Transformation of Added Lead and Nickel in Different Soil Conditions: A Comparative Study

Geeta Tewari[1*], P.C. Srivastava[2], Bali Ram[3] and Neeta Joshi[4]

1. Department of Chemistry, D.S.B.Campus, Kumaun University, Nainital, India
2. Department of Soil Science, G. B. P. U. A. & T., Pantnagar-263145, India
3. Department of Chemistry, B. H. U., Banaras, India
4. Department of Chemistry, M.B.G..P.G. College, Haldwani, India

geeta_k@rediffmail.com

Abstract: Contamination of soils with heavy metals is widespread and poses a long-term risk to ground water quality and ecosystem health. A laboratory incubation experiment was done to study the effect of moisture regime on the transformation of lead and nickel in three soils (acidic, neutral and alkaline) polluted by inorganic salt and sludge incubated for a period of 16 months. DTPA extractable-Pb content was the highest in neutral soil followed by alkaline and acidic soils while DTPA extractable-Ni content was highest in acidic soil followed by neutral and alkaline soils. In comparison to field capacity, flooding moisture regime maintained higher DTPA extractable-Pb content in all soils while DTPA extractable-Ni content in alkaline soils. In acidic and neutral soils, field capacity moisture regime maintained higher DTPA extractable-Ni content as compared to flooding moisture regime. The DTPA extractable-Pb content increased whereas the DTPA extractable-Ni content decreased with the time of incubation in all soils. The extractability of the transformed metals depends on the nature of soil and moisture regime. Lead bioavailability increased with time indicating higher pollution danger due to this metal especially under flooding moisture regime.

[Geeta Tewari, P.C. Srivastava, Bali Ram and Neeta Joshi. Transformation of Added Lead and Nickel in Different Soil Conditions: A Comparative Study. Researcher. 2011;3(1):113-118]. (ISSN: 1553-9865). http://www.sciencepub.net.

Key words: Incubation, DTPA extractable lead, sludge, transformation, moisture regime, nickel

1 Introduction

Lead (Pb) is neither an essential nor a beneficial element for plants or animals. It is poisonous for mammals and lead toxicity causes inhibition of hemoglobin formation (anemia), sterility, hypertension, learning disabilities, abortion, kidney damage in humans and mental impairment in young children. Soil and dust are important source of Pb for young children and lead in blood can be related directly to lead in soil (Wixson and Davies, 1994). Lead is present in uncontaminated soil at concentrations less < 20 mg kg^{-1} but much higher concentrations have been reported in many areas as a result of anthropogenic emissions, often over many years. Nickel (Ni) is a heavy metal that generally exists as an ion in the environment at very low levels (0.5–25 mg kg^{-1}). It is considered a micronutrient for some crops, but may become toxic to plants, animals and humans if normal levels are exceeded. High concentration of Ni causes various kinds of cancer on different sites within the bodies of animals, mainly of those that live near refineries. High nickel concentrations on sandy soils can clearly damage plants and high nickel concentrations in surface waters can diminish the growth rates of algae. Microrganisms can also suffer from growth decline due to the presence of nickel, but they usually develop resistance to nickel after a while. Human exposure pathways include air, water, food, cigarettes and skin contact. Soil is a sink for anthropogenic Pb and Ni. Soil pH, source of metal addition and moisture regime are the most important factors controlling Pb and Ni solubility, sorption and mobility in the soil (Suavé et al., 2000, Kabata-Pendias and Mukherjee, 2007). To understand the chemistry of heavy metals in soil and their interaction with other soil components such as clay minerals, organic matter and soil solution, or to assess their mobility and retention as well as their availability to plants, the usual approach is to use selective chemical extraction (Ure, 1996). The available concentration of Pb and Ni in soil must be accurately measured to properly assess its potential risk to plants, animals, and humans. Soluble, exchangeable and chelated forms of metal in the soils are the labile fractions available for plants and can be assessed by DTPA extraction. Therefore, the present study was to study effect of moisture regime, soil type and source of metal addition on their availability.

