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Evaluation of Toxic Heavy Metal Contamination in the Drinking Water of Ulhasnagar City, Maharashtra, India

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Abstract: *The water quality in Ulhasnagar city is significantly affected by the presence of numerous industries, as observed data reveals contamination of drinking water with toxic heavy metals such as chromium, copper, cadmium, lead, and nickel. Among these, chromium is found in particularly high concentrations due to the widespread use of the chrome tanning process in local leather industries for dehairing and dehiding. The elevated levels of chromium and other heavy metals in drinking water pose serious health risks to humans, highlighting the urgent need to implement advanced technological solutions to maintain these toxic substances within permissible limits..*

Keywords: Chrome tanning, Water contamination, Industrial pollution, Heavy metals, Health risks

I. INTRODUCTION

Metals are widely distributed in the environment and accumulate in three main reservoirs: water, sediment, and living organisms. In river systems, heavy metals originate from both natural sources, such as the geological composition of the area, and human activities like industrial processes and agriculture. Human-induced contributions include atmospheric deposition, waste disposal and incineration, urban runoff, vehicle emissions, using fertilizers, and the long-term discharge of sewage and sludge into waterways. Similarly, pesticides enter aquatic environments through various routes, including direct application, agricultural runoff, wastewater discharge, improper disposal of containers, and equipment rinsing. These chemicals often reach water bodies via runoff, sediment transport, or by leaching into groundwater during rainfall or irrigation, leading to harmful effects on non-target organisms and disrupting food web dynamics [1]. Many pesticides and their breakdown products can persist in groundwater for extended periods, sometimes lasting for years [2]. The World Bank estimates that the population in the region will double within the next 20 to 40 years, while the global demand for scarce water resources is expected to increase at nearly twice that pace. Water demand in India is expected to increase sharply from 552 billion cubic meters (BCM) to 1,050 BCM by 2025, underscoring the critical need for efficient and sustainable management of all water resources. Currently, agriculture accounts for nearly 92.94% of the nation's total water consumption. Alarmingly, six out of India's twenty major river basins have already crossed the water scarcity threshold of 1,000 cubic meters per capita per year, with five more likely to reach this critical level within the next thirty years. Over the last five decades, the extensive and rising use of agrochemicals has severely contaminated both surface water and groundwater resources. Heavy metals represent one of the most severe and hazardous threats to water quality among all water pollutants.

Heavy metals are a broadly categorized group of around 65 metallic elements with densities greater than 5 g/cm³. While they display a wide range of physical, chemical, and biological characteristics, they generally become harmful to living organisms when their concentrations exceed safe limits. Although elevated concentrations of toxic heavy metals can naturally occur in certain areas, their overall abundance in the environment tends to be low. Most naturally occurring heavy metals are found in stable, immobilized forms within sediments, which serve as important reservoirs of environmental data [3]. Sediments are now widely recognized as both carriers and potential sources of pollution in aquatic ecosystems. A continuous exchange of contaminants takes place between sediments and the overlying water,

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largely driven by tidal movements. Pollutants carried by suspended sediments are deposited on the riverbed, while tidal action and wave-induced resuspension can release these contaminants back into the water column [4].

Human activities such as ore mining and industrial processes have profoundly disrupted natural biogeochemical cycles, resulting in elevated heavy metal accumulation in both terrestrial and aquatic environments. Major contributors to heavy metal pollution include fossil fuel combustion, waste generated from breweries and distilleries, the use of biocides and preservatives, as well as industrial practices like refining, cleaning, and metal plating. Among the most concerning heavy metals are copper, chromium, cadmium, lead, nickel, and mercury due to their persistence and toxicity.

Heavy metal contamination mainly raises concerns such as:

- The detrimental effects on ecosystems, particularly on biological communities.
- Serious public health risks linked to documented cases of mercury, lead, and cadmium poisoning.
- Consequently, routine monitoring of drinking water quality and evaluating heavy metal concentrations are essential to mitigate potential health risks and prevent heavy metal poisoning.

II. MATERIALS AND METHODS

Ulhasnagar, situated about 26 kilometers from Thane City in Maharashtra's Thane district, is a part of the Mumbai Metropolitan Region under the governance of the Mumbai Metropolitan Region Development Authority (MMRDA). With an estimated population of around 696,000 in 2023, it functions as both a municipal city and the administrative center of its namesake Tahsil. Internationally recognized for its leather industry, Ulhasnagar grapples with severe water pollution, primarily due to the discharge of tannery wastewater into the Ulhas River, the region's main water source. Industries like metal plating and refining further worsen the pollution, heightening environmental and public health risks.

