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Heavy metal contaminants in water-soil-plant-animal continuum due to pollution of Musi river around Hyderabad in India

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With rapid urbanization and industrialization in major cities, large quantities of industrial effluents get mixed with urban sewage water and also with river water in some cases. Hence the water is getting contaminated with harmful heavy metals, which are accumulating through the out flows from these industries. The soils irrigated continuously with polluted water subject to chemical degradation (Singh 2002, Giridhar *et al.* 2002). In the water-soil-plant-animal continuum, the contaminants may be carried over to the milk of animals and from there to human system when the contaminated milk is consumed. Present study was therefore, undertaken to survey the extent of heavy metal contamination in untreated sewage water of Musi river and impact of continuous irrigation on heavy metal accumulation in soil-plant-milch animal continuum.

A survey was carried out all along the Musi river (Ranga Reddy and Hyderabad districts of Andhra Pradesh in India) to study the relationship between water, soil, plant and animal system. Effluent water, soil and plant samples were collected along the Musi river (from 22 sites with a spacing of 1 to 2 km) along the down stream by following the stratified random sampling technique. Besides this, urine, milk and serum samples were also collected from milch animals, which were fed with the grass grown with sewage water on these polluted sites. Sewage water, urine and milk samples were analysed for micronutrients and heavy metals. Soil samples were extracted with DTPA extractant (Lindsay and Norwell 1978). Plant samples were acid digested after thorough washing and were analyzed for micro nutrients and heavy metals (Jackson 1973). Serum samples immediately after collection were added with heparin, an anticoagulant to avoid coagulation. Water, milk, urine and serum samples were directly fed to the atomic absorption spectrophotometer for analyzing the micronutrients and heavy metals. An interpretation of the data was done using the available permissible limits in the literature.

Composition of untreated sewage water

The effluent water was slightly acidic to neutral in reaction (pH-6.3 to 7.5). Soluble salt content ranged from 2.58 to 4.07 dS m^{-1}. Sewage water collected all along the Musi river at different sites was contaminated with high amounts of heavy metals like cobalt, cadmium, nickel and lead which ranged from 0.017 to 0.11 mg L^{-1}, 0.002 to 0.054 mg L^{-1}, 0.003 to 0.21 mg L^{-1} and 0.03 to 0.80 mg L^{-1}, respectively, and the corresponding mean contents were 0.053, 0.025, 0.062 and 0.21 mg L^{-1} (Table 1). Samples analyzed had excess amounts of cadmium, cobalt and nickel to an extent of 89, 68 and 11% respectively. Cobalt was 10.6-times more followed by cadmium (5-times) than the permissible limits (WHO 1995). The water samples were not contaminated with other trace metals. Similar study was also reported by Rai *et al.* (2001) in Lucknow district of Uttar Pradesh, India as the most of the water bodies being used for the cultivation of the edible aquatic plants were found to be contaminated with a variety of toxic metals like iron, copper, chromium, manganese and lead. The concentrations of chromium, lead and iron in the water were much higher than the recommended permissible limits of WHO (1995).

Heavy metal accumulation in soils

The soils under study were acidic to almost neutral in reaction (5.04 to 7.58), electrical conductivity ranged from 0.02 to 6.12 dS m^{-1}, which may be due to high amounts of soluble salts in irrigation water such as chlorides, sulphates and bicarbonates due to the contamination. Sharma *et al.* (1994) also reported similar results. Organic carbon content was 0.59 to 15.32% and these higher values may be due to higher contents of organic matter in the sewage water (Bhupal

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Table 1. Heavy metal contents in untreated sewage effluent, soils and plants of Musi river of Hyderabad city

Element	Effluent (mg/L)		Soil (mg/kg)		Plant (mg/kg)	
	Range	Mean	Range	Mean	Range	Mean
Cadmium	0.002 –.054	0.025	0.016–2.43	0.37	0.42–3.95	0.79
Chromium	Traces .	Traces	0.18–2.27	1.32	1.80–11.6	4.90
Nickel	0.003 – .210	0.062	0.29–8.21	2.79	2.10–6.78	4.34
Lead	0.03 – 0.80	0.21	1.44–68.56	12.58	11.25–7.70	19.22
Cobalt	0.017 – .110	0.053	0.18–2.60	0.52	0.70–4.25	2.39
Zinc	Traces –026	0.003	0.91–19.56	10.96	9.3–90.9	44.88
Copper	0.011 – 0.20	0.011	1.21–39.60	15.83	4.6–44.5	12.76
Iron	Traces	Traces	11.10–149.48	75.90	23 -1735	459
Manganese	Traces	Traces	5.43–24.2	13.60	22.7–249.0	92.86

Raj *et al.* 1997). Soils irrigated with Musi sewage waters were highly polluted with heavy metals. The contents of iron, copper, lead, nickel and cadmium are given in Table 1.

