CHAPTER IV

Results and Discussions

4.1 Chemical and Physical Properties of Soils

Some selected chemical and physical properties of Bm, Ks, Pc and Nw series are presented in Table 4.1. The textures of the first three series were identified to be fine or clay for Pc, moderately fine or silty clay loam for Bm and medium or loam for Ks. Because of their contents of minerals and low in organic matter (less than 20%) they are ordinary termed as mineral soil. The major species of clay in Bm, Ks and Pc series were Mt>>Kt, Kt>I, and Kt>Mt, respectively. Their pH values extended slightly acid to slightly alkaline (6.4-7.3 in $CaCl_2$). The highest in CEC and carbonate content were found in Bm series. In addition, their percentages of free iron oxides seem to be normal. In the last soil series, Nw, was very low in pH value and the highest in both CEC (205.70 meq/100g) and percentage of organic carbon (19.45%). Thus, Nw series was termed as organic soils.

One of three mineral soils, Bm series was the most cation exchange capacity, suggested that its clay minerals content (mostly identified as montmorillonite) probably influenced CEC although its percentage of clay is less than Pc series. Generally, the CEC of humus, vermiculite, montmorillonite, hydrous mica and chlorite, kaolinite and hydrous oxide are more or less in the order of 200, 150, 100, 30, 8 and 4 meq/100 g. soil (Brady, 1974). The marked difference between the CEC of Bm and Pc series may be due to the dominance of 2:1 - type clay in the Bm series and of 1:1 - type clay in the Pc series. However, the major clay species in both Pc and Ks series are kaolinite but the clay content of the first one is higher than the second. It is corresponding to being higher CEC in Pc than Ks series. Nw

Table 4.1 Physical and Chemical Properties of Soil Samples

Properties	Soil Series			
	Bm	Ks	Pc	Nw
Texture	Silty clay loam	Loam	Clay	Organic Soils
Major species	Mt>>Kt	Kt > I	Kt > Mt	nd
Sand (%)	8.4	43.6	9.9	nd
Silt (%)	59.5	33.0	15.9	nd
Clay (%)	32.0	23.4	74.2	nd
CEC (meq/100g)	48.06	12.22	34.16	205.70
pH in H_2O (1:1)	7.40	6.57	7.56	3.31
pH in $CaCl_2$ (1:2)	7.24	6.38	7.29	3.16
Carbonate (%)	8.33	1.30	3.39	nd
Free Fe oxide (%)	0.089	0.180	0.116	nd
Organic carbon (%)	2.08	1.36	1.74	19.45

Abbreviation : Mt = Montmorillonite, Kt = Kaolinite, I = Illite
nd = not determined

series is organic soil so that its, CEC is highest.

4.2 The Adsorption Isotherms of Heavy Metals from Natural Soil Series

4.2.1 Cadmium (Cd)

The adsorption isotherms of Cd by Bm, Ks, Pc and Nw series are shown in Fig.4.1. Cd adsorption capability of Bm series was found to be the highest than another soil series. Initially, its ability sharply increase until it reaches the maximum. After that, its ability decrease. The decline in Cd adsorption may be explained by negative adsorption or steric effect. (Talibudeen, 1981). Eventhough, organic soil is the most cation exchange capacity, but the selective adsorption of Cd in Nw series found here is less than another series. Very strong acidity of this soil may affect on the Cd adsorption. The adsorption ability of Ks series was quite low because of its major clay species, kaolinite crystals. Its effective surface is restricted to its outer surface and limited adsorptive capacity for cations (Brady, 1974). Although the major clay species in Pc series was kaolinite, its adsorption ability was higher than Ks series. It may be due to montmorillonite in Pc series.

4.2.2 Nickel (Ni)

From Fig.4.2. the adsorption isotherm of Ni by Bm and Pc series do not differ in selective adsorption capability and both are quite high. Commonly, cations are attracted between montmorillonite crystal units but kaolinite does not exhibit this property. The results indicated that selective sites (internal or external surface) or affinity of Ni in both Bm and Pc series seem to be similar. Comparing with the above two soil series, Ni adsorption ability of Ks and Nw series were quite low. The explanations of the lowering in Ni adsorption capability are as

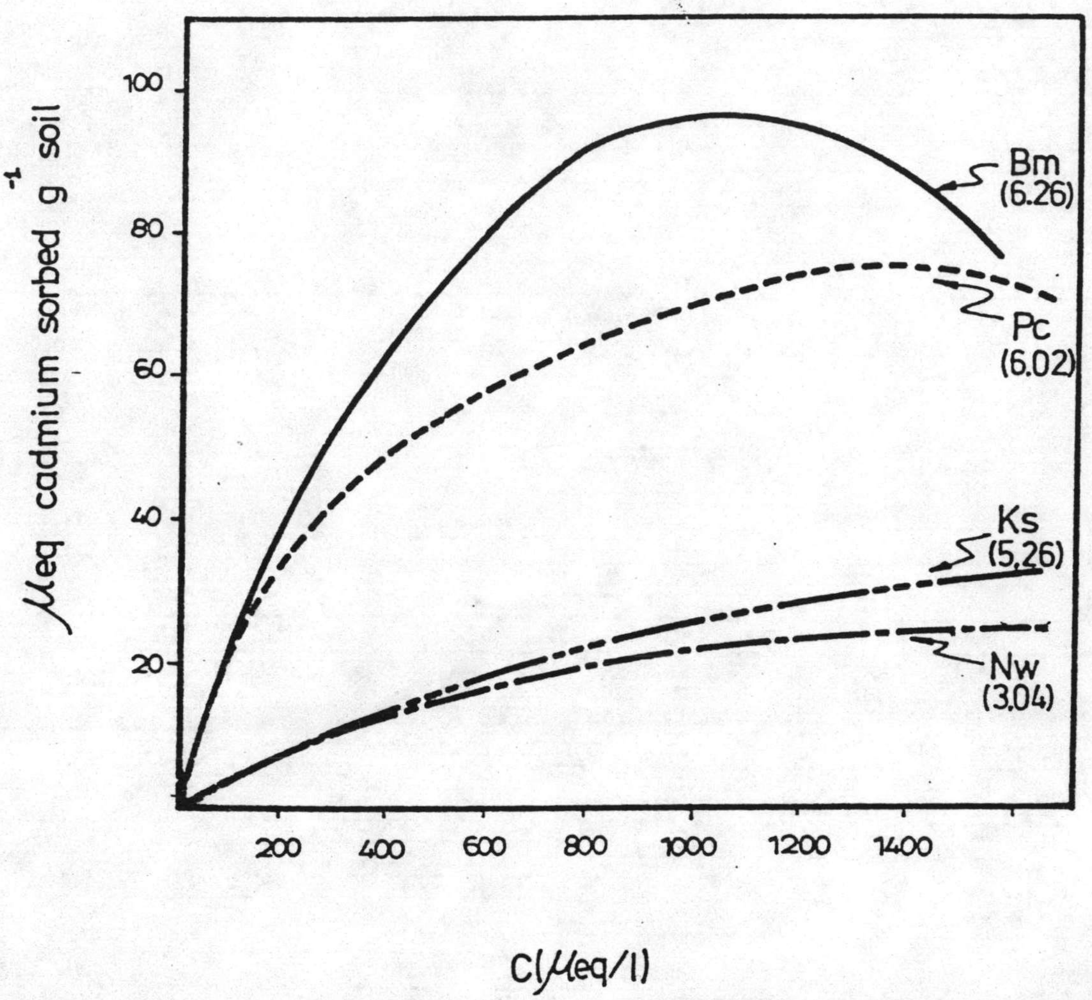

FIGURE 4.1 The adsorption isotherms of cadmium by natural soil series (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

