# Heavy Metal Accumulation in Crops Irrigated with Poor Quality Water

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**Abstract**

Use of poor quality water in agriculture is growing globally. Discharge of untreated urban and industrial effluents in river and landfill deteriorates the surface and ground water quality for irrigation and domestic purpose. Only 31 and 60 percent of the urban effluent and industrial effluent are treated and rest are discharged as such in the ecosystem which is of concern. The periurban agriculture is mainly poor quality water based that receives sewage water from the urban parts which is growing day by day due to increase in population, industrialization and urbanisation.

A field study has been conducted in the Patna bye-pass area where farmers grow a variety of vegetables and field crops viz., red spinach, cowpea, okra, radish, bittergourd, sugarbeet, cabbage, turnip, spongegourd and pumpkin by lifting sewage water through pumps and open wells. Over the last 50 years the area receives a continuous disposal of sewage sludge from the city. Soils, plants and ground water samples were collected from sixteen sampling sites and analysed to estimate the heavy metal content.

The results depict that there was gradual increase in EC along the distance mostly up to 9.0 km away from the discharge point due to accumulation of soluble salts owing to disposal of sewage sludge, but the extent was below the tolerance limit for most of the crops. The organic carbon content in soils of various locations varied from 0.56 to 8.73 per cent with highest amount of organic carbon content nearest to the discharge point of sewage sludge. The Zn, Cu, Fe, Mn, Ni, Cr, Cd, Pb content in soils of various locations ranged from 2.41 to 4.32; 3.25 to 42.31; 10.43 to 25.08; 5.31 to 16.39; 1.0 to 6.8; 0.01 to 0.10; 0.08 to 0.68 and 3.2 to 10.20 ppm, respectively. The soils nearest to the discharge point of sewage treatment plant contained appreciably higher amount than other sampling sites away from the discharge point. The concentration of Zn and Cu in different crop species based on mean was found highest in Cabbage followed by Red spinach> Sugar beet> Chilli > Pumpkin > Maize > Cow pea> Okra > Brinjal > Spongegourd. The mean Fe concentration was found highest in Sugar beet followed by Red spinach> Cabbage> Maize> Chilli> Okra> Cow pea> Spongegourd> Pumpkin> Brinjal and mean Mn concentration varied in the order Red spinach> Sugar beet> Cabbage> Chilli> Spongegourd> Okra > Maize> Pumpkin > Brinjal > Cow pea. The mean Cd concentration in different crop species was found in the order: Red spinach> Poi>Sugar beet> Brinjal> Okra> Cabbage>Cow pea> Chilli>Sponge gourd> Pumpkin. Considering the mean Pb content in different plant species the crops were estimated as Cabbage>Poi>Red spinach>Sugar beet> Chilli>Brinjal>Okra> Cow pea> sponge gourd> Pumpkin>Maize. It has been observed that leafy vegetables contain more amounts of heavy metals which are of concern. Micro irrigation system, integrated water management and minimizing the concentration of the heavy metals in the source through pre-treatments are some of the suitable options for effective utilization of poor quality water in peri- urban agriculture.

## INTRODUCTION

Use of poor quality water in agriculture is growing globally. Poor quality water comprises of contaminated surface and groundwater owing to disposal of untreated polluted wastewater in the natural environment. Discharge of untreated urban effluent combining black water (faeces, urine and associated sludge, i.e. toilet water), grey water (kitchen and bathing wastewater), industrial effluent containing hazardous chemicals and other wastewater (van der Hoek, 2004) in river and landfill deteriorates the surface and ground water quality used for irrigation and domestic purpose. About 80 to 90 percent of the urban water supply for domestic purpose is returned to the urban environment as wastewater (Asano *et al.*, 2007). Only 31 and 60 percent of the urban effluent and industrial effluent are treated and rest are discharged as such in the ecosystem which is of concern. The periurban agriculture is mainly based on poor quality water i.e. direct or indirect use of untreated urban effluent which is growing day by day due to increase in population, industrialization and urbanisation. Sewage water being a rich source of nutrient, economically viable and easily available is used directly (through sewage outlet) or indirectly (polluted stream or river water) for vegetable production eaten raw or cooked.

