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Persistence, degradation and mobility of carbofuran and heavy metals in soils: Effect of sewage-sludge, nitrogen fertilizer and pH.

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ABSTRACT

Effect of pH, sewage sludge and nitrogen fertilizer on the degradation and mobility of carbofuran and on mobility of heavy metal on three different soils viz., red, alluvial and black at 30% soil-moisture content was studied at 25±2^{0}C. The data obey the first order kinetics equation. The degradation and mobility of carbofuran was in the order alluvial > red > black soil. The degradation of carbofuran was more in alkaline soil than in acidic soil. The addition of sewage sludge or nitrogen decreased the degradation and mobility of carbofuran and heavy metal in different soil segments. The mobility was in the order: unamended soil > nitrogen amended soil > sewage sludge amended soil. The degradation, mobility of carbofuran and mobility of heavy metals in soils was influenced by soil organic matter, soil pH and clay minerals.

Key words: carbofuran, mobility, persistence, soil, heavy metal

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INTRODUCTION

Carbofuran (2, 3 dihydro-2, 2 dimethyl-7-benzofuranyl N-methyl carbamate) is one of the widely used carbamate insecticides in agriculture. The persistence, degradation and mobility of pesticides in soil depends on adsorption[1] and is influenced by amount of soil organic matter, its fraction (humic acid and fulvic acids), soil type, soil pH, amount of sewage-sludge free metal oxide and fertilizers[2,3]. A good number of reports on fate and mobility of carbofuran in normal agricultural soils [4] are available; but information on the fate and mobility of this insecticide at different pH, in presence of sewage sludge and nitrogen fertilizer on soils is meager. So, it was considered worthwhile to study the degradation and mobility of carbofuran in three soils, viz. red, alluvial and black soils under different soil pH, different amount of sewage-sludge and nitrogen fertilizer.

MATERIAL AND METHODS

Three typical soil samples viz. black, red and alluvial with a broad range of properties pertinent to pesticide adsorption were collected. They were collected from surface (0-25 cm depth) and had no history of carbofuran application. The physical and chemical properties of these soils (< 70 mesh) and untreated sewage sludge were determined by usual methods[5] and are given in Table 1. All the experiments were done in triplicate with suitable blanks.

Persistence Studies

For persistence and degradation studies, 20 g of soils were incubated with 2000 μg of carbofuran in acetone (100 $\mu g\ g^{-1}$) at 30% soil-water content level in several bottles. The bottles were shaken thoroughly and tightly covered with polyethene sheet to prevent loss of water by evaporation. The sample bottles were stored at 25±2^{o}C. 10 mL of sample was collected at the time interval of 1, 5, 10, 20, 40, 60 days after incubation. The collected samples were extracted with 30 mL of chloroform-diethyl ether (1:1: v/v) in a separating funnel with teflon stopper. The organic fraction was collected and the supernatant was extracted with 20 mL of chloroform-diethyl ether (1:1: v/v) for two more times. The extractant was evaporated to dryness and residue was dissolved in known amount of acetone and was analyzed on a Perkin Elmer GC model 8700 gas chromatograph, equipped with a ^{63}Ni electron capture detector fitted with SE 54 capillary column (60 m, 0.2 mm id). The operating conditions were as follows: column temperature 190^{o}C, injector 220^{o}C and detector 280^{o}C. The flow rate of nitrogen gas was 30 mL min^{-1}. The retention time was 2.2 min. Recovery was 93-99% and minimum detection was 0.05 $\mu g\ g^{-1}$.

Mobility studies

The mobility studies were conducted in 55 cm x 7.5 cm PVC pipes. The lower ends of pipes were sealed with cotton cloth. The pipes were filled with 10 kg of each soil upto the height of 50 cm. The PVC columns were allowed to stand vertically in a wooden box so that they did not get disturbed. 1 g of standard carbofuran (100 $\mu g\ g^{-1}$ soil) was applied separately in three types of soils; 200 mL of water was added into each column after every alternate day (preliminary studies showed that 200 g water was evaporated in two days).

