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Chromium Distribution in Soil and Water in the Vicinity of Chromium Mine Area of Sukinda, Orissa

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Abstract

From Sukinda chromite mining area 162 nos. of surface soil samples and 100 nos. of water samples within radious of 0—15 km distance were collected and analyzed for pH and available hexavalent chromium. The data revealed that pH of soil and water ranged from 4.56—8.72 and 6.7—9.55 respectively and the hexavalent chromium content ranged from trace to 10.074, trace to 0.553 and trace to 0.192 ppm in soil and 0.008 to 1.93, trace to 0.081 and 0.03 to 0.351 ppm in water within distance of 0—5, 5—10 and 10—15 km respectively. In pot culture study 10 grass spp. were grown in overburden soil and normal soil along with and without fertilizer and FYM. The mean biomass yield of different grass species ranged from 10.35 to 30.82 g/pot. Thin napier grass produced highest significant biomass yield of 41.02 g/pot which was 108.64% higher than overburden soil. Highest significant mean chromium content of 142.50 ppm was recorded when grass species was grown in overburden soil but this value was reduced to 100.41 ppm when overburden soil treated with FYM and fertilizer. The grasses like *Sefaria* spp. and *Stylo hamata* showed lowest values of mean chromium content of 25.85 and 28.28 ppm respectively when grown in all types of soil.
Key words : Overburden soil, Chromium, Grass species, FYM.

Rapid development of industries and urbanization in India led to environmental pollution. The state of Orissa has vast deposits of about 185 million tonnes of (96% India) of chromite ores spreading over an area of 9197 ha of Sukinda in district of Jajpur which causes serious damage to the environment on its exploration. Hexavalent chromium is toxic to plant, human and animals. Tiwana et al. (1) and Subba Rao (2) reported its adverse effect on soil and crops. Keeping in view of hazardous effect of chro-

Table 1. Hexavalent chromium content of soil samples collected around 0—15 km radius from the mine area.

Name of the villages	Distance from mine area (km)	No. of samples collected	Range of pH	Range of Cr^{6+} (ppm)	Mean of Cr^{6+} (ppm)
Kalaringatta	1	23	5.26—8.17	trace—1.971	0.408
Kaliapani	2	23	5.52—7.53	trace—10.074	0.623
South Kaliapani	2	3	5.84—8.48	0.360—2.524	1.097
Chirgunia	2	9	4.97—6.59	0.026—0.721	0.403
Gurujung	2	5	5.30—5.73	0.07—1.082	0.399
Ostia	2	5	5.05—5.81	0.288—1.731	0.846
Sukurungi	3	6	5.08—5.80	0.240—0.721	0.461
Dhabahal	3	6	5.55—6.00	0.216—0.961	0.424
Purunapani	4	10	5.72—8.01	trace—0.673	0.176
Chingudipal	4	9	5.10—5.77	0.240—1.129	0.486
Koiposi	4	5	5.51—5.65	0.360—0.505	0.443
Bansari	5	5	4.56—5.85	0.192—0.745	0.404
Kantabani	5	5	5.40—5.67	0.216—0.360	0.293
Kusumundia	6	10	4.86—6.70	trace—0.433	0.144
Bhalikipatala	8	9	5.03—6.97	0.120—0.553	0.309
Garamia	9	9	5.14—6.41	0.048—0.288	0.133
Kankadapal	11	10	5.43—8.72	trace—0.192	0.106
Kuhika	15	10	4.90—6.03	0.024—0.192	0.117

Table 2. Hexavalent chromium (Cr^{6+}) content of surface water sample collected around 0—15 km radius from the mine area.