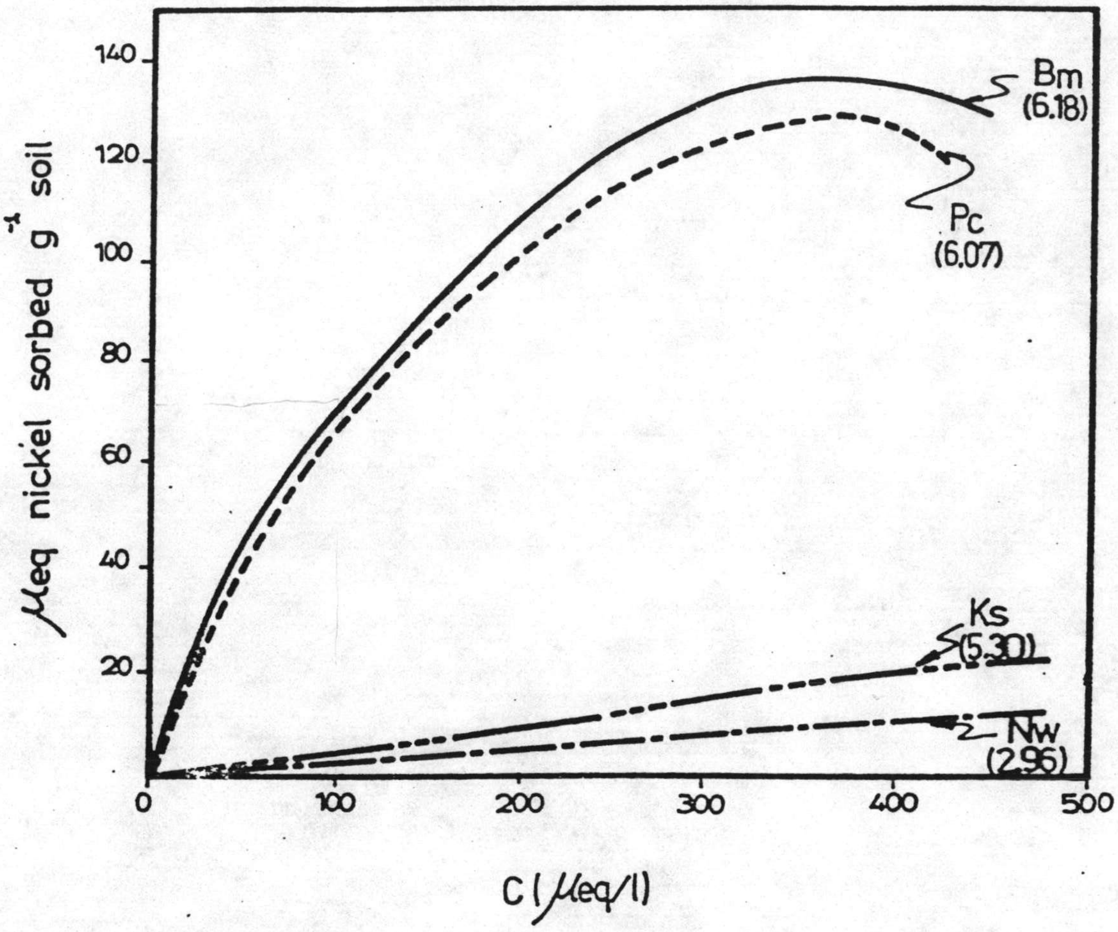

FIGURE 4.2 The adsorption isotherms of nickel by natural soil series (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

follows : firstly, similar to Cd adsorption, it possibly dues to kaolinite crystal content in Ks series; and secondly, it may be the effect of pH of Nw series.

4.2.3 Zinc (Zn)

Fig.4.3 shows Zn adsorption capability of the four tested soil series. Extremely high affinity of Zn adsorption was found in Bm series. The result also showed that Zn adsorption was greater than other cations (Cd, Ni). It may be due to its montmorillonite content and precipitation of zinc hydroxide [$Zn(OH)_2$] or hydroxycarbonates. It is possibly that free Fe oxide in mineral soils may be partially changed to Fe hydroxide. The presence of Fe hydroxide may also influence the adsorption (Davies, 1980). The lower degree of Zn affinity was found in Pc series, it may be depend on the certain amount of montmorillonite. The high affinity in both Bm and Pc series show that their soil colloids are more selective for Zn than that in Ks series. Similar to Cd and Ni selective adsorption , Nw series showed the quite low quantity of Zn adsorption. It may be due to its acidity.

Ordering among three test mineral soils, it was indicated that the decreasing order of adsorption affinity of three heavy metals (Cd, Ni, and Zn) was Bm, Pc and Ks series respectively. Comparing with mineral soils and organic soil,the adsorption capability of Cd and Ni by Nw series (organic soil) was lower than Ks series. In the other hands, its capability of Zn by Nw series was higher than Ks series.

4.3 The Adsorption Isotherms of Heavy Metals from Calcium-Saturated Soils

4.3.1 Cd

After calcium-saturated treatment, the exchange sites in minerals soils were attracted with calcium ions. From

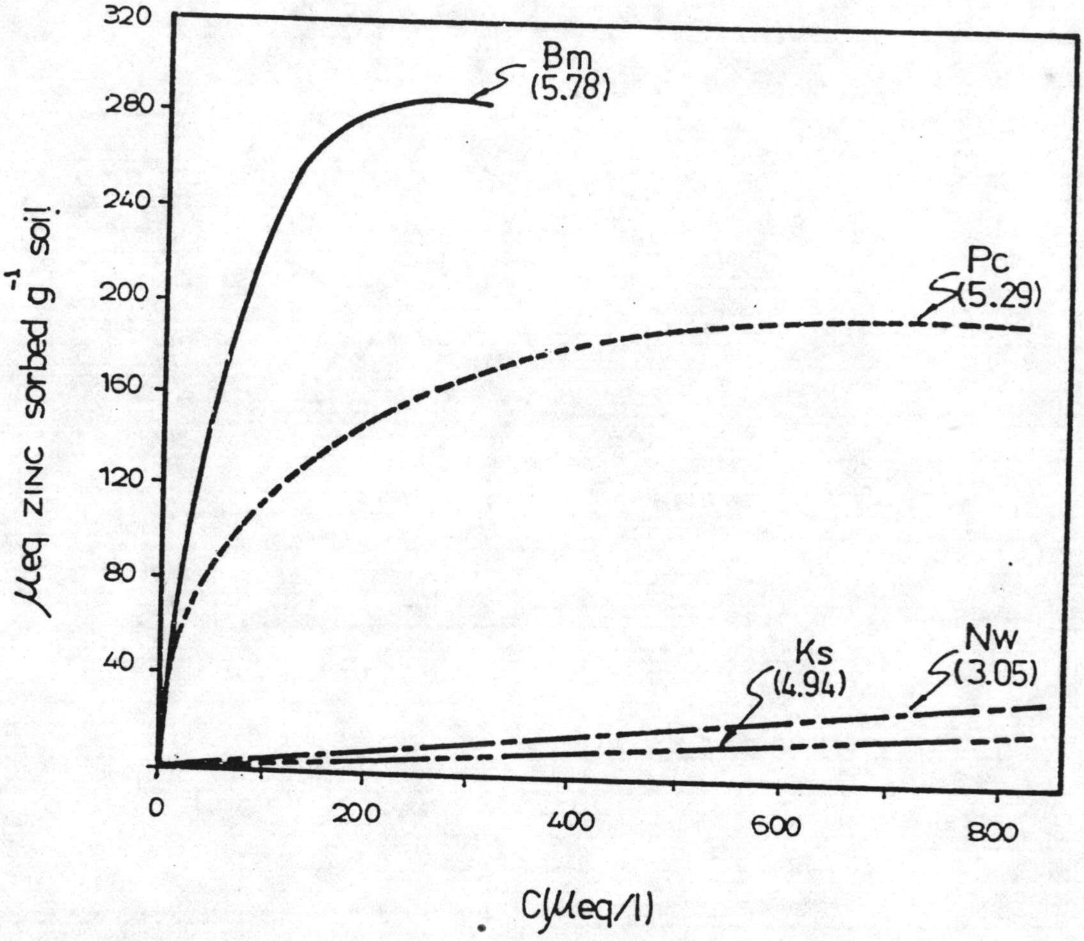

FIGURE 4.3 The adsorption isotherms of zinc by natural soil series (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