2 Materials and method

Surface (0-15 cm) samples of acidic, neutral and alkaline soils were collected from Vivekanand laboratory Almora, Majhola (about 5 km from Moradabad) and Crop Research Center, Pantnagar respectively. Sludge was collected from Karula Nala (Moradabad), receiving all the sewage effluents from local industries and municipality. General properties of soil samples were determined by the procedure given by Page *et al.* (1982). The total metal content of the soils was determined in HF-$HClO_4$ digests by Atomic Absorption Spectrophotometry. The properties of soil samples taken in this study are given in Table 1.

Fifteen grams of each soil were taken in a series of 200 mL plastic cups and treated with 10 g air-dried sludge. The content of Pb added in the treatment amounted to 40 mg kg^{-1} and that of Ni amounted to 40 mg kg^{-1}. In another series, the similar level of Pb and Ni were added through inorganic salts. Treated soils were incubated at field capacity or continuous flooding (maintaining 2.5 cm water level above the soil surface) regimes at room temperature (25±2ºC). The moisture content was maintained throughout the study. At the end of 1w (week), 2w, 4w, 6w, 8w, 16w, 32w, 48w and 16m (month) of incubation, each treatment combination in triplicate was selected for moisture determination and extracted for DTPA extractable-Pb and -Ni following the procedure developed by Lindsay & Norvell (1978). The content in the extractable fraction was estimated by atomic absorption spectrophotometry and contents were expressed on an oven dry weight basis.

The data were statistically analyzed using variance analysis (ANOVA) in an asymmetrical three factorial design set-up to evaluate the contribution to the total variance of time of incubation, metal source and moisture regime in the three different soils. The statistical significance was tested by F-test at p=0.05.

Table 1 Properties of soil samples used in the study

General properties	Acidic soil	Neutral soil	Alkaline soil
Texture	Sandy clay loam	Clay loam	Clay loam
pH (1:2)	6.13	7.00	9.57
O.C. %	0.94	1.20	0.84
% CaCO3	0.39	0.78	2.22
C.E.C. (c mol kg^{-1})	11.04	15.75	12.49
Field capacity (%)	29.33	27.23	24.28
Total Ni (mg kg^{-1} soil)	36.30	41.05	52.04
Total Ni (mg kg^{-1} soil) after sludge addition	169.87	188.75	177.63
Total Ni (mg kg^{-1} soil) after salt addition	133.50	130.00	149.13
Total Pb (mg kg^{-1} soil)	38.8	18.97	23.76
Total Pb (mg kg^{-1} soil) after sludge addition	144.25	138.75	166
Total Pb (mg kg^{-1} soil) after salt addition	66.75	56.38	61.50

3 Results and discussion

3.1 DTPA extractable-Ni in soils (DTPA-Ni)

As shown in Table 2, in general, the mean content of DTPA-Ni was the highest in acidic soil followed by neutral and alkaline soil. The mean content of DTPA-Ni was higher under field capacity moisture regime than flooding water regime in acidic and neutral soils while reverse was true for alkaline soil. Sludge maintained mean higher content of DTPA-Ni as compared to inorganic salts in acidic and alkaline soils while the in neutral soil, inorganic source increased the DTPA-Ni. The mean concentration of DTPA-Ni decreased with incubation in all soils.

As shown in Table 2, with inorganic salt as source

of heavy metal under field capacity moisture regime the highest concentration of DTPA-Ni form was observed at 8w (44.26 mg kg^{-1}) in acidic soil, 6w (56.42mg kg^{-1}) in neutral soil and at 2w (15.57 mg kg^{-1}) in alkaline soil. With inorganic source under flooding moisture regime the peak concentration of DTPA-Ni was observed at 6w in acidic (11.59 mg kg^{-1}), neutral (22.55 mg kg^{-1}) and alkaline (8.22 mg kg^{-1}) soils.

With sludge under field capacity moisture the peak concentration of DTPA-Ni form was recorded at 6w in acidic (39.29 mg kg^{-1}) and neutral (48.70 mg kg^{-1}) soils while 1w (13.32 mg kg^{-1}) in alkaline soil. With enriched, acidic sludge under flooding moisture regime the peak concentration of this form was noted at 1w (30.50 mg kg^{-1}) in acidic soil, 8w (35.69 mg kg^{-1}) in neutral soil and at 4w (17.08 mg kg^{-1}) in alkaline soil.