The soil samples were drawn periodically from the depths of 0-10, 11-20, 21-30, 31-40, 40-50 cm after 1, 5, 20, 40 and 80 d. The carbofuran was estimated as discussed earlier. The diethylene triamine pentaacetic acid (DTPA) extractable Zn, Cu, Cr and Cd in soil samples were determined using atomic absorption spectrophotometer.

pH Study

Effect of pH on persistence and degradation of carbofuran on different soil samples were studied at pH 4, 6, 9 by adding 100 μg g^{-1} of carbofuran (in acetone) in 30% moistened soil samples. The soil pH was amended by HCl and NaOH. The samples were monitored at the different time intervals and residues were estimated.

Effect of sewage-sludge

Effect of sewage sludge on persistence and degradation was studied by amending 30% moistened soil samples with 100 μg g^{-1} of carbofuran and 0, 1 and 2 g of undigested sewage-sludge@ kg^{-1} soil. The samples were taken out at different time intervals and residues were estimated. For mobility studies, soil samples were amended with 100 mg carbofuran and 2 g anaerobically digested sewage sludge@ kg^{-1} soil. The soil samples were drawn and carbofuran and DTPA extractable metals were estimated.

Effect of nitrogen fertilizer

Effect of nitrogen fertilizer on carbofuran degradation in three different soils was studied by amending 30% moistened soil samples with 100 μg g^{-1} of carbofuran and 0, 50 and 100 mg of nitrogen (as urea) kg^{-1} soil separately. The residues were extracted different time intervals and were estimated similarly as discussed earlier. For mobility studies soil samples were amended with 100 mg carbofuran and 0.5 g urea kg^{-1} soil. The amount of carbofuran and DTPA extractable metals at different depths and time interval were estimated.

RESULTS AND DISCUSSION

The results showed that the rate of dissipation of carbofuran on studied soils followed the first order kinetics, since all the regression lines have a coefficient of determination (R^2) more than 0.9. Similar result was also reported by other workers [6,7].

Influence of soil type

At 30% soil water content the rate of degradation and mobility of carbofuran in the studied soil was in order: black < red < alluvial (Tables 2-4). The role of soil organic matter, surface area and clay content etc. on its degradation needs scrutiny [8]. In black soil which has maximum organic matter and clay content, lesser amount of carbofuran was available for degradation. The data of mobility (Table 3) also denoted that maximum amount of carbofuran was found in upper most layer (0-10 cm) as at the depth of 41-50 cm no carbofuran was found after 1d of application in all the studied soil samples. As the values of

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$t_{1/2}$ for studied soils were of similar magnitude (19.6-22.2 days), it can be inferred that there was almost similar mechanism of microbial activity in these soils[9]. Similar results were also reported by Pandey and Agnihotri[10].

Table - I
Physical and chemical properties of the soils

Properties	Types of soils			
	Black (Vertisol)	Red (Alfisol)	Alluvial (Inceptisol)	Sewage-sludge
Sand (%)	3.0	33.9	54.4	-
Silt (%)	16.0	47.7	42.6	-
Clay (%)	81.0	18.4	3.0	-
Soil pH	7.6	7.2	8.1	7.6
Organic matter ($g\ Kg^{-1}$)	18.8	8.1	8.6	186.0
Water holding Capacity (%)	70	42	36	-
CEC [c mol $(p^{+})\ kg^{-1}$]	9.75	6.07	6.00	-
EC (m mhos/cm)	2.3	0.3	0.2	1.9
Total heavy metals ($\mu g\ g^{-1}$)				
Zn	6.8	6.3	6.2	540.0
Cu	1.8	1.4	1.4	306.0
Mn	32	30	32	600.0
Fe	2100	2600	2000	2010.0
Cr	4.6	3.6	4.0	42.0
Ni	0.6	0.4	0.5	24.0
Pb	1.6	1.6	1.7	76.0
Cd	0.12	Traces	Traces	3.0
DTPA extractable heavy metals ($\mu g\ g^{-1}$)				
Zn	0.68	0.66	0.42	-
Cu	0.68	0.60	0.64	-
Mn	3.0	2.6	2.8	-
Fe	8.8	18.8	3.8	-
Cr	0.22	0.2	0.2	-
Ni	0.02	0.02	0.04	-
Pb	0.03	0.06	0.04	-
Cd	0.02	Traces	Traces	-

Efect of pH

Solution pH (Tables 4 and 5) influenced the degradation of carbofuran in studied soils. The degradation of carbofuran was faster in alkaline than in acidic medium. The degradation of carbofuran in the studied soils was in order: alluvial > red > black soil. The results were in the line of the work of Howard [11].

