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Impact of Heavy Metals on Enzymes and Microbial Activities in the Soils Adjacent to Mines and Industrial Areas of Odisha

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Abstract

A study was undertaken to assess the microbial diversity and enzyme activities in relation to soil properties in the soils adjacent to mining and industrial areas of Jajpur, Keonjhar and Angul districts of Odisha. The effluents from the mines are causing environmental pollution to the adjacent areas and their impact on the quality of atmosphere is alarming. The soils contain toxic levels of iron, manganese, chromium and relatively higher status of available zinc. The soils of Jajpur district contain more available Fe (114.7mg kg^{-1}), Mn (94.1mg kg^{-1}) and Cr (152.75mg kg^{-1}) over that of iron mining areas of Keonjhar. Highest dehydrogenase activity and acid phosphatase activity was observed in the soils from iron mining areas of Keonjhar district. The study emphasized that toxic levels of heavy metals in these mining and industrial areas and there is an urgent need to adopt proper remedial measures so as to minimize the levels of these elements in the soil-plant-animal-human chain.

Keywords: Heavy metals, Microbial diversity, Enzyme activities, Mining areas, Soil properties

Introduction

Sukinda valley of Odisha is the major production site of chromium (Cr) and is the serious threat to the humans as it produces potential carcinogenic substances, which are harmful for lungs and causes nose cancer. Most common heavy metals produced by industrial activities are lead, mercury, cadmium, arsenic, chromium, manganese, iron and zinc, and accumulated slowly in the surrounding water and soil. Some metals e.g. iron, zinc, copper, nickel, cobalt are of vital importance for many microbial activities when occur at low concentrations. Lead and mercury are more readily accumulated by fungi and actinomycetes in comparison to zinc, manganese, cadmium, nickel and cobalt which make selective accumulation of heavy metals by fungi different from many bacteria and yeast. Actinomycetes are important in forming stable humus, which enhances soil structure, improves retention of soil water and nutrients.

Soil biological activities depends on the metabolic state of soil microorganisms and are affected by numerous factors such as soil type, pH etc. Fluorescein Diacetate Hydrolysis Assay (FDA) can be used to measure the microbial activity in soils and is correlated with microbial respiration as it is a simple, non-specific, but sensitive technique that can be used to estimate relative levels of microbial activity in soils to assess the soil quality (Green et al., 2006). The present investigation was undertaken to assess the microbial activities as influenced by heavy metals in the mining and industrial areas in some parts of Odisha.

Materials and methods

A total of 16 surface (0.30 m) soil samples were collected from three districts of Odisha (4 samples from chromium (Cr) mining areas representing Sukinda block of Jajpur, 9 samples from iron (Fe) mining areas representing from Banspal and Joda blocks of Keonjhar and 2 samples adjacent to ash ponds of thermal power plant of Talcher block of Angul, 1 sample adjacent to ash pond of aluminium refinery from Banarpal block of Angul) and 1 soil sample from the cultivated fields (non polluted areas) from Raghunathpur block of Cuttack district. Fresh soil samples were used for enumeration of microbes and estimation of enzyme activities.

Dehydrogenase activity (DHA) and Fluorescein diacetate hydrolysis assay (FDA) were determined by the methods as described by Casida et al. (1964) and Green *et al*. (2006), respectively. Phosphatase activity was determined by the method as described by Tabatabai and Bremner (1969). Physico-chemical properties of the soils were determined by the standard procedures. Correlation coefficients were derived between enzyme activities with soil microbial counts and physico-chemical properties to establish the relationship between the microbial variables and soil properties.

Results and discussion

Physico-chemical properties

Relatively higher soil pH (Table 1) was observed in the soils of Cr mining areas (7.02) than the Fe mining areas (6.62). Highest mean value of organic C (0.998%) was observed in the soils of Keonjhar. Total N content in the polluted soils of the present study was ranged from 0.0728-0.2744%. Highest mean available N (kg ha^{-1}) was noticed in Keonjhar (331) followed by Angul (311). Mean available P (kg ha^{-1}) was found to be the highest in Jajpur (53.9) followed by Keonjhar (46.14). Highest mean available K (kg ha^{-1}) was observed in Keonjhar (336) followed by Jajpur (322). However, the cultivated field of Cuttack district has recorded 188, 6.72 and 242 kg ha^{-1} of available N, P and K, respectively.