In general, the mean content of DTPA-Pb was the highest in neutral soil followed alkaline and acidic soil. The mean content of DTPA-Pb was higher under flooding water regime than field capacity moisture regime. Sludge maintained higher mean content of DTPA-Pb form in neutral and alkaline soils as compared to inorganic source while the reverse was the case of acidic soil.

Table 2. Changes in the concentration of DTPA extractable-Ni in different soils amended with inorganic salt and sludge under field capacity (F.C.) and flooding moisture regime

DTPA extractable fraction of Ni in acidic soil (mg kg^{-1})

Time interval	Inorganic source			Sludge			Mean		
	F.C.	Flooding	Av	F.C.	Flooding	Av	F.C.	Flooding	Av
T_{1w}	22.36	11.33	16.84	37.22	**30.50**	33.86	29.79	20.91	25.35
T_{2w}	23.42	10.02	16.72	33.10	27.49	30.30	28.26	18.75	23.51
T_{4w}	15.86	8.59	12.22	24.10	30.49	27.30	19.98	19.54	19.76
T_{6w}	43.32	**11.59**	27.46	**39.29**	22.82	31.06	41.31	17.21	29.26
T_{8w}	**44.26**	7.34	25.80	24.46	29.08	26.77	34.36	18.21	26.28
T_{16w}	34.30	8.09	21.19	32.77	20.30	26.54	33.54	14.19	23.86
T_{32w}	35.31	8.02	21.67	12.42	15.13	13.78	23.87	11.58	17.72
T_{48w}	32.48	10.39	21.44	21.03	19.79	20.41	26.76	15.09	20.92
T_{16m}	38.17	10.46	24.31	18.89	25.76	22.33	28.53	18.11	23.32
Av.	32.16	9.54	20.85	27.03	24.60	25.81	29.60	17.07	
Effects	S	M	T	S X M	M X T	S X T	S X M X T		
S.e.m.	0.34	0.34	0.72	0.48	1.02	1.02	1.44		
c.d.	0.98	0.98	2.06	1.38	2.93	2.93	4.13		

DTPA extractable fraction of Ni in neutral soil (mg kg^{-1})

Time interval	Inorganic source			Sludge			Mean		
	F.C.	Flooding	Av	F.C.	Flooding	Av	F.C.	Flooding	Av
T_{1w}	30.51	17.35	23.93	32.33	30.33	31.33	31.42	23.84	27.63
T_{2w}	30.22	15.68	22.95	32.43	25.75	29.09	31.33	20.71	26.02
T_{4w}	30.04	16.51	23.28	29.85	35.02	32.43	29.95	25.77	27.86
T_{6w}	**56.42**	**22.55**	39.49	**48.70**	28.35	38.53	52.56	25.45	39.01
T_{8w}	36.79	20.71	28.75	16.83	**35.69**	26.26	26.81	28.20	27.50
T_{16w}	36.14	16.47	26.31	18.67	17.09	17.88	27.40	16.78	22.09
T_{32w}	26.39	13.06	19.73	7.91	11.11	9.51	17.15	12.08	14.62
T_{48w}	33.79	18.18	25.99	13.53	16.20	14.87	23.66	17.19	20.43
T_{16m}	35.08	23.47	29.27	12.81	20.71	16.76	23.94	22.09	23.02
Av.	35.04	18.22	26.63	23.67	24.47	24.07	29.36	21.35	
Effects	S	M	T	S X M	M X T	S X T	S X M X T		
S.e.m.	0.31	0.31	0.66	0.44	0.93	0.93	1.31		
c.d.	0.89	0.89	1.89	1.26	2.67	2.67	3.76		

DTPA extractable fraction of Ni in alkaline soil (mg kg^{-1})

