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MOVEMENT AND RETENTION ,OF LEAD AND CHROMIUM IN SOIL APPLIED WITH IRRIGATION WATER

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In a Lysimeter experiment, the impact of CI- and SOt anions on the movement/retention of lead and chromium in a sandy loam soil was studied. The treatments were: canal water application alone, solutions of $PbCI_2$,' $CrCI_3$, $Cr2(S04)3$'$PbCl2$ + $CrCl3$ and $PbCl_2$ + $Cr2(S04)3$in canal water containing 10 mg of each metal. These leaching solutions were applied in four splits, each equal to one pore volume (PV), while the fifth PV was the canal water. Lysimeters were protected from evaporation and rainfall by' putting a plastic sheet at about 30 cm height above the top of lysimeters. After infiltration of each P~ leachates were collected, measured and analysed for these metals by using atomic absorption spectrophotometer. After termination of the experiment, soil samples from lysimeters were drawn and processed for determination of Pb and Cr by using the. same atomic absorption spectrophotometer. It was observed that soil retained more Cr^{3}+from added as $CrCl_3$ than that as Cr2(S04)3 solution. However, there was no consistent effect of anions on leaching of Pb through soil. Ammonium bicarbonate-DTPA extractable Pb in soil was more for the added Cl' salts than that for the Sot salt solutions. Since the soil originally contained high concentration of Pb and Cr, the canal water because of its high water potential affected considerable leaching of these metals. Overall, a fraction of the applied Pb (1.59 - 4.56 %) and Cr (3.82 - 13.78 %) was removed in leachates while the rest was retained by soil.

Key words: lead, chromium, leachate, sandy loam, pore volume, retention, water potential, chloride, sulphate

INTRODUcnON

Farmers near big cities are using effluent for irrigating crops and vegetables. Such effiuents contain Pb, Cr and other metal ions which contaminate soils and agricultural produce. The. chemistry of Pb and Cr in soils is affected by specific, non-specific and/or exchange absorption (Bittel and Miller, 1974), precipitation as sparingly soluble compounds (Olsen and Skogerboe, 1975) and formation of complex ions or chelates with soil organic matter. Sawhney et al. (1994) investigated municipal solid waste and reported that Pb and Cr leached at relatively high concentrations initially, followed by continued leaching at low concentration. In addition, adsorption and movement of metal ions in soils is also affected by complementary anions. Based on thermodynamic calculations, Hahne and Kroontje (1973) concluded that both hydroxy and chloride ligands might contributed to the mobilization of Pb, Cd, Hg etc. in soils. Formation of C-compounds reduced the sorption and thus increased the mobility of Pb and Cd (Roy et aI., 1993). Almost all the agriculturally important soils of Pakistan are alkaline in reaction and have Cl' and Sot ions in the ratio of about 50 : 50. Keeping these in view, distribution pattern of Pb and Cr in soil added as Cl- and/or SO42, salts dissolved in canal water was studied.

MATERIALS AND METHODS

Bulk soil sample was collected from surface 15 cm layer of a field. After sieving through a 2 mm sieve, 3.5 kg of sandy loam soil (table 1) was filled in each of the 18 lysimeters. The experiment was laid in the Department of Soil Science, University of Agriculture, Faisalabad during 1998. There were sixtreatments, viz. canal water (control), application of $PbCI_2$, $CrCI_3$, Cr2(S04)3' $PbCl_2$ + $CrCl_3$ and $PbCl_2$ + Cr_2 SOJ3 solutions prepared in canal water. The concentration of Pb and Cr in the leaching solutions was 10,000 µg VI excluding their concentration in canal water. The canal water had EC of 0.24 dS m,l and contained 320 and 1588 J.l.gVI Pb^{2}+and CrJ+, respectively. Solutions equal to 4 PV were applied to lysimeters and for the fifth PV canal water was added. Leachates were collected after infiltration of each added PV and analysed for cations and anions (Page et aI., 1982).

