CHAPTER EIGHT

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SUMMARY AND CONCLUSION

8.1 Introduction

The increased inputs of heavy metals to soils that come from the widespread disposal of industrial wastes have created an increased attention on the issue of their fate, bioavailability and environmental role (Holdgate, 1979). In an attempt to understand the fate and the environmental significance of heavy metals dumped in soils this study is investigating what happens to cadmium, lead, nickel and zinc if such additions are made to three soils of different chemical properties. The study have focused on the partitioning of the added metals between the solid and solution phases, studied the detailed chemical speciation, examined the plant uptake of the added metals and predicted the long-term soil-plant-human exposure pathway. By integrating these aspects the study is aiming to develop prediction procedure for of the long-term effects of wastes containing high levels of heavy metals to improve the environmental management practices involved in their disposal.

8.2 Adsorption and desorption of the studied metals

The chemical behavior, the ultimate fate and the potential risk of heavy metals in the soil environment depend to a large extent on their sorption and desorption reactions with the soil particles (Brian, 1980and Brady and Weil, 1999). Thus, the understanding of the variation between metals adsorption and desorption reaction mechanisms in the soil environment is critical to compare their fate and their potential hazards.

In general the outcome of adding cadmium, lead, nickel and zinc to the three soils is that substantial adsorption took place in solid phase, although heavy Cd, Pb, Ni and Zn cations absorbed to the soils at low concentrations, increasing their mass loading resulted in positive correlations of the adsorption of these metal cations with their amendment level. The solution concentration of the above-mentioned metals is showed positive correlation with the metals amendment level concentrations in soil solution and solid phases. This consistent with previously published data by Linda and Chang, (1992); Andreu *et al*., (1996); McBride *et al*., (1997a) and Percival (1999).

The three soils adsorbed the added metals to different extents. The sandy clay loam (soil III) adsorbed the added metals to larger extent than the sandy loam (soils I and II). In contrast, the solution concentration of the added metals is higher in soil I and II. This illustrates the significance of CEC, pH and hydrous oxides in the adsorption capacity of soils (Papadopoulus and Rowell 1988; Basta *et al*., (1993); Mench *et al*., (1994 and Bolton and Evans 1996). The effect of soil properties on the chemical behavior and the fate of metals in the soil environment is clearly demonstrated

The metals distribution in soil phases is also influence by the residence time. At the early stage of incubation time most of the added metals adsorbed to the solid phase, as incubation proceeds, positive correlations are obtained between the concentration in the soil solution and the residence time of metal amendment. As justified in the findings of Bibak *et al*., (1995); Schultz *et al*., (1987); McLaren *et al*., (1986), that soils reach their maximum soil sorption capacity and most of the added amendment remained in the solution phase with aging

The studied metals are varied in their adsorption and desorption characteristics (Brian, 1980). Under equal experimental conditions the different adsorption values of Cd, Pb, Ni and Zn are varied greatly. The concentration of Zn solution is the highest among the studies metals followed in descending manner by Ni, Cd and Pb in the three soils. While Pb is the most adsorbed metal followed in descending order are by Cd Ni and Zn. The results are in agreement with what has been recorded by Kuo et al., (1983).

8.3 Speciation of the studied metals

The quantification of the chemical species of heavy metal contaminants present in the soil is proved to be essential in understanding their significance in the soil environment (Viets 1962; Soon and Bates, 1982 Sager and Stoeppler 1992; Legret; 1993; Mench et al., 1993; and Winistorfer, 1995). The quantitative distribution of the added cadmium, lead, nickel and zinc between their different chemical forms demonstrate the clear difference between the studied metals and the effect of soil type and residence time on the environmental fate of the metals.

The speciation of the added heavy metals varies greatly with soil type. As stated by Brian, (1980); Salomons and Stigliani, (1995) and Brady and Weil (1999), the chemical speciation of heavy metal in the soil environment is largely determined by the soil properties. Soils I and II reported highest percentages of the added Cd, Pb Ni, and Zn in the exchangeable form of form soil was than that in soil III. This can be justified by the effect of soil pH (Cavallaro and McBride 1979; Eilliott 1983; Kuo et al., 1983; Boekhold et al., 1993; Merrington, & Alloway 1994 and McBride et al., 1997). Soil III showed the greatest percentage of complexed metal, that is due to the higher clay, CEC and Fe and Al content compared to the other two soils (Jenne 1968; Papadopoulus and Rowell 1988; Borrow et al., 1989and Wenzel et al., (1992). The percentage of acid soluble fractions of Cd, Ni and Zn are is higher in soil III, which illustrated by the strong adsorption capacity of soil III and its ability to form strong bound complexations with metal cations (Jenne, 1968; Cavallaro and McBride 1979; Kuo et al., 1983; Eilliott 1983; Eilliott et al., 1986; McBride, 1989; Winistorfer, 1995; and Zachara et al., 1992).

The speciation of the added heavy metals is greatly influenced by the residence time. The influence of residence time on metals distribution into their different chemical forms in the soil environment be demonstrated by the influence of other soil properties which are subjected to change through time like the soil pH, redox potential and organic complexes (Bardy and Weil, 1999). Generally, the exchangeable fractions of Cd, Pb, Ni and Zn showed positive correlations with the incubation time, both the complexed and precipitated pools were higher in the first months of incubation and gradually decrease as the incubation time proceeded. (Schultz et al., 1987; McLaren et al., 1986 Salomons, 1993 and Bibak et al., 1995)).

