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Assessment of Heavy Metal Contents in Some Vegetables Grown in Polluted Water of Industrial Town Gajraula, Uttar Pradesh, India

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Abstract: The present study was carried out to quantitatively analyze the contents of eight heavy metals in four important Indian vegetables grown in the soil irrigated with different concentrations of industrial waste water of the industrial town Gajraula, North India. The dried powdered vegetable materials thus grown were subjected to microwave assisted wet digestion for the preparation of test samples for analysis. The vegetable and water samples were analyzed by using atomic absorption spectrophotometer (AAS). From the results of the present investigation, it can be concluded the industrial waste water of Gajraula if suitably mixed with fresh ground water may be used for cultivation of vegetables that could be safe for human consumption.

Key words: Vegetables · Toxicity · Heavy Metals · Cultivation · Waste Water

INTRODUCTION

Accumulation of toxic industrial effluents in the soil, air and water is continuously increasing due to fast urbanization and extensive pollution of the environment. Among these toxic substances, presence of heavy metals which are ubiquitous in nature, cause serious harmful effects on living organisms [1]. Plants are sensitive to environmental conditions and they accumulate these heavy metals in their harvestable parts (*via* root uptake, foliar adsorption and deposition of specific elements in leaves) and intensity of this uptake process can change the overall elemental composition of the plant [2]. Trace quantities of certain heavy metals, such as chromium, cobalt, copper, manganese and zinc are essential micronutrients for higher animals and for plant growth. Some of the heavy metals namely arsenic, lead, cadmium and mercury are not essential for plants and these are insidiously toxic to mammals.

Accumulation of heavy metals by plants may depend on plant species and soil properties. These heavy metals are not abundant in soil, but there may be an accumulation of these heavy metals through urban wastes and industrial effluents. The uptake of heavy metals in cereals and vegetables is likely to be higher and accumulation of these toxic metals in human body created growing concern in the recent days [3].

A major pathway of soil contamination is through atmospheric deposition of heavy metals from point sources, such as metalliferous mining, smelting and industrial activities. Other non point sources of contamination affecting predominately agricultural soils are due to various inputs, such as fertilizers, pesticides, sewage sludge, organic manure and compost [4]. Water is the next important input to fertilizer for crop production. If water is polluted, it may be dangerous for plants, animals as well as for human beings.

Vegetables are important food crops of India and are rich in vitamins and minerals which are wholesome and very essential for maintaining good health. Maximum vegetarian people of the world live in India. Different kinds of vegetables are grown during the year in India. The possibility that the toxic heavy metals can be transmitted to humans and animals through the use of vegetables grown in polluted areas is a major concern today. Consumption of vegetables grown in polluted sites can cause serious consequences on human health. Therefore, there is a relevant necessity for assessment of these heavy metals in urban grown vegetables especially in industrially polluted areas to ascertain the level of heavy metal contaminants. Such information is vital for the production of quality vegetables as well as healthy foodstuffs. With this objective, the present study was designed to quantitatively analyze the levels of eight toxic

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Table 1: Vegetables used in the study

Serial Number	Common Names	Botanical Names	Parts used/analyzed
1	Spinach	*Spinacia oleracea*	Aerial parts
2	Brinjal	*Solanum melongena*	Fruits
3	Cauliflower	*Brassica oleracea*	Aerial parts
4	Radish	*Raphanus sativus*	Roots

heavy metals namely copper (Cu), cadmium (Cd), lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), nickel (Ni) and manganese (Mn) in four vegetables (Table 1) grown in the soil irrigated with different concentrations of waste water of the North Indian industrial town, Gajraula.

MATERIALS AND METHODS

Location and Growing of Vegetables: Gajraula town is approximately 115 Km. away from India's capital New Delhi on national highway NH-24, Delhi-Lucknow road. Gajraula is well known and one of the oldest industrial area of Uttar Pradesh (U.P.) state of India situated on globe at a longitude 78°13'48.75" E and latitude 28° 50'59.26" N at 679 feet above sea level (207 msl). The effluents and wastewater from all the industries (chemical units, pulp and paper, phosphate and fertilizer plant, textiles, pharmaceuticals, dairy products processing units and others) collectively drain through a local stream known as *Bagad nallah* which assumes the shape of a small river, especially in rainy season. Waste water was collected from this ditch for irrigation. The vegetables were cultivated in Peepli Ghosi region of Gajraula, J.P. Nagar (U.P.) in four groups (separate fields) during 2012-2013 in following ways:

- Vegetables irrigated with fresh ground water (from hand-pump).
- Vegetables irrigated with waste water (100%).
- Vegetables irrigated with fresh water mixed with 50% of waste water.
- Vegetables irrigated with fresh water mixed with 25% of waste water.

