Comparative Assessment of Four Toxic Heavy Metals Occurring in the River Beds of Ganga at Three Major Cities of U.P., India

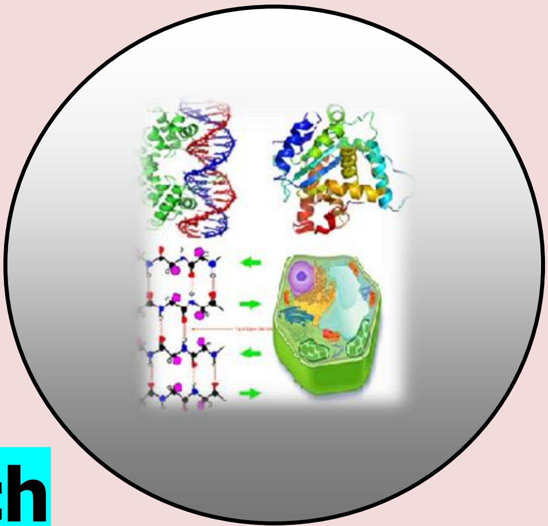
By

Saqib Ul Kalam, Fauzia Naushin and Fareed Ahmad Khan

ISSN 2319-3077 Online/Electronic
ISSN 0970-4973 Print

UGC Approved Journal No. 62923
MCI Validated Journal
Index Copernicus International Value
IC Value of Journal 82.43 Poland, Europe (2016)
Journal Impact Factor: 4.275
Global Impact factor of Journal: 0.876
Scientific Journals Impact Factor: 3.285
InfoBase Impact Factor: 3.66

J. Biol. Chem. Research
Volume 36 (1) 2019 Pages No. 86-91



Journal of Biological and Chemical Research

An International Peer Reviewed / Referred Journal of Life Sciences and Chemistry

Indexed, Abstracted and Cited in various International and National Scientific Databases

Published by Society for Advancement of Sciences®

J. Biol. Chem. Research. Vol. 36, No. 1: 86-91, 2019
(An International Peer Reviewed / Refereed Journal of Life Sciences and Chemistry)
Ms 36/01/87/2019

ISSN 2319-3077 (Online/Electronic)
ISSN 0970-4973 (Print)

Saqib Ul Kalam
http:// www.sasjournals.com
http:// www.jbcr.co.in
jbiolchemres@gmail.com

RESEARCH PAPER

Received: 25/12/2018 Revised: 18/01/2019 Accepted: 19/01/2019

Comparative Assessment of Four Toxic Heavy Metals Occurring in the River Beds of Ganga at Three Major Cities of U.P., India

Saqib Ul Kalam, Fauzia Naushin and Fareed Ahmad Khan
Department of Botany, Aligarh Muslim University, Aligarh (202002), U.P., India

ABSTRACT

Fifteen water and soil sediment samples were collected from 1.5 km stretch of Ganga river bank at Kanpur, Allahabad and Varanasi. The samples of each city were pooled to make one composite sample of soil and another of water collected from each city. The concentrations of four heavy metals (Cd, Cr, Ni and Pb) were analyzed in triplicate in each composite sample of all three cities on AAS. The concentrations of all four heavy metals were relatively higher in the soil as compared to water sampled from all the cities. The concentrations of Ni in soil and water samples of all cities were highest. The relative concentrations of all four heavy metals estimated were in the order of magnitude as Ni>Cr>Cd>Pb in all three cities. The occurrences of the heavy metals in the water and soil samples of Ganga river bank are of anthropogenic sources. The concentrations of these heavy metals in water samples and Cd concentrations in soil samples of all three cities were above the permissible limit set by WHO (2003). Nickel concentrations in soil samples of Kanpur and Varanasi were above WHO (2003) permissible limit.
Keywords: Heavy metals, River Ganga, Kanpur, Allahabad and Varanasi.