Sample collection

To evaluate the physico-chemical characteristics of drinking water in Ulhasnagar city, samples were collected from multiple locations, encompassing both groundwater and municipal water supplies. In addition, samples from the Ulhas River were obtained to assess the level of heavy metal contamination.

Analysis of Toxic Heavy Metals Using AAS:

The quantification of toxic heavy metals was carried out using an Atomic Absorption Spectrometer (AANALYST100). Calibration of the instrument was performed with standard metal solutions (Cr, Ni, Cu, Cd, and Pb) at concentrations of 0.01, 0.1, 1.0, 10.0, and 100 ppm. After successful calibration, water samples were aspirated into the flame, with the burner position adjusted to maintain the optimal flame conditions observed during solvent aspiration. Before analysis, samples were digested with concentrated nitric acid (HNO_3) and then introduced into the nebulizer (atomizer). Upon aspiration into the flame, the digested samples yielded the mean concentrations of the respective heavy metals.

III. RESULTS AND DISCUSSION

The data indicates that heavy metals such as chromium, copper, and lead exceed their permissible limits in the drinking water samples collected from Ulhasnagar city. Table 1 compares the concentrations of various heavy metals across different water sources and evaluates them against the permissible limits set by the ISI standards [5].

Chromium concentrations in groundwater samples range between 0.3 and 0.4 mg/L, significantly surpassing the desirable limit of 0.05 mg/L established by the Central Pollution Control Board. Notably, the Ulhas River sample exhibited the highest chromium concentration, approximately ten times greater than the recommended limit.

Moreover, the Ulhas River water is heavily contaminated with copper, registering concentrations around 7 mg/L, whereas copper levels in municipal drinking water remain within permissible limits.

Lead contamination was detected in both river and groundwater samples, with municipal water showing slightly elevated lead concentrations above the acceptable threshold.

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Conversely, the concentrations of other heavy metals, such as mercury, zinc, and iron, remained within their prescribed limits.

A detailed statistical summary of individual heavy metal concentrations in Ulhasnagar's drinking water is presented in Table 1.

Toxicological Impact on the Environment:

Chromium exposure is known to cause occupational allergic contact dermatitis, with trivalent chromium serving as the sensitizing agent. Hexavalent chromium (Cr VI) can be released from chromium metal due to the corrosive action of sweat, facilitating skin penetration. Extended exposure to Cr (VI) compounds may result in ulceration and perforation of the nasal septum, as well as characteristic skin lesions known as "chrome holes."

Copper intoxication can manifest as vomiting, hypertension, coma, and, in severe cases, death. Chronic copper exposure leads to hepatic damage, including hepatitis, cirrhosis, liver failure, and ultimately, death. Additionally, copper promotes hepatic peroxidation through the generation of hydroxyl radicals, worsening liver injury.

Lead, even at low concentrations, interferes with haemoglobin synthesis by inhibiting iron incorporation into protoporphyrin, causing reduced haemoglobin levels and anaemia. Lead toxicity can also induce abdominal pain and adversely affect both the central and peripheral nervous systems [6].

The electroplating industry in Ulhasnagar significantly contributes to cadmium contamination in drinking water. Chronic exposure to cadmium, even at low levels, is associated with arteriosclerosis, hypertension, and cardiovascular diseases. Acute cadmium poisoning can cause pneumonitis, while renal damage resulting in proteinuria serves as a key indicator of cadmium toxicity. Furthermore, cadmium disrupts the activity of various enzymes, impairing numerous biochemical processes within the body [7].

Table 1

Sr. No.	Toxic heavy metal	ISI Standard	Concentration in the groundwater sample	Concentration in the river water sample	Concentration in the municipal water sample
1.	Chromium	0.05	0.309	0.664	0.084
2.	Copper	1.0	2.670	7.086	0.5202
3.	Lead	<0.05	0.167	0.428	0.074
4.	Cadmium	0.01	0.589	0.865	0.012
5.	Iron	<0.03	0.0245	0.001	0.001
6.	Mercury	0.001	<0.001	<0.001	<0.001
7.	Zinc	5.5	3.41	1.16	1.15
8.	Silver	0.05	0.01	0.008	0.008

IV. CONCLUSION

The study reveals that the drinking water in Ulhasnagar city is heavily contaminated with toxic heavy metals, presenting serious health hazards to the local population. The findings highlight that residents are at considerable risk of developing various health issues as a result of this contamination. Immediate action is essential to control and reduce heavy metal pollution to protect public health.

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