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Research Paper:

Seasonal Variations of Lead and Chromium Concentrations in the Water Samples From Yamuna River in Delhi, India

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ABSTRACT

Background: According to Hindu mythology, Yamuna River plays an impotent role as a holy water resource in Delhi, India. The lead and chromium concentrations were determined from the water samples collected from five different locations around this river in Delhi area. The contaminated water from this river is mostly used for drinking, agriculture, aquaculture, and storage as a holy water.

Methods: The seasonal variations of heavy metal concentrations in the water samples collected from Yamuna river were determined for the summer, monsoon and winter supplies, using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Atomic Absorption Spectroscopy (AAS).

Results: In the summer water samples, we found greater concentrations of both heavy metals than those for the monsoon season. The concentrations of lead and chromium in the water samples were higher than the permissible limits recommended by the World Health Organization (WHO). The water quality was not safe for drinking, cleaning and agriculture, nor for the aquatic animals, such as fish, amphibians and others.

Conclusion: The condition of the water in Yamuna river is of great health concerns. Therefore, it is vital to take necessary actions to decontaminate the water from this river, and to draw effective strategies to minimize or prevent the current and future contaminations added to this important water resource in India.

Keywords: Lead, Chromium, Yamuna River, Water resources, Toxicity, Human and aquatic health

Introduction

Rivers are vital human resources for consumption by people and communities. Water is vital for numerous human needs, such as agriculture, and essential for hydropower plants, and to refine the climate, among others [1]. Yamuna river portrays a significant character in the daily life of many people in India who reside on its shores and the vicinity. This river has a broad catchment zone covering numerous Provinces near Delhi and is being used for many agricultural, manufacturing and residential purposes. With the rapid growth of the population and technology during the last decades, this river has become one of the most contaminated streams in India. Waste waters from the manufacturing plants and marshlands represent the primary sources of pollutants added to this river, causing its current grave situation. In Delhi area itself, there are 22 submerged sewers and drains that pour their contaminated waters into the Yamuna river [2]. Insecticides leakage from farm lands and heavy metals from

manufacturing plants and wastelands are often poured at large scales into this river. Also, this river has become a dumpster for cattle manure, and other contaminated overflow from the surrounding lands.

Some heavy metals are capable of activating various enzymes, which can be lethal to humans even at very low concentrations [3]. Since many farms around Delhi use the water from this river for agricultural purposes, the heavy metals, such as lead and chromium, from the water eventually find their way into the food chains, causing great health concerns and leading to numerous diseases in humans and animals [4]. Further, heavy metals are found in the earth's crust and may enter water resources through natural processes, i.e., heavy rain falls that leach them out of the soil and add them to local streams and eventually poured into Yamuna river [5-10]. In this context, Yamuna river is facing its darkest point in history, not only because of the large amounts of contaminants being continually added to it, but also because the alternative water resources in the area are being exhausted due to environmental mismanagement.

Considering the absence of appropriate environmental regulations and lack of modern water treatment plants to refurbish the water in Yamuna river, it has become an unfit resource to provide for otherwise desired role in Delhi area [11]. This river is currently one of the dirtiest water resources in India because of its toxic heavy metal contents [12-15]. The contaminated water from this river is of great concerns as numerous populations in Delhi areas depend on it for their water needs. The accumulation of lead and chromium poses extreme harms to the health of humans and animals alike [16-21]. Currently, waste waters from manufacturing plants are the major sources of heavy metals entering the waters of Yamuna river [22, 23]. Since heavy metal toxicity is a threat to human and animal health, this study aimed to investigate the seasonal variations of lead and chromium in Yamuna river under a variety of environmental conditions.

Materials and Methods

Samples collection: The water samples were collected from five different sites around Yamuna river in Delhi area as follows: 1. Okhala Bird Sanctuary; 2. Kalindi Kunj Ghat; 3. Okhala Barrage; 4. Yamuna Bridge, and 5. Yamuna Banks. All of these locations were the consumers of the water from Yamuna river for agricultural and human consumption purposes. Several water samples (1.5 liters) were collected for laboratory examination from each location in sterile polyethylene bottles that had been washed with de-ionized water and 10% nitric acid. Prior to sampling, the containers were washed at least 3 times with water from the specimen locations. The containers were deep to about 20cm under the water surface to stop pollution of trace elements from the air also gathered for examination from every location.