INTRODUCTION

River Ganga is the largest river in India often referred as Ganges. The Ganga is a trans-boundary river of Indian subcontinent which flows from India to Bangladesh. Ganga rise originally from Himalayas and empty into Bay of Bengal. Ganga is considered sacred by Hindus. Over the years, Ganga got heavily polluted due to direct or indirect discharge of industrial effluents, partially treated sewage sludge and several other forms of wastes from man-made sources (CPCB 2013). The dense population, urbanization, rituals, socio-religious offerings, discharge of industrial effluents, tanneries waste, and sewage water are the main cause of pollution in the river and industrial effluents discharged mainly from Kanpur, Allahabad and Varanasi make the river highly polluted (CPCB 2013; Pandey et al. 2014; Agarwal 2015). In the stretch between Kanpur and Varanasi, about 3000 MLD of wastewater is released into the river from various sources (CPCB 2013). The boom of tannery in the bank of the river at Jajmau, Kanpur add huge amounts of heavy metals mainly Cr, As, Co, Fe, Cu, Mn, Zn, Pb, Cd, and Ni in the river stream as reported earlier (Khade and Adholya 2009; Bhatnagar et al. 2013). The fixation of heavy metals in soil is above the permissible limit (US EPA) near the river bank at Allahabad (Pandey et al. 2016). The sources of heavy metals contaminating the river water at Allahabad are of anthropogenic origin (Pandey et al. 2013; Pandey et al. 2014). The concentrations of Cd, Cr, Ni and Pb have been reported above WHO permissible limit in the river water at Allahabad (Pandey et al. 2013; Pandey and Singh 2017). In Varanasi, the large quantities of industrial and municipality discharges are the main sources of heavy metal pollution in the river (Kumar et al. 2015).

The heavy metal contamination of soil is of prime environmental concern in the world (Khan et al. 2011). High levels of contamination of heavy metals in soil and water adversely affect the terrestrial and aquatic organisms (Pandey and Madhuri 2014). The heavy metals introduced into the environment persist for a long time and are not easily biodegraded (Mohammed et al. 2011). Heavy metal contaminates underground and surface water bodies including their basin and subsequently pollutes the soil sediments (Duruibe et al. 2007). The occurrence of high amounts of Cd, Cr, Ni and Pb in soil and water bodies affects the plants, animals and ecosystem functioning adversely (Veena 1997; Xu and Shi 2000; Shankar et al. 2005; Sharma and Dubey 2005; Hasan et al. 2009; Najafian et al. 2012; Bhaleroa et al. 2015). The Cd and Pb occurring in the soil are absorbed by the plants and bio-transferred to organisms of second and third traffic levels (Dar et al. 2015).

Heavy metals such as Cd and Pb are non-essential elements for plants. These heavy metals present in larger amounts in the soil, adversely affect the absorption and transport of essential elements by the plants, disturb their metabolism, and reduce the growth and reproduction (Xu and Shi 2000). Cd and Cr are considered to be one of the most hazardous pollutants of the aquatic ecosystems due to their longer persistence in the environment and tendency of getting concentrated in aquatic organisms (Veena et al. 1997) and along food chains (Dar et al. 2015, 2017). Toxic symptoms of Cd in plants (i.e. growth retardation, alterations of photosynthesis, stomatal movement, enzymatic activities, water relations, interferences with mineral uptake, protein metabolism, membrane functioning have been reported in a numbers of plants (Hasan et al. 2009; Rehman et al. 2011; Dar et al. 2015). Cr is the non-essential heavy metal and becomes toxic for plants if present in larger quantities in the soil (Najafian et al. 2012). Chromium causes deleterious effects on some physiological processes of plants such as photosynthesis, water relations and mineral nutrition (Shankar et al. 2005). Excess Pb in the soil, results in growth stunting, chlorosis, blackening of root system, Photosynthesis, mineral nutrition alters water balance, changes hormonal status and adversely affects membrane structure and permeability (Sharma and Dubey 2005; Rehman et al. 2011). Excess concentrations of Ni in plants cause chlorosis and necrosis, due to disruption of Fe uptake and metabolism (Bhalero et al. 2015). Elevated concentrations of Ni inhibit miotic cell division in root meristems in non-tolerant plants and decrease plant growth (Bhalerao et al. 2015).