About 75000 ha area in India is treated with untreated wastewater after China (4 Mha) and Mexico (1.9 Mha) (Scott *et al.*, 2010). The Indo-Gangetic basin area is the most fertile irrigated plain in India which is intensively cultivated under paddy-wheat cropping system. On the other hand wastewater use in periurban areas are prevalent for vegetable cultivation. An attempt has been made to assess the heavy and trace metal contamination in vegetables in the Patna bye-pass area where farmers grow a variety of vegetables and field crops viz., red spinach, cowpea, okra, radish, bittergourd, sugarbeet, cabbage, turnip, spongegourd and pumpkin by lifting sewage water through pumps and open wells.

## MATERIAL AND METHODS

The Patna bye-pass area is situated on both sides of National highway No. 31. The whole area is receiving a continuous disposal of sewage sludge for a period of over 50 years. The farmers grow a variety of vegetables and field crops by lifting sewage water through pumps and open wells. Altogether, 16 sampling sites were selected for collecting surface soils and various crop species during the year (Table 1).

Sixteen bulk surface soil samples (0-15 cm) of old alluvium (Vertisol) soils of bye-pass, Patna receiving sewage sludge effluents were collected and the chemical properties viz. pH, EC, organic carbon, available P, and available K were estimated as per standard procedure (Tandon 1993). The DTPA extractable micronutrients and heavy metal cations of soil samples viz., Zn, Cu, Mn, Fe and Ni, Cr, Co, Cd, Pb respectively were estimated using atomic absorption spectrophotometer.

The plant samples were also collected from the above mentioned sites from which soils samples were collected. The plants with roots were uprooted from the soils at the age of 45-50 days of the crops. The whole plants were washed thoroughly in acidulated water and then in distilled water. The washed samples were first dried in air then in an oven at $65^0$C. The dried samples were powdered in grinder. Powdered plant samples (0.5 g) were digested in tri-acid mixture of $HNO_3$:$HClO_4$:$H_2SO_4$ in the ratio of 10:3:1 on hot plate. It was fully digested till few drops of white residue were left. The residue was dissolved in double-glass distilled water and final volume was made to 50 ml. The samples were filtered and used for analysis for Zn, Cu, Mn, Fe, Ni, Cr, Cd and Pb through atomic absorption spectrophotometer.

## RESULTS AND DISCUSSION

### Soil characteristics

The pH, EC and organic carbon content of the soils ranged between 6.07 to 8.13, 0.33 to 2.30 $dSm^{-1}$ and 0.56 to 8.73 per cent respectively. The pH increased (r = 0.81**) and organic carbon decreased (r = -0.86**) with distance whereas EC fluctuated showing overall decrease with increase in the distance from the discharge point. This might be due to disposal of soluble salt through the open channel. Although, there was accumulation of soluble salts due to disposal of sewage sludge, but the extent was below the tolerance limit for most of the crops. The available phosphorous and potassium ranged from 114 to 489 kg $P_2O_5$/ha and 215 to 1486 kg $K_2O$/ha. The availability of both the nutrients P (r = -0.93**) and K (r = -0.69**) decreased significantly with increase in distance from the discharge sites. It was noticed that nearest site ($S_1$) contained highest (489 kg/ha) $P_2O_5$ and highest (1486 kg/ha) $K_2O$ as compared to distant site of the discharge point. The results indicated higher accumulation of nutrients in surface soil due to sewage water application. The results depict that the organic carbon content in the soil positively influences the availability of P (r = 0.83**) significantly. Moreover the pH of the surface soil decreased significantly with increase in organic matter in the soil (r = -0.72**).

The DTPA extractable trace metals viz., Zn, Cu, Fe, Mn ranged from 2.41 to 4.32, 3.62 to 9.93, 10.34 to 24.93, 5.31 to 16.39 ppm respectively. The Zn, Cu and Fe content in the soil decreased significantly with increase in distance from the discharge point (r = - 0.80**, - 0.88** and -0.064** respectively) and pH (r = - 0.66**, -0.71** and - 0.63** respectively) and increased significantly with organic matter content in the soil (r = 0.80**, 0.91** and 0.55* respectively). The DTPA extractable heavy metals viz., Ni, Cr, Cd and Pb ranged from 1.10 to 6.8, 0.01 to 0.10, 0.08 to 0.68 and 3.2 to 10.2 ppm respectively. Similar to the trace elements Ni, Cr, Cd and Pb content decreased significantly with increase in distance from the discharge point (r = -0.98**, -0.56*, -0.95**, -0.98** respectively) and increased significantly with organic carbon content in the soil (r = 0.85**, 0.72**, 0.92**and 0.89** respectively). The Ni (r = -0.77**), Cd (r = - 0.75**) and Pb content (r = - 0.77**) in the soil decreased significantly with increase in pH of the soil. The results depict that the disposal of sewage sludge accumulates higher amount of macro and micro nutrients alongwith heavy metals in the nearby soil and then gets reduced with the distance away from the discharge points.