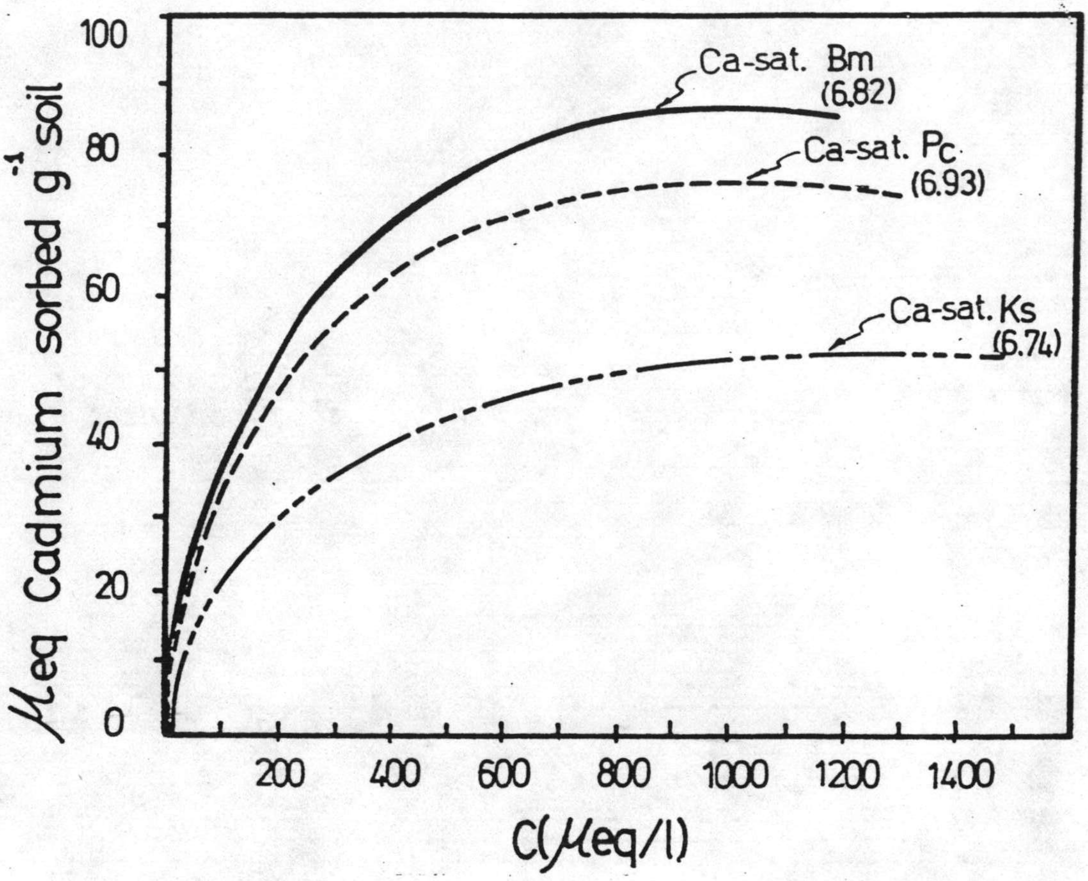

FIGURE 4.4 The adsorption isotherms of cadmium by calcium saturated soils (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

Fig.4.4, the sequence of the soil series is derived for the selective adsorption of Cd : Bm (Mt) > Pc (Kt+Mt) > Ks (Kt+I). The results disagree with Abd-Elfattah and his colleague (1981). They concluded that Cd adsorption was in the order of soil containing Fe-ox > A-Im > humus > A, Kt > Ht, Mt. The possible reasons may depend on the difference in soil genesis and natural soil component (see also Table 4.1). The selective adsorption depended on the suitable matching between cation size and the active surface. In the experiment Ca - sat. Bm adsorbed Cd in high affinity than the others.

4.3.2 Ni

Fig.4.5 shows the adsorption isotherm of Ni by calcium-saturated treatment of three tested mineral soils, i.e., Bm, Ks and Pc series. Their patterns of Ni selective adsorption seemed to be similar to those by natural soils. The highest adsorption capability was found on Bm series and followed by Pc series and the lowest on Ks series. As mentioned before, Kt did not attract cations between its crystalline units. The fixed lattice dues to hydrogen bonding by oxygen atoms which are shared by the silicon and aluminium atoms. The effective surface is thus restricted to its outer surface (Brady, 1974).

4.3.3 Zn

The adsorption isotherm of Zn by calcium-saturated treatment of three mineral soils are presented in Fig.4.6. The trends of selective Zn adsorption were the same as Cd and Ni. The ability was in the order Bm > Pc > Ks. Similar to Cd adsorption, the results disagreed with Abd-Elfattah and Wada (1981). They showed that the selective adsorption sequence of Zn by soil containing extractable iron oxide > Ht, A-Im > Kt > A, humus > Mt. It may be proposed that difference in soil genesis and natural soil components affect the different result in this studying (See also Table 4.1). Anyway, cation exchange capacity may be used as a major factor to explain the different retentions

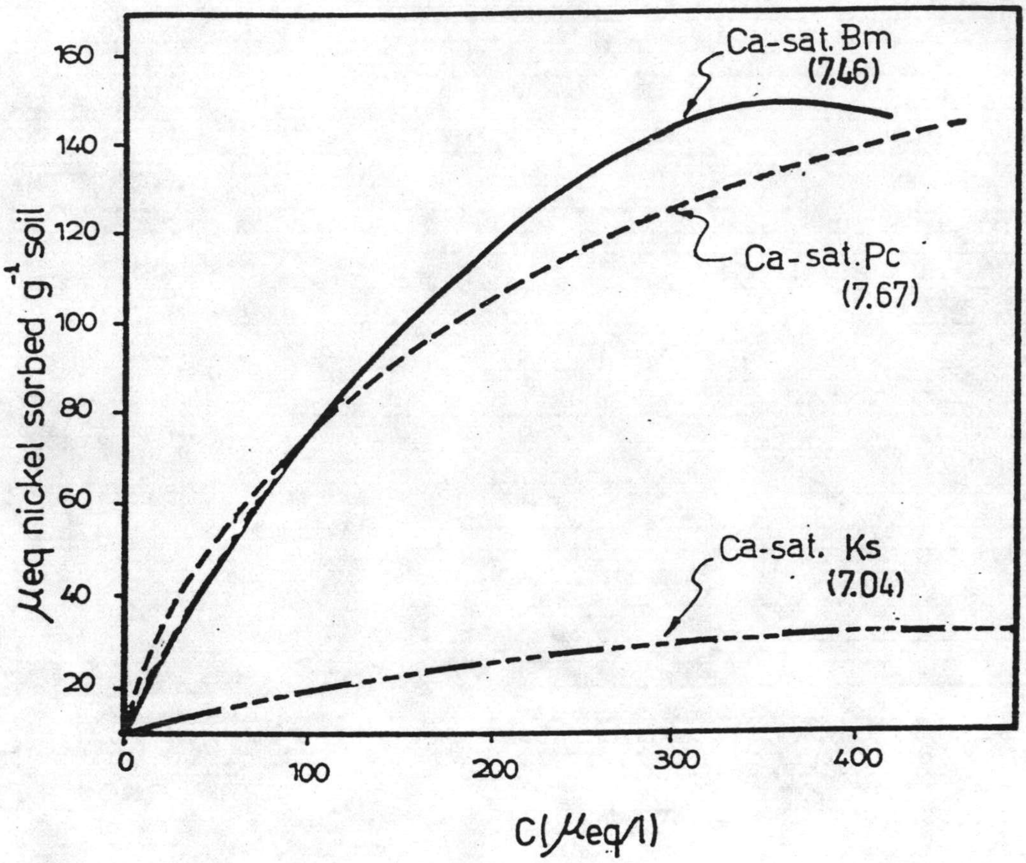

FIGURE 4.5 The adsorption isotherms of nickel by calcium saturated soils (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

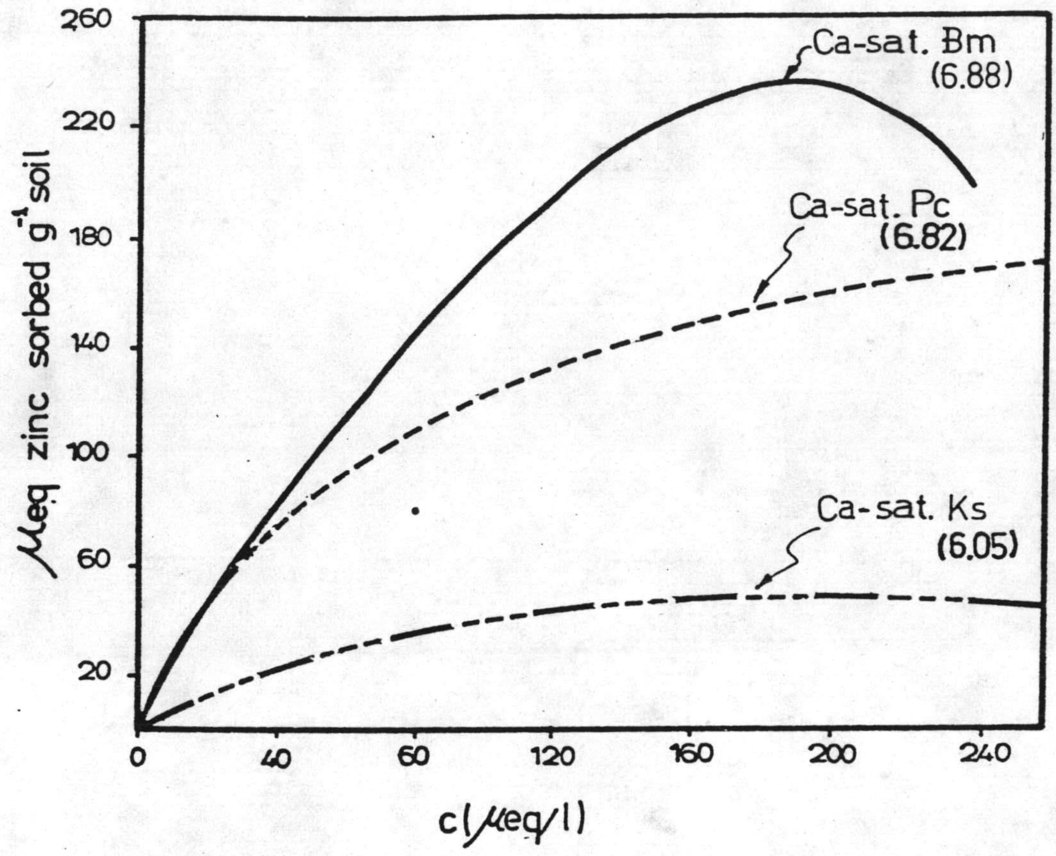

FIGURE 4.6 The adsorption isotherms of zinc by calcium saturated soils (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

among the adsorption of calcium - saturated soils.

