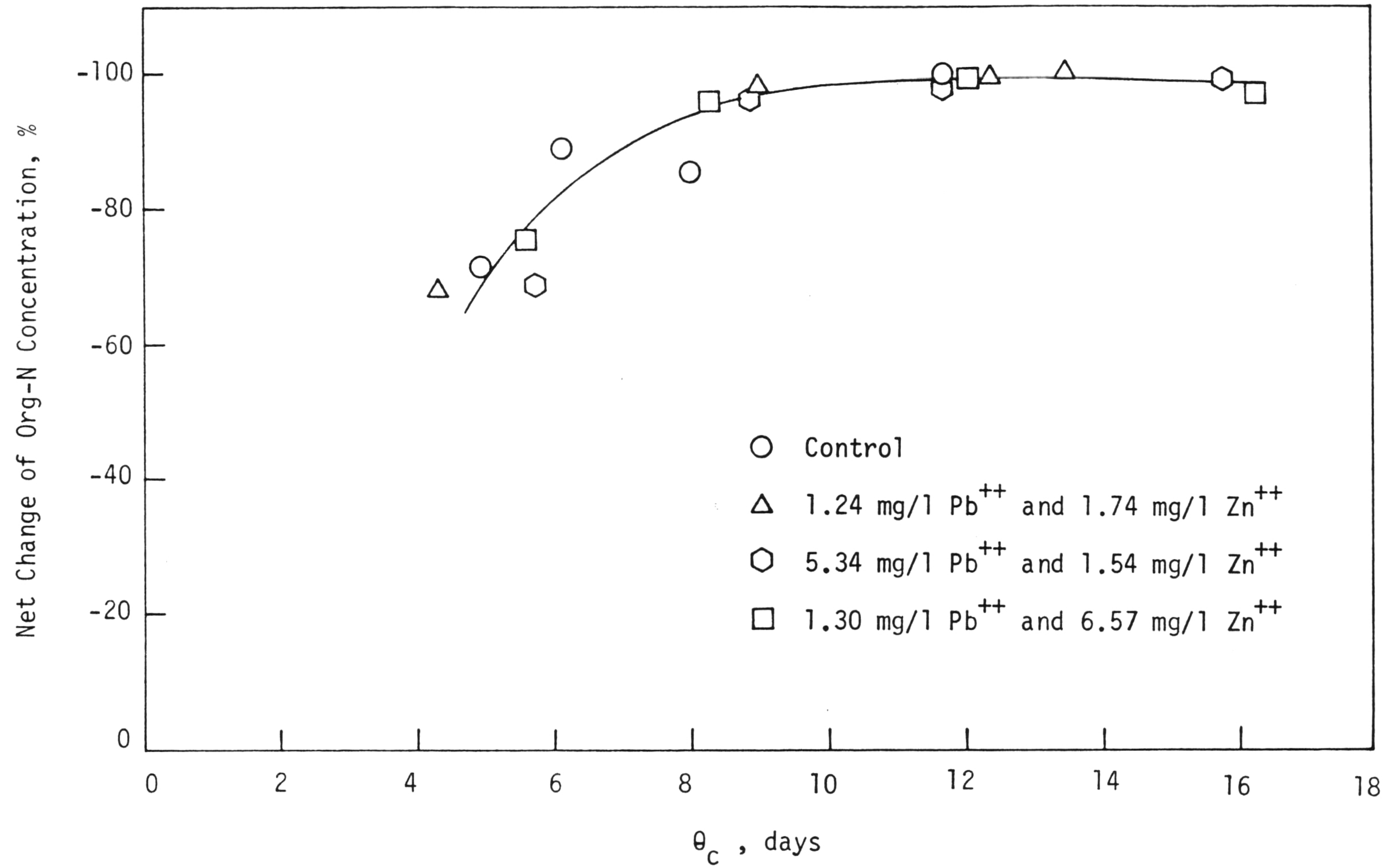

Figure 16. Net Change of Org-N Concentration as a Function of Mean Cell Residence Time.

indicated that the effects of lead and zinc were antagonistic while increasing the concentrations of lead to 5.34 mg/l or zinc to 6.57 mg/l in feed solution. This result can be explained that the complexation of lead and zinc or with other ions might be formed and thereby decreased the toxicity.