### Trace metals in crops

The Zn, Cu, Fe and Mn concentration in different crop species varied widely. The content of the trace metal in crops decreased significantly with distance (Fig 1). Accumulation of trace metal cations in different plant species differed widely which varied from crop to crop and along the distance. The relative accumulation of Zn, Fe, Cu and Mn in different plant species were as Cabbage > Red spinach > Sugarbeet > Pumpkin > Maize > Chilli > Okra > Cowpea > Sponge gourd > Brinjal, Sugarbeet > Red spinach > Cabbage > Maize > Chilli > Okra > Cowpea > Spongegourd > Pumpkin > Brinjal, Cabbage > Red spinach > Sugarbeet > Pumpkin > Maize > Chilli > Okra > Cowpea > Spongegourd > Brinjal and Red spinach > Sugarbeet > Cabbage > Chilli > Spongegourd > Okra > Maize = Pumpkin > Brinjal > Cowpea, respectively. It was observed that leafy vegetables as well as root crops accumulated most of trace metal cations to a greater extent at nearer site of the disposal point.

### Heavy metals in crops

The heavy metal content viz., Ni, Cr, Cd and Pb concentration in different plant species also varied widely. All the heavy metal content in the crops decreased significantly with increase in distance away from the sewage disposal site (Fig 2). Accumulation of trace metal cations in different plant species differed widely which varied from crop to crop and along the distance. The relative accumulation of Ni, Cr, Cd and Pb were observed as sugarbeet > red spinach > poi > chilli > okra > sponge gourd > cabbage > pumpkin, red spinach > sugarbeet > okra > cowpea > poi > sponge gourd > maize > cabbage > brinjal > pumpkin, red spinach > poi> sugarbeet > brinjal > okra > cabbage > cowpea > chilli > sponge gourd > pumpkin and cabbage > poi > red spinach > sugarbeet > chilli > brinjal > okra > cowpea > chilli > sponge gourd > pumpkin > maize respectively.

Similar to trace element content, heavy metal content in plants were observed more in leafy vegetables. To minimise the health hazards in humans and judicious use of sewage water restricted and unrestricted irrigation may be planned under controlled irrigation using sewage water to grow crops that are eaten cooked and using treated sewage water for crops eaten raw (WHO 2006; Jiménez *et al*., 2010). Moreover, the leafy vegetables viz., red spinach, spinach, poi and cabbage may not be grown using sewage water or near the sites as they accumulate more heavy metals.

**Conclusions:**

The study revealed that the sewage disposal sites are rich in macronutrient, micronutrient and heavy metal content and the concentration of nutrients decreased significantly with distance away from the sewage disposal site. Continuous disposal of sewage-sludge, containing domestic and industrial effluents on agricultural land is a major source of plant nutrients, but it also contains a sufficient amount of non-essential and heavy metals causing soil pollution. Transfer of metals from added sewage sludge to the soils and subsequently uptake by the plants that enter the feed and food-chain which pose threats for human health and animals. Micro irrigation system, integrated water management and minimising the concentration of the heavy metals in the source through pre-treatments are some of the suitable options for effective utilization of poor quality water in peri- urban agriculture.