Time interval	Inorganic source			Sludge			Mean		
	F.C.	Flooding	Av	F.C.	Flooding	Av	F.C.	Flooding	Av
T_{1w}	13.99	7.62	10.80	**13.32**	11.85	12.59	13.65	9.73	11.69
T_{2w}	**15.57**	7.67	11.62	12.45	10.11	11.28	14.01	8.89	11.45
T_{4w}	6.77	5.54	6.15	6.78	**17.08**	11.93	6.77	11.31	9.04
T_{6w}	3.92	**8.22**	6.07	8.76	12.48	10.62	6.34	10.35	8.34
T_{8w}	3.87	4.98	4.42	3.86	8.34	6.10	3.87	6.66	5.26
T_{16w}	1.20	1.16	1.18	2.75	3.74	3.25	1.98	2.45	2.21
T_{32w}	0.66	0.60	0.63	2.29	3.20	2.75	1.48	1.90	1.69
T_{48w}	1.77	2.33	2.05	3.74	4.43	4.08	2.76	3.38	3.07
T_{16m}	0.74	1.33	1.04	3.05	4.06	3.56	1.90	2.70	2.30
Av.	5.39	4.38	4.88	6.33	8.36	7.35	5.86	6.37	
Effects	S	M	T	S X M	M X T	S X T	S X M X T		
S.e.m.	0.08	0.08	0.16	0.11	0.23	0.23	0.32		
c.d.	0.23	0.23	0.46	0.32	0.66	0.66	0.92		

The mean concentration of DTPA-Pb increased with incubation period in all soils and highest value was noted at 48w after incubation.

3.2 DTPA extractable-Pb in soils (DTPA-Pb)

As shown in Table 3, with inorganic salt as source of heavy metal under field capacity moisture regime the highest concentration of DTPA-Pb form was recorded at 8w (42.11 mg kg^{-1}) in acidic soil, 48w (25.50 mg kg^{-1}) in neutral soil and 4w (24.32 mg kg^{-1}) in alkaline soil. With inorganic source under flooding moisture regime the peak concentration of DTPA-Pb was obtained at 8w in acidic (38.96 mg kg^{-1}), neutral (35.70 mg kg^{-1}) and alkaline (27.62 mg kg^{-1}) soils.

With sludge under field capacity moisture the peak concentration of DTPA-Pb form was noted at 48w in acidic (35.27 mg kg^{-1}), neutral (42.20 mg kg^{-1}) and alkaline (44.28 mg kg^{-1}) soils. With sludge under flooding moisture regime the peak concentration of this

form was observed at 8w in acidic (56.92 mg kg^{-1}) and neutral (50.31 mg kg^{-1}) soils and 48w (48.72 mg kg^{-1}) in alkaline soil.

The DTPA extractable content-Pb was highest in neutral soil followed by alkaline and acidic soils. The DTPA extractable-Ni was also highest in neutral soil followed by acidic and alkaline soils. Flooding water regime maintained higher content of DTPA extractable-Pb than field capacity while the reverse was true for DTPA extractable-Ni in acidic and neutral soils. However, Sommers *et al.* (1979) suggested that DTPA extractable-Pb from soils maintained under anaerobic conditions decreased possibly due to the formation of metal sulfides. Organic matter, clay and hydrous oxides are known to adsorb considerable amount of metals. Sludge also resulted higher content of DTPA extractable-Pb in neutral and alkaline soils and regime Ni in acidic and alkaline soils as compared to inorganic salts.

The lower availability of added metals in alkaline soils with inorganic salts for Ni and Pb might be attributed to the fixation of these metals in clay and formation of relatively insoluble carbonates forms so that precipitation becomes significant when pH of soil is high (Misra *et al.*, 1990). However, inorganic salts as source of heavy metal gave higher content of DTPA extractable-Pb in acidic soil and Ni in neutral soil. In general, the content of DTPA extractable-Ni declined at the end of incubation while in case of Pb increased at the end of incubation.

Table 3 Changes in the concentration of DTPA extractable-Pb in different soils amended with inorganic salt and sludge under field capacity (F.C.) and flooding moisture

DTPA extractable fraction of Pb in acidic soil (mg kg^{-1})