4.4 Effects of the Nature of Cations on Selective Adsorption of Natural Soils

4.4.1 Ban Mi Series (Bm)

On Ban Mi series, the selective affinities of Cd, Ni and Zn increased in the order of Cd < Ni < Zn. Marked difference of Zn adsorption to other heavy metals is presented in Fig.4.7. The observed sequence is correlated neither with the sequence of their ionic radii ; Ni (0.77 A°) < Zn (0.83 A°) < Cd (0.97 A°) nor with the sequence of their electronegativity ; Zn (1.6-1.7) < Ni=Cd (1.7). The selective adsorption site may be suitable for Zn more than Ni and Cd. However, several investigators are interested in paralled reactions between adsorption and precipitation as hydroxides of heavy metal cations (Abd-Elfattah and Wada, 1981). In fact, soil constituents of Bm series are montmorillonic clay. Cations (as well as water molecules) are attracted between crystal units causing internal surface adsorption. In addition, Davies (1980) reported that montmorillonite was capable of adsorbing Zn in amounts greater than CEC. Thus, the most adsorbed metal was zinc.

4.4.2 Kamphaeng Saen Series (Ks)

The selective adsorption affinities of three test cations (Cd, Ni, Zn) are shown in Fig.4.8. Their affinities were not differ at low concentration, but the anomaly sequences were found at higher concentration (Ni < Cd < Zn). Comparing with Kinniburgh and his colleague, 1976 (cited by Abd-Elfattah et.al., 1981), who found that selective adsorptions of heavy metal cation in two synthetic gels containing aluminium hydrous oxide were; Cd < Co < Ni < Zn < Pb < Cu and of iron hydrous oxide were; Co < Cd < Ni < Zn < Cu < Pb. The results here seemed to partially confirm their investigations. The possible explanation for the higher Zn adsorption may concern with both adsorption and

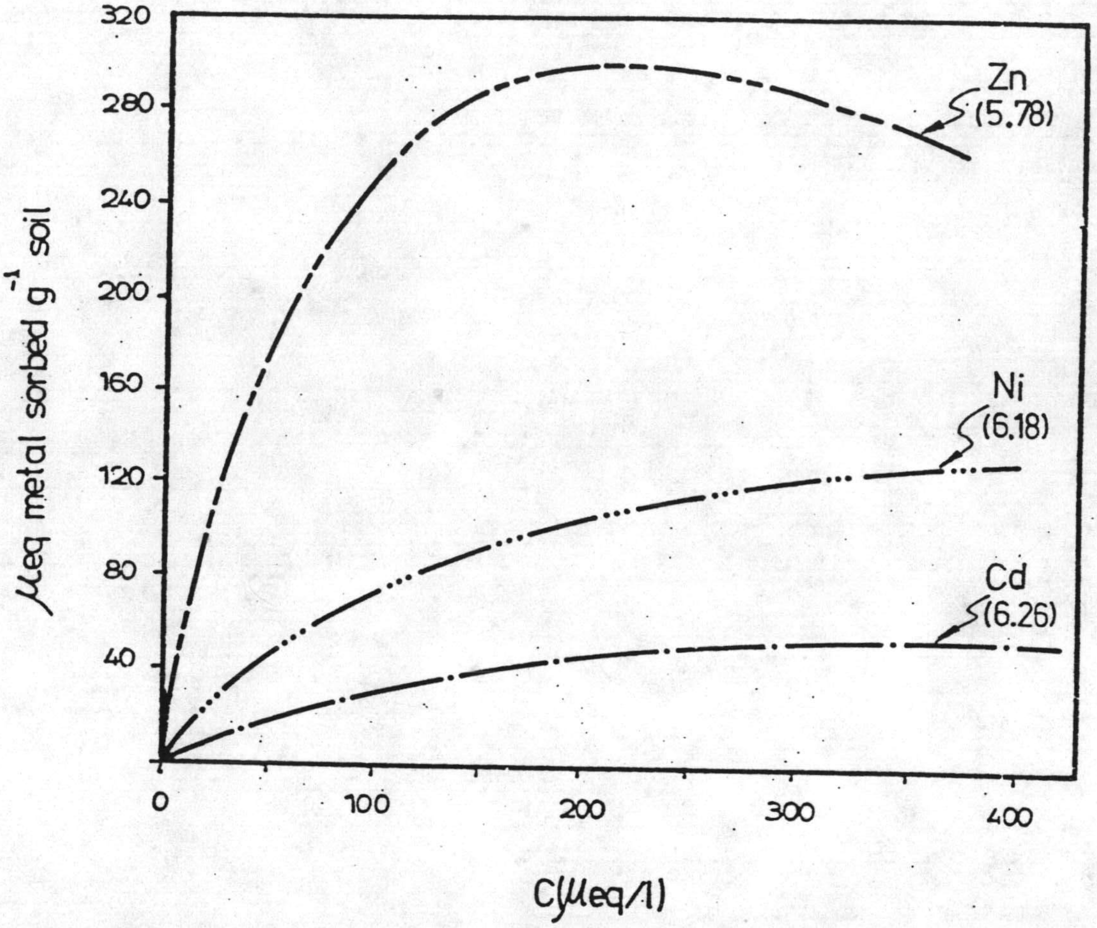

FIGURE 4.7 The adsorption isotherms of Ban Mi series (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

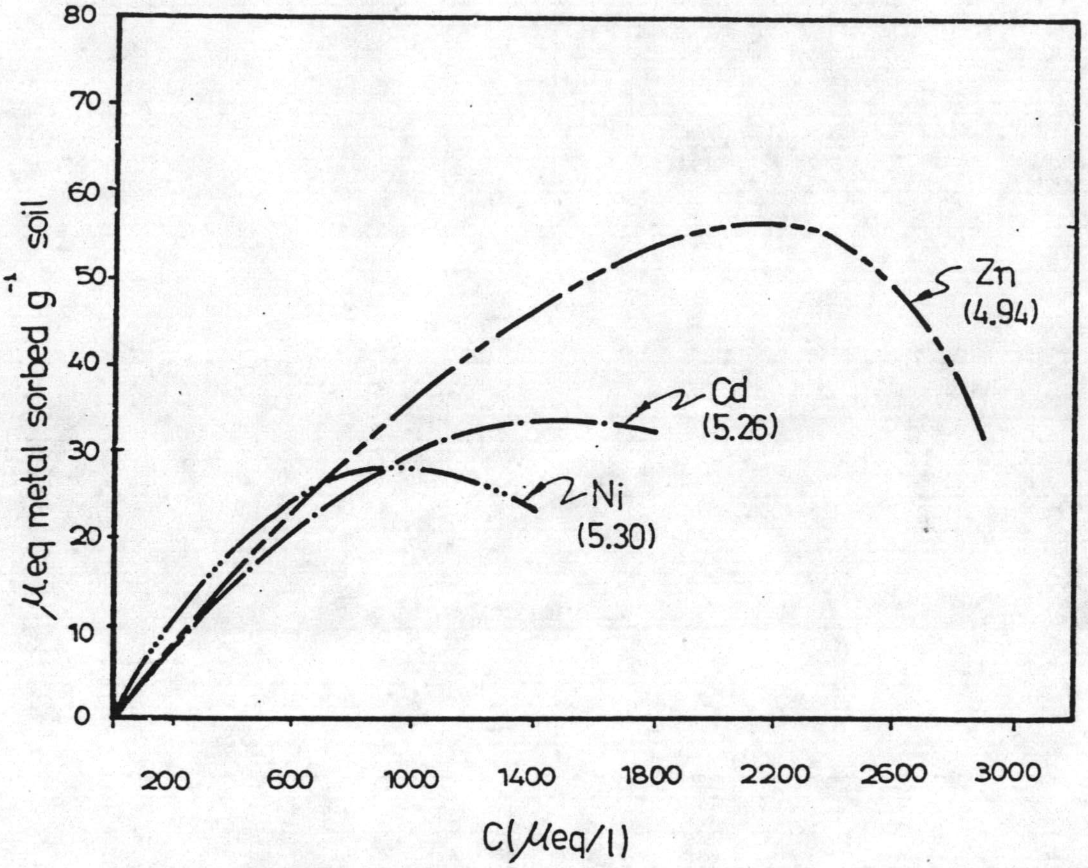

FIGURE 4.8 The adsorption isotherms of Kamphaeng Saen series (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

precipitation as in the case of Bm series.

