Original article

Groundwater contamination with cadmium concentrations in some West U.P. Regions, India

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ABSTRACT

Water is considered a vital resource because it is necessary for all aspects of human and ecosystem survival. However, due to natural processes and anthropogenic activities, various pollutants have been added to the ground water system. Among these, heavy metals are some of the most serious pollutants. Cd, a toxic heavy metal used in Ni-Cd batteries, the colouration of plastic and various discarded electronic products released into the water system causes serious health issues. The chronic exposure to Cd produces a wide variety of acute and chronic effects in humans. Cd accumulates in the human body, especially in the kidneys, resulting in kidney damage (renal tubular damage), which is a critical health effect. Other effects of Cd exposure are disturbances in calcium metabolism, hypercalciuria and the formation of kidney stones. High exposure to Cd can lead to lung cancer and prostate cancer; hence, poor quality water that may result in Cd toxicity has become a global concern. Thus, the aim of this study is to determine the concentration of Cd in underground water sources in western U.P. regions. Water samples were acidified to 1% with nitric acid and then stored in double-capped polyethylene bottles for further analysis by an atomic absorption spectrophotometer. After comparing the data to the WHO (2011) permissible limit, the study revealed that the concentration of Cd was higher than the regulatory threshold; therefore, the underground water system is seriously affected by Cd toxicity.

1. Introduction

Environmental pollution is a recent major concern due to the serious risk to biota. Rapid industrialization and modern technology play a major role in polluting the environment. Heavy metals are highly toxic metals that are usually present in industrial, municipal and urban runoff and can be harmful to humans and biotic life. Increased urbanization and industrialization are responsible for increases in levels of trace metals, especially heavy metals, in our waterways (Singh et al., 2011). There are many dangerous chemical elements released into the environment that further accumulate in the soil and sediments of water bodies (Begum et al., 2009). These toxic metals have a marked effect on the aquatic flora and fauna, ultimately entering the food chain via bio magnification and result in serious effects on human health (Lokhande et al., 2011). Heavy metals such as Cd, arsenic, lead, chromium, copper, and mercury in drinking water are linked most often to human poisoning. Some of these metals are essential for life in small amounts, whereas some have no biological functions. However, all are highly toxic in large doses and are therefore considered environmentally hazardous substances. Cd is an extremely toxic heavy metal, even in low concentrations. It leaches into the soil through water and further bio-accumulates in organisms and ecosystems; in addition, Cd has a long biological half-life in the human body, ranging from 10 to 33 years. The long-term exposure to Cd induces renal damage. It also disturbs calcium metabolism in the body, and cases of prostate cancer and lungs cancer have been reported in cases of high Cd exposure. Thus, Cd is considered a priority pollutant form a monitoring perspective by most countries

and international organizations. The contamination of water is directly related to water pollution; hence, there is a need to continuously monitor the quality of underground and surface water sources.

2. Materials and methods

A survey of the contaminant level of Cd in western Uttar Pradesh (India) was conducted in December 2017. Four districts were selected for the study from western UP viz. Shahjehanpur, Bareilly, Moradabad and Rampur. Six locations were selected from each district for sampling. Samples of water were collected from the tap and hand-pumps of different boring depths (30–150 feet below ground level) in prewashed (with detergent followed by HNO_3 and double deionised distilled water) double-capped glass bottles. Prior to collection, the water was allowed to run for 05 min as demonstrated by Bajaj et al. (2016). The samples were acidified to 1% with nitric acid and then stored in 100 ml double-capped glass bottles that had been prewashed in the previously described manner by Mebrahtu and Zerabruk (2011). The detection of the heavy metal concentration in the collected samples was done with the help of atomic absorption spectroscopy [AAS] (Mohammad et al., 1992; Alcantara et al., 2004).

The contamination factor (CF) of the water samples is shown in Fig. 2. The CF was determined by the given formula:

$$\text{Contamination factor} = \frac{\text{present study mean}}{\text{value of WHO permissible limit}}$$

Where WHO is: World Health Organization

2.1. Statistical analysis

The measurements thus obtained were analyzed by using t-test method and the results are expressed as Mean ± SD. Standard Error was also calculated.