No fertilizers/insecticides were applied for cultivation. The crops were harvested on maturity. After harvesting, the required plant parts (Table 1) were cleaned thoroughly with running tap water, cut into small pieces and dried artificially at 40°C and ground mechanically into coarse powders and subjected to analysis. The water (fresh and waste) samples were also analyzed.

Table 2: Operating parameters for the instrument.

S. No	Heavy metals	Wave length (nm)	Lamp Current (mA)	Slit width (nm)
1	As	193.7	380	0.7
2	Pb	283.3	380	0.7
3	Cd	228.8	4	0.7
4	Cr	357.9	25	0.7
5	Ni	232.0	25	0.2
6	Cu	324.8	25	0.7
7	Zn	213.9	25	0.7
8	Mn	279.5	25	0.2

Reagents and Standards: Analytical grade hydrogen peroxide and Suprapure nitric acid were from Merck, Germany. NIST Traceable Standard stock solutions of all test heavy metals were from Merck, Germany. All the solutions and dilutions were prepared by using Milli-Q water.

Sample Preparation: The samples of vegetables were prepared by microwave assisted wet digestion [5]. Briefly, 0.5 g of powdered vegetable material was mixed with 5 ml of nitric acid (68%) and 1 ml of hydrogen peroxide (30%) solution in a clean dry Teflon digestion tube and subjected to microwave digestion in a microwave digester (CEM Corp., USA). After digestion the digest was filtered and transferred into 25 ml volumetric flask and made up to volume with Milli-Q water. Further dilutions were made if necessary. The water samples were used as received without digestion.

Instrumental Procedure: The standard stock solutions were diluted to obtain working standard solutions and stored at 4°C. The prepared samples were immediately analyzed using atomic absorption spectrophotometer (AAS PerkinElmer Analyst 400 controlled by the WinLab32™ for AA software) equipped with graphite furnace (HGA® 900 graphite furnace *i.e.*, GF). The instrument was operated in GF mode, the argon gas flow was 3 L/min and the temperature parameters were followed as recommended by the manufacturer. Optimized operating parameters of various heavy metals are listed in Table 2. All analyses were run in batches, which included standards (for calibration curves), reagent blanks and plant samples. The heavy metal concentrations were expressed in parts per million (ppm) by weight in case of water samples and with respect to the dry weight of the vegetables. All the samples were analyzed in duplicates and the result averaged.

RESULTS AND DISCUSSION

Nowadays, atmosphere, water and soil are continuously being polluted with chemicals along with heavy metals due to dynamic development of industries and modernization along with extensive use of pesticides and fertilizers in cultivation of crops. In turn, these pollutants and heavy metals are getting accumulated in the plants growing in the polluted areas, which subsequently enter the human food chain *via* plant parts and extracts or preparations thereof. The environmental impact of these metals, as well as, their adverse health effects has been a source of major concern [6].

Recently, vegetable crops have been criticized as a potential source of heavy metal toxicity to both human and animals. The most potential heavy metals implicated in human toxicity include arsenic, lead, cadmium and mercury; although nickel, manganese, zinc, copper and chromium may also cause toxicity [7]. However, vegetables are being regularly cultivated in industrial areas for consumption owing to gradual shrinkage of pure cultivation lands due to rapid industrialization and urbanization.

In the present study, except copper and zinc in very low levels, the fresh ground water did not show presence of any other heavy metals tested *i.e.*, Cd, Pb, Cr, As, Ni, Mn (Table 3). The results indicated that this water is satisfactory as non-polluted water in terms of metallic contamination. Therefore, it represented the non-polluted water control in the present study.

The water quality of *Bagad nallah* is a great concern to deteriorate the quality of the water (both surface water and ground water) and soil due to releasing their effluent without any adequate treatment and polluting the upper water table through the leaching process in and around the said industrial area [8]. The present study confirmed this fact in terms of heavy metal pollution. The waste water was found to be really contaminated with heavy metals. All the eight metals tested were found increasing in waste waters used for irrigation in a concentration dependent manner; Lead being the highest and arsenic being the lowest quantity present (Table 4).

Table 3: Heavy metal contents of fresh water.