Cd, Cr, Ni and Pb cause several disorders in human beings (US EPA 1995a, b; Martin and Griswold 2009). Exposure to high levels of Cd results in the disorder of digestive system, kidney, lungs and bones (Martin and Griswold 2009), Cr exposure disorder respiratory, kidney, circulatory and nervous system in addition to skin irritation (Martin and Griswold 2009). Ni exposure affects the respiratory system and long-term exposure may even cause cancer (US EPA 1995a, b). The exposure of infants to lead, delays physical or mental development, could show slight deficits in attention span and learning abilities of children and kidney problems as well as high blood pressure in adults (US EPA 2009). The US, EPA has fixed the permissible limit of Cd, Cr, Ni and Pb in drinking water as 0.005 ppm, 0.1 ppm, 0.1 ppm and 15 ppb, respectively (US EPA 1995a, b, 2009). The Ganga river water is extensively used for drinking and irrigation. Large scale cultivation of cucurbits is performed in Ganga river basin (Gopalkrishnan 2007; Pandey and Karmakar 2014; Kumari et al. 2018). About 65% of India's total cucurbit fruits and vegetables are cultivated in the river beds (Kumari et al. 2018). The uptake and accumulation of toxic heavy metals in the plants grown in polluted and irrigated with contaminated water have been reported (Baker 1981; Wuana and Okieimen 2011).

The objective of the present work was to determine the concentration of four toxic heavy metals, namely, Cd, Cr, Ni and Pb in the soil sediments and water samples of river Ganga in three major cities of Uttar Pradesh namely, Kanpur, Allahabad (now Prayagraj) and Varanasi.

MATERIAL AND METHODS

Location of sites and sampling

The soil and water sampling sites of three selected cities are were on the right bank of the Ganga river at Jajmau, Kanpur (26°26′ N and 80°24′ E) close the major point of discharge of tanneries effluents in the river (Site-1), Sangam area (25°25′ N and 81°53′ E), before the confluence of Yamuna river at Allahabad (Site-2) and Ghats of Varanasi (25°17′ N and 83°00′ E) at the left bank (Site-3) (Fig. 1). Fifteen soil and water samples were collected from about 1.5 km stretch of the river bank from all three sites. All fifteen samples of soil sediments and water of each cities/sites were pooled separately to make one composite sample of soil sediment and another of water. The concentration of Cd, Cr, Ni and Pb were determined in triplicates to serve as replicate in statistical analysis.

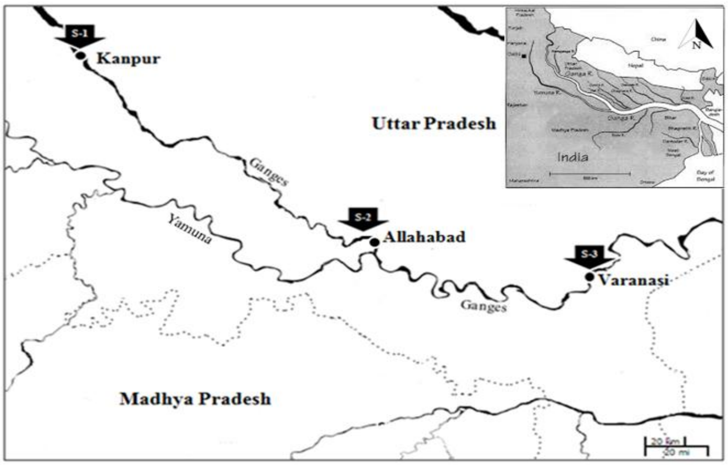


Figure 1. Map showing different sampling sites. S-1= Site-1(Kanpur), S-2= Site-2 (Allahabad) and S-3= Site-3 (Varanasi) at the bank of river Ganga. Source: Sharma (1997); World map (Harvard education), Stamen Toner (modified) to show location of sites.

Soil and water analysis

The concentrations of the heavy metals were determined following EPA Method 3051A (1995). 1.0 g of soil sample and 1ml of water sample (in three replicate) were digested separately in 9 ml concentrated nitric acid and 3 ml hydrofluoric acid for 15 minutes at 180ºC kept on a hot plate for digestion until the brown fume evolving from the conical flask turned white. The digest was allowed to cool, diluted with DDW, and filtered with Whatman's filter paper 42, leaving a whitish residue. The volume of the filtrate was made to 25ml with double distilled water and analyzed for heavy metal on AAS (GBC Scientific Equipment, Dandenong, Australia).