Time interval	Inorganic source			Sludge			Mean		
	F.C.	Flooding	Av	F.C.	Flooding	Av	F.C.	Flooding	Av
T_{1w}	13.92	20.36	17.14	0.45	15.95	8.20	7.18	18.15	12.67
T_{2w}	14.45	22.31	18.38	0.51	22.38	11.44	7.48	22.35	14.91
T_{4w}	20.45	26.26	23.35	1.45	49.94	25.69	10.95	38.10	24.52
T_{6w}	22.77	27.26	25.02	2.45	46.94	24.69	12.61	37.10	24.85
T_{8w}	**42.11**	**38.96**	40.54	5.52	**56.92**	31.22	23.82	47.94	35.88
T_{16w}	29.97	31.49	30.73	6.73	37.61	22.17	18.35	34.55	26.45
T_{32w}	18.84	23.26	21.05	15.42	33.93	24.68	17.13	28.60	22.86
T_{48w}	36.72	29.54	33.13	**35.27**	40.68	37.97	35.99	35.11	35.55
T_{16m}	24.77	24.13	24.45	17.99	30.26	24.13	21.38	27.20	24.29
Av.	24.89	27.06	25.97	9.53	37.18	23.35	17.21	32.12	
Effects	S	M	T	S X M	M X T	S X T	S X M X T		
S.e.m.	0.20	0.20	0.42	0.28	0.59	0.59	0.83		
c.d.	0.57	0.57	1.20	0.80	1.69	1.69	2.38		

DTPA extractable fraction of Pb in neutral soil (mg kg^{-1})

Time interval	Inorganic source			Sludge			Mean		
	F.C.	Flooding	Av	F.C.	Flooding	Av	F.C.	Flooding	Av
T_{1w}	19.11	21.39	20.25	11.39	24.42	17.90	15.25	22.91	19.08
T_{2w}	21.22	24.10	22.66	11.57	27.75	19.66	16.39	25.93	21.16
T_{4w}	23.95	26.31	25.13	17.50	47.87	32.68	20.72	37.09	28.90
T_{6w}	19.95	29.27	24.61	20.66	49.87	35.26	20.30	39.57	29.93
T_{8w}	17.28	**35.70**	26.49	32.18	**50.31**	41.25	24.73	43.01	33.87
T_{16w}	16.28	24.66	20.47	28.24	39.38	33.81	22.26	32.02	27.14
T_{32w}	21.36	19.71	20.53	27.99	31.03	29.51	24.67	25.37	25.02
T_{48w}	**25.50**	27.08	26.29	**42.20**	45.50	43.85	33.85	36.29	35.07
T_{16m}	22.65	31.41	27.03	35.43	43.02	39.22	29.04	37.21	33.12
Av.	20.81	26.62	23.72	25.24	39.90	32.57	23.02	33.26	
Effects	S	M	T	S X M	M X T	S X T	S X M X T		
S.e.m.	0.11	0.11	0.24	0.16	0.34	0.34	0.48		
c.d.	0.32	0.32	0.69	0.46	0.98	0.98	1.38		

DTPA extractable fraction of Pb in alkaline soil (mg kg^{-1})

Time interval	Inorganic source			Sludge			Mean		
	F.C.	Flooding	Av	F.C.	Flooding	Av	F.C.	Flooding	Av
T_{1w}	20.52	13.43	16.97	5.72	38.43	22.08	13.12	25.93	19.52
T_{2w}	21.61	18.95	20.28	17.51	30.24	23.88	19.56	24.60	22.08
T_{4w}	**24.32**	21.34	22.83	20.93	34.48	27.70	22.62	27.91	25.27
T_{6w}	20.32	17.34	18.83	30.93	31.48	31.20	25.62	24.41	25.01
T_{8w}	16.38	**27.62**	22.00	40.25	32.55	36.40	28.31	30.09	29.20
T_{16w}	10.20	18.39	14.29	33.95	34.65	34.30	22.07	26.52	24.29
T_{32w}	11.89	10.64	11.26	35.98	39.54	37.76	23.93	25.09	24.51
T_{48w}	19.78	21.49	20.63	**44.28**	**48.72**	46.50	32.03	35.10	33.57
T_{16m}	15.07	17.00	16.04	31.78	40.95	36.36	23.42	28.97	26.20
Av.	17.79	18.46	18.12	29.03	36.78	32.91	23.41	27.62	
Effects	S	M	T	S X M	M X T	S X T	S X M X T		
S.e.m.	0.10	0.10	0.21	0.14	0.29	0.29	0.42		
c.d.	0.29	0.29	0.60	0.40	0.83	0.83	1.20		

3.3 Changes in overall percent of DTPA extractable-Pb and -Ni

As shown in Fig. 1, the percent of DTPA-Pb was higher than DTPA-Ni except in acidic soil amended with sludge. Under field capacity moisture regime, percent DTPA-Ni decreased in all soils except acidic soil where source of metal addition was inorganic salt. Percent DTPA-Pb increased except in alkaline soil when Pb was added as inorganic salt. As shown in Fig. 2, the percent of DTPA-Pb was higher than DTPA-Ni in all the soil types. In all the soils, there was an increase in DTPA-Pb with time, which is an indication of increase in the availability of Pb in soils while DTPA-Ni decreased with time of incubation.