According to Viets (1962) and Soon and Bates, (1982), the quantification of water soluble, exchangeable, and complexed and acid soluble pools of heavy metals in soil environment provides a useful approach to predicting their bioavailability of metals. Based on that the present investigation may conclude that Zn is the most bioavaiable metal, followed by Cd and Ni. While in soil III Cd is the most bioavaiable followed by Zn and Ni while Pb was primarily found in strongly bound forms resulting in limited solubility and availability in the three experimental soils.

8.4 Plant uptake studied metals

The bioconcentration of heavy metals by plants is the major route for metal contaminants to enter the human body (USEPA, 1992). Thus it is essential to gain understanding of the soil-plant relationship that govern the transfer of contaminant from soil to the plant tissues (Ali 1993 and Brown et al., 1995). The bioavailability and potential risk of cadmium, lead, nickel and zinc added to sandy clay loam soils was studied using lettuce (*Lactuce sativa)* based on its ability to adsorb and tolerate such metals (Mench *et al.*, 1998; Kastori 1992 and Kulli et al., 1999). Simple regression analysis revealed significant positive relationships between the bioconcentration of Cd, Pb, Ni and Zn by plant and the metal amendments level (R^2= 0.928, 0.968, 0.948 and 0.960 respectively), which is consistent with the findings of Murthy, (1982); Sterrett et al., (1996); Qian et al., (1996); Solan et al., (1997); Arnesen and Singh (1998); Ma and Uren (1996); Singh et al., (1995); Robert et al., (1995), and Rooney et al., (1999).

Simple regression analysis of the Cd, Pb, Ni and Zn uptake data with the different chemical species revealed positive correlations with the percentage of exchangeable chemical pool (R^2= 0.879, 0.966, .919 and 0.936) respectively. Results are supported by the findings of Jinadasa et al., (1997); Murthy, (1982); Roca and Pomares (1991); Heinz, (1996): Sterrett et al., (1996); Qian et al., (1996); Sloan et al., (1997); Miner et al., (1997); Lorenz et al., (1997; Singh et al., (1997); Arnesen and Singh (1998) and Rooney et al., 1999).

The bioconcentration of Cd, Pb, Ni and Zn in lettuce enhanced significantly as the residence time increases (R^2 = 0.974, 0.964, 0.977 and 0.891 respectively). The present results are in agreement with the findings of Ylaranta, (1996; Brallier et al., 1996; Logan et al., (1997); Canet et al., (1998); Smit et al., (1998); Chaney et al., 1998); Narwal et al., (1999 and Merrington and Madden (2000)

The relative bioavailability of the studied heavy metals is in this order Zn > Ni> Pb>Cd. That may refer to the less mobility of Cd (Adriano, 1986: Chang et al., 1984 and Dowdy et al., 1991). Among the metals studied, Zn and Ni showed the highest bioavailability index in terms of the metals concentrations in the harvested lettuce. This is consistent with the findings of Phillips and Chapple (1995); Misra et al., (1994); Merrington and Alloway. (1994); Misra et al., (1994); Nemeth et al., (1993); Moreno et al., (1997); Chang et al., (1984); Dowdy et al., (1991) and Williams et al., (1987).

8.5 Risk assessment of metals dumped in soils

Heavy metals contaminated soils pose a continuing and increasing threat to human health, from soils the usual mode of entry of metals into the human body is by the route of food chain: soil-plant-man, which is identified as the major exposure pathway to contaminants (USEPA, 1990b and USEPA, 1992). Thus the soil–plant bioconcentration transfer models are essential in determining the amount of contaminant available for human intake.

The plant- soil bioconcentration factor for Cd, Pb, Ni and Zn is with in the published range and is undergoing gradual trace elevation with the residence time of contaminant in the soil. An attempt for risk assessment is currently proposed by this study, which is based on deterministic estimations of initial contamination level, and the estimation of the risk to human health is based on the qualitative soil-plant-human relation. Using the simple model extracted from the regression analysis of plant- soil bioconcentration factor (Br) against contaminant residence the study concludes that the amount of heavy metal contaminants that it is available for human intake is subjected to gradual elevation in response to the length of time soils are exposed to the specific contaminants.

Battery wastes are among the significant sources that contribute in heavy metals contamination of the environment; almost all kind of batteries contains high concentrations of at least one of the heavy metals under the current investigation (Alloway, 1995; Eklund, 1995 and Skinner and Salin 1995). The currently applied risk assessment equation may also be implemented to estimate the fates of metals from the disposal of battery waste assuming the same soil type and the metals in battery cell are in mineral form. The nickel-cadmium as an example contains 20-30% nickel and 13-25% cadmium on weight bases. Knowing the amount of waste disposed of in the soil and the length of time soils are exposed to contaminant we may predict the concentration of Cd and Ni available for plant and consequently to human intake.

8.6 Future prospects

Cadmium, lead, nickel and zinc are among the heavy metals that are found in the industrial wastes, including materials from the extractive industries, production of batteries, chemical production, electroplating and heat treatment. In the soil environment, heavy metals often persist for long periods bound to soils. The dynamics of heavy metal contaminants in the soil environment is subjected to short and long term fluctuation and undergoing gradual alteration in response to management practices and environmental factors. These factors are needed to be considered in decisions on the use of soils as sink for the disposal of waste material containing high levels of heavy metals.

For the development of more reliable database on the environmental significance of heavy metals from the disposal of battery wastes, the present investigation suggest worthwhile to develop a proper risk assessment methodology consist of the following:

1 Survey and statistical analysis for the published information and additional data on the level of heavy metals in soils near industrial areas and wastes disposal sites.

2 Long term field trials using the waste material and wastewater to estimate bioconcentration factor and the soil screening level of contaminant soil-plant-human exposure pathway.

3 In the risk estimation step, integration of the results of the previous steps should be carried out, in order to produce a quantitative estimate of the likelihood of risk for the waste disposal sites.