4.4.3 Pak Chong Series (Pc)

Zinc and nickel adsorption isotherms are high affinity (H-type), while Cd exhibit the Langmuir (L-type). It was found that selectivities of Pc series for Zn and Ni were higher than for Cd (Cd < Ni < Zn) (see Fig.4.9). Similar to Ks series, the major clay species are kaolinite but in Pc series, montmorillonite are presented. This maked the selective affinity in Pc series was common with in Bm series(Mt).

4.4.4 Narathiwat Series (Nw)

The selective adsorption affinities of Cd, Ni and Zn in Narathiwat series are presented in Fig.4.10. Comparing with the mineral soil samples, affinity in organic soil is quite low. In acidic condition, hydrogenion is tightly bound at the active surface then heavy metal cations can slightly replacable. Organic contents in ordinary mineral soils may be used as a major factor to explain retention difference among soil samples, despite the fact that no correlation was found between metal retention and organic content (Harter, 1983). Cation affinities in Nw series were in the order of Cd < Zn < Ni. The sequence confirmed the result from Tiller et al. (1984). They reported that heavy metal ions associated with organic surfaces for which metal-ion hydrolysis was of little significance and difference in metal-ion affinity. At lower pH value, Cd and Ni were somewhat prefered over Zn, with converse at higher pH values. Nevertheless, no adequate methodology of extracting active organic matter has yet been divised, possible suggestion that humic and fulvic acid fractions of organic matter are very important in adsorption (Davies, 1980).

4.4.5 Calcium Saturated Soils

Calcium saturation increases both amount of adsorbed metal cations and the affinity with which the soil holds them. Because calcium ions which adsorbed on the exchangable

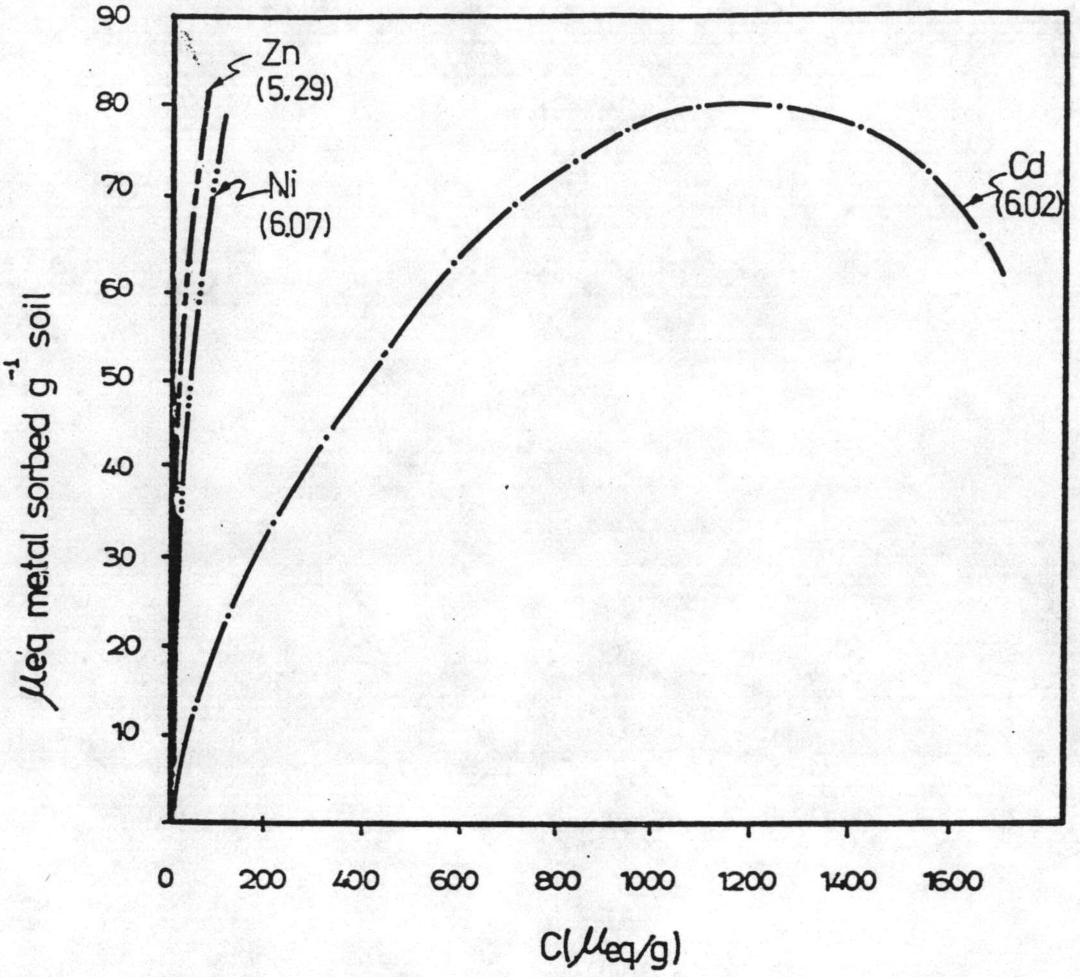

FIGURE 4.9 The adsorption isotherms of Pak Chong series (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

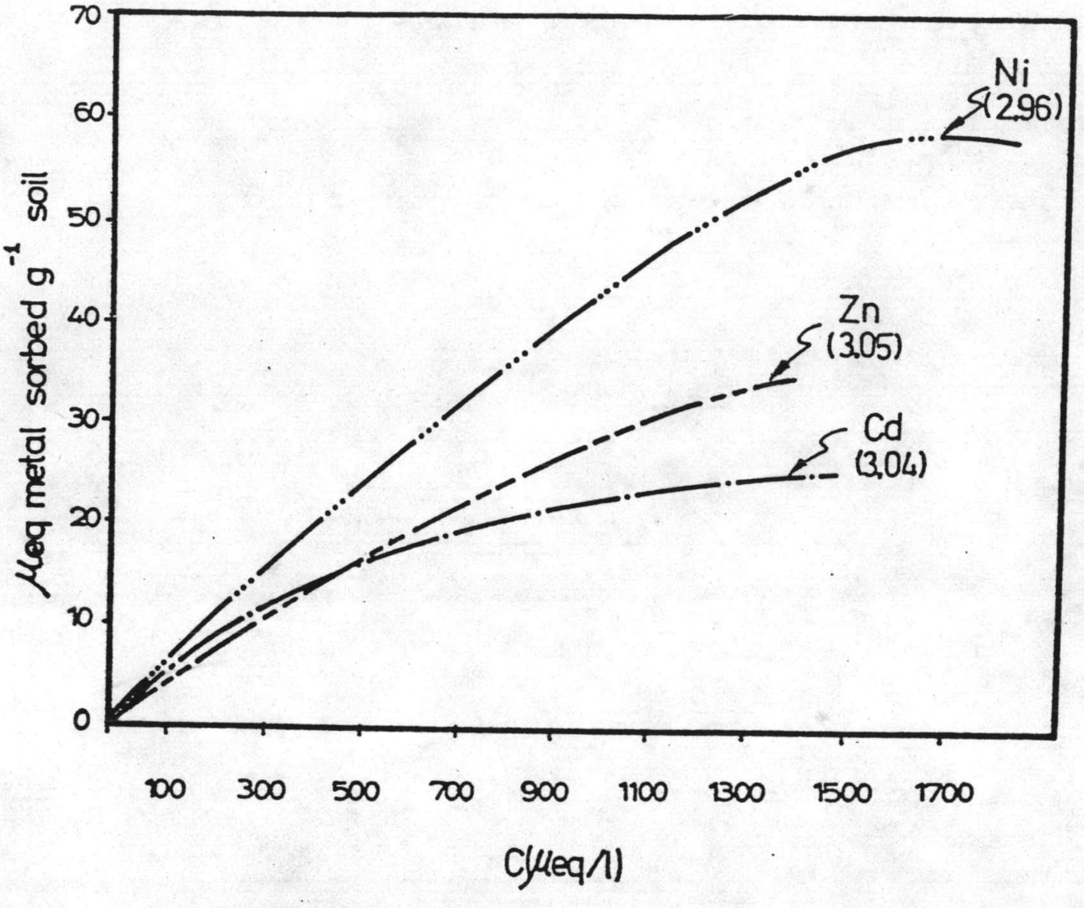

FIGURE 4.10 The adsorption isotherms of Narathiwat series (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

