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Effect of Municipal Sewage on Soil Biological Properties in the Vicinity of Jaipur City of Eastern Rajasthan, India

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A B S T R A C T

An experiment entitled "Effect of municipal sewage on soil properties and build up of heavy metals in vegetable crops grown in vicinity of Jaipur city" was undertaken with the aim to assess the suitability of sewage water for irrigation and their effect on the soil properties. Sewage water samples from Amanishah Nala and tube well were collected and analysed to Judge their suitability for irrigation. Soil samples from the fields irrigated with sewage, dilute sewage and tube well water were collected and analysed. The sewage water from Aminishah Nala contain higher values of metallic cation (Zn, Cu, Fe, Mn, Ni, Pb, Cd and Cr), however, the metallic cations (Cu, Mn, Ni, Pb and Cd) content were above the recommended maximum concentration. The use of sewage water for irrigation in light textured soil of Jaipur, microbial biomass C, N, P and alkaline phosphatase and dehydrogenase activity decreased in sewage irrigated fields. A higher inorganic and organic loading of sewage water with degradation of soil biological properties under study call for passing of the sewage water through an effluent treatment plant before being diverted for irrigation.

Introduction

Use of sewage sludge in agriculture is the most convenient practices of sludge disposal. Agriculture can use large and increasing quantities of sludge because it improve soil fertility by increasing the soil organic matter, microbial activity and plant nutrients and by improving the soil physical properties (Stamatiadis *et al.*, 1999). The waste waters are suitable for crop production provided the content of major plant nutrients is high and that of toxic elements is low. Its long term application would affect the physical, chemical and biological properties of soil (Antil, 2012). All the microbially-mediated biochemical reactions involving nutrient cycling are catalyzed by enzyme and depending on their nature and level of contamination, many heavy metals have been found to impede soil enzyme activities to different extents (Yang *et al.*, 2008).

The entry of toxic elements of the heavy metals create serious problem whenever they get accumulate in the environment. Some exceptions were observed and were attributed to the adsorption of these elements by organic materials. Maintenance of a diverse and functioning microbial community is important for soil sustainability. Loss of microbial diversity makes biological systems less able to adapt to environmental stresses. Low soil microbial diversity indicates stressed conditions in soil while high diversity is an indicator of a healthy soil (Rao, 2007). The activity of various soil enzymes has been suggested as a measure of microbial activity an early indication of changes brought about by soil management. Soil microorganisms are indeed affected by heavy metals as the result of a multiplicity of interactions that can occur between microbial cells and other environmental constituents. The clay minerals (montmorillonite and kaolinite) protect microorganisms, including bacteria, actionomycetes and filamentous fungi from inhibitory effects of Cd and the protective ability of clays is correlated with their CEC. Besides this, microbial resistance to heavy metals may also be genetically determined, depending on the ability of some micro organisms to biochemically transform toxic metals and to control cell uptake and permeability. Population of various microorganisms and activities of dehydrogenase and phosphatases enzymes had reduced significantly with the use of contaminated waters for irrigation was also reported by Rao *et al.,* (1993) and Tripathi *et al.,* (2006).