Lead and Zinc Distribution

The concentration of lead and zinc accumulated in each reactor at various mean cell residence time is shown in Figure 17. Results obtained indicated that concentration of each metal accumulated in the reactor would be larger as mean cell residence time increases. In reality, the increase of mean cell residence time causes the increasing of the microorganism in the reactor. Consequently, as the concentration of lead and zinc in soluble form is low,this can be explained that the metal accumulation is significantly originated from the uptake of biological solids.

Figure 18 shows zinc removal efficiency for each metal laden reactor. Capable to be seen from this graph, zinc removal efficiency was high at low mean cell residence time then became lower at the middle period of mean cell residence time operating in this study and finally trended to the high level again at high mean cell residence time. In addition, zinc removal efficiency would be higher if increasing zinc concentration in reactor. These are attributed to the larger quantity of zinc was removed in the higher sludge production at lower mean cell residence time and the uptake by biological solids.

Unfortunately, the Atomic Absorbtion Spectrophotometer which was utilized to analyze heavy metal concentration values in this

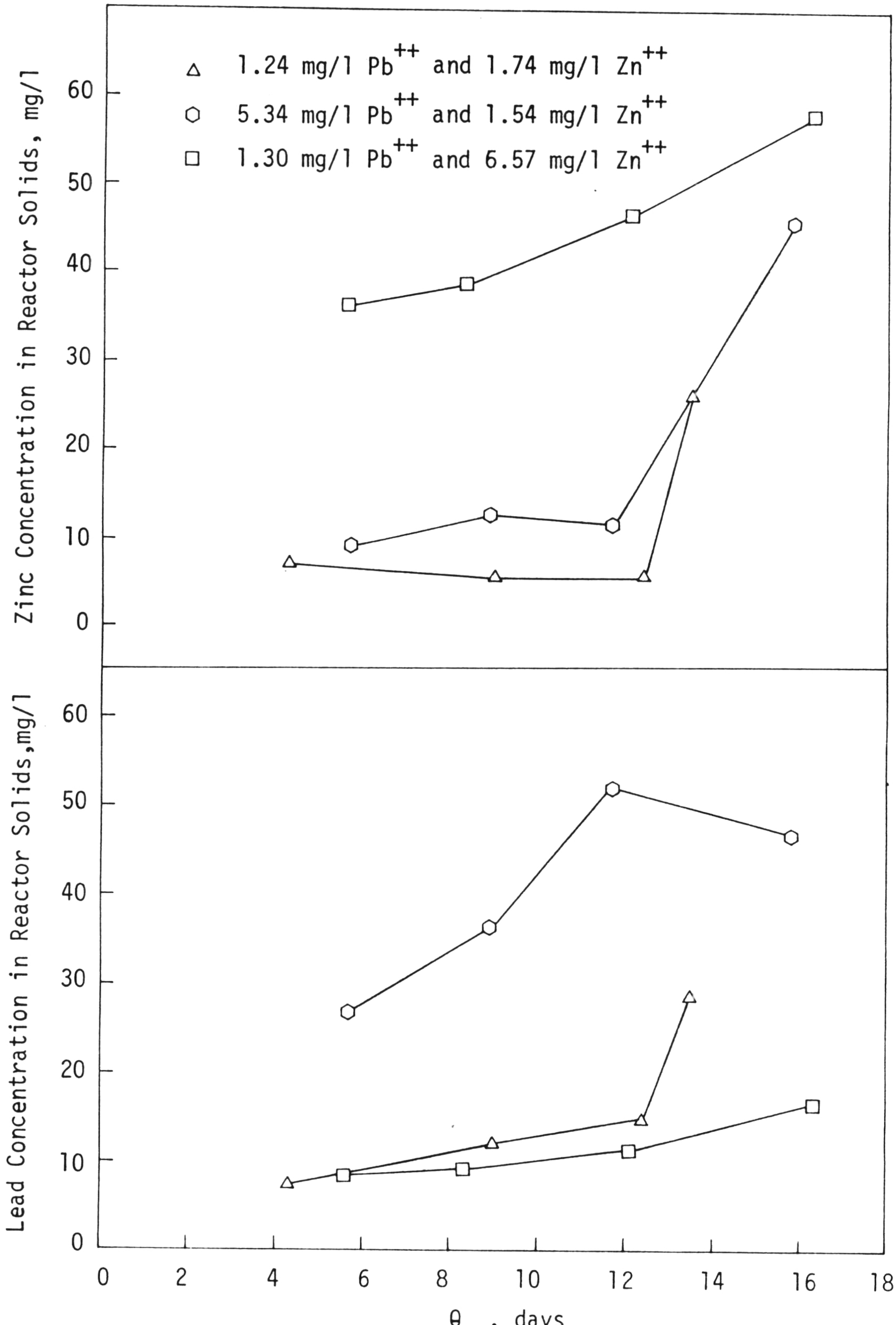

Figure 17 Lead and Zinc Concentration in Reactor Solids as a Function of Mean Cell Residence Time.