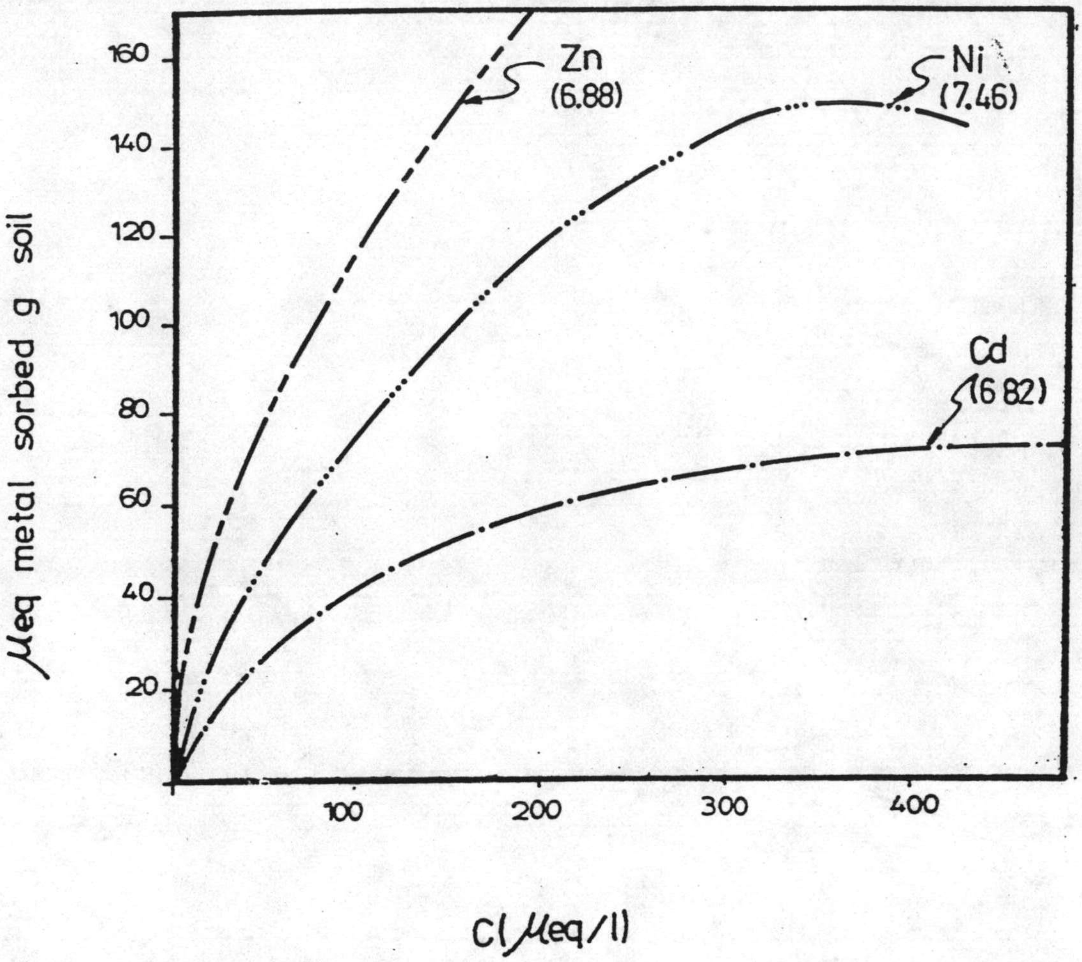

FIGURE 4.11 The adsorption isotherms of calcium-saturated Bm soil (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

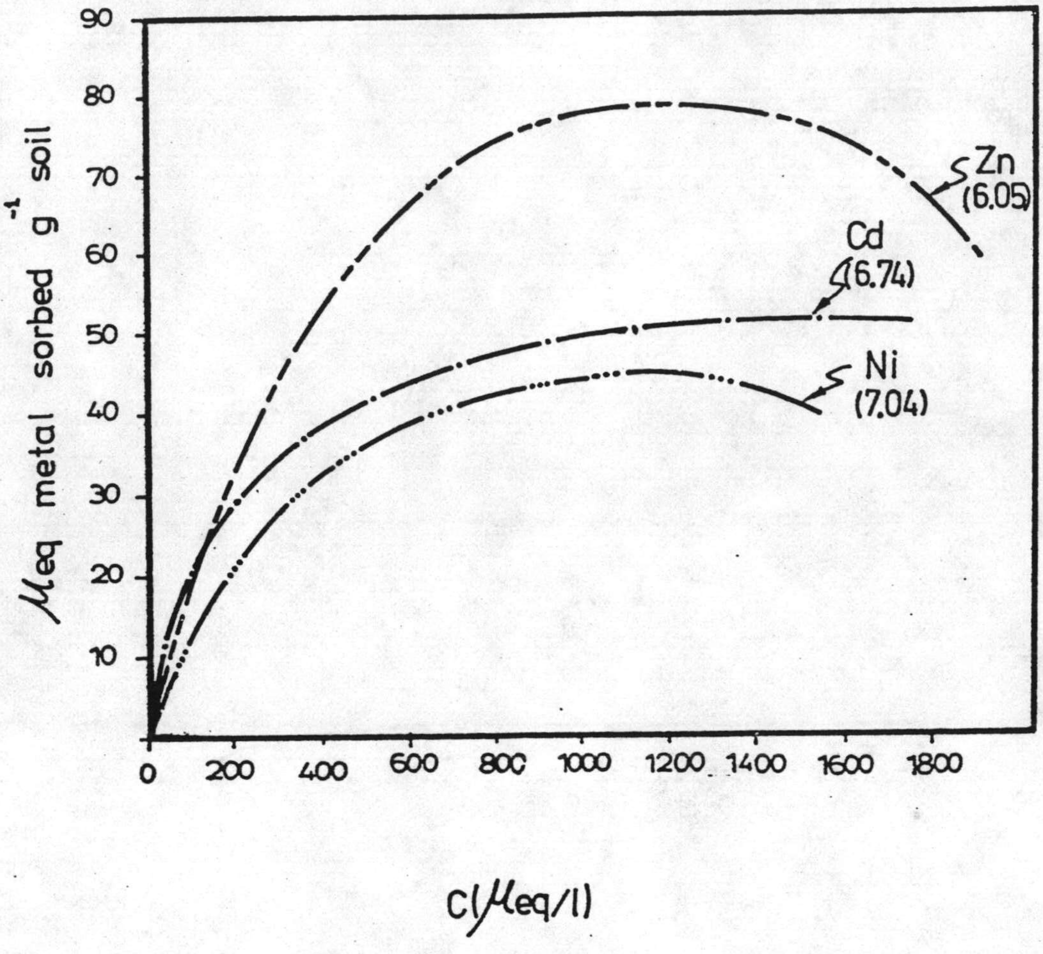

FIGURE 4.12 The adsorption isotherms of calcium-saturated Ks soil (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

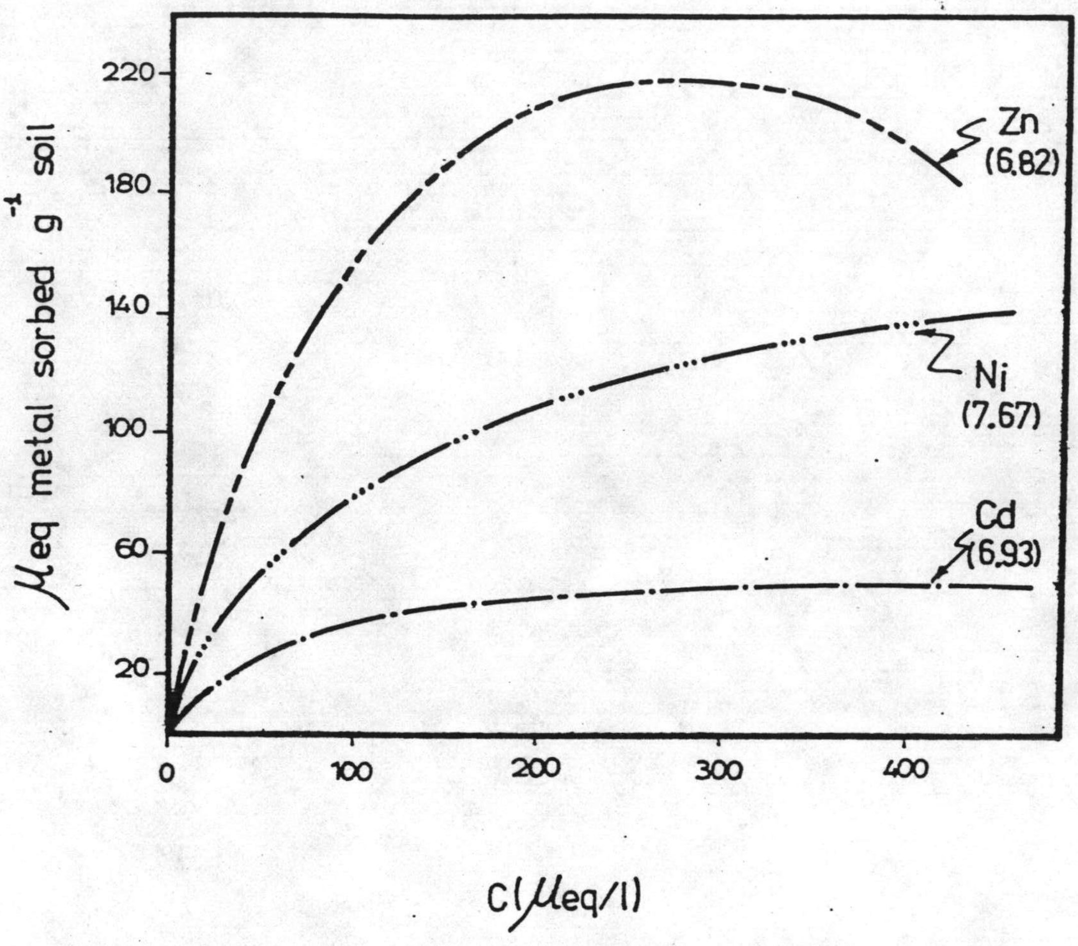

FIGURE 4.13 The adsorption isotherms of calcium-saturated Pc soil (The number in parenthesis was the equilibrium pH at which maximum concentration of heavy metal was added)