Effect of sewage-sludge

The rate of degradation and mobility of carbofuran decreased by adding untreated sewage-sludge (Tables 2-4), which might be due to increase in adsorption capacity of soils by adding sewage-sludge[12]. The maximum persistence of carbofuran was in soils which were amended with 2 g of sewage-sludge kg^{-1} soil.

Effect of nitrogen

Rate of dissipation and mobility of carbofuran decreased with the addition of different amounts of nitrogen (Tables 2-4). The decrease in rate of dissipation may be due to decrease in soil pH which retards microbial activity [13,14] and enhance soil adsorption.

Mobility of DTPA extractable heavy metals

Data of tables (6-8) indicate that heavy metal content decreased with depth. Comparatively fewer amounts of metals in lower horizons were due to the reduced mobility of the metals into lower horizons. Specific adsorption of the heavy metals by organic-matter, manganese oxides, iron oxides, clay minerals, humic acid, fulvic acid etc. possibly have restricted their mobility to the deeper horizons. The data also denote that mobility was in the order: alluvial > red > black soil.

The statistical analyses denoted that there was a significant positive correlation (r^2=0.8) in between DTPA extractable heavy metals and soil organic carbon and soil CEC and negatively correlated with soil pH.

The results of Tables 6-8 denote that in presence of urea the mobility of heavy metals in different soil-profile increased which may be due to decrease in pH by addition of urea[15]. The data of Table 6-8 also showed that mobility of heavy metals was in the order: alluvial > red > black soil. The concentration of heavy metals in upper soil-profile amended with sewage-sludge was more than in unamended soil. The mobility of heavy metals in lower horizon (31-40 cm) was less, which may be due to more adsorption of heavy metals by organic matter, humic acid, fulvic acid (added via sewage-slduge).

From these studies it may be concluded that organic matter, pH, sewage sludge and nitrogen influenced the rate of degradation and mobility of carbofuran in red, alluvial and black soils. The mobility of carbofuran was in the order unamended soil > nitrogen amended soil > sewage-sludge amended soil.

Table 2. Persistence of carbofuran (µ g/g^{-1}) in presence of different amount of sewage-sludge and urea in 100 µ g g^{-1} carbofuran fortified three soils (Black, Red and Alluvial) at 30% soil moisture content

Time (days)	Black soil						Red soil						Alluvial soil					
	Amount of sewage sludge added(g kg^{-1} Soil)			Amount of urea added (mg kg^{-1} soil)			Amount of sewage sludge added(g kg^{-1} soil)			Amount of urea added (mg kg^{-1} soil)			Amount of sewage sludge added (g kg^{-1} soil)			Amount of urea added (mg kg^{-1} soil)		
	0	1	2	0	50	100	0	1	2	0	50	100	0	1	2	0	50	100
1	97.1	97.1	97.3	97.1	97.0	97.0	96.8	96.9	97.1	96.8	96.7	96.8	96.6	96.7	96.9	96.6	96.6	96.6
5	85.7	86.2	87.3	85.7	85.7	86.1	84.7	85.3	86.2	84.7	84.9	85.1	83.9	84.7	85.2	83.9	83.9	84.1
10	73.3	74.4	76.2	73.3	73.5	74.1	71.0	72.8	74.4	71.0	72.0	72.5	69.7	71.8	72.6	69.7	70.5	70.8
20	53.7	55.3	58.0	53.7	54.0	54.9	51.5	52.9	55.3	51.5	51.9	52.5	49.3	51.7	52.7	49.3	49.7	50.1
40	28.8	30.6	33.7	28.8	29.2	30.1	26.6	28.0	30.6	26.6	26.9	27.6	24.3	26.5	27.8	24.3	24.7	25.1
60	15.4	16.9	19.6	15.4	15.8	16.5	13.4	14.8	16.9	13.4	14.0	14.7	12.0	13.6	14.7	12.0	12.3	12.5
$t_{1/2}$	22.2	23.5	25.5	22.2	22.5	23.1	20.8	21.8	23.9	20.8	21.2	21.7	19.6	20.9	21.7	19.6	19.8	20.1