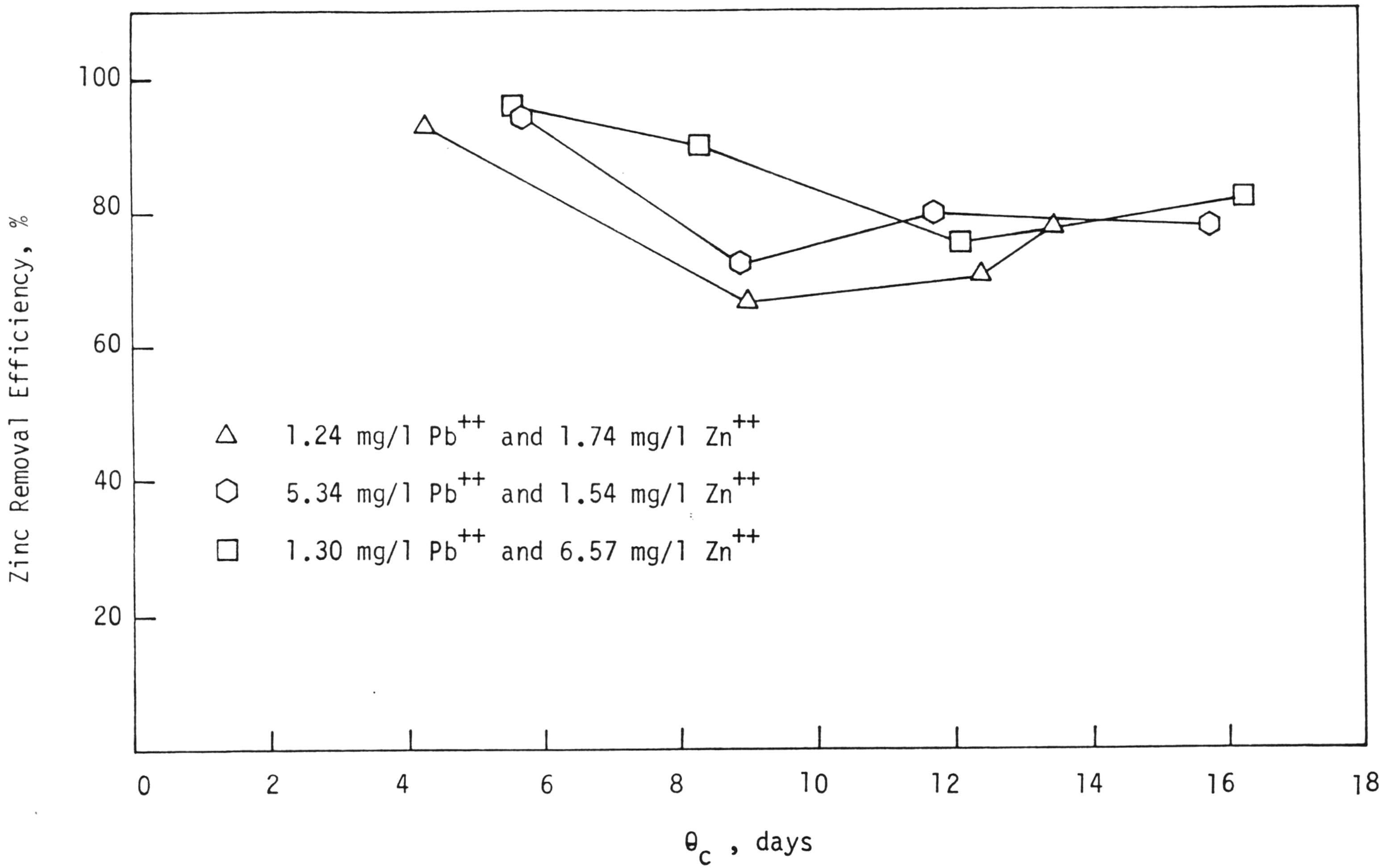

Figure 18. Zinc Removal Efficiency as a Function of Mean Cell Residence Time.