site were easy to exchange with heavy metal ions. The selective adsorption affinities of Cd, Ni and Zn in the tested calcium-saturated soils, i.e., Ca-sat. Bm, Ca-sat. Ks, and Ca-sat. Pc are shown serially in Fig 4.11 - 4.13. It was found that affinity pattern was not differ from natural soils. From three tested cations, Zn is the most selective cation. The evidence showed that differences in those cations may depend on the cation exchange materials. The results confirmed to other groups of investigator (Wada and Abd-Elfattah, 1978; 1980 ; and Abd-Elfattah and Wada, 1981). The equilibrium pH for calcium-saturated soil at which the maximum of heavy metal concentration added was raisen (comparing to the natural soils). At lower pH value the adsorptions are competitive adsorption between proton (H^+) and metal cations. The decreasing of H^+ (pH arising) causes the increasing of heavy metal adsorption (Brady, 1974). Hence, amounts of adsorbed heavy metal cations were increased.

4.5 The Maximum and Affinity of Selective Adsorption

Transformed Langmuir isotherm is linear form and the two parameters, the adsorption maximum, M and the affinity parameter, K are easily estimated by linear regression (Table 4.2). The data showed linear correlation between c/n and c. Coefficient of determination, R^2, indicates that approximately percentage of the variation (c/n) is accounted for by a linear relationships with c (Wapole and Myers, 1972). The adsorption data of Ni by calcium-saturated Pc soil shows the best linear relationships. Estimated 99.5% of c/n is accounted for Langmuir equation with c ($R^2 = 0.995$). The transforming of this equation is fit for the adsorption data which R^2 values are nearly 1.00. The calculated R^2 value showed the suitable between adsorption data and Langmuir adsorption isotherm.

Table 4.2 The Adsorption Maximum, M and the Constants of Langmuir Equation, K (p=0.05)

Cations/Soil samples	M(μeq/g)	Kx10^{-3} (l/μeq)	R square(r^2)
Cd			
Bm	91.42-110.70	2.7-5.0	0.957
Ks	37.07-65.15	0.4-1.3	0.524
Pc	78.98-88.33	3.2-5.9	0.971
Nw	23.19-33.22	1.4-8.0	0.744
Ca-sat.Bm	98.28-108.40	4.2-6.3	0.979
Ca-sat.Ks	56.93-67.62	2.4-4.8	0.932
Ca-sat.Pc	80.73-89.31	5.0-8.6	0.978
Ni			
Bm	207.94-385.55	1.5-4.2	0.557
Ks	33.37-39.41	1.5-2.5	0.932
Pc	169.66-262.60	2.3-5.6	0.716
Nw	102.72-148.37	0.3-0.6	0.722
Ca-sat.Bm	214.72-358.34	2.1-5.3	0.633
Ca-sat.Ks	47.72-54.23	2.9-5.4	0.960
Ca-sat.Pc	183.37-192.71	7.0-8.1	0.995
Zn			
Bm	358.57-476.73	5.9-11.4	0.873
Ks	59.18-95.08	0.3-0.9	0.636
Pc	185.52-202.23	14.7-44.8	0.987
Nw	64.23-120.22	0.2-0.6	0.468
Ca-sat.Bm	391.42-525.16	3.2-5.2	0.833
Ca-sat.Ks	64.44-90.00	1.5-7.0	0.801
Ca-sat.Pc	219.11-250.86	10.4-18.9	0.965

On the basis of selective adsorption, the following sequences of soil are derived for the adsorption maximum of the Cd, Ni and Zn cations : Bm > Pc > Nw > Ks. However, comparing the affinity of selective adsorption constant, k, the sequences are expressed as follows : Pc > Bm > Nw   Ks. (see Table 4.2).

Tiller et.al (1984) have shown that the greater relative affinity for Ni shown by clay fractions dominated by fine kaolinites when compared with other clays. The results of the experiment agree with those conclusion. Pc soils are the highest affinity constant, k, (compared with another soils), where kaolinite is the major species. Although major clay species of Ks was kaolinite but percentage of clay were less so its affinity constant was less than the other mineral soils.

From Table 4.3 shows that the adsorption of heavy metals by Bm soils are the extra-adsorption. The total adsorption between calcium and heavy metal ions were more than its CEC (480.6 µeq/g soil). The amounts of calcium and heavy metals adsorbed (Cd, Ni and Zn) on calcium-saturated Bm soil were 562.6, 526.1 and 660 µeq/g, respectively. The extra adsorption probably indicated that the cation exchange sites developed at high pH value due to ionization of surface - OH and - COOH groups are important, but those active site due to isomorphous substitution in the silicate minerals are not (Abd-Elfattah and Wada, 1981). Consequently, the parallel reaction between adsorption, hydrolysis and precipitation may be pointed out. The selective coefficients depend on the CEC of the adsorbent and the ratios of concentrations of the reactants (Tiller et.al, 1984). The results (Table 4.3) only express the trend for selective adsorption of heavy metal by calcium - saturated soils. The selective coefficients, K, for heavy metal are the sequence as follows;

Cd : Ks > Pc > Bm
Ni : Pc > Bm   Ks
Zn : Pc > Bm > Ks

Table 4.3 The Selectivity Coefficients K, for Calcium-saturated Soils

Metals/Soil Series	[M]sol^n 1/ x10^{-4}M	[Ca]soil 2/ (μeq/g)	[M]soil 3/ (μeq/g)	[Ca]sol^n 4/ x10^{-3}M	K	[Ca+M] soil 5/ (μeq/g)	[M]/CEC 6/ (%)	[M]initial x10^{-4}M
Cd								
Ca-sat.Bm	5.1	473	89.6	8.74	3.2	562.6	18.6	9.58
Ca-sat.Ks	6.9	41	52.2	8.32	15.4	93.2	42.7	9.58
Ca-sat.Pc	5.8	132	75.0	8.98	8.8	207.0	22.0	9.58
Ni								
Ca-sat.Bm	1.85	374	152.1	9.05	19.9	526.1	31.6	9.57
Ca-sat.Ks	7.42	24	42.3	8.19	19.4	66.3	34.6	9.57
Ca-sat.Pc	2.25	99	145.4	8.95	58.4	244.4	42.6	9.57
Zn								
Ca-sat.Bm	1.06	425	235	8.97	46.8	660	48.9	12.62
Ca-sat.Ks	8.84	43	75	8.30	16.4	118	61.1	12.62
Ca-sat.Pc	1.78	121	217	9.04	56.7	338	63.6	12.62

Remarks : 1/ = heavy metal concentration at equilibrium

2/ = calcium adsorbed on soil

3/ = heavy metal adsorbed on soil

4/ = calcium concentration at equilibrium

5/ = [Ca] soil + [M] soil

6/ = approved CEC from Tabel 4.1 (Bm = 480.6, Ks = 122.2, Pc = 341.6 μeq/g)

4.6 Effect of pH on the Selective Adsorption

4.6.1 Ban Mi Series

As the pH of heavy metal solution was raised, the mean values of each adsorbed metal performed at tested pH level on Bm soil were not equal at significant level 0.01 (See Appendix C). Hydrogen atom held by the remaining organic and inorganic colloids becomes ionized and are replaceable. In addition, the adsorbed aluminium hydroxy ions, [$Al(OH)^{2+}$] are removed, and aluminium hydroxide, [$Al(OH)_3$] is formed, thereby additional exchange sites are released on the mineral colloids, thus, resulted in increasing of the cation exchange capacity (Brady, 1974). Although, exchangeable sites increase with the pH risen, but selective adsorption of Cd trends to decrease. As reference ions, calcium itself was able to compete with and more preferential than cadmium ion in certain exchangeable site. Effects of pH on adsorption of three tested cations by Bm soil (Cd, Ni and Zn) are presented in Table 4.4.