Table 1. Analysis of soil for the experiment

Characteristic	Value	Characteristic	Value
EC.,dSm'l	1.90	Cl', mmol, VI	2.65
SAR, (mmol *L-t)1I2*	1.14	*Sot,* mmolL:'	14.95
pH,	7.58	$Cac0_3$, %	2.60
Pb, µg kg'-	2081.00	Clay, %	16.20
Cr, µg kg:'-	1733.00	Organic ¥atter, %	0.46

After the termination of experiment, Pb^{2}+and CrJ+in the soil were extracted with ammonium bicarbonate diethylene triamine penta acetic acid (AB-DTPA) as described by Soltanpour (1985). Lead and chromium in leachates as well as in AB-DTPA extract of soil were analysed by atomic absorption spectrophotometer (Model Varian SpectrAA 250 plus).

RESULTS AND DISCUSSION

Composition of Leachates: The Pb in leachates ranged from 155 µg in the third leachate (L) of T_2 to 457 µg in L_1 of T_1 (Table 2). In general, removal of metal ions gradually decreased from L_1 to L) and then again increased. More removal of Pb in L_1 might be due to less compaction, more porosity and both helped rapid infiltration of soil solution (Giardano et aI., 1983), thus allowed less time for reactions and conversion of soluble Pb into insoluble .forms. The enhanced leaching of Pb in L_4 and L_5 might be due to increased activity of Cl- ions in response to its fast and more leaching than that of SOt. since Pb compounds with Cl' are more soluble (Giardano et a1. 1983). Considerable Pb leached from the control treatment which could be due to presence of Pb in the soil and irrigation water (2081 µg kg:· and 320 J.lgL"1,respectively). The high Pb in L_1 appears due to high potential of simple canal water to affect better carrying capacity for ions.

Table 2. Lead in the leachates (J.lgLeaehate")

Treatment	L_1	L_2	L_3	L_4	Mean	L_5
T_1 : Canal water	457.0	196.7	165.3	305.9	281.8	668.8
T_2 : $PbCl_2$	401.9	175.8	154.9	345.8	269.6	666.0
T_3 : $CrCl_3$	392.4	198.6	173.9	365.3	280.3	681.2
T_4 : $Cr_2(SO_4)_3$	268.9	177.7	172.0	288.8	226.9	704.9
T_2 : $PbCl_2 + CrCl_3$	335.4	196.7	164.4	397.1	273.4	788.5
T_2 : $PbCl_2 + Cr_2(SO_4)_3$	376.4	276.3	172.7	417.9	310.8	771.4
Mean	371.2	205.5	168.1	349.9	—	713.5

Sulphate ions generally have inhibitory effect on leaching Pb through forming sparingly soluble compounds like PbS04 (Olsen and Skogerboe, 1975). However, presence of Cl' ions in the system promoted its mobility by the formation of ion pairs, like PbCl+, $PbCl_2^0$ (Roy et al. 1993; Swallow et aI., 1980). In our soil SOt was the dominant anion (Table 1) which helped precipitation of Pb and caused maximum retention of applied Pb. The pattern of Cr leaching was almost similar to that of Pb starting from the very first leaching to L_5 (Table 3). Leaching was maximum where Cr_2(S04») salt was added. Chromium has very low affinity to form complexes with Cl- ions (Giardono et aI., 1983). Therefore, presence of excessive C1- ions could induce precipitation and/or adsorption of Cr ions. As there is more AB-DTPA extractable Cr (13.3 %) for CrCl) treatment, the most probably adsorption has occurred. Leaching of Cr was more through soil columns compared to that of Pb (comparison of Tables 2 and 3). Giusquiani et al. (1992) found higher mobility of Cr than Pb in soils of pH 7.5 and 8.3.