Sample preparation: All water specimens were brought to the lab where they were filtered through Whatman's #41 (0.45 µm pore size) filter paper. The specimens were acidified with 2ml concentrated nitric acid to prevent precipitation of Chromium, decrease adsorption of the analytes onto the walls of containers, and to avoid microbial growth. These water samples were then stored at 4°C until further analysis [24]. The lead and chromium concentrations were determined in the water samples from Yamuna river for summer, monsoon and winter seasons. The determined concentrations were compared to the admissible limits recommended by the World Health Organization (WHO). Water samples were also collected from the specimens dated back to the point before a directive was issued to regulate the water contamination in the Yamuna river.

Instrumentation: The concentrations of lead and chromium were determined in all samples by inductively coupled plasma mass spectrometry and atomic absorption spectroscopy. It is a standard laboratory diagnostic device for metal detection.

Statistical analyses: The levels of lead and chromium contaminations were measured in all water samples collected in different seasons. The data were analyzed, using two-way Analysis of Variance (ANOVA) followed by Fand Tukey's tests ($P<0.005$).

Results

Seasonal Variations in Lead: The seasonal variations in the concentrations of lead in the water samples from Yamuna river are shown in Figure 1. The contamination findings were not consistent with those permissible by the World Health Organization. The lead contamination also differed depending on the climate condition, such as rainfall and temperature changes. For instance, the water samples collected in the summertime displayed significantly greater concentrations of lead ($P<0.005$) followed by those from the winter and rainy seasons. The mean square values of the lead contents were greater in the summer followed by winter and monsoon. Table 1 shows the comparison of the means for different seasons based on Tukey's test. The results confirmed that the wastewater and effluent samples were the key cause of lead contamination in the river water. Reduction in the volume of

Table 1. Tukey's test of multiple comparisons of the means for lead concentrations in different seasons.

Season	Difference	Lower	Upper	P
Summer-Monsoon	1.15060	0.83442891	1.4667711	0.0000000
Winter-Monsoon	0.21004	0.09227739	0.5123574	0.2241085
Winter-Summer	-0.94056	1.21825625	0.6628637	0.0000000

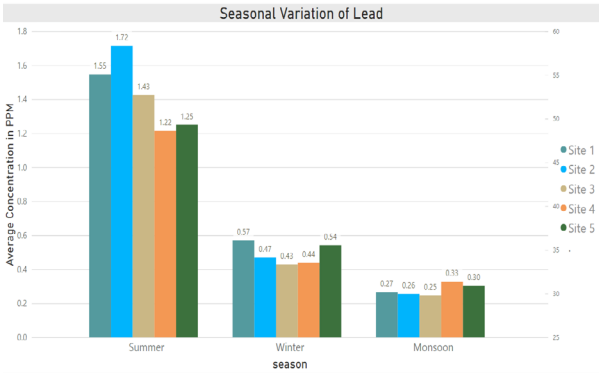

Figure 1. Sessional variation of lead in Yamuna river water samples

the river water during the summer season caused a major surge in the lead concentration. Table 1 shows comparisons of multiple seasons. Pairs of seasons indicate that the research was conducted during those periods.

Seasonal variations of chromium: The seasonal variations in the concentrations of chromium in the water samples from Yamuna river are shown in Figure 2. The results were not consistent with the permissible level recommended by the World Health Organization. The chromium concentration varied under different conditions, i.e., summer, monsoon, winter. The chromium concentration in the summer period was greater than those for the winter and rainy seasons. The order of the mean square values of lead contents was greater in the summer followed by the winter, monsoon and rainy seasons. The multiple comparisons of the means based on Tukey's test are shown in Table 2. The data indicated that sewage waters, anthropogenic activities and effluents were the major source of chromium contamination in the river water. The reduction in water volume due to evaporation during hot seasons led to an upsurge in the contents of chromium and other heavy metals in the river.Table 2 shows comparisons of multiple seasons. Pairs of seasons indicate that the research was conducted during those periods.