Name of the village	Distance from mine area (km)	No. of samples collected	Range of pH	Range of Cr^{6+} (ppm)	Mean of Cr^{6+} (ppm)	% of sample above toxic level
TISCO mine	1	1	9.17	0.013	0.013	0
Bhimtangiri	1	1	9.05	0.068	0.068	100
FACOR mine	1	4	7.5—8.20	0.014—1.993	0.550	50
Kaliapani	2	10	7.6—9.13	0.008—0.741	0.237	60
S. Kaliapani	2	9	7.5—9.35	0.025—0.55	0.364	88
Gurujung	2	3	6.8—7.80	0.021—0.03	0.024	0
Chirigunia	2	5	7.10—7.90	0.025—0.360	0.114	60
Sukurungi	3	2	8.5—8.95	0.013—0.567	0.290	50
Dhabahal	3	3	6.8—8.20	0.021—0.148	0.064	33
Purunapani	4	4	9.11—9.38	0.008—0.567	0.023	25
Chingudipal	4	3	6.7—8.20	0.004—0.03	0.019	0
Bansari	5	3	6.7—7.60	0.008—0.04	0.015	0
Kusumundia	6	1	8.27	0.008	0.008	0
Bhalikipatala	8	1	7.14	0.372	0.372	100
Garamia	9	2	8.45—8.55	trace—0.081	0.025	50
Kuhika	15	3	7.85—9.15	0.03—0.351	0.231	66

mium, the present study was carried out in chrome mine area of Sukinda in Jajpur district of Orissa.

Methods

During 2000-2001 a total numbers of 162 surface soil samples around mines and 100 surface water samples within 0—15 km radius from open well, tube well, rivulets, canals, ponds, rice fields and mining dams adjacent to the mine were collected. Sampling was done at 100 m grid within 15 km radius from mine area at 1 km interval. The soil samples were processed and analyzed for pH, EC, soil texture and organic carbon. DTPA extracted chromium in soil and water was determined by atomic absorption spectrometer. Hexavalent chromium in soil and water was determined colorimetrically (3).

A pot culture experiment was conducted with overburden and normal soil to study the effect of FYM on uptake of Chromium by different grass species. This experiment was conducted in earthen pots of 20.3 cm diameter containing 6 kg of soil. The experiment consists of three main treatments (T_1 : over burden soil ; T_2 : overburden soil + recommended dose of fertilizer + FYM at 10 t/ha ; T_3 : Normal soil + recommended dose of fertilizer + FYM at 10 t/ha) and 10 sub-treatments with 10 grass species. All together there were 30 treatments replicated twice in a factorial

Table 3. Hexavalent chromium content of water sample collected from different sources around 0—2 km vicinity of mine area.

Sources of water sample	No. of samples collected	Range of pH	Range of hexavalent chromium (ppm)	Mean of hexavalent chromium (ppm)	Percent of sample above toxic level
Tubewell	16	6.7—9.38	trace—0.068	0.021	6.25
Well	9	6.7—9.28	0.004—0.005	0.027	22.22
Pond	7	7.14—9.36	0.008—0.374	0.161	57.14
Rivulet	5	7.50—8.20	0.093—0.313	0.178	100.0
Flood water from rice field	5	7.10—8.20	0.025—0.465	0.189	60.0
Mine dam	3	8.50—9.55	0.550—0.741	0.619	100.0

Table 4. Effect of chemical fertilizer and FYM on total dry matter production of different grass species at 45 days after planting.

	Name of the grass species	Biomass production (g/pot) T1 : Overburden soil from mine area	T2 : Overburden soil + RD fertilizer + FYM	T3 : Normal soil (lateritic) +RD fertilizer + FYM	Mean
S_1	Sabai grass	8.98	10.42	15.12	11.51
S_2	Thin napier	19.66	41.02	31.79	30.82
S_3	Dharaf grass	11.31	18.35	11.99	13.88
S_4	Guina grass	10.65	14.77	14.87	13.43
S_5	Sadabahar	8.93	11.22	10.89	10.35
S_6	Himidicola	8.73	13.91	20.55	14.40
S_7	Malases grass	16.69	27.31	29.79	24.60
S_8	Congo signal	7.53	13.56	19.07	13.39
S_9	*Sefaria* spp.	16.84	22.39	19.51	19.58
S_{10}	*Stylo hamata*	9.78	18.26	18.32	15.45
	Mean	11.91	19.12	19.19	
	CD (0.05)	T	S	T × S	
		3.42	6.26	7.67	

randomized block design. A recommended dose of 60-30-30 kg of N-P_2O_5-K_2O kg/ha (on weight basis) in form of urea, single super phosphate and KCl, respectively were applied to each plot. FYM was thoroughly mixed with soil. Four seedling of each grass species were planted in each plot with light irrigation. The seedlings were allowed to grow for 45 days and then harvested by uprooting roots. The plant samples were washed, oven dried and grinded for chromium estimation.