The per cent samples having excess amount of heavy metals were 66, 56, 32, 22 and 10 for iron, copper, lead, nickel and cadmium, respectively. Iron was 7.6-times more than the normal level followed by copper (3.2), lead (2.5), zinc (2.2) and nickel (1.4). Though copper and iron were low in waters, the absorption of these nutrients by the soils may be high which was reflected in higher quantities in soils. Sujatha *et al.* (2001) analyzed water, soil, suspended load and biomass samples collected from a sewage and sludge treated lake around Mysore of Karnataka state of India and revealed that all the matrices suspended particulate matter, lake bed sediment and biomass of the lake showed higher concentrations of heavy metal cations when compared to the WHO standards, indicating metal toxicity in the lake. Patel *et al.* (2004) also reported that the soils irrigated with the effluents had higher contents of micronutrients and heavy metals as compared to the corresponding well irrigated soils.

Heavy metal accumulation in plants

Plants growing on polluted soil irrigated with sewage water recorded high amounts of heavy metals. The contents of heavy metals i.e., lead, iron, chromium, nickel, zinc, copper, manganese and cobalt are given in Table 1. The per cent samples having excess amounts ranged from 4% (Cd) to 100% (Pb). All the samples analyzed had excess amounts of lead (100 %), iron (60 %), zinc (56%), chromium (36 %), nickel (24 %) and cadmium (4%).

The above results are in conformity with that of Rai *et al.* (2001) who reported that the edible parts of aquatic plants grown on the water bodies in Lucknow district in Uttar Pradesh state of India were bio-concentrated from their surrounding water with metals like chromium, lead and iron significantly and the concentration of these metals were higher than the recommended permissible levels in water and also Bansal (2004) where in the concentration of heavy metals was found to be more in different parts of vegetables which were grown in sewage water irrigated soils than in tube well water irrigated samples.

Table 2. Heavy metal contamination in milk, urine and serum of milch animals fed on forage grown on soils irrigated with untreated sewage of Musi river

Element	Milk (mg/L)		Urine (mg/L)		Serum (mg/L)	
	Range	Mean	Range	Mean	Range	Mean
Cadmium	0.042–0.76	0.062	0.016–0.121	0.053	0.013–0.033	0.022
Chromium	0.45–1.41	0.78	0.102–0.305	0.226	0.038–0.966	0.140
Nickel	0.150–0.231	0.197	0.108–0.333	0.224	0.002–0.990	0.029
Lead	0.52–0.96	0.73	0.450–1.220	0.850	0.154–0.814	0.385
Cobalt	ND	ND	0.070–1.342	0.345	0.460–0.150	0.077
Zinc	2.64–16.3	6.3	0.006–0.199	0.074	0.276–0.697	0.496
Copper	0.19–0.77	0.42	0.002–0.534	0.06	0.128–0.454	0.302
Iron	1–35.7	11.9	0.130–0.830	0.37	4.30–26.68	24.16
Manganese	0.44–1.80	0.92	0.020–0.090	0.058	0.02–0.60	0.04

ND, Not determined.

Heavy metal contamination in milk

Milk samples were highly contaminated with all the heavy metals except copper. All the heavy metals except zinc were in toxic limits to an extent of 100%. The contents of iron, chromium, lead, cadmium, manganese, nickel and zinc are given in Table 2. Lead, cadmium, copper and zinc accumulation and concentration in certain tissues and organs of cows markedly exceeded maximum admitted limits in an area of heavy industrial pollution with heavy metals in particular (Avram *et al.* 2000). Iron content is 40-times more than the normal permissible limits for drinking waters (BIS 1991) followed by chromium (15.6 times), lead (14.6 times), cadmium (12.4 times), manganese (9 times), nickel (3.4 times) and zinc (1.26 times). Swarup *et al.* (1997) also reported that the concentrations of lead and cadmium in blood and milk samples of milch animals in Kanpur city, India were significantly high.

Heavy metal content in the urine and serum of milch animals

Urine and serum samples of the milch animals fed with polluted grass were also analyzed for heavy metals. The pollutant elements in these were comparatively higher than their contents in normal milch animals, though the permissible limits for urine and serum are not known (Table 2). Cadmium content of the grain crops grown on acid soils in Hungary was significantly high. In the blood serum of cows consuming these crops, cadmium levels of 23–24 nmol L^{-1} were detected (Kovacs *et al.* 1998).

Irrigation of soil continuously with Musi river effluents likely to cause high build up of heavy metal pollutants in soils and in forage plants, thereby almost all milk samples obtained from animals fed with such forages had higher amounts of contaminants i.e., above the safe limits which might have carried over through forage and polluted water into dairy animals. There is also possibility of transmittance of heavy metal load into the human food chain through milk or meat produced in such areas as urine and serum of milch animals contained high amounts of heavy metals.

SUMMARY

The present study was undertaken to survey the extent of heavy metal contamination in untreated sewage water of Musi river and impact of irrigation with this water on soil-plant-milch animal continuum. Values of cadmium, chromium, nickel, lead, cobalt, zinc, copper, iron and manganese were studied in milk, urine and serum.

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