Materials and Methods

The area under study falls under agro climatic zone III A (semi arid eastern plain zone) of Sanganer tehsil of Jaipur district of Rajasthan and the geographical bearing of the area are 26^0. 49' to 26^o45'N (latitude) and 75^0.46 to 75^0.44 E longitude comprising have four villages. This water from nala normally made available to the farmers along nala in the periphery of 1 km. Sewage effluent water is pumped out to the field by farmers through hose pipe and collect into cemented tank of size 10 x 10 x 2 m (approximately). The collected sewage water applied to vegetable field as such by farmers and some farmers applied sewage water after dilution with tube well water of own in the same tank in equal proportion and irrigated the vegetable crops by field channel *viz.,* Sanganer, Ramsinghpura, Shikarpura and Govindpura. Microbial biomass C, N and P were determined using the fumigation extraction methods (Brookes *et al.,* 1982; Vance *et al.,* 1987; Brookes *et al.,* 1985). Soil samples were conditioned by maintaining moisture to 40 % water holding capacity to measure microbial biomass C, N and P. The preconditioned soil samples were fumigated by saturating with liquid ethanol free chloroform ($CHCl_3$) in desiccators and stored in the dark room for 24 hr (Srivastava and Singh, 1988). $CHCl_3$ was subsequently removed by repeated evacuation and samples were extracted with 0.5 M K_2SO_4 (1:4) for 30 minutes. In the same way, the unfumigated soil samples were also extracted. Organic carbon in the soil extract was measured using the acid dichromate method (Vance *et al.,* 1987). C_{mic} was estimated as BC=2.64 EC, where EC (extractable carbon) is the difference between carbon extracted from fumigated and unfumigated treatments both expressed in the same measurement unit N_{mic} was also determined by $CHCl_3$ fumigation method (Brookes *et al.,* 1985) using the same K_2SO_4 extract, which was used for C_{mic}. The soil extract was analysed for total N using Kjeldahl digestion method. Soil N_{mic} was estimated as BN=EN/0.54 (Brookes *et al.,* 1985 and Srivastava and Singh, 1989), where EN (extractable nitrogen) is the difference between N extracted from fumigated and unfumigated samples Measurement of P_{mic} was also done in preconditioned soil samples (Brookes *et al.,* 1982). Soil was fumigated in the same way as that of C_{mic} estimation. P_{mic} was calculated from the difference between the amount of inorganic P (Pi) extracted by 0.5 M $NaHCO_3$ (pH 8.5) from soil fumigated with $CHCl_3$ and unfumigated soil. Inorganic-P (Pi) in the extracts was determined by ammonium-molybdate-staneous chloride method (Olsen *et al.,* 1954). P_{mic} was then computed as the ratio of $CHCl_3$ release Pi with a kp value of 0.40 (Brookes *et al.,* 1982 and Srivastava and Singh, 1988) by assuming that 40 % of the Pi in the soil microbial biomass is rendered extractable as Pi by $CHCl_3$. Dehydrogenase activity was measured by the method given by Casida *et al.,* (1964).

In the method, the soil samples were incubated with 2, 3, 5- triphenyl tetrazolium chloride at 35^0 C and the production of triphenyl formazan (TPF) was measured on a spectrophotometer at 485nm. The assay of alkaline phosphatase was carried out according to the method of Tabatabai and Bremner (1969) with borax-NaOH buffer (pH 9.4) using *p*-nitrophenyl phosphate disodium salt as substrate at 35^0C.

Results and Discussion

Biological properties

Microbial biomass carbon, P and nitrogen

Microbial biomass plays a key role in the process of soil organic matter dynamics and soil nutrient availability in the agricultural ecosystem.

Soil management practices strongly affect the microbial biomass, particularly the input of carbon substance (Brooks *et al.*, 1990). Result of this study revealed that the amount of microbial biomass C, N and P declined with irrigation with sewage water (Table 2). This reduction in the microbial biomass was due to deleterious effect of heavy metal on microbial cell synthesis which is accumulated in soil by metals contained sewage water (Table 1).

Heavy metal contamination of soils results in long term decease in microbial biomass (Chander and Brookes, 1999a).

Brokes *et al.,* (1986) also found smaller microbial biomass in soil which had received metal contaminated sludge from 1942 to 1961 compared to similar uncontaminated soils. The existence of negative correlation between microbial biomass C, N and P and heavy metal content of soil (Table 4). This is also supports the findings of present investigation (Hassan, 1996 and Jinping *et al.*, 2010).

Table.1 Seasonal variation in heavy metal concentration (µg L^{-1}) of sewage, dilute sewage and tube well water during mansoon and winter season

S.No		Sewage		Dilute Sewage		Tube well	
Parameters		Mansoon	Winter	Mansoon	Winter	Mansoon	Winter
1	Zn	285.11	318.16	150.76	172.83	33.75	35.50
2	Cu	232.41	331.51	116.38	173.65	19.90	20.78
3	Fe	3.06	3.31	1.64	1.73	0.132	0.136
4	Mn	341.65	384.93	169.10	187.67	34.81	30.77
5	Ni	75.78	116.63	30.12	47.72	ND	ND
6	Pb	403.08	473.79	199.57	232.73	ND	ND
7	Cd	36.08	52.39	15.47	27.76	ND	ND
8	Cr	40.95	57.72	18.28	32.55	ND	ND