Table 3. Mean values of carbofuran in vertical soil columns mg kg^{-1} soil

Soil	Depth (cm)	100 mg Carbofuran kg^{-1} soil						100 mg Carbofuran + 0.5 g Urea kg^{-1} soil						100 mg Carbofuran + 2 g sewage sludge kg^{-1} soil					
		(Days)																	
		1	5	10	20	40	80	1	5	10	20	40	80	1	5	10	20	40	80
Black	0-10	86	72	56	52	40	27	88	80	68	55	42	30	92	87	72	57	45	32
	11-20	2.9	7.7	11.8	6.0	5.0	3.0	3.6	9.2	12.4	8.0	8.2	6.2	2.6	8.6	9.1	8.4	8.0	2.0
	21-30	1.8	5.5	12.0	4.0	3.0	1.5	1.9	6.4	9.2	10.5	8.0	10.9	1.2	6.0	6.8	9.0	9.0	1.9
	31-40	0.0	3.6	5.2	2.0	1.6	1.6	0.0	2.8	6.2	8.2	7.9	6.0	0.0	2.6	4.4	8.0	7.1	1.7
	41-50	0.0	1.4	2.7	1.0	1.0	1.7	0.0	1.8	2.7	5.4	6.8	7.9	0.0	1.8	3.0	4.6	7.6	0.9
Red	0-10	80	62	45	34	25	10	84	78	66	49	36	22.4	86	79	66	53	38	24
	11-20	20	6.2	10.3	9.2	9.6	3.2	2.7	7.9	11.0	8.9	7.6	6.6	1.6	7.2	8.4	8.2	8.4	2.8
	21-30	1.5	5.1	10.5	7.2	7.6	2.8	1.8	5.4	8.8	10.5	6.0	5.0	1.4	2.4	6,6	6.4	8.2	2.6
	31-40	0.0	3.0	4.8	7.8	6.2	3.4	0.0	2.7	5.8	5.6	6.0	6.0	0.0	1.6	3.6	6.9	6.0	5.4
	41-50	0.0	1.2	2.5	4.8	5.3	2.8	0.0	1.2	2.3	2.8	7.9	4.0	0.0	1.0	2.7	3.4	7.2	9.6
Alluvial	0-10	78	58	40	28	18.2	8.2	81	76	62	40	26.6	10.6	83	76	60	50	33	15
	11-20	1.8	5.5	8.2	8.0	7.8	2.6	2.5	6.2	8.9	8.3	7.9	2.7	1.0	3.0	7.6	7.1	7.0	3.3
	21-30	1.5	4.7	8.0	6.2	6.3	2.5	1.5	5.3	8.3	7.7	7.1	2.6	0.0	2.5	6.5	6.1	5.8	2.8
	31-40	0.7	2.5	3.2	7.2	5.2	3.1	0.0	2.5	5.5	8.0	6.2	5.5	0.0	1.2	3.2	6.7	5.1	5.2
	41-50	0.0	0.7	2.0	3.2	5.6	2.7	0.0	1.3	2.0	5.5	6.9	3.6	0.0	0.6	2.1	3.3	6.1	3.1

Table 4: The rate constant, half life period and coefficient of determination for carbofuran degradation in black, red and alluvial soil at different pH, in presence different concentration of sewage-sludge and urea