experiment was unable to detect lower than 0.5 mg/l of lead concentration. However, lead removal efficiency for each metal laden reactor is depicted in Table 18. These results can be concluded that the averaged lead removal efficiency is higher than 59.0, 90.8 and 60.8 percent for 1.24 mg/l Pb^{++} and 1.74 mg/l Zn^{++} fed reactor, 5.34 mg/l Pb^{++} and 1.54 mg/l Zn^{++} fed reactor and 1.30 mg/l Pb^{++} and 6.57 mg/l Zn^{++} fed reactor, respectively.

Table 19 and 20 depict the distribution of lead and zinc in each of metal laden reactors. The influent quantities of lead and zinc were removed by being retained at the initial stage in the reactor, either precipitated or uptaken by biological solids, then during wasting operations, and finally released in the effluent in either the soluble or insoluble form. As can be seen from Table 19 and 20, the descrepancies observed in the mass balances of lead and zinc in each metal laden reactor was possibly due to precipitation and/or complexation of the influent metals in the feed containers, the inability of the digestion procedure utilized to release the metals from biological solids, and/or experimental errors.

TABLE 18

LEAD REMOVAL EFFICIENCY

Reactor	1.24 mg/l Pb^{++} and 1.74 mg/l Zn^{++}				5.34 mg/l Pb^{++} and 1.54 mg/l Zn^{++}				1.30 mg/l Pb^{++} and 6.57 mg/l Zn^{++}			
θ_c (days)	4.3	9.0	12.4	13.5	5.7	8.9	11.7	15.8	5.6	8.3	12.1	16.3
Lead removal efficiency(%)	>54.0	>62.1	>63.6	>56.3	>90.7	>90.9	>90.6	>90.9	>55.8	>59.9	>66.2	>61.4
Average of lead removal efficiency(%)	>59.0				>90.8				>60.8			

TABLE 19

LEAD DISTRIBUTION IN LADEN REACTORS

Reactor	Pb^{++}=1.24 mg/l and Zn^{++}=1.74 mg/l				Pb^{++}=5.34 mg/l and Zn^{++}=1.54 mg/l				Pb^{++}=1.30 mg/l and Zn^{++}=6.57 mg/l			
θ_c days	4.3	9.0	12.4	13.5	5.7	8.9	11.7	15.8	5.6	8.3	12.1	16.3
Pb^{++} (mg/day) Feed	19.44	23.94	25.20	20.70	96.48	92.70	95.76	99.36	20.34	23.40	26.64	23.40
Pb^{++} (mg/day) Reactor Waste	11.93	11.25	11.40	15.73	44.02	37.30	39.02	25.70	13.79	9.17	18.38	9.05
Pb^{++} (mg/day) Effluent	<8.18	<8.53	<8.61	<8.73	<8.67	<13.42	13.80	<8.73	<8.18	<8.50	10.87	<8.73
Pb^{++} accumulated in the reactor (mg)	72.3	119.7	146.2	286.0	266.8	369.3	520.2	467.3	83.6	90.8	111.7	164.6

TABLE 20

ZINC DISTRIBUTION IN LADEN REACTORS

Reactor	Pb^{++}=1.24 mg/l and Zn^{++}=1.74 mg/l				Pb^{++}=5.34 mg/l and Zn^{++}=1.54 mg/l				Pb^{++}=1.30 mg/l and Zn^{++}=6.57 mg/l			
θ_c days	4.3	9.0	12.4	13.5	5.7	8.9	11.7	15.8	5.6	8.3	12.1	16.3
Zn^{++} (mg/day) Feed	31.32	32.04	32.22	29.52	26.46	24.48	29.16	30.42	113.94	121.4	123.66	114.48
Zn^{++} (mg/day) Reactor Waste	11.96	5.52	4.58	14.44	15.36	13.05	8.87	25.27	59.78	39.27	35.05	31.96
Zn^{++} (mg/day) Effluent	8. 8	11.43	11.88	10.47	6.05	12.92	12.08	12.04	27.96	37.38	45.89	28.97
Zn^{++} accumulated in the reactor (mg)	72.5	58.3	58.7	262.5	93.1	129.2	118.2	459.5	362.3	1388.8	467.3	581.0