Assessment of heavy metal contamination zones of biota of Western Uttar Pradesh Terrain, India using atomic absorption spectroscopy

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Abstract: In the present work, heavy metal contamination of water and soil in western Uttar Pradesh terrain, India was assessed. About 16 boreholes and tap water samples and ten soil samples were studied using atomic absorption spectrophotometer (AAS) for arsenic (As) and lead (Pb) content, and the levels were compared with World Health Organization (WHO) specified maximum contaminant level (MCL). According to WHO, the MCL for As and Pb is 0.01 mg/L. From the results obtained, about 75% of biota samples analysed contained As and Pb in concentrations above MCL. The subject of health concern is the increasing concentration of As in Modinagar and Meerut residential area. The effluents from industries, pesticides used in agriculture land and improper waste management are the reasons responsible for heavy metal toxicity in this belt. The deep bore water samples of Muradnagar, Modinagar, Meerut and Mawana showed high concentrations of As.

Keywords: heavy metals; biota; atomic absorption spectroscopy; AAS; maximum contaminant level; MCL; arsenic and lead; India.


Biographical notes: Nazia Tarannum is an Assistant Professor in the Department of Chemistry, Chaudhary Charan Singh University, Meerut, India. She received her PhD from the Banaras Hindu University. Her research interest includes polyelectrolytes, hydrogels and organogels and polymer waste management.
1 Introduction

Heavy metals are the vital, natural and crucial component of the Earth’s crust. An unbalanced human civilisation has led to the heavy metal toxicity of our biota. These heavy metals are not being degraded and enter our bodies via food and water cycle. As trace elements, some heavy metals are essential in maintaining the metabolism of the human body but at higher concentrations, these prove to be toxic. Bioaccumulation of heavy metals in the ecosystem is a growing concern. Heavy metals accumulate in living things, and their rate of accumulation is higher than the rate of excretion. The uptake of heavy metals in the food chain is through soil and plants especially leafy vegetables (Chen et al., 2010; Fairbrother et al., 2007). Ground water contamination of heavy metal at a very low concentration has known to cause strong toxicity (Macrovecchio et al., 2007; Vodela et al., 1997). Water resources are contaminated by heavy metal through various agencies like drinking water contamination via Pb (lead) pipes, and natural sources of water are being contaminated by sediment eroded minerals, extruded products of volcanoes and leaching of ore deposits. Further, another important cause of polluted water is man-made and of anthropogenic origin like solid waste disposal, effluents from industries or household, harbour channel dredging. Heavy metal produce toxicity in the body by forming complexes with thiol, amino or carboxylic groups of proteins resulting in modified biological molecule or inactivation of the enzyme system that cause death of the cells.

The issue of heavy metal contamination and its impact on ecosystem toxicity has engrossed the attention of US Environmental Protection Agency (EPA). Various agencies concerned with environmental protection issues have formulated the permissible level of heavy metals needed for plants, animals, humans and biota. An elevation observed this level is regarded toxic to ecosystem (Borgmann et al., 2008; Chen et al., 2010). According to a survey conducted by United Nations, India is likely to face serious water stress by 2025 and Yamuna River in Delhi is marked as the most polluted river in India.
Assessment of heavy metal contamination zones of biota (UNIPCC, 2014). As concentration (107 μg/L) in drinking water in India was found to be approximately 11 times higher than the permissible limit given by WHO (Roychowdhury et al., 2003; WHO, 2008). Chatterjee et al. (1995) have reported heavy metal contamination in ground water the maximum permissible limit in several districts of West Bengal, India, affecting millions of people. Later, a report by Von Ehrenstein et al. (2005, 2006) revealed health defects in the people due to As contaminated water. In Assam, India water was found polluted by Pb (Borah et al., 2010).