Soil	pH	$kx10^{-2}$ (d^{-1})	$t_{1/2}$ (d)	R^2	Amount of sewage-sludge amended per kg soil	$kx10^{-2}$ (d^{-1})	$t_{1/2}$ (d)	R^2	Amount of urea amended per kg soil	$kx10^{-2}$ (d^{-1})	$t_{1/2}$ (d)	R^2
Black	4	1.80	38.5	0.938	0 g	3.09	22.4	0.956	0 mg	3.09	22.4	0.958
	6	2.44	28.5	0.958	1 g	2.96	23.4	0.944	50 mg	3.08	22.5	0.944
	9	3.25	21.3	0.966	2 g	2.72	25.5	0.946	100 mg	3.00	23.1	0.936
Red	4	2.20	31.6	0.942	0 g	3.31	20.9	0.978	0 mg	3.31	20.9	0.978
	6	2.67	25.9	0.968	1 g	3.18	21.8	0.966	50 mg	3.28	21.1	0.964
	9	3.54	19.6	0.956	2 g	2.96	23.4	0.956	100 mg	3.20	21.7	0.954
Alluvial	4	2.41	28.7	0.952	0 g	3.53	19.6	0.984	0 mg	3.53	19.6	0.986
	6	2.79	24.8	0.970	1 g	3.32	20.9	0.978	50 mg	3.50	19.8	0.974
	9	3.86	18.9	0.978	2 g	3.20	21.7	0.968	100 mg	3.46	20.0	0.966

Table 5 : Persistence of carbofuran(μg/g) after different time interval at different pH in three soils fortified by with 100 μg g^{-1} of pesticide

Soil	pH	1st day	5th day	10th day	20th day	40th day	60th day
Black	4	98.27	91.57	83.56	69.77	48.30	32.80
	6	97.67	88.71	78.52	61.64	37.07	21.79
	9	96.87	85.13	72.34	52.11	26.94	13.64
Red	4	97.86	89.78	80.26	64.41	41.16	23.70
	6	97.43	87.74	76.64	58.29	33.97	19.32
	9	96.58	83.86	70.33	49.27	23.89	11.40
Alluvial	4	97.65	88.52	78.52	61.64	37.64	22.86
	6	97.14	86.43	74.38	55.33	30.37	16.14
	9	96.24	82.54	67.98	46.21	21.19	9.64

Table 6. Mean values of DTPA extractable heavy metals in vertical black soil columns mg kg^{-1} soil