The soils of Jajpur contain relatively higher available Fe (114.68mg kg^{-1}) and Mn (94.05mg kg^{-1}). Highest mean available Zn (4.96mg kg^{-1}) and Cu (0.71mg kg^{-1}) were observed in the soils of Keonjhar. The cultivated field of Cuttack district was recorded 12.48, 9.62, 0.25 and 0.25mg kg^{-1} of available Fe, Mn, Cu and Zn, respectively. Highest mean Cr values were observed in the mining areas of Jajpur (152.75mg kg^{-1}). Thus, it was observed that Sukinda block of Jajpur district contain very high values of Cr, which is toxic to crops, livestock and human beings.

Microbial diversity and enzyme activities

Highest microbial counts were observed in the soils from Keonjhar (Table 2) as compared to Jajpur and Angul. Highest mean DHA and FDA were noticed in the soils of Keonjhar. Higher biological activities in these polluted soils may be ascribed to greater availability of substrates that support such activities as well as the cofactors of several enzymes were highly influenced by supplementing of micronutrients (Kremer and Jianmei Li, 2003). Both acid and alkaline phosphatase activities were found highest in Jajpur. The activities of both alkaline and acid phosphatases were closely related to soil pH, with acid phosphatase dominating in acid soils, and alkaline phosphatase in alkaline soils, and the results of the present study are in concurrent with the findings of Eivazi and Tabatabai (1977).

Table 1: Physico-chemical properties in the soils from mining and industrial areas.

Location	Block & District	pH (1:2.5)	Org. C (%)	Total N (%)	Available nutrient (kg ha^{-1})			Available micro nutrients (mg kg^{-1})				
					N	P	K	Fe	Cu	Mn	Zn	Cr
Malhar Hatting Tisco Tata	Sukinda, Jajpur	6.51	1.22	0.252	323	18.96	286	145.9	0.24	129.2	1.76	178.3
Malhar Hatting Tisco Tata	Sukinda, Jajpur	6.82	0.67	0.088	284	17.20	176	135.5	0.46	121.0	0.73	159.6
Kaliapani	Sukinda, Jajpur	7.24	0.88	0.164	296	22.64	247	117.2	0.32	82.6	1.57	135.2
Hatibari	Sukinda, Jajpur	7.51	0.94	0.168	318	156.8	580	60.1	0.21	43.5	4.34	137.8
Palaskaa	Joda, Keonjhar	6.2	1.02	0.185	363	32.44	376	210.2	0.25	182.5	1.48	79.5
Baneikela	Joda, Keonjhar	7.78	0.79	0.185	281	86.40	327	115.2	0.54	95.7	11.21	40.2
Baneikela	Joda, Keonjhar	6.65	0.75	0.174	316	92.80	365	125.8	0.33	114.4	11.57	50.4
Lohanda	Joda, Keonjhar	6.35	0.85	0.151	263	16.44	204	85.1	0.26	65.2	2.3	38.2
Lohanda	Joda, Keonjhar	5.96	0.87	0.151	414	14.56	240	91.1	0.57	79.6	2.58	45.4
Suakati	Banspal, Keonjhar	6.06	1.88	0.274	451	18.64	374	33.8	0.60	27.0	1.31	62.3
TolaJagar	Banspal, Keonjhar	7.71	1.47	0.202	351	124.8	618	95.6	1.03	60.4	8.05	52.3
TolaJagar	Banspal, Keonjhar	5.89	0.63	0.090	251	9.72	284	103.3	1.33	84.4	0.91	24.9
UperJagar	Banspal, Keonjhar	6.95	0.74	0.174	289	19.42	236	90.4	1.51	74.3	5.27	28.3
Santhapada	Talcher, Angul	5.75	0.69	0.142	389	13.68	166	74.9	0.39	54.7	1.48	15.3
Kudulau	Talcher, Angul	7.85	1.12	0.106	306	22.40	279	69.6	0.22	57.1	0.96	10.4
Bhogabereni	Banarpal, Angul	6.91	0.35	0.073	238	8.78	123	65.9	0.34	42.6	0.87	13.2
Tarapur	Raghunathpur, Cuttack	6.16	0.70	0.146	188	6.72	242	12.5	0.25	9.6	0.76	1.85

Table 2: Soil microbial activities from mining and industrial areas.