Sl. No.	Parameters	UOM	Test Results
1	Copper (as Cu)	ppm	0.03
2	Cadmium (as Cd)	ppm	ND, [DL-0.002]
3	Lead (as Pb)	ppm	ND, [DL-0.005]
4	Chromium (as Cr)	ppm	ND, [DL-0.025]
5	Arsenic (as As)	ppm	ND, [DL-0.005]
6	Zinc (as Zn)	ppm	0.28
7	Nickel (as Ni)	ppm	ND, [DL-0.02]
8	Manganese (as Mn)	ppm	ND, [DL-0.05]

ND: Not detected. DL: Detection limit. UOM: Unit of measurement

Arsenic was not detected in any vegetables cultivated with all concentrations of waste water as well as with fresh water. Levels of other seven test heavy metals were increased with increasing concentration of waste water in irrigation. Among them, vegetables grown in 25% waste water exhibited very close heavy metal composition as compared with those grown in freshwater (Tables 5-8) indicating the reliable safety in terms of heavy metal contamination.

Arsenic, lead and cadmium are non essential elements for plants and these are potentially toxic to humans. However, arsenic was not detected here. The concentration levels of Pb and Cd in our study is higher than the allowable levels of Pb and Cd as set by the Commission of the European Communities (CEC) and WHO. Lead limit set by the CEC was 0.3 ppm fresh weights for leafy vegetables and 0.1 ppm fresh weights

Table 4: Heavy metal contents of waste water.

			Test Results		
Sl. No.	Parameters	UOM	Wastewater 25%	Wastewater 50%	Wastewater 100%
1	Copper (as Cu)	ppm	0.19	0.39	0.64
2	Cadmium (as Cd)	ppm	0.07	0.14	0.26
3	Lead (as Pb)	ppm	0.34	0.67	1.12
4	Chromium (as Cr)	ppm	0.09	0.22	0.42
5	Arsenic (as As)	ppm	0.03	0.06	0.13
6	Zinc (as Zn)	ppm	0.26	0.49	0.88
7	Nickel (as Ni)	ppm	0.13	0.26	0.44
8	Manganese (as Mn)	ppm	0.25	0.43	0.79

UOM: Unit of measurement

Table 5: Heavy metal contents of spinach.

			Test Results			
SI.No.	Parameters	UOM	Grown in soil irrigated with fresh water	Grown in soil irrigated with 25% wastewater	Grown in soil irrigated with 50% wastewater	Grown in soil irrigated with 100% wastewater
1	Copper (as Cu)	ppm	10.84	12.62	15.40	22.60
2	Cadmium (as Cd)	ppm	0.96	1.08	1.06	1.75
3	Lead (as Pb)	ppm	4.84	5.06	5.21	5.47
4	Chromium (as Cr)	ppm	0.56	0.60	0.62	0.66
5	Arsenic (as As)	ppm	ND, [DL-0.02]	ND, [DL-0.02]	ND, [DL-0.02]	ND, [DL-0.02]
6	Zinc (as Zn)	ppm	17.0	18.7	23.2	43.1
7	Nickel (as Ni)	ppm	2.15	2.65	3.94	5.72
8	Manganese (as Mn)	ppm	8.6	9.6	12.49	23.2

ND: Not detected. DL: Detection limit. UOM: Unit of measurement

Table 6: Heavy metal contents of brinjal.

			Test Results			
SI.No.	Parameters	UOM	Grown in soil irrigated with fresh water	Grown in soil irrigated with 25% wastewater	Grown in soil irrigated with 50% wastewater	Grown in soil irrigated with 100% wastewater
1	Copper (as Cu)	ppm	5.59	6.11	6.87	6.91
2	Cadmium (as Cd)	ppm	0.97	1.09	1.80	1.88
3	Lead (as Pb)	ppm	0.66	0.77	0.77	0.82
4	Chromium (as Cr)	ppm	0.39	0.44	0.47	0.48
5	Arsenic (as As)	ppm	ND, [DL-0.02]	ND, [DL-0.02]	ND, [DL-0.02]	ND, [DL-0.02]
6	Zinc (as Zn)	ppm	19.31	20.15	24.15	31.52
7	Nickel (as Ni)	ppm	0.73	0.79	0.84	0.92
8	Manganese (as Mn)	ppm	12.15	13.66	18.66	24.52

ND: Not detected. DL: Detection limit. UOM: Unit of measurement

Table 7: Heavy metal contents of cauliflower.