Table 3. Chromium in the leachates (J.lgLeachate-)

Treatment	L_1	t_2	I_3	L4	Mean	t_5
Tt: Canal water	1165.7	491.2	566.2	715.4	734.6	1285.4
T_2: $PbCI_2$	738.2	1096.7	514.0	1012.7	833.7	872.1
T3:CrC~	731.5	684.0	933.9	653.6	750.8	970.0
T4: Cr_2(S°.JB	1235.0	1009.9	1331.0	1115.3	1172.8	739.1
T_5 : R>$C1_2$+ CrCI3	854.1	824.6	852.2	752.4	820.8	1378.5
T_6: $PbCl_2$ + Cr_2(S°.JB	729.1	382.5	485.6	955.0	638.0	662.2
Mean	909.1	732.6	779.6	867.3	—	984.5

Lead and Chromium in the Post-Experiment Soil: With the application of Pb. its available form (AB-DTPA extractable) increased by 209.6 to 372.4 % (Table 4) over the original level of 2081 µg Pb per kg soil (Table 1) and increase was only 140.4 % for the control treatment.. In the present experiment, 40,000 µg of Pb per lysimeter was added in addition to the amount (320 µg L") present in canal water. Hence a fraction of applied Pb leached and the rest was retained by soil in different forms. The canal water and soil (Table 1) contained SO/-. Soil studied was calcareous with pH, of 7.58, hence Pb might formed precipitates with OH- and *Cot.* Basta and Tabatabai (1992) also observed similar results.

Table 4.AB-DTPA extractable Pb and Cr (J,1g kg!)

Treatment	Pb	O	% increase (+) or decrease (-) over original value Pb^{2+}	 C~
T_1 : Canal water	5002	1889	140.4	+ 9.0
T_2: $PbCl_2$	6443	1171	209.6	-32.4
T):C~	3483	1963	67.4	+13,3
T_4: Cr_2(SOJ)	2783	1743	33.7	+0.6
T, :PbC~+ crC~	9831	l(i79	372.4	- 3.1
T_6: $PbCl_2$ + Cr_2(SOJ)	7931	1398	281,1	-19.3

Maximum AB-DTPA extractable Pbwas found for treatment receiving $PbCl_2$ + CrCl) followed by T_6 and T_2 treatments. The Cl- has the capacity to retain Pb in soluble form (Giardano et aI., 1983, Roy et aI., 1993) which tended to decrease precipitation. This enhanced movement as well as adsorption onto soils. Hahne and Kroontje (1973) reported that PbCI+ species of Pb were found at Cl- concentrations between one and ten mmol$_c$ VI. Schulthess and Huang (1990) reported that above pH 5.9, Pb(OHt was the metal species adsorbed by the silicon adsorption sites in montmorillonite. They concluded that Pb^{2+} and Pb(OHt were present between pH 5 and 9. So adsorption of Pb in this soil might have occurred as Pb^{2+},Pb(OHt and Pb(Cltspecies.

Maximum increase in AB-DTPA extractable Cr (13.3%) over the original status of soil was recorded for the CrCl) treatment followed by canal water (9.0 %) and Cr_2(S0$^{4»}$) treatments (0.6 %), whereas a decrease occurred for all the other treatments. Since a fraction (3.82 to 13.78 % in different leachates) of the applied Cr (10,000 J.1gin each of the four irrigations) leached from the soil, its presence in soil must be in such a type that has not been extracted by AB-DTPA Hernandez et al. (1991) observed no increase in available Crwhen sewage sludge was added to soil. Adsorption of Cr has been reported in the form of Cr^{3+},$Cr(OH)^{2+}$,$Cr(OH)^{2+}$by Yu et al. (1996). Moreover, Fendorf et al. (1996) observed formation of precipitates on the surface of silica ($Si0_2$) which might be true for other Si-bearing minerals which could not be extracted with AB-DTPA

Conclusions: With the application of metals, their level in soil increased. Generally, AB-DTPA extractable Pb and Cr in soil increased more with Cl- than that for with *SOt.* salt solution. Overall, a fraction of the applied Pb (1.59 - 4.56 %) and Cr (3.82 - 13.78 %) leached while the rest was retained by soil. However, there was no consistent effect of Cl- and SO_4^{2-} anions on leaching of Pb or Cr into filtrates.

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