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BIOACCUMULATION OF HEAVY METALS BY WHEAT AND RAIRA PLANTS GROWN IN CONTAMINATED SOILS

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ABSTRACT

The rapid growth of industrialization and urbanization led to the acute problem of shortage of water and the use of industrial and sewage wastewaters albeit untreated as an alternative water resource for irrigation. The irrigation with untreated sewage wastewaters have been found to give better yields to cereal crops. The ground water, soils and contaminated soils and the plant crops, wheat and raira irrigated using the sewage waste water have been analysed for Fe, Cu, Zn, Mn, Cr, Cd, Pb, Co and Ni for three consecutive years 2001, 2002 and 2003 by AAS. It was found that the concentration of metal ions is continuously increasing. The DTPA soil test is unable to predict precisely the uptake of metals by plants.

Key words : Bioaccumulation, wheat, Raira, contaminated soil, Heavy metals.

INTRODUCTION

The main features of the desert are typical high differential temperature during day and night, high wind velocity, high solar radiations and an over all erratic rain fall occupying million square kilo meters. The North–West Rajasthan (India) constitutes the famous 'Thar Desert' with total area of about 0.2 15–20 cms during a year. The geological make up of the region is basically alluvial composed of discontinuous heterogeneous mixtures of gravel and wind blow sand derived from 'Vindhayan Rocks'. The fertility status of the soil[1] is poor and is characterized by low organic carbon (0.18–0.11%), very poor water holding capacity, high infiltration rate, low nitrogen content (100.35–0.15), phosphorus (35–5), exchangeable potassium (465–175), sodium (800–375), calcium (900–350) and magnesium (300–155) (all in mg/kg).

The ground water is the only natural resource of irrigation and drinking purpose. The quality of water, too is deteriorating with rapid growth of industrialization and urbanization, and as such this region is experiencing an acute problem of shortage of water. This has led to the use of industrial and sewage wastewaters albeit untreated as an alternative water resource of

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irrigation. The irrigation of cereal crops and vegetables with untreated wastewaters have been found to give better yields[2,3].

The concentration of metal ions in the sewage wastewaters has been found more as compared to ground water[4]. The continual use of untreated sewage effluents on agricultural soils is apt to increase the concentration of potential toxic metal ions such as Cd, Pb, Hg etc. in the soils and plants, growing in it, to a harmful level.[5–10] The effluents of this region has not been paid proper attention. In the present communication, the analysis of metal ions, namely manganese, iron, cobalt, nickel, copper, zinc, cadmium and lead in the contaminated soils and in the cereal plants irrigated with sewage wastewater and fresh water has been reported. The efforts are also made to correlate the results with the predicted uptake of trace metals by plants using DTPA–Soil Test.

EXPERIMENTAL

Materials : Two fields around Jodhpur using purely sewage waste water and ground water for the irrigation of wheat and raira crops were selected for this study. These fields are situated at the bank of Jojari river, approximately 16–17 km away from Jodhpur. The sampling of the soils, wheat and raira plants were made, by standard procedures[11], fortnightly, from November to February over two consecutive years, 2001 and 2003.

Reagent and chemicals : All the chemicals used in this study were of analytical grade and all the solutions were prepared in double distilled water obtained from an all glass still.

Methods : The soils were sum dried and pulverized to pass through 40 mesh sieve, 3 g of each sample were digested in HNO_3–$HClO_4$ mixture for over two hours, filtered and washed thrice with distilled water. The filtrates were mixed together, the volumes were made up to 25 mL and analysed for the selected metal ions by AAS (Shimadzu, Japan).

The wheat and raira plants were collected from the field selected for the study, washed with water followed by washing with distilled water and air dried. These were separately powdered to pass through the 40 mesh sieve. 2 g of each powder were digested in 100 mL water containing 30 mL concentrated HNO_3 and 12 mL $HClO_4$ (70%) for three hours on medium heat, cooled and the residue was redigested in concentrated nitric acid, heated for thirty minutes, cooled and filtered. The filtered aliquots were mixed, concentrated on water bath, made up to 25 mL and analysed for trace metal ions using AAS.

The concentration of metals in soils was evaluated from DTPA extract, which was obtained by stirring 50 g soil in 100 mL solution of DTPA (0.01 M) in ethanolamine for one hour at 150–200 RPM.