The AAS values were converted to actual concentration of metal in the samples using the following equation:

$$\text{Concentration } \mu g\ g^{-1} / \mu g\ ml^{-1} = \frac{\text{Calibration reading} \times \text{Extract volume}}{\text{Sample weight}}$$

Where, calibration reading is obtained from the AAS with pre-installed Avanta Software Package, version 2.02. Extract volume is the final volume of the digest used for spectrometric analysis.

The data were analyzed using SPSS Version 17.0 for Windows (IBM USA, 2009).

RESULTS AND DISCUSSION

The concentrations of all four selected heavy metals collected from all three cities were relatively lesser in the water samples than in the soil samples (Fig. 2). The concentration of Pb was lowest than other heavy metals in the water and soil samples of all three selected cities (Fig. 2). In recent reports the heavy metal concentration has been estimated specifically in Ganga river water from these cities (Beg and Ali 2008; Pandey et al. 2010; Singh 2011; Bhatnagar et al. 2013; Naushad et al. 2014; Pandey et al. 2016). Pandey et al. (2016) reported high concentration Cr (131.8 mg kg^{-1}) and Pb (23.8 mg kg^{-1}) in Ganga river soil sediments at Sangam area of Allahabad. The heavy metals estimated in these reports and present work varied. But the overall concentrations patterns of Cd, Cr, Ni and Pb in the water and soil samples were almost similar in all three selected cities (Fig. 2).

The Ni had highest concentration variation in between soil and water samples in all three cities (Fig. 2). Specifically the concentration of Ni in soil samples were over twice in the order of magnitude than in the water samples at Kanpur and Allahabad (Fig. 2a, 2b). This indicates that the heavy metals discharged over the years in the water stream were feasibly retained in the soil sediments than in the water samples. The decline in heavy metal concentrations in Sabarmati river Gujarat (Kumar et al. 2013) and Ganga river at Varanasi (Pandey and Singh 2017) during summer were caused by low river flow. On the other hand, the increased river flow in rainy season causes dilution of heavy metals (Pandey and Singh 2017). Higher concentration of heavy metals in winter than rainy season could be linked similarly to decrease in river flow during winter (Kumar et al. 2013; Pandey and Singh 2017). Pandey et al (2010) reported high seasonal variations in metal concentration at Varanasi. These temporal variations were governed by the seasonal variation in atmospheric deposition of metals urban industrial emission and wind directions (Clarke et al. 1996; Pandey and Pandey 2009; Pandey et al. 2010).

The spatial variation concentrations (with respect to Ghats in up and down streams) were also found related with the variation in the rate of discharge of the heavy metals (Pandey et al. 2010). In our findings, (Fig. 2) the relative concentrations of each metal in soil and water samples of three cities (Ni>Cr>Cd>Pb) indicate similar pattern but spatial variations among the cities along the river stream.

Relatively higher concentrations of each metal in the soil than in the water show a temporal effect in our findings (Fig. 2). Cr in downstream sediment was reported 30-fold higher than in upstream sediment and its concentration was above the probable effect level at Kanpur (Beg and Ali 2008). In our findings, the concentration of Pb was least among four heavy metals estimated in the water and soil of all the three cities (Fig. 2). Our findings are in agreement with the report of Naushad et al. (2014) showing relatively lower concentration of Pb than other heavy metals in water samples at Allahabad. High quantities of Cr (22.4-54.9 $\mu g\ g^{-1}$), Cd (5.2-7.8 $\mu g\ g^{-1}$) and Pb (30.8-72.0 $\mu g\ g^{-1}$) have been recorded at effluent discharge point in Ganga river water at Kanpur and Varanasi (Kumar et al 2008). In contrary, Singh (2011) found the heavy metal concentration patterns in the order of the magnitude as Pb>Cr>Cd. Over 80% of the water samples of Ganga river contained Cd and over 70% samples had Pb above their respective permissible limits of 3.0 and 10.0 $\mu g\ L^{-1}$ at Varanasi (Singh and Pandey 2014).