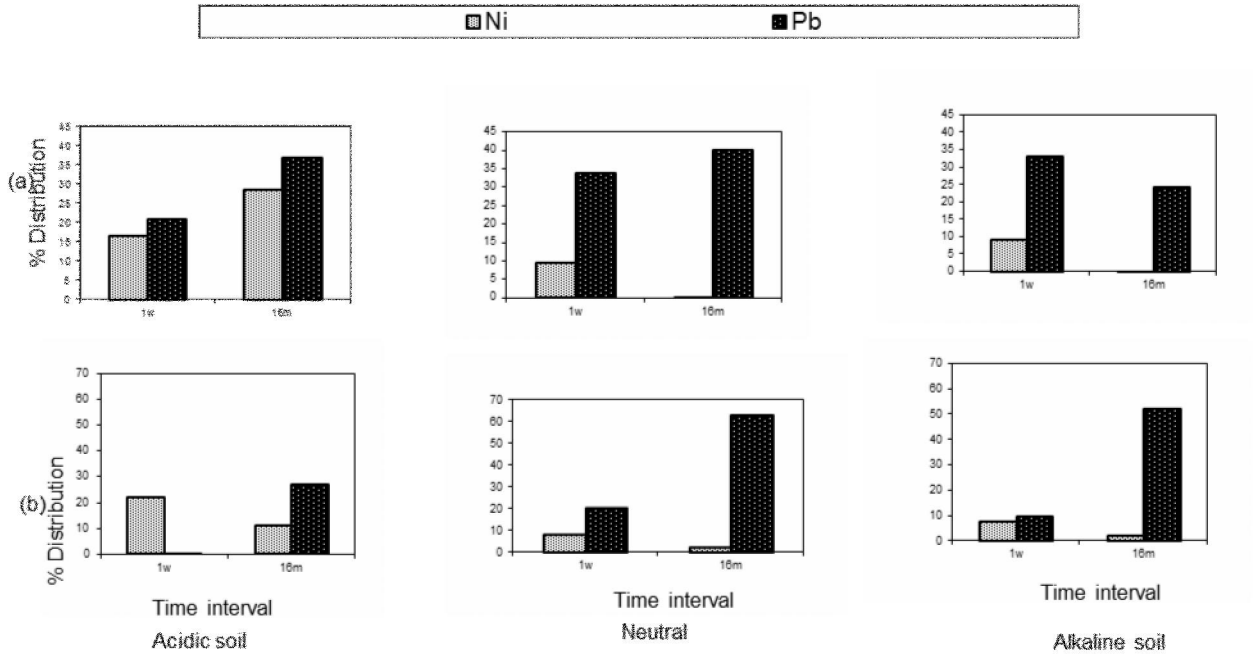

Fig. 1 Changes in overall percent of DTPA extractable Ni and Pb in different soils amended with (a) inorganic salt and (b) sludge under field capacity moisture regime