**Table 1**  Effect of acute and chronic exposure of Pb and As on human body

<table>
<thead>
<tr>
<th>Element</th>
<th>Acute exposure</th>
<th>Chronic exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>Encephalopathy brain Dysfunction Nausea Vomiting Encephalopathy</td>
<td>Anaemia Encephalopathy Foot drop/wrist drop (palsy) Nephropathy (kidney disease) Diabetes</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Multi-organ effects Arrhythmia</td>
<td>Hypopigmentation/hyperkeratosis Cancer</td>
</tr>
</tbody>
</table>

**Note:** Lead (Pb) and arsenic (As) contaminated geographical regions of Western Uttar Pradesh, India (inset). Herein this study, soil, groundwater and tap water samples from various belts of western Uttar Pradesh, India (Figure 1) have been collected and analysed for the heavy metals (Pb...
and As) contamination in relation to their natural background level. The expected level of the two heavy metals in the biota samples of the region analysed showed toxicity of soil and water. These heavy metals in humans have known to be the cause of Alzheimer’s and Parkinson’s disease, senility and dementia, cancer, abdominal pain, skin lesions and many more diseases as presented in Table 1. As far as literature survey is concerned, no such study of heavy metal contamination of soil and water samples is being reported so far. The study is important in raising public awareness about the situation to the people.

2 Materials and methods

2.1 Chemical and equipment

The glassware and pipettes were cleaned with tap water and rinsed with deionised distilled water. Perchloric acid was procured from Merek, Mumbai, India whereas nitric acid (suprapure grade) and hydrochloric acid from SDFCL, India. Lanthanum nitrate and the stock solution of As and Pb were obtained from Thomas Baker, Mumbai, India. All the chemicals were of analytical grade and used as received. Fresh polythene self-sealing bags and bottles have been used for soil and water sample collection. Supra pure grade nitric acid was used to acidify the samples. 7,000 SP atomic absorption spectroscopy (AAS), Lab India is used for the quantitative determination of heavy metals in water and soil samples. Graphite furnace method was used and the wavelength for the determination of Pb and As were 217 nm and 193.7 nm, respectively. All the samples under study were analysed in duplicate with the concentration of metal represented in tabular data from standard curve extrapolation. AAS analysis parameters used herein are mentioned in Table 2.

Table 2 Atomic absorption spectroscopy (AAS) analysis parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slit (nm)</td>
<td>0.2</td>
</tr>
<tr>
<td>Lamp current (mA)</td>
<td>5.00</td>
</tr>
<tr>
<td>Shield gas: N₂</td>
<td></td>
</tr>
<tr>
<td>Shield gas volume of injector (µL)</td>
<td>20</td>
</tr>
<tr>
<td>Ash temperature (ºC)</td>
<td>800</td>
</tr>
<tr>
<td>Sampling speed:</td>
<td>10</td>
</tr>
<tr>
<td>Calculated by: peak height</td>
<td></td>
</tr>
<tr>
<td>Auto sampler: no using</td>
<td></td>
</tr>
<tr>
<td>High voltage (V)</td>
<td>341.11</td>
</tr>
<tr>
<td>Background correction</td>
<td>off</td>
</tr>
<tr>
<td>Shield gas flow rate (L/min)</td>
<td>0.00</td>
</tr>
<tr>
<td>Pressure (MPa)</td>
<td>0.00</td>
</tr>
<tr>
<td>Atom temperature (ºC)</td>
<td>2,000</td>
</tr>
<tr>
<td>Smooth curve factor:</td>
<td>1</td>
</tr>
<tr>
<td>Extend ruler (0.1–100):</td>
<td>1.00</td>
</tr>
<tr>
<td>Units: ppb (parts per billion)</td>
<td></td>
</tr>
</tbody>
</table>

2.2 Area of study and collection of samples

Sixteen water samples and ten soil samples were collected from places in and around Meerut, Western Uttar Pradesh belt, India. Eight water samples were collected from deep bores at different locations whereas other eight water samples were tap water. Ten soil samples were collected from different sites around Meerut, Western Uttar Pradesh. Samples have been collected from residential, industrial and agriculture areas. All the samples were collected around the month of April 2014.
2.3 **Storage of samples**

Standard methods were adopted for the analysis of samples for water quality. Water samples were collected from each sampling location in two polyethylene bottles. The bottles were rinsed three times with sample water before collection. Self-sealing polybags were used to keep soil samples from different places.