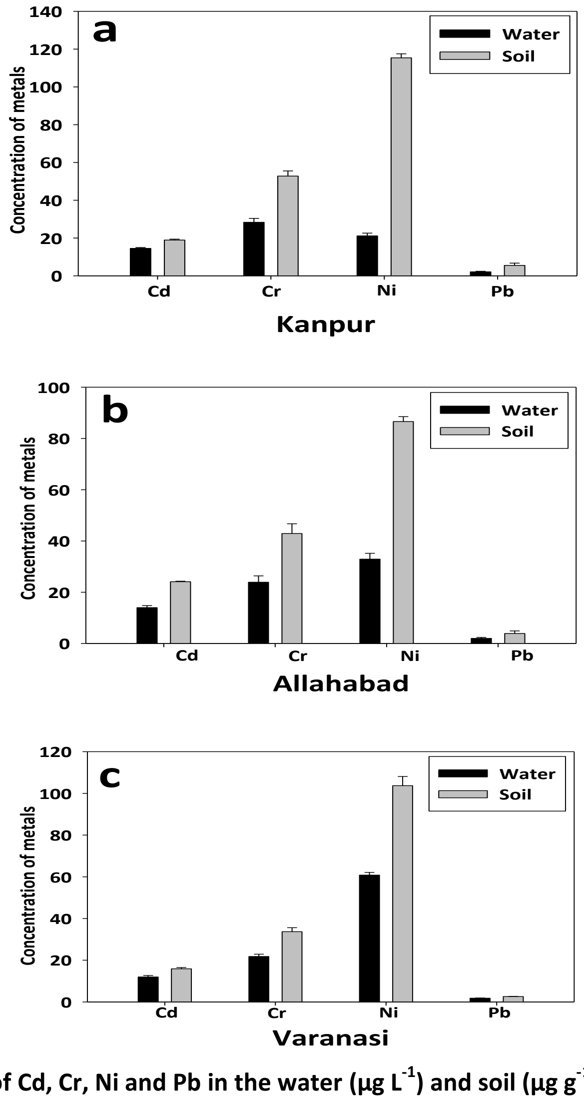


Figure 2. Concentration of Cd, Cr, Ni and Pb in the water ($\mu g\ L^{-1}$) and soil ($\mu g\ g^{-1}$) samples of river Ganga at Kanpur (a), Allahabad (b) and Varanasi (c).

CONCLUSION

It is inferred from the result that the Ni and Cr concentrations at Kanpur had direct relationship with the discharge of tanneries effluents consisting of higher quantities of Ni and Cr.

As per WHO norms, the concentrations of all four heavy metal were above the permissible limits in water samples of river Ganga of all three cities. The Cd concentrations in soil samples of all cities and Ni concentrations in soil samples of Kanpur and Varanasi were above the permissible limit of WHO (2003).

ACKNOWLEDGEMENTS

SK is thankful to the Aligarh Muslim University for the award of University fellowship and Chairperson, Department of Botany for necessary laboratory facilities.

REFERENCES

Agarwal, P.K. (2015). A Review of Ganga River Pollution-Reasons and Remedies. *J. Ind. Wat. Res. Soc.* 35 no3.

Baker, A.J.M. (1981). Accumulators and excluders -strategies in the response of plants to heavy metals. *J. Pla. Nut.* 3(1-4):643-654.

Beg, K.R. and Ali, S. (2008). Chemical contaminants and toxicity of Ganga river sediment from up and down stream area at Kanpur. *Am. J. Environ. Sci.* 4:362-36.

Bhalerao, S.A., Sharma, A.S. and Poojari, A.C. (2015). Toxicity of Nickel in Plants. *Int. J. Pure. App. Biosci.* 3(2):345-355 .

Bhatnagar, M.K., Singh, R., Gupta, S. and Bhatnagar, P. (2013). Study of Tannery effluents and its effects on sediments of river Ganga in special reference to heavy metals at Jajmau, Kanpur, India. *J. Environ. Res. Dev.* 8(1):56-59.

Clarke, A.G., Chen, J.M., Pipitsangchand, S. and Azasi, B. (1996). Vehicular particulate emission and roadside air pollution. *The Sci. Tot. Environ.* 190: 417-422.