Location	Bacteria ($1x10^5$ cfu g^{-1})	Fungi	Actinomycetes	DHA (µg TPF hr^{-1} g^{-1})	FDA (µg g^{-1} hr^{-1})	Acid Phosphatase	Alk. Phosphatase
		---------- ($1x10^4$ cfu g^{-1}) -----------				------------ (µg PNP g^{-1} hr^{-1}) ---------	
Malhar Hatting Tisco Tata	30	34	29	2.183	2.475	69.96	31.83
Malhar Hatting Tisco Tata	25	29	19	0.745	0.865	59.12	26.08
Kaliapani	37	42	25	2.457	2.511	65.91	29.88
Hatibari	34	38	27	2.356	2.522	75.38	36.1
Palaskaa	45	50	36	2.502	2.656	60.17	27.08
Baneikela	36	35	32	2.265	2.458	70.14	33.1
Baneikela	44	42	37	2.485	2.135	71.45	31.71
Lohanda	30	32	23	1.085	1.112	52.03	24.57
Lohanda	48	30	23	1.591	1.601	51.08	23.21
Suakati	35	47	46	2.506	2.707	62.95	28.87
TolaJagar	38	41	33	2.429	2.555	72.98	33.56
TolaJagar	45	27	24	0.741	1.88	72.71	35.04
UperJagar	32	37	29	2.106	2.285	62.02	29.74
Santhapada	31	26	18	0.686	0.882	66.79	28.35
Kudulau	36	46	31	2.346	2.456	73.63	37.34
Bhagubeini	34	29	22	0.733	1.338	56.78	26.21
Tarapur	25	32	20	1.74	1.932	60.26	27.17

Table 3: Relationship (r) between soil chemical properties and soil microbial variables.

Soil properties	Bacteria	Fungi	Actinomycetes	DHA	FDA	Acid phosphatase	Alkaline phosphatase
pH	-0.107	0.352	0.478*	0.485*	0.422*	0.486*	0.595**
Organic C	0.076	0.641**	0.735**	0.621**	0.405*	0.464*	0.437*
Total N	0.381	0.518*	0.699**	0.694**	0.629**	0.169	0.186
Available N	0.397	0.369	0.503*	0.415*	0.402*	0.234	0.082
Available P	0.178	0.302	0.428*	0.495*	0.425*	0.689**	0.573**
Available K	0.293	0.533*	0.556*	0.653**	0.669**	0.589**	0.566**

*and** Significant at 5.0 and 1.0 per cent level, respectively.

Relationship between soil properties and microbial variables

The soil pH had significant relationship with DHA, FDA, phosphatase activities (Table 3). Increase in soil pH had positive favorably influenced the multiplication of actinomycetes. The changes in microbial biomass and microbial activities were related to the increase in pH, which induce the development of bacteria to the detriment of fungi, and to the nutrient levels after addition of various organic amendments (Zelles *et al*., 1987).

The DHA, FDA and phosphatases had positively significant relationship with soil organic C. Organic matter is the store house of various groups of microbes and hence improvement in organic matter had significant role in accumulation of micro-flora and various groups of enzymes involved in different bio-chemical processes in the soil. Both DHA and FDA had significant relationship with available nutrients, indicated that these enzymes are involved in the transformation of N, P and K. Acid phosphatase had significant relationship with available P and it had greater contribution in the buildup of available P status of the soil rather than alkaline phosphatase activity. Organic amendments and associated plant residues may supply additional sources of labile C and P to the soil, which can stimulate microbial growth and biochemical activity (Carpenter-Boggs et al., 2000).

Conclusions

The soils adjacent to mining and industrial areas in some parts of Odisha contain toxic levels of Cr, Fe and Mn limiting the productivity of various crops and these heavy metals suppress the soil enzyme activities, thus deteriorating the soil quality. Accumulation of heavy metals due to mining activities and release of effluents from industrial areas and consequently their entry into the soil-plant system is very much harmful and there is an urgent need to advocate proper remedial measures so as to minimize the levels of these toxic elements in the soil-plant-animal-human chain.

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