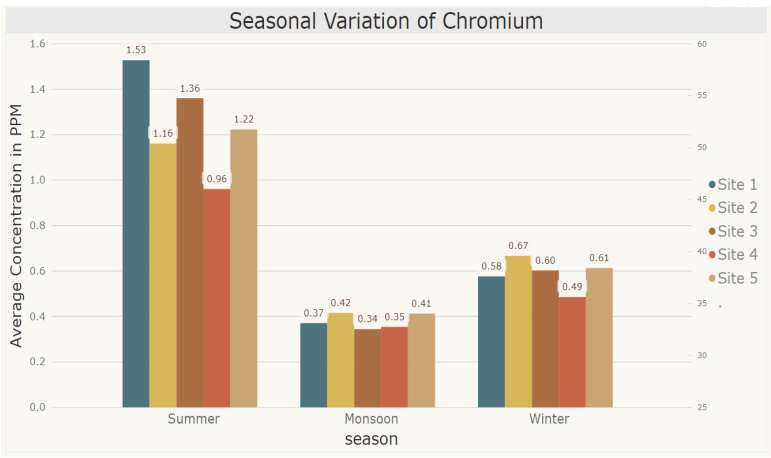

Figure 2. Sessional variation of chromium in Yamuna river water samples

Table 2. Tukey's test for chromium by multiple comparisons of the means in different seasons

Season	Difference	Lower	Upper	P
Summer-Monsoon	0.86755	0.642479182	1.0926208	0.0000000
Winter-Monsoon	0.20956	0.005648865	0.4247689	0.0578548
Winter-Summer	-0.65799	-0.855671965	-0.4603080	0.0000000

Discussion

The Seasonal variations in the concentrations of lead and chromium exceeded or were barely at the margin of the acceptable limits permissible by the World Health Organization in the river waters. Our study findings supported by the statistical analyses indicate that the lead and chromium concentrations the river water have exceeded the permissible limits. Human health is definitely and adversely affected by the ingestion of such contaminated water either directly or as residues in vegetables, fish, plants, fruits, and other food chains.

Heavy metals are commonly found in the water bodies & these are dangerous for both aquatic and human life. There are various studies related to heavy metal toxicity in previous literature reporting the levels of heavy metals in water bodies. The WHO had strictly suggested the permissible limit but most of water bodies are contaminated with waste waters released from the industries and nearby factories. Of note, the drinking water samples contained heavy metal concentrations, which were more than the admissible levels recommended by WHO. Toxicology studies have frequently detected heavy metal concentrations in various water bodies in India. The rise in the elemental pollution makes water and fish not suitable for consumption and may cause severe human health problems.

Conclusions

Based on the current study findings, most of the agricultural activities in Delhi areas occur near Yamuna river where the industrial wastes, sewage, natural sources and anthropogenic waste materials contaminate Yamuna river water with hazardous pollutants. Consequently, major diseases, such as kidney failure, slow growth, cancer and neurotoxicity are associated with the contaminated Yamuna river water in the surrounding areas. The Individuals residing near the river should be fully informed of the adverse effects of drinking the water and edibles irrigated with the river water. Our analyses clearly indicate that the drinking water samples in the Yamuna area contain heavy metals, such as lead and chromium with the levels being beyond the WHO permissible limits. Most of the examined water samples were too contaminated to be used for drinking, cooking or washing purposes.

Limitation of the study: At times, there may be occasional rises in the concentrations of heavy metals beyond the levels demonstrated by this study. This implies that the industrial discharges and effluents may increase suddenly, which adversely impacts the quality of the river water.

Recommendation for future studies: Considering the implication of the river water with the health of humans who rely on it, we recommend that future research be planned on the environmental toxicology of Yamuna river, using modern methods to assess its heavy metal contaminations.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Author's contributions

Conceptualization and Methodology: Rajeev Kumar and Lalit Prasad; Data collection: Mahipal Singh Sankhla; Data analysis: Rajeev Kumar; All authors read and approved the final manuscript.

Conflict of interest

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

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