CPCB (Central Pollution Control Board) (2013). Pollution Assessment: River Ganga, Ministry of Environment and Forests, Govt. of India.

Dar, M.I., Khan, F.A., Green, I.D. and Naikoo, M.I. (2015). The transfer and fate of Pb from sewage sludge amended soil in a multi-trophic food chain: a comparison with the labile elements Cd and Zn. *Environ. Sci. Pollut. Res.* 22(20):16133-16142.

Dar, M.I., Green, I.D., Naikoo, M.I., Khan, F.A., Ansari, A.A. and Lone, M.I. (2017). Assessment of biotransfer and bioaccumulation of cadmium, lead and zinc from fly ash amended soil in mustard–aphid–beetle food chain. *Sci. Tot. Environ.* 584:1221-1229.

Duruibe, J.O., Ogwuegbu, M.O.C. and Egwurugwu, J.N. (2007). Heavy metal pollution and human biotoxic effects. *Inter. J. Phy. Sci.* 2(5):112-118.

Gopalkrishnan, T. R. (2007) Vegetable Crop, Horticulture Science Series. *New. Ind. Pub. Age.* Vol 4.

Hasan, S.A., Fariduddin, Q., Ali B., Hayat, S. and Ahmad, A. (2009). Cadmium: Toxicity and tolerance in plants *J. Environ. Bio.* 30:165-174.

IBM® USA SPSS Statistics Editions (2009). IBM Corporation Software Group, United States of America.

Khade, S.W. and Adholeya, A. (2009). Arbuscular Mycorrhizal Association in Plants Growing on Metal-Contaminated and Noncontaminated Soils Adjoining Kanpur Tanneries, Uttar Pradesh. *Ind Wat. Air Soi. Pollut.* 202:45-56.

Khan, M.S., Zaidi, A., Goel, R. and Musarrat, J. (2011). Biomanagement of Metal Contaminated Soils. Springer NY, USA.

Kumar, A., Jaiswal, D. and Watal, G. (2008). Studies on chemical composition and energy transformation in river Ganga at Kanpur and Varanasi due to environmental degradation. *J. Environ. Bio.* 30:445-450 .

Kumar, R.N., Solanki, R. and Kumar, J.N. (2013). Seasonal variation in heavy metal contamination in water and sediments of river Sabarmati and Kharicut canal at Ahmedabad, Gujrat. *Environ. Mon. Assess.* 185:359–368.

Kumar, P., Kaushal, R.K., and Nigam, A.K. (2015). Assessment and Management of Ganga River Water Quality Using Multivariate Statistical Techniques in India. *Asi. J. Wat. Environ. Poll.* 12(4):61-69.

Kumari, R., Sharma, A., Bhagta, S. and Kumar, R. (2018). River Bed Cultivation: A Kind of Vegetable Forcing for Remunerative Returns. *Inter. J. Cur Micro. App. Sci.* 7(04):359-365.

Martin, S. and Griswold, W. (2009). Human Health Effects of Heavy Metals. *Cen. Haz. Sub. Res.* 15:1-6.

Mohammed, A.S., Kapri, A. and Goel, R. (2011). Heavy Metal Pollution: Source, Impact, and Remedies. Environ. Poll. vol 20.

Najafian, M., Kafilzadeh, F., Azad, H.N. and Tahery, Y. (2012). Toxicity of Chromium (Cr^{6+}) on Growth, Ions and Some Biochemical Parameters of *Brassica napus L.*. *Wor. App. Sci. J.* 16(8):1104-1109**.**

Naushad, S.S., Lall, A.M. and Charan, A.A. (2014). Determination of metal in water of Ganga and Yamuna river basin in Allahabad. *Inter. J. Cur. Res.* 6(11):10131-1013.

Pandey, J. and Pandey, U. (2009). Accumulation of heavy metals in dietary vegetables and cultivated soil horizon in organic farming system in relation to atmospheric deposition in a seasonally dry tropical region of India. *Environ. Monit. Assess.* 148: 61-74.