The samples of water and waste water were collected and analysed for pH, dissolved solids, dissolved oxygen, chemical oxygen demand, conductivity, hardness, fluoride, phosphate, sulfate, N–nitrate, N–nitrite, chloride, copper, cadmium, iron, nickel, cobalt, zinc and manganese by known procedures[12].

RESULTS AND DISCUSSION

Analysis of water and waste–water : The chemical analysis of ground water and sewage waste water is given in table 1. The sewage waste water is colorless and foul–smelling.

Table 1. Physico–chemical properties of ground water and sewage waste water

Parameter	Ground water	Sewage waste water
Color	Colorless	Dirty
pH	7.5–8.5	8.0–8.5
Dissolved Solids	2400–3000	3500–4300
Suspended Solids	–	150–550
Dissolved Oxygen	6.2–6.8	Nil
Chemical Oxygen Demand	–	380–650
Hardness	200–380	50–120
Fluoride	1.05–1.15	1.00–1.03
Phosphate	0.1–0.25	0.5–0.85
Sulphate	250–320	280–350
N–Nitrate	Nil	Nil
Chloride	450–600	450–700
Alkalinity	170–190	45–120

* an average of at least 12 samples; * In mg/L except pH.

These are found deficient in dissolved oxygen and had high chemical oxygen demand. The results in Table 1 shows an increase of total dissolved solids by 50% as compared to ground water. A five fold increase in the phosphate was also observed which may be considered useful for the plant growth. Both ground water and sewage waste water contain fluoride, 1–1.5 mg/L which is higher than the permissible limits (1 ppm for drinking water). The increased fluoride in drinking water is highly undesirable as fluoride tends to accumulate in human bones progressively with the age and an excess of it can cause mottling of the enamel in the teeth of human beings and domestic animals. The ground waters of this region are characterized by high salt contents[13], the total hardness, measured as calcium, in the sewage water (50–120 ppm) was found to be much lower as compared to the ground water (250–380). This can be attributed to the formation of some insoluble salts of calcium and magnesium which are removed during the passage of waste water. The result of the analysis of metal ions for the period of three consecutive years 2001–03 in the soils, sewage waste waters and the wheat and raira plants irrigated at all the stages of growth by the fresh water and the sewage waste water have been reported in the Table 2. The results show that the concentration of metal ions in the sewage waste water is 2 to 3 times higher than the ground water. The concentration of metal ions in the contaminated soils is considerably high as compared to uncontaminated soils. This can be attributed to the accumulation of metals due to the continuous irrigation with sewage waste waters from the periods unknown. The increased concentration of metals in the soils is absorbed by the plants growing in it and enters in the food chain through it.

Table 2. Metal ion concentration in ground water, sewage waste waster and soil

Metal Ion	Ground water mg/L	Sewage waste water mg/L	Soils uncontaminated μg/g	Contaminated μg/g
Fe	110–150	145–250	650	710
Cu	0.4–1.0	1.5–2.0	0.045	13.5
Zn	1.6–2.1	4.0–5.8	0.031	13.8
Mn	0.02–0.06	0.04–0.08	0.052	0.90
Cr	0.02–0.05	0.03–0.51	0.003	0.75
Cd	0.00–0.00	0.01–0.04	0.005	0.05
Pb	0.02–0.08	0.06–0.38	Nil	11.8
Co	Traces	Traces	Traces	Traces
Ni	Traces	Traces	Traces	0.032–0.05

Table 3. Metal ion concentration in wheat and raira plants and DTPA soil test

Metal Ion	Wheat (μg/g)			Raira (μg/g)			DTPA soil test μg/g
	2001	2002	2003	2001	2002	2003	
Mn	31.0	32.0	31.8	35.0	34.0	35.5	29.31
Fe	40.0	41.4	42.0	40.0	41.8	42.0	35.50
Co	2.0	2.2	2.1	Traces	Traces	Traces	2.50
Ni	Traces	Traces	Traces	Traces	Traces	Traces	Traces
Cu	20.8	21.0	21.5	26.0	27.0	25.5	34.00
Zn	8.40	8.0	8.10	7.80	8.20	8.40	9.50
Cd	0.98	1.30	1.25	1.63	1.70	2.00	3.50
Pb	Traces	Traces	Traces	Traces	Traces	Traces	5.80
Cr	3.30	3.40	3.30	3.60	3.80	3.70	5.90

Concentration of metal ions in wheat and raira : The mean concentration of Fe, Co, Ni, Cu, Zn, Cd, Pb and Mn in wheat and raira plants of at least 12 samples in triplicate, irrigated with round water as well as sewage waste water is given in Table 3. These plants do not show any preferential absorption and accumulation of metal ions under investigation, except for Cd and Ni.