3. Results and discussion

The t-test value obtained from the given data was calculated for group I, II, III, IV were 13.96, 16.41, 13.96, 11.51 respectively at $p < 0.05$ significance level with degree of freedom i.e., 5 (Table 1). The results obtained after the analysis of Cd concentrations in underground water samples by the AAS method from selected districts of western Uttar Pradesh, India, are shown in Tables 2–5. The tables also contain the mean values, standard deviations and standard errors of the data. The results show that all the selected districts are at an alarming stage, with high Cd concentrations. The regulatory body the World Health Organization (2011) recommended a concentration of Cd below 0.003 mg/l in drinking water, but the results showed all the selected sites had concentrations of the toxic metal that exceeded the recommended threshold.

Cd is carcinogenic in nature, as reported by Stewart and Kliehues (2003). As the shown by the results in Tables 2–5, all districts had high levels of Cd toxicity, but two districts, i.e., Bareilly

Table 1
Cadmium concentration analyzed with t-test.

Group	WHO limit of Cd (h)	Sample mean (x)	S.D.	D.F.	t- statistic value
I	0.003	0.06	0.01	5	13.96
II	0.003	0.07	0.01	5	16.41
III	0.003	0.06	0.01	5	13.96
IV	0.003	0.05	0.01	5	11.51

S.D.: Standard Deviation; D.F.: Degree of Freedom.

Table 2
Cd concentration in water samples collected from Shahjehanpur, (U.P.) India.

Serial No.	Sample No.	Cadmium concentration (mg/l)	Mean (±S.D.)	S.E.
1	S-1	0.04	0.06 ± 0.01	0.004
2	S-2	0.05		
3	S-3	0.06		
4	S-4	0.06		
5	S-5	0.07		
6	S-6	0.07		

±S.D.:Standard Deviation; S.E.: Standard Error.

Table 3
Cd concentration in water samples collected from Bareilly, (U.P.) India.

Serial No.	Sample No.	Cadmium concentration (mg/l)	Mean (±S.D.)	S.E.
1	S-7	0.06	0.07 ± 0.01	0.002
2	S-8	0.07		
3	S-9	0.06		
4	S-10	0.06		
5	S-11	0.07		
6	S-12	0.07		

±S.D.:Standard Deviation; S.E.: Standard Error.

Table 4
Cd concentration in water samples collected from Moradabad, (U.P.) India.

Serial No.	Sample No.	Cadmium concentration (mg/l)	Mean (±S.D.)	S.E.
1	S-13	0.04	0.06 ± 0.01	0.005
2	S-14	0.05		
3	S-15	0.06		
4	S-16	0.07		
5	S-17	0.07		
6	S-18	0.07		

±S.D.:Standard Deviation; S.E.: Standard Error.

Table 5
Cd concentration in water samples collected from Rampur, (U.P.) India.

Serial No.	Sample No.	Cadmium concentration (mg/l)	Mean (±S.D.)	S.E.
1	S-19	0.05	0.05 ± 0.01	0.002
2	S-20	0.06		
3	S-21	0.04		
4	S-22	0.05		
5	S-23	0.05		
6	S-24	0.05		

±S.D.:Standard Deviation; S.E.: Standard Error.

and Moradabad, were at a particularly alarming stage. The Cd concentrations of the selected districts demonstrated the following order: Cd Bareilly > Moradabad > Shahjehanpur > Rampur.

Drinking water samples from all the selected sites in Shahjehanpur had elevated concentrations of Cd, as shown in Table 2. The mean Cd concentration was 0.06 mg/l, which is higher than the permissible limit recommended by the World Health Organization (2011).

Table 3 shows the Cd concentrations in underground water samples in the selected locations of the Bareilly district in India. The values obtained after the heavy metal analysis were 0.06, 0.07, 0.06, 0.06, 0.07 and 0.07. The Moradabad district also had high concentrations of Cd in its water samples as the mean

concentration was 0.06 mg/l (Table 4). These results may be because these areas are densely populated, developed and industrialized. These districts are hubs of electronic industries, so the possibility of the illegal dismantling of E-wastes is high within these regions. The dismantling of E-wastes is followed by either open-air burning, dissolving by acid, or other methods to get valuable parts from the waste. It has been found that Cd ions are leached from disposed E-waste materials such as cathode ray tubes and electronic chips. A significant amount of lead and cadmium ions from the broken cone glass of cathode ray tubes and other electronics can mix with water and turn it acidic, which is a common occurrence in landfills. The toxic fallout from open-air burning affects the local environment and broader global air currents, depositing highly toxic by-products in many places throughout the world, as suggested by Sivakumar et al. (2011); Ramachandra and Saira (2004).