2.4 **Water sample preparation**

Each water sample (2 L) was collected and homogeneous sample was prepared for analysis of physicochemical parameters. Separately 100 mL of each water sample was collected, and acidified with concentrated nitric acid. Before collecting the samples, the sample containers were soaked overnight in 2% nitric acid and washed with double distilled water. All the samples were collected in polyethylene containers and stored at 4°C.

2.5 **Soil sample preparation**

Digestion of soil sample was carried out to reduce As (V), if any, to As (III). A known weight (0.5 g) of a soil sludge sample was placed in a 10 mL beaker and extracted four times with a 2.5 mL portion of concentrated hydrochloric acid. The extract was boiled for about 30 minutes. The solution was cooled and diluted to 10 mL with distilled water. Further, this solution was diluted ten times.

2.6 **Preparation of standard solutions of heavy metals**

Standard sample solution of Pb was prepared using the known quantity of lanthanum nitrate in double distilled water at different concentration solution in ppb, i.e., 100, 50, 25, 12.5. Standard sample solution of the known quantity of As in 0.1% nitric acid solution was prepared at different concentration solutions in ppb, i.e., 100, 50, 40, 25 ppb. The solution for calibration of As and Pb ions were prepared from standard stock solution by serial dilution.

3 **Results and discussion**

Several organisations and agencies have formulated drinking water quality guidelines for heavy metals (Fernández-Luqueño et al., 2013). The upper limit of Pb and As as proposed by WHO (2008), USEPA (2011), and Federal-Provincial-Territorial Committee on Drinking Water (2010) has been given as 0.01 mg/L.

Calibration curves for Pb and As were plotted at different concentrations of the standards of both metals. All the calibration curves were found to be linear with correlation coefficient ranging from 0.959 to 0.967. The control used for study was distilled water with detectable range of heavy metal. The minimum and maximum concentration range of Pb in soil was 4.10 to 7.36 µg/g and As in soil was 0.00 to 71.82 µg/g, respectively. Figure 2 shows the concentration and the comparison level of Pb and As in soil samples.
Lead and arsenic concentration (μg/g) in different soil samples (see online version for colours)

Notes: Site of collection of samples are as following (Sample SH1: Muradnagar residential area; Sample SH2: Muradnagar agriculture area; Sample SH3: Ghaziabad agriculture area; Sample SH4: Modinagar residential area; Sample SH5: Modinagar agriculture area; Sample SH6: Muradnagar near river area; Sample SH7: Meerut near drainage area; Sample SH8: Meerut agriculture area; Sample SH9: Hapur agriculture area; Sample SH10: Modinagar near roadside).

The highest concentration of heavy metals were found in soil samples collected from the areas localised near high traffic zones and residential area with heavy use of heating influences. The data shows that there was a significant difference in the concentration of Pb and As. From the result obtained, it is clear that the soil samples from different places studied had high content of heavy metals capable of toxicating our ecosystem. The concentration of Pb is approximately same in all soil samples whereas the concentration of As is highly variable from place to place. Soil samples SH1 and SH2 collected from residential and agriculture area of Muradnagar, respectively showed an unexpected elevated level of As concentration, i.e., 71.82 and 33.96 μg/g, respectively, whereas soil sample (SH3) from agriculture area of Ghaziabad district showed fairly good content of As, i.e., 51.46 μg/g. Soil sample of residential area of Muradnagar showed higher concentration of As as compared to agriculture area. Muradnagar and Ghaziabad are adjacent cities located in the western zones of Uttar Pradesh (Figure 1) experiencing rapid urbanisation and high industrial growth. This zone is amongst the top hundred districts in India having more than 4,500 small scale industries (Sharma et al., 2016). High content of As in soil is due to pesticide use, mining and ore processing operations, operating coal burning power plants, and waste disposal from industries and sites of former tanneries. Further, the subject of health concern is the increasing concentration of As in Modinagar and Meerut residential area. The effluents from industries, pesticides used in agriculture land and improper waste management are the reasons responsible for heavy metal toxicity in this belt.
Figure 3  Pb and As concentration (mg/L) in (a) deep bore water samples (DB1-DB8) (b) tap water samples (TW9-TW16) (see online version for colours)