Metal	Depth (cm)	100 mg Carbofuran kg^{-1} soil						100 mg Carbofuran + 0.5 g Urea kg^{-1} soil						100 mg Carbofuran + 2 g sewage sludge kg^{-1} soil					
		(Days)																	
		1	5	10	20	40	80	1	5	10	20	40	80	1	5	10	20	40	80
Fe	0-10	8.8	8.4	8.0	7.6	7.4	6.4	9.0	8.6	8.2	7.8	7.2	6.2	9.4	9.0	8.2	8.0	7.6	6.6
	11-20	8.8	9.0	9.2	9.4	9.4	9.4	9.0	9.2	9.2	9.4	9.6	9.8	9.0	9.2	9.6	10.0	10.0	10.6
	21-30	8.8	9.0	9.0	9.2	9.4	9.6	8.8	8.8	9.0	9.2	9.4	9.8	8.8	8.6	8.8	9.0	9.6	9.0
	31-40	8.8	8.8	8.6	8.6	8.4	8.0	8.8	8.8	8.8	8.6	8.8	8.6	8.8	9.0	9.0	9.0	9.0	9.0
	41-50	8.8	8.8	8.8	8.2	8.2	8.6	8.8	8.8	8.8	8.6	8.4	7.2	8.8	8.8	8.8	8.8	8.6	7.4
Zn	0-10	0.68	0.66	0.64	0.60	0.54	0.46	0.70	0.68	0.62	0.60	0.50	0.44	0.74	0.66	0.68	0.62	0.56	0.48
	11-20	0.68	0.70	0.70	0.72	0.74	0.76	0.68	0.72	0.74	0.72	0.76	0.80	0.68	0.72	0.72	0.76	0.78	0.78
	21-30	0.68	0.68	0.70	0.70	0.72	0.76	0.68	0.68	0.70	0.76	0.76	0.80	0.68	0.70	0.74	0.74	0.76	0.86
	31-40	0.68	0.68	0.68	0.68	0.70	0.70	0.68	0.68	0.68	0.64	0.68	0.74	0.68	0.66	0.66	0.68	0.70	0.72
	41-50	0.68	0.68	0.68	0.64	0.62	0.54	0.68	0.68	0.66	0.62	0.60	0.54	0.68	0.68	0.66	0.64	0.62	0.54
Cu	0-10	0.68	0.66	0.64	0.60	0.56	0.50	0.70	0.66	0.62	0.58	0.54	0.48	0.74	0.70	0.66	0.62	0.58	0.52
	11-20	0.68	0.70	0.72	0.76	0.76	0.78	0.68	0.72	0.72	0.74	0.76	0.76	0.68	0.70	0.72	0.74	0.78	0.76
	21-30	0.68	0.68	0.68	0.66	0.72	0.76	0.68	0.68	0.72	0.72	0.74	0.78	0.68	0.70	0.70	0.72	0.76	0.88
	31-40	0.68	0.68	0.68	0.70	0.70	0.68	0.68	0.68	0.68	0.68	0.66	0.68	0.68	0.66	0.68	0.66	0.68	0.66
	41-50	0.68	0.68	0.66	0.64	0.62	0.62	0.68	0.68	0.68	0.62	0.60	0.60	0.68	0.68	0.66	0.64	0.64	0.64
Cr	0-10	0.22	0.20	0.18	0.16	0.12	0.08	0.24	0.20	0.16	0.14	0.10	0.06	0.26	0.20	0.20	0.16	0.14	0.08
	11-20	0.22	0.24	0.24	0.26	0.24	0.26	0.22	0.26	0.24	0.28	0.30	0.30	0.22	0.26	0.28	0.30	0.32	0.30
	21-30	0.22	0.22	0.24	0.24	0.26	0.26	0.22	0.22	0.24	0.26	0.26	0.28	0.22	0.22	0.24	0.26	0.26	0.30
	31-40	0.22	0.22	0.20	0.22	0.20	0.16	0.22	0.22	0.24	0.20	0.18	0.16	0.22	0.22	0.20	0.18	0.22	0.18
	41-50	0.22	0.22	0.18	0.18	0.14	0.12	0.22	0.22	0.18	0.18	0.14	0.14	0.22	0.22	0.20	0.20	0.16	0.14
Cd	0-10	0.02	0.02	Tr	Tr	Tr	Tr	0.02	Tr	Tr	Tr	Tr	Tr	0.02	0.02	0.02	Tr	Tr	Tr
	11-20	002	002	0.04	0.04	0.02	0.02	0.02	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.02
	21-30	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.04
	31-40	0.02	0.02	0.02	0.02	0.02	Tr	0.02	0.02	0.02	0.02	0.04	Tr	0.02	0.02	0.02	0.02	0.02	0.02
	41-50	0.02	0.02	0.02	Tr	Tr	Tr	0.02	0.02	0.02	Tr	Tr	Tr	0.02	0.02	0.02	0.02	Tr	Tr

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Table 7. Mean values of DTPA extractable heavy metals in vertical Red soil columns mg kg^{-1} soil