Results and Discussion

Chromium in Soil

The hexavalent chromium contents of surface soil samples collected around 0—15 km radius from the mine area are presented in Table 1. The data

Table 5. Effect of chemical fertilizer and FYM on chromium content of grass species.

	Name of the grass species	Chromium content (mg/kg) T1 : Overburden soil from mine area	T2 : Overburden soil + RD fertilizer +FYM	Percent Reduction in chromium content	T3 : Normal soil (lateritic) + RD fertilizer + FYM	Mean
S_1	Sabai grass	229.60	163.50	28.79	7.60	133.57
S_2	Thin napier	238.10	189.55	20.39	21.55	149.73
S_3	Dharaf grass	114.00	77.05	32.14	9.90	66.98
S_4	Guina grass	240.10	208.45	13.18	30.40	159.65
S_5	Sadabahar	95.90	48.25	49.68	9.55	51.23
S_6	Himidicola	203.80	132.00	35.23	22.25	119.35
S_7	Malases grass	113.00	64.90	42.56	10.50	62.80
S_8	Congo signal	97.75	69.40	29.00	11.05	59.40
S_9	*Sefaria* spp.	43.35	23.90	44.86	10.30	25.85
S_{10}	*Stylo hamata*	49.35	27.10	45.09	8.40	28.28
	Mean	142.50	100.41		14.15	
	CD (0.05)	T	S	T × S		
		21.65	39.53	68.47		

showed that the pH of the surface soil collected within 0—15 km radius ranged from 4.56 to 8.72. Most of the soils were moderately acidic and few were neutral to slightly alkaline in reaction (Table 1). The EC of the soils were generally low and ranged from 0.01 to 0.22 dS/m. The organic carbon content of soils ranged from 0.38 to 0.56%. The hexavalent chromium ranged from trace to 10.074, trace to 0.553 and trace to 0.192 ppm within 0—5, 5—10 and 10—15 km radius, respectively. However, the average hexavalent chromium varied from 0.293 to 1.097, 0.144 to 0.309 and 0.106 to 0.117 ppm within 0—5, 5—10 and 10—15 km radius, respectively. The soil samples collected from villages like Kalaringatta, Kaliapani, S. Kaliapani, Chirgunia, Gurujung, and Ostia within 0—2 km radius showed high value of hexavalent chromium of 0.408, 0.623, 1.097, 0.403, 0.399 and 0.846 ppm, respectively. The mean hexavalent chromium content in the soil samples collected from two villages at 3 km distance, 3 villages at 4 km distance and 2 villages at 5 km distance ranged from 0.424 to 0.461, 0.176 to 0.486 and 0.293 to 0.404 ppm, respectively. This indicated that the hexavalent chromium content in soils decreased with increasing distance from the mine area. Similar observations were also reported by Polomski et al. (4) and Haidouti (5). The hexavalent chromium contents of the soil samples collected within 5—10 km radius were lower than the soils collected from 0—5 km radius except for Bhalikipatala village which contained average hexavalent chromium of 0.309 probably because of flow of the effluent water around this village. The soil samples collected from S. Kalipani village (at 2 km distance) showed highest mean value of hexavalent chromium (1.097 ppm) because this village is situated towards south direction of mine area through which effluent water from mine was draining.

Hexavalent Chromium in Water

The hexavalent chromium content of pond water samples varied from 0.008 to 1.993, trace to 0.081 and 0.03 to 0.351 ppm within 0—5, 5—10 and 10 —15 km radius, respectively. Similarly, the average hexavalent chromium content of pond water varied from 0.019 to 0.550, 0.008 to 0.372 and 0.231 within 0—5, 5—10 and 10—15 km radius, respectively (Table 2). In all water samples, the average hexavalent chromium content were higher than the critical limit (0.02 ppm) except Chingudipal, Bansari and Kusumundia village. The pond water samples collected from Facor mine recorded highest value of hexavalent chromium (0.550 ppm) followed by south Kalipani and Kalipani areas which posed a serious problem for the human and animal health. These polluted water caused several skin diseases and digestion problem in human as reported by villagers in that surrounding areas.