Notes: Site of collection of samples are as following: (Sample DB1: Muradnagar submersible; Sample DB2: Modinagar submersible; Sample DB3: Muradnagar tubewell; Sample DB4: Muradnagar tubewell; Sample DB5: Meerut submersible; Sample DB6: Ghaziabad submersible; Sample DB7: Sardhana submersible; Sample DB8: Mawana tubewell; Sample TW9: Badot tap water; Sample TW10: Modinagar tap water; Sample TW11: Muradnagar factory water supply; Sample TW12: Hastinapur tap water; Sample TW13: Meerut tap water; Sample TW14: Duhai tap water; Sample TW15: Ghaziabad tap water; Sample TW16: Garhmukteswer tap water).

The minimum and maximum concentration of Pb in tap water samples and in deep bore water samples are reported as 0.01–0.05 mg/L and 0.01–0.06 mg/L, respectively. The minimum and maximum concentration of As in water was 0.0–0.3 mg/L. The maximum allowable limit for Pb and As as per WHO guidelines is 0.01 mg/L. All the water samples under study for Pb contamination showed concentration higher than the maximum (0.01 mg/L) of WHO quality guideline, except samples DB6, DB7, DB8, TW11, TW12. The comparison of Pb and As in water samples is shown in Figure 3. About 75% of water samples under analysis showed the level of As and Pb the maximum contaminant level...
(MCL) given by WHO guideline. The previous study done by Gaur et al. (2012) has reported the ill effect of heavy metal, i.e., cadmium, chromium, aluminium and lead on the population in western Uttar Pradesh, India. The people in this region suffer with diseases like aggressive behaviour, loss of appetite, eyes and speech problem, lack of memory and early aging due to the consumption of excess heavy metal contaminated water. The concentration of Pb is very high in Modinagar submersible water sample. The deep bore water samples of Muradnagar, Modinagar, Meerut and Mawana showed soaring concentration of As. The major concern is for heavy metal contamination in tap water. The tap water supply of Baraut, Modinagar, Meerut, Ghaziabad and Garhmukteswer detected concentration of As much higher than the MCL of WHO guidelines. Pb contamination is also detected in tap water samples of foresaid zone.

4 Conclusions

The determination of heavy metals in biota is very important since human intake of toxic trace elements even at low dose over a long period of time may lead to malfunction organs and chronic toxicity. Hence, it is necessary to obtain more information on the soils and water (biota), the life source that contain high concentration of heavy metals. The soil contaminated by these effluents will produce unhealthy food as heavy metals can enter the food chain and thus be consumed by human beings. The objective of this work is to determine heavy metal (Pb and As) in soil and water samples and to compare the concentration of heavy metal in both with that of permissible ranges formulated by WHO. The water and soil samples were collected from various locations of western Uttar Pradesh, India for the determination of As and Pb by using AAS. The concentration of Pb is approximately same in all soil samples whereas the concentration of As is highly variable from place to place. Soil samples collected from residential and agriculture area of Muradnagar showed an unexpected level of As concentration whereas soil sample from agriculture area of Ghaziabad district showed fairly good content of As. Further, the analysis of data of water samples clearly showed presence of high percentage of Pb and As in water in and around Meerut, Modinagar and Ghaziabad.

References


Assessment of heavy metal contamination zones of biota