Copper

The concentration of copper in the wheat and raira plants grown in the two conditions was found to be of the same order (21–26 μg/g). These results are in agreement to the observations of Timperlay *et al.*[13] that the concentration of copper in the vegetation tends to remain fairly constant irrespective of the amount of the copper present in the soils. The toxicity of this metal have not been properly studied. The absorption of copper in large amounts, however, results in "Wilson Disease", in which the metal is deposited in the brain, skin, liver, pancreas and myocardium of humans.

Cadmium

The concentration of Cd in wheat irrigated with fresh water do not reach our detection limit, whereas in case of wheat irrigated with sewage waste water, the concentration of cadmium was found to be 1.3 μg/g. The cadmium in raira irrigated with ground water as well as the sewage waste water, however, was found in detectable concentrations (1.3 and 2.0 μg/g). The results of this study show that the cadmium concentration in these plants increases with increasing concentration of Cd in soils and sewage waste water. The increased contamination of soils with cadmium may lead to higher accumulation of Cd in wheat as well as raira. It is highly undesirable, as the Cd is one of the toxic metals, which is of particular concern to humans. It is reported that Cd accumulates in kidney, liver and reproductive organs.[15] It decreases growth and reduces protein and fat digestion. Thus the use of sewage waste water without any treatment for irrigation of cereal crops in these regions may prove dangerous in the long run.

Iron

The concentration of iron in the wheat and raira plants grown in two diverse conditions was found to be of the same order. However, the wheat plants were found to have three times more iron content than raira (Table 3). The iron in the prosthetic group of respiratory enzymes[16] is affected by excess metal.

Cobalt

The concentration of cobalt in the wheat plants does not reach our detection level, although it exists in trace amounts in the soils. The results indicate that raira plants contain 5 μg/g of cobalt. This may be due to the absorption of Co from the soils. The cobalt is not normally considered as hazardous; however in high doses, it is known to effect haemoglobin content of blood[17].

Nickel

The average amount of nickel found in the wheat and raira plants is 13 to 22 μg/g, respectively. Nickel has a wide range of industrial usage. There are fair amounts of evidence about this element being carcinogenic[18,19] and therefore, the presence of the nickel in these plants is a serious matter.

Zinc

Zinc is perhaps the least toxic of all the heavy metals. Zinc acts as an enzyme activator[16]. It is, infact, an essential element in the plant and animal nutrition. However, it is our contention that all the elements may prove toxic if absorbed in excess and zinc is no exception to it. The concentration of Zn in the two plants was found to be 8.00 to 8.50 μg/g.

Lead

The concentration of lead in wheat and raira plants do not reach our detection level, although it is very much present in the fresh as well as sewage waste waters and also in the soils (Tables 2 and 3). The results of this study therefore, show that the increased contamination of lead in the soils shall not elevate the concentration of this metal in the wheat and raira plants and this may also be true for other plants too.

Manganese

The concentration of manganese in these plants grown in the two different conditions was found to be of the same order i.e. 31–35 μg. Manganese is probably the third trace metal found in larger amounts in the animals and plant life[20]. The introduction of this element in the environment is not really a serious problem, as its natural level in the soil, water, plants and animals is too high to raise their concentration significantly by human activity.

DTPA–Soil Test

The mean concentration of DTPA extractable metals have been given in Table 3. The lead has been found as the major species extractable by DTPA followed by chromium, cadmium, zinc and copper, respectively. From the results in Table 3, it is evident that the cobalt and lead have been discarded by wheat and raira although they are present in the soils as well as in DTPA–Soil extract. It was also found that the concentration of the copper and manganese in these plants is maintained at a constant level irrespective of the concentration in the soils, however the increased concentration of zinc and iron in the soils do increase the concentration of these metals in the plants. The concentration of iron, manganese, cobalt and nickel in the DTPA extract were found smaller as compared to other metals, although these metals have been found in appreciable quantities in these plants. The results are in accordance with the findings of Lindsay and Norwell[22] that the DTPA–soil extract method has not been found to predict precisely the uptake of metals and nutrients from the soils by plants.

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