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**BRIEF PROFILE OF THE AUTHORS**

Dr. Mausumi Raychaudhuri obtained MSc (Ag) and Ph.D. in Soil Science and Agricultural Chemistry from the University of Calcutta. From 1990 to 1992 she worked for Soil and Land Use Survey of India (Formerly All India Soil and Land Use Survey), IARI, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India and used GIS and Remote Sensing tools in soil survey with several software applications to develop classified images and thematic maps. Since 1992 working in ICAR as Scientist and then Senior Scientist and addressed the problems of the farmers of north-eastern parts of India through a multidisciplinary farming system approach and developed technologies for amelioration and management of acid soils for better crop production. Since 2008 she is working on prospects of poor quality water use in agriculture, assessment of soil and land quality on the basis of soil physical, hydrological, chemical and biological parameters, development of efficient irrigation and cropping practices under irrigated ecosystems to mitigate excess and deficit water situations in the context of climate change, developed Decision Support system to assess the suitability of low quality water used in irrigated agriculture on food production in association with Bulgarian Scientists and also contributing to Reuse options for marginal quality water in urban and peri urban agriculture with European Consortia as PI or CO-PI of NAIP, NICRA, NPP, DST sponsored national and International Projects.

Dr. A. K. Singh obtained his B. Sc. (Ag) in 1988, M. Sc. (Ag) in Soil Science in 1991 and Ph.D. in Soil Science in 1995 from Rajendra Agricultural University, Pusa Bihar. He has been working on soil fertility/ soil chemistry and soil microbiology for last 20 years in different capacities. He is presently working as Assistant Professor of AICRP on Groundwater Utilisation in Rajendra Agricultural University, Pusa.

Dr. S. K. Jain graduated in B. Tech. (Agril Engg) in 1984 from J. N. Krishi Vishwa Vidyalaya, Jabalpur and obtained M. Tech. (Soil & Water Conservation Engg.) in 1985 from IIT Kharagpur. He was awarded Ph. D. in Irrigation and Drainage Engineering in 2001 from G. B. Pant University of Agri. & Tech. Pantnagar. He has been working on various aspects of irrigation engineering and ground water for the past 24 years. He is presently working as Associate Professor and Chief Scientist of AICRP on Groundwater Utilisation in Rajendra Agricultural University, Pusa.

Er. Ravish Chandra graduated in B. Tech. (Agril Engg) in 1998 from Rajendra Agricultural University, Pusa, Bihar and then obtained his M. Tech. (Soil & Water Conservation Engg.) from Maharana Pratap University of Agril and Tech., Udaipur. He is presently engaged as Assistant Professor of AICRP on Groundwater Utilisation in Rajendra Agricultural University, Pusa. He has been working on ground water assessment and productivity for the last 6 years.

Dr. Ashwani Kumar is a renowned professional, visionary person with excellent academic records, outstanding caliber and eminence with administrative acumen, varied experience in research management, planning, co-ordination, capacity building, institute building, monitoring of research outcomes, evaluation and resource generation. Out of 34 years of experience, 17 years was in administration, financial management, research management and planning and human resources development. Joined Agricultural Research Service (ARS) of Indian Council of Agricultural Research (ICAR), Ministry of Agriculture, GoI in 1977 and did outstanding contribution in the subject of Agricultural Engineering, Science and Technology, particularly in the field of micro-irrigation, plasticulture, hydrology, remote sensing, Geographic Information System (GIS), agro-climatic analysis, drought management, crop-weather interaction, crop modelling, crop diversification, contingency planning, climate change mitigation and adaptations. He has vast scientific and practical knowledge and experience in managing water for agriculture under different agro-climatic regions and land ecologies of the country for optimum production of crops, fish, horticulture etc. He is presently working as the Director of Directorate of Water Management, ICAR, Bhubaneswar.

**Table-1. Details of soil and Plant sampling sites of bye-pass Patna**

| Sl.No. | Sampling Sites | Distance from source (km) | Soil | Crops |
|---|---|---|---|---|
| 1. | Chhoti Pahari | 0.2 | S1 | Red Spinach, Spongegourd, Spinach, |
| | | 0.50 | S2 | Red Spinach, Chilli, Cowpea |
| 2.. | Bari Pahari | 1.50 | S3 | Pumpkin, Red Spinach, Okra, Cowpea |
| | | 2.50 | S4 | Poi, Chilli, Okra, Pumpkin |
| 3. | Ranipur Pajhaba | 4.00 | S5 | Cabbage, Okra, Pumpkin |
| | | 4.50 | S6 | Cabbage, Pumpkin, Brinjal |
| 4. | Mahadeo Sthan | 6.00 | S7 | Spongegourd, Cowpea, Red spinach, Okra, Sugar beat |
| | | 6.50 | S8 | Chilli, Red Spinach, Spongegourd, Maize |
| 5. | Begampur | 8.50 | S9 | Sugar beat, Pumpkin, Spongegourd, Okra, |
| | | 9.00 | S10 | Chilli, Spongegourd, Red spinach, Poi, Cowpea |
| 6. | Karmali Chowk | 10.0 | S11 | Spongegourd, Cowpea, Okra, Maize |
| | | 10.5 | S12 | Okra, Spongegourd, Red spinach |
| 7. | Sati Chowk | 11.5 | S13 | Okra, Red spinach, Pumpkin |
| | | 12.0 | S14 | Chilli, Cowpea, Brinjal, Okra |
| 8. | Deedarganj | 13.5 | S15 | Okra, Cowpea, Cucumber |
| | | 14.0 | S16 | Spongegourd, Cowpea, Okra |