ND= Not detected

Table.2 Effect of sewage, dilute sewage and tube well water on microbial biomass (µg g^{-1} soil) of soil during mansoon and winter season

treatments	**microbial biomass C (µg g^{-1} soil)**		**microbial biomass N (µg g^{-1} soil)**		**microbial biomass P (µg g^{-1} soil)**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Mansoon						
Sewage	147.85	137.08	25.19	23.23	16.60	14.46
SD	8.87	8.07	1.51	1.38	0.98	0.86
Dilute sewage	165.05	156.09	26.22	26.30	15.44	15.00
SD	9.94	8.65	1.50	1.55	0.94	0.41
Tube well	176.15	181.62	27.25	29.38	14.28	15.53
SD	10.43	9.22	1.49	1.77	0.90	0.87
Winter						
Sewage	140.69	129.72	23.98	22.00	13.08	11.78
SD	7.83	7.83	1.44	1.32	0.81	0.75
Dilute sewage	154.71	142.06	24.60	23.99	13.50	13.35
SD	9.16	8.21	1.47	1.44	0.82	0.38
Tube well	178.43	175.83	25.22	25.97	15.27	14.92
SD	10.48	8.59	1.50	1.56	0.82	0.89

Table.3 Effect of sewage, dilute sewage and tube well water on enzyme of soil during mansoon and winter season

treatments	**alkaline phosphate enzyme activity (µ ml PNP sec^{-1})**		**dehydrogenase enzyme activity (P kat kg^{-1})**	
	Pre	**Post**	**Pre**	**Post**
mansoon				
Sewage	16.81	13.99	16.39	12.58
SD	0.99	0.85	0.91	0.79
Dilute sewage	14.77	14.03	17.86	15.65
SD	0.88	0.83	0.98	0.97
Tube well	12.72	14.35	19.34	18.72
SD	0.75	1.95	1.05	0.53
winter				
Sewage	12.50	11.56	12.77	12.49
SD	0.67	0.71	0.63	1.08
Dilute sewage	12.10	12.21	15.74	13.48
SD	0.62	0.70	0.89	0.80
Tube well	11.70	12.85	18.72	14.47
SD	0.57	0.43	1.14	0.92

Table.4 Correlation coefficient (r) between metallic cations in soil and biological properties of soil in sewage irrigated field

DTPA metallic cations / biological properties of soil	Zn	Fe	Cu	Mn	Ni	Pb	Cd	Cr
Mansoon								
MBC	-0.466	-0.512*	-0.520*	-0.539*	-0.357	-0.213	-0.403	-0.462
MBP	-0.489	-0.551*	-0.573*	-0.566*	-0.387	-0.262	-0.483	-0.460
MBN	-0.386	-0.436	-0.475	-0.449	-0.223	-0.214	-0.329	-0.367
Dehydrogenese	-0.715**	-0.777**	-0.802**	-0.813**	-0.582*	-0.420	-0.658*	-0.708**
Alkaline phosphatase	-0.592*	-0.644*	-0.620*	-0.655*	-0.390	-0.271	-0.506*	-0.582*
Winter								
MBC	-0.550*	-0.517*	-0.576*	-0.547*	-0.528*	-0.366	-0.451	-0.344
MBP	-0.823**	-0.802**	-0.833**	-0.824**	-0.779**	-0.629*	-0.714**	-0.604*
MBN	-0.523*	-0.469	-0.556*	-0.500*	-0.488	-0.315	-0.422	-0.312
Dehydrogenase	-0.647*	-0.611*	-0.669**	-0.634*	-0.604*	-0.446	-0.540*	-0.431
Alkaline phosphatase	-0.695**	-0.652*	-0.713**	-0.669**	-0.633*	-0.484	-0.587*	-0.483

Dehydrogenase and alkaline phosphatase enzymes

Activities of dehydrogenase and alkaline phosphatase enzymes were also lower in sewage and diluted sewage irrigated soil over tube well water (Table 3). This might be due to the build- up of heavy metal toxicity in soil. This reduced dehydrogenase activity in sewage irrigated soil was due to toxic effect. This is in conformity with the results of Rao *et al.,* (1993) who reported lower activities of various enzymes in contaminated soils, irrigated with various industrial effluents.

Dehydrogenase activity decreased with increased extent of contamination. Heavy metal inhibits enzymatic reaction by bonding themselves to substrate, creating complex with substrate, blocking reactive functional group of enzymes (Mikanova, 2006). Negative correlation between dehydrogenase enzyme and heavy metal was also reported by Friedlova (2010). The results get support from the finding of Mikanova (2006) and Victor (2008)

It can be concluded that continuous use of sewage irrigation recorded, the amount of microbial biomass C, N and P and soil enzyme activity declined irrigated soils as compared to tube well irrigated soils. Thus, it is justifiable to establish a municipal sewage treatments plant before such sewage water is diverted for the irrigation.

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