The water samples collected from open wells, ponds, rivulets paddy fields and mine dam were found to be highly polluted with hexavalent chromium (Table 3). The hexavalent chromium in these water bodies ranged from 0.027 to 0.619 ppm. The water in mine dam (where pumped water from mine is stored) contained highest amount of hexvalent chromium of 0.619 ppm. The flood water from nearby paddy fields contained 0.189 ppm hexavalent chromium which were contaminated through effluent water coming from mine dam. However, the tube well water collected from 16 sites around 0—2 km radius contained average hexavalent chromium of 0.021 ppm which were below critical limit. The exhaustive study made by Punjab Pollution Control Board (6) revealed that irrigation of soils with industrial effluents changed the soil characteristics and the soils became unfit for agricultural purposes.

Effect of Chemical Fertilizer and FYM on Biomass Yield and Chromium Content of Different Grass Species

The overburden soil collected from chromium mine area was used for the pot culture study. The soils had loamy sand soil texture, pH 8.2, EC 1.28 dS/m. The soil had CEC value of 4.82 cmol (p^+)/ kg with exchangeable Ca, Mg, Na and K of 3.0, 1.21, 0.62 and 0.67 cmol (p^+)/kg, respectively. The water soluble chromium was 1.68 ppm and total chromium 1.68%. The mean dry matter production and chromium content of different grass species after 45 d of planting are presented in Tables 4 and 5, respectively. The data revealed that the mean biomass yield of different grass species ranged from 8.73 to 19.66, 10.42 to 41.02 and 11.99 to 31.79 g/pot with mean values of 11.91, 19.12 and 19.19 g /plot in T_1 (overburden soil), T_2 (overburden soil + fertilizer + FYM) and T_3 (normal soil + fertilizer + FYM), respectively. The yield recorded in T_2 was significantly superior to T_1 but at par with T_3 which indicated that over burden soil can be efficiently put under crop production after its reclamation with amendments. It would behave like a normal soil for production after treated with recommended doses of fertilizers and FYM. The mean biomass yield of different grass species ranged from 10.35 to 30.82 g/pot. Thin napier grass recorded highest mean biomass yield of 30.82 g/pot which was significantly better than all other grass species but at par with molasses grass. Thin napier produced highest significant yield of 41.02 g/pot in T_2. The grass species like thin napier and molasses grass were found to be more effective for overburden soil as compared to other spp. The biomass yield of these two spp increased from 63.63 to 108.64% and 61.69 to 78.49% in T_2 (overburden soil + fertilizer+FYM) and T_3 (normal soil + fertilizer +FYM), respectively over T_1 (only overburden soil).

Chromium content of grass species ranged from 43.35 to 240.10, 23.90 to 208.45 and 7.60 to 30.40 ppm with mean values of 142.50, 100.41 and 14.15 ppm, in T_1, T_2 and T_3, respectively (Table 5). Highest significant mean chromium content of 142.50 ppm was reported when the grass species were grown in over burden soil. But this value reduced to 100.41 ppm when the over burden soil was treated with chemical fertilizer and FYM. The reduction in chromium content of different grass species ranged from 13.18 to 49.68%. Minimum chromium content of 14.15 ppm was reported when the grasses were grown in normal soil. Among ten grass species, gunia grass contained highest amount of chromium (159.65 ppm) which was at par with sabai grass and thin napier grass but was significantly higher than all other spp. The grass species like *Sefaria* spp. and *Stylo hamata* recorded lowest values of chromium in all types of soil.

Thus it can be concluded that hexavalent chromium content in soil and water were above toxic level around mine area which decreases with increasing distance. Application of chemical fertilizer and FYM was found to be beneficial in in creasing dry matter yield of different grass species and reduced the chromium uptake over overburden soil alone. The study thus indicates the need for the adoption of necessary pollution control measures to prevent the build up of chromium in water and soil around the chromium mine area.

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