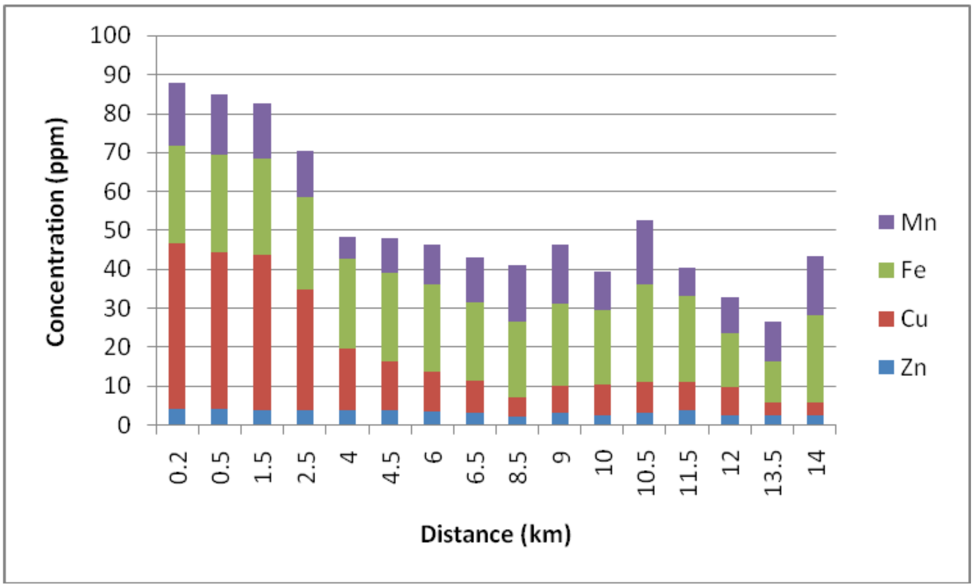


Fig 1. Concentration of trace elements in crops along the distance from the sewage disposal site

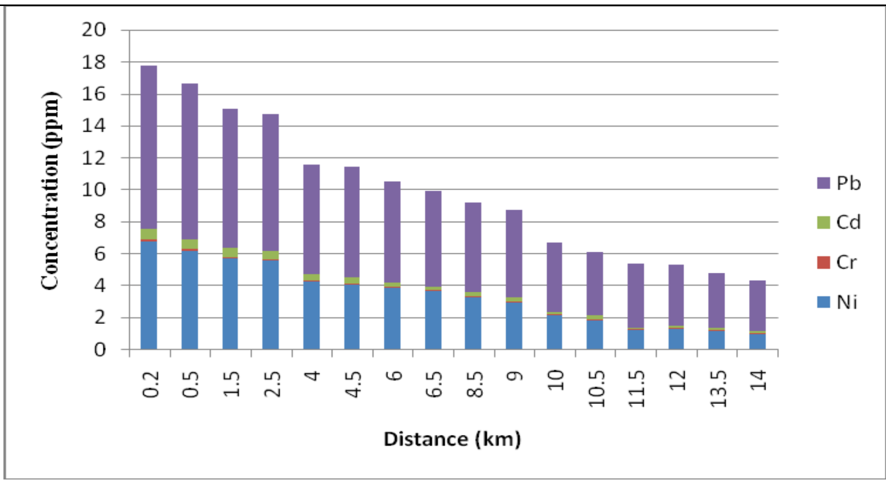


Fig 2. Concentration of heavy metals in crops along the distance from the sewage disposal site