			Test Results			
SI.No.	Parameters	UOM	Grown in soil irrigated with fresh water	Grown in soil irrigated with 25% wastewater	Grown in soil irrigated with 50% wastewater	Grown in soil irrigated with 100% wastewater
1	Copper (as Cu)	ppm	6.07	6.62	7.96	9.21
2	Cadmium (as Cd)	ppm	0.97	0.97	1.01	1.09
3	Lead (as Pb)	ppm	1.72	1.64	1.80	1.86
4	Chromium (as Cr)	ppm	0.24	0.24	0.25	0.25
5	Arsenic (as As)	ppm	ND, [DL-0.02]	ND, [DL-0.02]	ND, [DL-0.02]	ND, [DL-0.02]
6	Zinc (as Zn)	ppm	30.38	32.65	40.11	52.62
7	Nickel (as Ni)	ppm	2.86	2.96	3.02	3.88
8	Manganese (as Mn)	ppm	22.56	24.11	28.80	39.66

ND: Not detected. DL: Detection limit. UOM: Unit of measurement

Table 8: Heavy metal contents of radish.

			Test Results			
Sl. No.	Parameters	UOM	Grown in soil irrigated with fresh water	Grown in soil irrigated with 25% wastewater	Grown in soil irrigated with 50% wastewater	Grown in soil irrigated with 100% wastewater
1	Copper (as Cu)	ppm	3.31	3.42	4.01	5.97
2	Cadmium (as Cd)	ppm	0.33	0.32	0.36	0.47
3	Lead (as Pb)	ppm	0.67	0.66	0.66	0.71
4	Chromium (as Cr)	ppm	0.11	0.12	0.17	0.21
5	Arsenic (as As)	ppm	ND, [DL-0.02]	ND, [DL-0.02]	ND, [DL-0.02]	ND, [DL-0.02]
6	Zinc (as Zn)	ppm	19.66	16.55	22.33	48.33
7	Nickel (as Ni)	ppm	2.10	2.16	2.35	3.13
8	Manganese (as Mn)	ppm	10.52	11.62	13.99	24.72

ND: Not detected. DL: Detection limit. UOM: Unit of Measurement

for all remaining vegetables. The allowable level of Cd, as set by the CEC and WHO was 0.2 ppm fresh weights for leafy vegetables and fresh herbs, 0.1 ppm for stem and root vegetables [9]. Thus, the level of Pb, Cd and Ni concentrations in the vegetables in our study were higher than those found in such vegetables from other countries, but they were lower than the maximum level allowed by Prevention of Food Adulteration Act (PFA), 1954, India for Pb, Cd and Ni are 2.5, 1.5 and 5.0 ppm, respectively [10]; when cultivated with 25% waste water.

High concentration of these heavy metals in polluted area's vegetables might be due to high contents of metals in the soil as caused by irrigation with metal contaminated waste water released from industries. Gajraula is a town in Amroha district of the state Uttar Pradesh, India. Gajraula, industrial area being a prominent industrial area of western Uttar Pradesh, its signifies to diverse group of industries, which includes large distillery and its associated chemical units, paper, phosphate fertilizer plant, textiles, pharmaceuticals, dairy and other units. The industrial effluents contain toxic chemicals, hazardous compounds, suspended solids and non-biodegradable materials. However, the higher concentrations of Pb, Cd and Ni in industrially polluted area (Gajraula) indicates that industrial activities, such as textile, paint, battery, milling and chemical industries contaminate or introduce heavy metals into the waste water and thus to soil.

Industrial effluents and urban pollution associated with sewage sludge, municipal waste water might have increased the levels of Pb, Cd and Ni intake of the vegetables. All these metals have toxic potential, but the detrimental impact becomes apparent only after decades of exposure (sub-chronic or chronic toxicity) [11]. Monitoring of heavy metals in edible plant tissues is essential in order to prevent excessive build-up of these metals in the human food chain.

Indian diet is primarily vegetarian and consists of various cereals and vegetables along with spices [12]. Vegetables are necessary not only to maintain balanced diet, nutrition and good health but certain vegetables have several health beneficial effects including amelioration of heavy metal induced toxicities [13, 14]. Therefore, it would be alarming if vegetables get contaminated with heavy metals.

Therefore, from the present investigation, it can be inferred that the industrial waste water form Gajraula town, polluted with heavy metals, should not be directly used for cultivation of vegetable crops; instead the same waste water if suitably mixed with fresh ground water of same region, may be used as irrigation water for cultivation of vegetables that could be safe for human consumption as the chronic health impact of heavy metal contamination thus would be nil or negligible. These findings suggest further work taking into consideration of variations in different heavy metals uptake for various plant species, fertilizers and different types of polluted water and soils.

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