Pandey, J., Shubhashish, K. and Pandey, R. (2010). Heavy metal contamination of Ganga river at Varanasi in relation to atmospheric deposition. *Trop. Ecol.* 51:365-373.

Pandey, A., Ramteke, P.W. and Verma, O.P. (2013). Evaluation of heavy metals in river Ganga and Yamuna, *Inter. J. Pha. Bio. Sci*. 4(3):1410-1417.

Pandey, G. and Madhuri, S. (2014). Heavy Metals Causing Toxicity in Animals and Fishes. *Res. J. Ani. Vet. Fis. Sci. Rev.* 2:17-23.

Pandey, S. and Karmakar, P. (2014). River bed Cultivation of Cucurbits, Vegetable Newsletter, ICASR – Indian Institute of Vegetable Research 1(1).

Pandey, J. and Singh, R. (2017). Heavy metals in sediments of Ganga River: up- and downstream urban influences. *Appl. Wat. Sci.* 7:1669–1678**.**

Pandey, R., Raghuvanshi, D. and Shukla, D.N. (2014). Water quality of river Ganga along Ghats in Allahabad City, U. P. *Ind. Adv. App. Sci. Res.* 5(4):181-186.

Pandey, R., Raghuvanshi, D., Sharma, P.K., Singh, H., Tripathi, B., Bajpai, S. and Dikshit, A. (2016). Evaluation of the status of the heavy metal contamination in sediment of the river Ganga at Allahabad, India. *Inter. J. Sci. Nat.* 7(4):852-859.

Rehman, F., Khan, F.A., Varshney, D., Naushin, F. and Rastogi, J. (2011). Effect of cadmium on the growth of tomato. *Bio. Med.* 3(2):187-190.

Shanker, A.K., Cervantes, C., Loza-Tavera, H. and Avudainayagam, S. (2005). Chromium toxicity in plants. *Environ. Inter.* 31(5):739-753**.**

Sharma, Y. (1997). Water pollution control: a guide to the use of water quality management principles / edited by Richard Helmer and Ivanildo Hespanhol. London: E & FN Spon. http://www.who.int/iris/handle/10665/41967.

Sharma, P. and Dubey, R.S. (2005). Lead Toxicity in Plants. *Braz. J. Pla. Phy.* 17(1):35-52.

Singh, A.L. (2011). Toxicity of heavy metals in the water of Ganga river at Varanasi, India: environmental implication. *Pol. Res.* 30:107-110 .

Singh, A.V. and Pandey, J. (2014). Heavy metals in the midstream of the Ganges River: spatio-temporal trends in a seasonally dry tropical region (India). *Wat. Inter.* 39(4):504-516.

US EPA (United States, Environmental Protection Agency) (1995). Test Methods for Evaluating Solid Waste, Physical/ Chemical Methods, SW-846, 3rd ed.; US Government Printing Office: Washington, DC.

US EPA (United States, Environmental Protection Agency) (1995a). Removal of Legally Obsolete or Redundant Rules, Safe Drinking Water Act, Final Rule Fed Register 60:33928-33930.

US EPA (United States, Environmental Protection Agency) (1995b). Nickel Drinking Water Health Advisory. Washington, DC: Office of Water.

US EPA (United States, Environmental Protection Agency) (2009). National Primary Drinking Water Regulations Complete, pp 7, 816-F-09-004.

Veena B., Radhakrishnan C. and Chacko K.J. (1997). Heavy metal induced biochemical effects in an estuarine teleost. *Ind. J. Mar. Sci*. 26: 74- 77.

WHO (2003). Guidelines for safe recreational water environments. Volume 1: coastal and fresh waters. World Health Organization, Geneva.

Wuana, R.A. and Okieimen, F.E. (2011). Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. *I.S.R.N. Ecol.* 2011:1-20.

Xu, Q. and Shi, G. (2000). The toxic effects of single Cd and interaction of Cd with Zn on some physiological index of [*Oenanthe javanica* (Blume) DC]. J Nanjing Normal University (Natural Science) 23(4):97-100**.**

Corresponing author: Saqib Ul Kalam, Department of Botany, Aligarh Muslim University, Aligarh (202002), U.P., India
Email: saqibulkalam@gmail.com