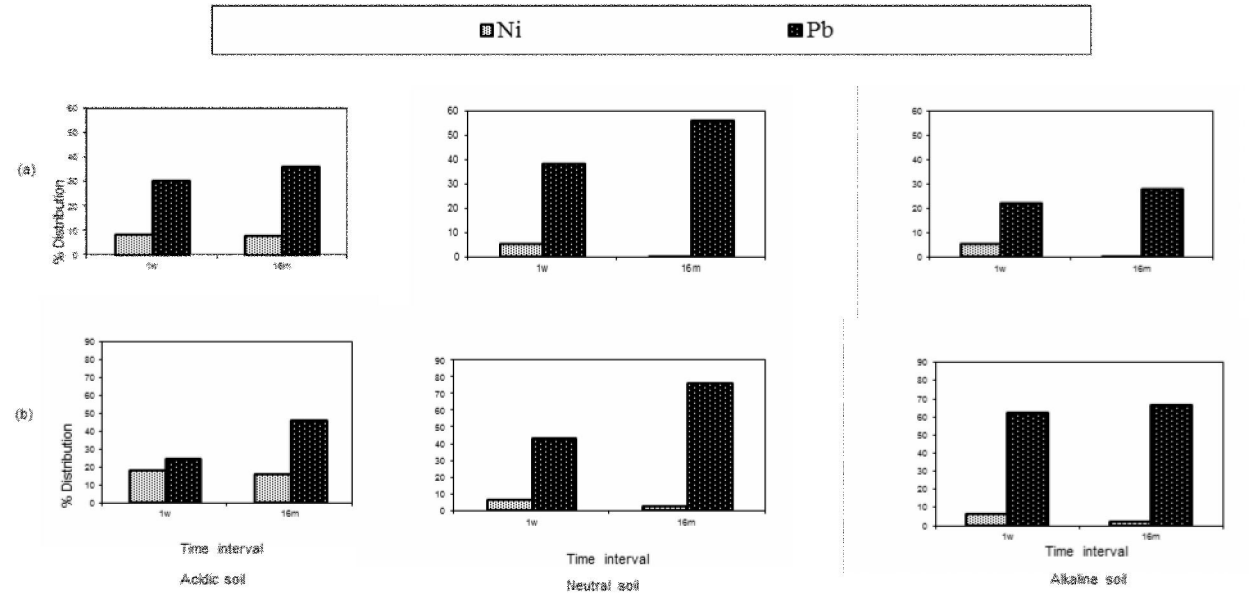

Fig. 2 Changes in overall percent of DTPA extractable Ni and Pb in different soils amended with (a) inorganic salt and (b) sludge under flooding moisture regime

4 Conclusions

Transformation of added heavy metals in soil depends upon soil type, moisture content and time of incubation. DTPA extractable-Pb content was the highest in neutral soil followed by alkaline and acidic soils while DTPA extractable-Ni content was highest in acidic soil followed by neutral and alkaline soils. In comparison to field capacity, flooding moisture regime maintained higher DTPA extractable-Pb content in all soils while DTPA extractable-Ni content in alkaline soils. In acidic and neutral soils, field capacity moisture regime maintained higher DTPA extractable-Ni content as compared to flooding moisture regime. The percent

of DTPA-Pb was higher than DTPA-Ni in all the soil types. In all the soils, there was an increase in DTPA-Pb with time, which is an indication of increase in the availability of Pb in soils while DTPA-Ni decreased with time of incubation.

11/8/2010

Correspondence to:
Dr. Geeta Tewari
Department of Chemistry
D.S.B. Campus, Kumaun University
Nainital, India
Email: geeta_k@rediffmailcom

References

[1] Wixson, N.G. and Davies, B.E.1994. Protective values for soil lead with respect to child health: a critique of UK guidelines. *Environmental Geochemistry and Health.* 30(6): 639-646.

[2] Suavé, S., Hendershot, W. and Allen, H.E., 2000. Solid-solution partitioning of metals in contaminated soils: Dependence on pH, total metal burden, and organic matter. *Environmental Science and Technology*, 34 (7), 1125 – 1131.

[3] Kabata-Pendias, A. and Mukherjee, A.B., 2007. Trace Elements from Soil to Human. Berlin: Springer-Verlag.

[4] Ure A. M. 1996.Single extraction schemes for soil analysis and related applications. The *Science of the Total Environment*.178: 3–10.

[5] Page, A.L., Miller, R.H. and Kenney, D.R. 1982. *Methods of Soil Analysis-Part 2*(Ed) No. 9, agronomy Series ASA-SSSA Publisher, Madison, Wisconsin, U.S.A.

[6] Lindsay, W.L. and Norvell, W.A. 1969. Development of a DTPA micronutrient soil test. *Agro. Abstr.* pp. 84.

[7] Sommers, L.E., Nelson, D.W. and Silviera, D.J. 1979. Transformation of carbon, nitrogen and metals in soils amended with waste materials. *J. Environ. Qual.* 8 : 287-294.

[8] Misra, A.K., Sarkunan, V., Mira Das and Nayar, P.K. 1990. Transformation of added heavy metals in soils under flooded condition. *J. Indian Soc. Soil Sci.* 38 : 416-418.