In the Rampur district, the Cd toxicity situation is also not good. Although the concentration was very high in the water samples, it was much lower than those from the selected stations of the other districts. The Cd concentrations were 0.05, 0.06, 0.04, 0.05, 0.05 and 0.05 in the selected sites of Rampur, as shown in Table 5. The mean ± S.D. was 0.05 ± 0.01, and the standard error was 0.002.

As Fig. 1 shows, all four selected districts had high concentrations of the toxic metal cadmium. Most of the Cd enters the atmosphere due to the burning of electrical and electronic wastes. In India, informal sectors consumed ninety percent of the E-waste. Most rag pickers collect electronic items in the form of office electronic scraps and household electric items, which are mined unscrupulously for metal. These discarded unwanted electric wastes are mostly handled by unskilled workers, and they do not
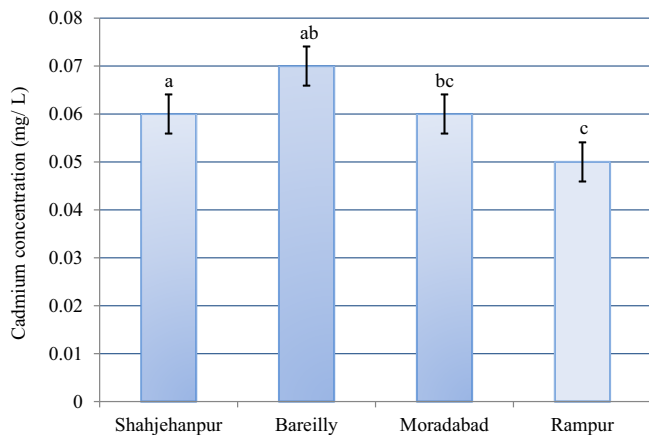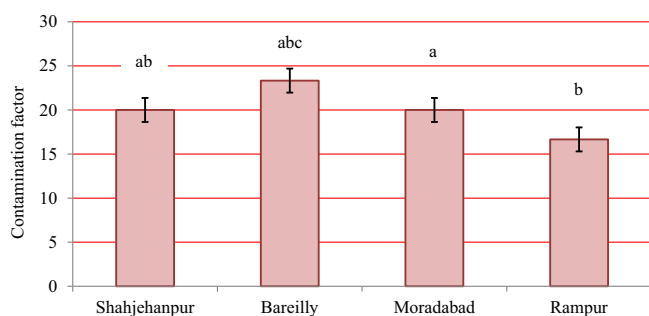
take proper safety measures. Therefore, due to the lack of appropriate knowledge and technology, recycling and disposal are not properly conducted; hence, there is currently urgent need to implement a proper E-waste management system in western U.P. Various industrial effluents discharge into the Ramganga and Kosi river system, so the quality of water has presently declined. Research technologies, innovations, recycling and environmental education at all levels and the creation of awareness in the E-waste generation sectors could make better results.

The Contamination Factor (CF) of all four districts were in the order of Bareilly > Moradabad > Shahjehanpur > Rampur, with values were 23.33, 20, 20 and 16.66 respectively. All districts have higher concentration of cadmium in water samples. The present results reveal that the water quality is not recommended for drinking due to heavy Cd stress. Chronic exposure to the heavy metal leads to many serious health risks; hence, the water quality should regularly be monitored because it is a vital resource and necessary for the survival of every organism on earth.

4. Conclusion

In conclusion, the present research revealed that the drinking water samples contain Cd concentrations higher than the permissible limit set by the World Health Organization (2011). Most of the underground water samples were at populace level and were not recommended for drinking purposes. The present contamination results indicate a major proportion of the populace are at a significant risk of Cd toxicity, as the water samples from the regions of western Uttar Pradesh were highly polluted by the metal. The overall heavy metal pollution situation is at an alarming stage. People may suffer serious health risks due to drinking water with high concentrations of heavy metals. They may have physiological effects on the kidney, digestive system, circulatory system, nervous system, and various other organs and systems in the body. Therefore, it is necessary to regularly monitor the toxicity and quality of the water system. Waste-water should be treated before being discharged into water sources. Other innovative methods, such as recycling, an eco-friendly method, should be considered to tackle the situation.

Fig. 1. Cadmium concentration in water samples in selected districts.

Fig. 2. Contamination factor of cadmium in water samples from the selected districts.

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