Generally, the evidence of metal adsorption is pH dependent. In this case, Ca ions trend to be prefered over other tested divalent cations. It may be due to high concentration of Ca ions in the reactive mixture (10 fold). Calcium ions may be attracted at the pH-dependent surface. Not only excessive Ca ions were adsorbed at those sites but also competed with other heavy metal ions at permanent charge surface. Otherwise, the repulsions between the same and/or different cations are possibly pointed out.

4.6.2 Kamphaeng Saen Series

At $p = 0.01$, the means of adsorbed heavy metal ions under several initial solution pH were not significant different (see Table 8, 11, and 14 in Appendix C). Active surface of Kt (major constituent in Ks series) is restricted to its outer surface. The results showed that pH of heavy

Table 4.4 Effect of pH on the Adsorption of Metals by Natural Soil Series

Soil Series, Cations	pH of inital heavy metal solutions		
	4.0	5.0	6.0
	------heavy metal adsorbed (μeq/g)------		
Bm			
Cd	85.98*	84.04*	73.48*
Ni	147.49*	146.03*	127.82*
Zn	233.69*	207.64*	216.25*
Ks			
Cd	17.43**	27.72**	21.32**
Ni	20.76**	20.59**	24.92**
Zn	25.64**	23.47**	35.35**
Pc			
Cd	63.13**	62.07**	54.48**
Ni	122.76**	126.22**	100.56**
Zn	183.71**	170.30**	181.68**

Remarks : * The mean values are significant difference.

** The mean values are not significant difference ($p = 0.01$)

The means are to be performed by the analysis of variance, one-way classification (see Appendix C) metal solution were not affected the selective sites on Ks series (Table 4.4). It may be proposed that the specification of selective sites for cations in this soil was due to isomorphic substitution or permanent charge on surface. Hence, the selective sites for Cd, Ni, and Zn on Ks series were pH independent.

4.6.3 Pak Chong Series

The major clay species of Pc series is similar to Ks series (Kt) and minor part of Pc series colloid is Mt. The quantities of each heavy metal adsorbed on Pc series are equal for every tested pH level at significant level 0.01 (see Table 9, 12, and 15 in Appendix C). Eventhough, the amount of Ca ions is higher than other cations but the selective adsorptions did not differ in several pH values. This occurence may be due to specification of selective sites as well as Ks series.

4.7 The Desorption of Heavy Metals by Diluted Hydrochloric Acid

4.7.1 Ban Mi Series

Table 4.5 showed that percentages of extractable of adsorbed heavy metals by mineral soils. The percentages of all extractable heavy metals of Bm series were lowest (5-18%) although Bm series exhibited high adsorption capabilities (73-233 ueq/g soil). This can be explained by 3 reasons. Firstly, montmorillonite, the major clay species in Bm series, tightly adsorbed all tested heavy metals so that adsorbed heavy metals were difficult to be desorbed. Secondly, the extractant (0.01 M HCl) may be reduced as the result of reaction between acid and carbonate in soil. The last reason was the combination of these two reasons. The relative affinity of extraction percentage was in the order; Cd Zn > Ni. Nickel was less extractable for Bm series (Mt) and this evidence confirmed Harter's investigation 1983).

Table 4.5 The Desorption of Heavy Metals by Diluted Hydrochloric Acid (0.01 M)

Soil Series, Cations	pH of initial heavy metal solutions 4.0	 5.0	 6.0
	amount extractable heavy metals(%)		
Bm			
Cd	16.22	15.27	17.70
Ni	5.47	5.81	6.57
Zn	14.61	15.20	15.28
Ks			
Cd	51.43	44.59	59.26
Ni	34.30	37.34	39.98
Zn	50.26	64.14	58.99
Pc			
Cd	41.34	44.09	44.25
Ni	21.76	22.53	27.16
Zn	29.63	37.95	31.34

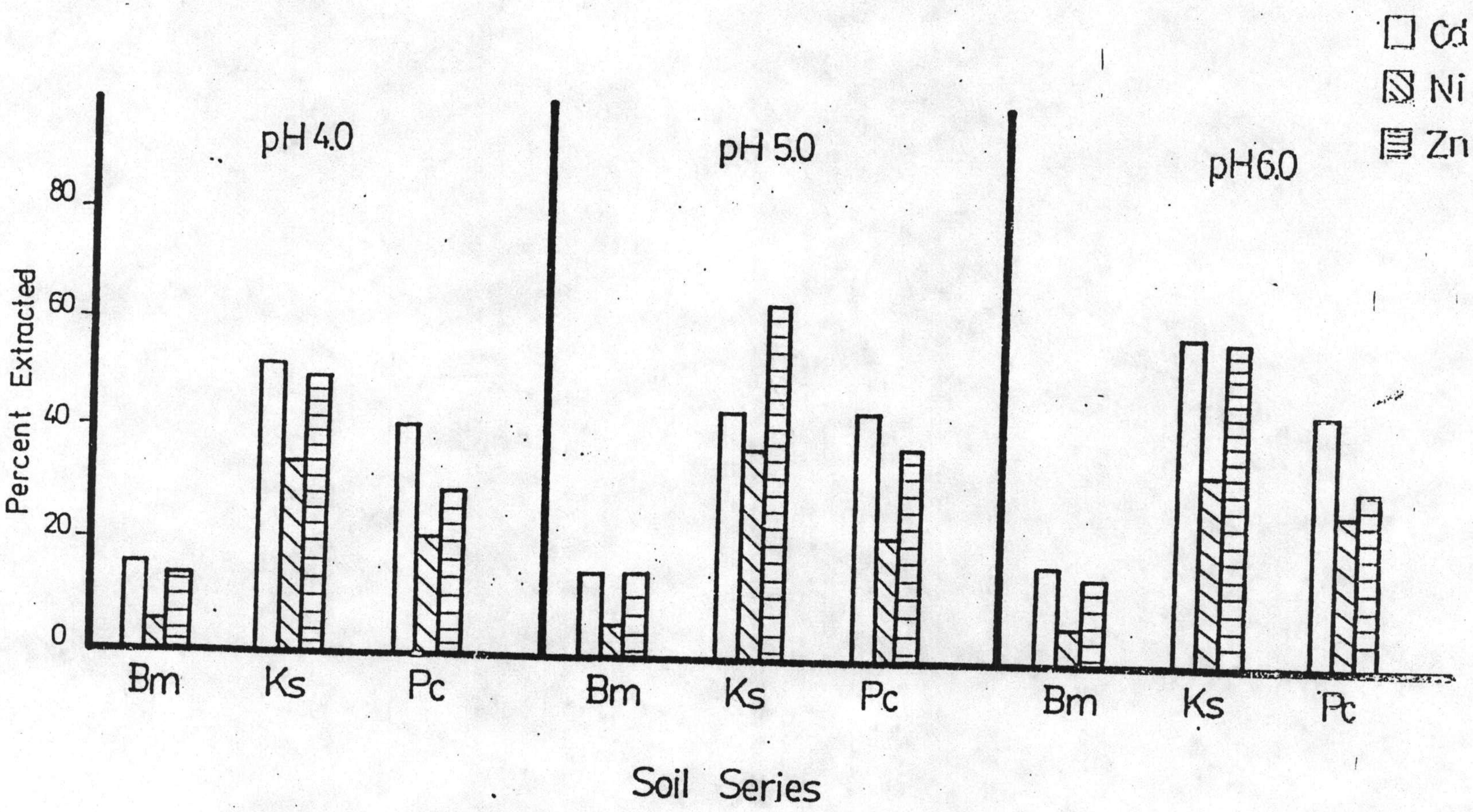

FIGURE 4.14 The desorption of heavy metals

4.7.2 Kamphaeng Saen Series

The percentages of extractable of adsorbed heavy metals from Ks series were highest (34-65%) as shown in Table 4.5. It may be proposed that all heavy metals were loosely adsorbed by Kt, the major clay species in Ks series, therefore, they were easily extracted. The relative affinity extraction of Ks series was in the order; Zn > Cd > Ni. Similar to Bm series, Ni was the least extractable.

4.7.3 Pak Chong Series

Table 4.5 shows the percentages of extractable of adsorbed heavy metals by Pc series were moderate (20-45%). Although Kt was the major clay species in both Pc and Ks series, but the percentage of extractable heavy metals was different from soil to soil. It was probably due to their different compositions. Pc series consisted of Kaolinite, montmorillonite and carbonate (see Table 4.1). Refer to Bm series, the last two constituents may be influenced the potential of heavy metals desorption by Pc series.

From Fig. 4.14, the percentages of adsorbed heavy metal extraction on the three tested mineral soils were compared. The decreasing order of heavy metal desorptions was Ks > Pc > Bm. Although, the percentages of heavy metal extraction on Bm surface were quite low (5-18% of adsorbed heavy metals) but the amounts of adsorbed metals were quite high (73-234 μeq/g soil). Hence, comparisons of those heavy metal availabilities for plants from three tested soils by reliance on measures of extracted quantities only without concentrated on amount and chemical forms of adsorbed metals may prejudice conclusion and predictions.