Metal	Depth (cm)	100 mg Carbofuran kg^{-1} soil						100 mg Carbofuran + 0.5 g Urea kg^{-1} soil						100 mg Carbofuran + 2 g sewage sludge kg^{-1} soil					
		(Days)																	
		1	5	10	20	40	80	1	5	10	20	40	80	1	5	10	20	40	80
Fe	0-10	18.8	18.4	17.6	17.8	16.8	15.8	19.4	18.8	18.6	17.8	16.6	15.6	20.2	19.2	18.6	17.8	17.0	16.0
	11-20	18.8	19.2	19.4	19.4	19.8	19.6	18.8	19.2	20.2	20.4	19.6	19.8	19.2	20.0	20.2	20.4	20.6	21.0
	21-30	18.8	18.8	19.2	19.2	19.4	19.6	18.8	18.8	19.4	19.6	19.8	20.0	18.8	19.0	19.4	19.6	19.8	20.2
	31-40	18.8	18.8	18.6	18.6	18.2	17.6	18.8	18.8	18.8	19.0	18.4	17.4	18.8	18.8	18.8	19.0	19.0	17.0
	41-50	18.8	18.8	19.0	18.2	17.6	16.4	18.8	18.8	18.8	18.4	17.2	16.2	18.8	18.8	18.8	18.4	17.6	16.4
Zn	0-10	0.66	0.64	0.62	0.58	0.50	0.40	0.70	0.66	0.60	0.56	0.46	0.34	0.72	0.68	0.62	0.60	0.52	0.46
	11-20	0.66	0.68	0.68	0.70	0.72	0.72	0.66	0.70	0.72	0.74	0.76	0.76	0.68	0.72	0.74	0.72	0.76	0.80
	21-30	0.66	0.66	0.68	0.68	0.72	0.74	0.66	0.66	0.68	0.74	0.74	0.80	0.66	0.66	0.68	0.68	0.66	0.78
	31-40	0.66	0.66	0.66	0.68	0.70	0.70	0.66	0.66	0.64	0.66	0.62	0.64	0.66	0.66	0.66	0.66	0.60	0.64
	41-50	0.66	0.66	0.66	0.62	0.58	0.56	0.68	0.66	0.66	0.64	0.60	0.58	0.66	0.66	0.66	0.66	0.40	0.58
Cu	0-10	0.60	0.56	0.54	0.50	0.42	0.34	0.64	0.58	0.52	0.44	0.38	0.32	0.70	0.64	0.58	0.52	0.44	0.36
	11-20	0.60	0.64	0.64	0.64	0.66	0.68	0.60	0.64	0.68	0.70	0.72	0.74	0.62	0.68	0.70	0.72	0.74	0.74
	21-30	0.60	0.60	0.62	0.66	0.68	0.70	0.60	0.62	0.64	0.68	0.72	0.74	0.60	0.60	0.64	0.68	0.68	0.72
	31-40	0.60	0.60	0.60	0.58	0.58	0.58	0.60	0.60	0.60	0.58	0.60	0.60	0.66	0.60	0.60	0.62	0.62	0.62
	41-50	0.60	0.60	0.58	0.56	0.50	0.52	0.60	0.60	0.58	0.56	0.52	0.48	0.60	0.60	0.60	0.58	0.52	0.50
Cr	0-10	0.20	0.18	0.16	0.12	0.10	0.04	0.22	0.18	0.14	0.10	0.05	0.04	0.24	0.18	0.18	0.16	0.12	0.06
	11-20	0.20	0.22	0.24	0.24	0.24	0.24	0.20	0.24	0.26	0.26	0.26	0.26	0.20	0.22	0.24	0.24	0.26	0.26
	21-30	0.20	0.20	0.20	0.22	0.24	0.26	0.20	0.20	0.22	0.24	0.26	0.28	0.20	0.22	0.22	0.24	0.28	0.26
	31-40	0.20	0.20	0.20	0.20	0.14	0.20	0.20	0.20	0.20	0.20	0.16	0.20	0.20	0.20	0.20	0.18	0.14	0.20
	41-50	0.20	0.20	0.20	0.16	0.14	0.14	0.20	0.20	0.18	0.16	0.16	0.14	0.20	0.20	0.20	0.18	0.16	0.16
Cd	0-10	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
	11-20	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
	21-30	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
	31-40	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
	41-50	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr

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Table 8. Mean values of DTPA extractable heavy metals in vertical alluvial soil columns mg kg^{-1} soil

Metal	Depth (cm)	100 mg Carbofuran kg^{-1} soil						100 mg Carbofuran + 0.5 g Urea kg^{-1} soil						100 mg Carbofuran + 2 g sewage sludge kg^{-1} soil					
		(Days)																	
		1	5	10	20	40	80	1	5	10	20	40	80	1	5	10	20	40	80
	0-10	3.8	3.6	3.4	2.8	2.6	2.4	4.2	3.8	3.2	2.6	2.4	2.2	4.6	4.0	3.6	3.2	2.6	2.4
	11-20	3.8	4.0	4.2	4.6	4.4	4.2	3.8	4.2	4.4	4.8	4.8	4.8	4.0	4.4	4.6	4.2	4.4	4.8
Fe	21-30	3.8	3.8	3.8	4.0	4.6	4.6	3.8	3.8	4.0	4.2	4.4	4.6	3.8	4.0	4.2	4.4	4.4	5.8
	31-40	3.8	3.8	3.8	3.8	3.8	4.0	3.8	3.8	3.8	4.0	4.0	4.0	3.8	3.8	3.8	4.0	4.2	4.0
	41-50	3.8	3.8	3.6	3.4	3.4	3.0	3.8	3.8	3.6	3.4	3.2	3.0	3.8	3.8	3.4	3.0	2.8	2.6
	0-10	0.42	0.40	0.36	0.32	0.30	0.26	0.44	0.40	0.34	0.30	0.28	0.24	0.48	0.44	0.40	0.36	0.28	0.28
	11-20	0.42	0.44	0.46	0.48	0.46	0.48	0.42	0.46	0.48	0.48	0.46	0.46	0.42	0.44	0.48	0.50	0.50	0.48
Zn	21-30	0.42	0.42	0.44	0.46	0.46	0.46	0.42	0.42	0.44	0.46	0.48	0.48	0.42	0.44	0.44	0.46	0.48	0.52
	31-40	0.42	0.42	0.42	0.40	0.40	0.38	0.42	0.42	0.40	0.42	0.40	0.40	0.42	0.42	0.40	0.38	0.44	0.42
	41-50	0.42	0.42	0.40	0.38	0.36	0.36	0.42	0.42	0.38	0.40	0.36	0.34	0.42	0.42	0.40	0.36	0.38	0.38
	0-10	0.64	0.62	0.60	0.54	0.48	0.40	0.70	0.64	0.58	0.52	0.46	0.38	0.76	0.70	0.64	0.58	0.52	0.42
	11-20	0.64	0.66	0.68	0.68	0.72	0.70	0.64	0.68	0.70	0.70	0.74	0.72	0.68	0.74	0.80	0.80	0.82	0.80
Cu	21-30	0.64	0.64	0.66	0.68	0.68	0.74	0.64	0.64	0.66	0.70	0.72	0.74	0.64	0.66	0.70	0.72	0.76	0.80
	31-40	0.64	0.64	0.62	0.64	0.62	0.62	0.64	0.64	0.62	0.64	0.66	0.64	0,.64	0.66	0.68	0.68	0.72	0.72
	41-50	0.64	0.64	0.62	0.56	0.50	0.46	0.64	0.64	0.62	0.56	0.48	0.44	0.64	0.66	0.64	0.58	0.54	0.48
	0-10	0.20	0.18	0.16	0.12	0.10	0.06	0.22	0.18	0.14	0.10	0.08	0.04	0.24	0.22	0.20	0.14	0.12	0.08
	11-20	0.20	0.22	0.22	0.24	0.22	0.24	0.20	0.24	0.22	0.24	0.24	0.24	0.20	0.24	0.26	0.26	0.28	0.28
Cr	21-30	0.20	0.20	0.22	0.22	0.24	0.26	0.20	0.20	0.24	0.22	0.22	0.26	0.20	0.20	0.22	0.24	0.26	0.28
	31-40	0.20	0.20	0.20	0.18	0.22	0.20	0.20	0.20	0.20	0.16	0.16	0.18	0.20	0.20	0.18	0.18	0.18	0.18
	41-50	0.20	0.20	0.20	0.16	0.12	0.10	0.20	0.20	0.20	0.18	0.14	0.10	0.20	0.20	0.22	0.20	0.16	0.14
	0-10	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
	11-20	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Cd	21-30	Tr	Tr	Tr	Tr	0.02	0.02	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.02	0.02	Tr	Tr
	31-40	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
	41-50	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr

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