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Heavy Metal Contamination In Drinking Water Near Dada Nagar, Kanpur: A Chemical Assessment

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Abstract

Heavy metal contamination of the local drinking water has been brought to light by industrial effluents from the Dada Nagar area of Kanpur. This study examines information on the levels of various metals in groundwater and piped water close to Dada Nagar including arsenic lead cadmium chromium and mercury. sampling (e. g., hand-pump or borewell collection) adheres to APHA standard procedures utilizing inductively-coupled plasma optical emission spectroscopy (ICP-OES) and atomic absorption spectroscopy (AAS) for analysis. According to reports As and Cr concentrations frequently surpass WHO and Bureau of Indian Standards (BIS) limits (e. g. As up to 448 µg/L in comparison. WHO limit: 10 µg/L Cr(VI) ~6200 µg/L vs. 50 µg/L BIS. Tens of µg/L of other metals including Pb Cd Cu and Zn are found. The chemical forms that affect toxicity include Cr(III)/Cr(VI) and arsenite/arsenate. Frequent exceedances of safety limits are revealed by comparisons with BIS/WHO standards. Geogenic (natural sediment leaching) and anthropogenic (tanneries plating chemical industries) sources are the sources of heavy metals in water. We talk about poisonous processes (e. g., carcinogenesis enzyme inhibition and health consequences. This evaluation emphasizes how urgently the drinking water in Dada Nagar needs to be monitored for and treated for heavy metal contamination.

Keywords: Heavy Metals, Drinking Water

Introduction

Water pollution from tanneries and metal-processing facilities has long been known to occur in Kanpur city particularly in its industrial areas like Dada Nagar and Jajmau. Untreated wastewater containing heavy metals is released by the leather and metal industries (e. g. lead, cadmium, mercury, arsenic, chromium and arsenic) that pollute surface and groundwater. The chemical and electroplating plants in Dada Nagar Industrial Estate produce sludge that is rich in chromium. According to research conducted by the Central Pollution Control Board (CPCB) Kanpur groundwater has a remarkably high concentration of hexavalent chromium (Cr(VI)).

A. It is orders of magnitude higher than the BIS drinking-water standard of 50 µg/L (~6. 2 mg/L = 6200 µg/L). There are additional heavy metals (As, Cd, Pb and Hg) that come from both man-made and geological sources. The aquifers of the Ganga Plain are known to contain arsenic a study conducted in the nearby town of Shukla Ganj revealed that groundwater levels of As could reach 448 µg/L (the average geogenic background is less than 10 µg/L). These metals toxicity (e. g. g. . As is a group-1 carcinogen Pb and Cd harm the neurological and renal systems and Cr(VI) is a known human carcinogen these substances raise public health concerns. In addition to summarizing reported heavy metal levels close to Dada Nagar and comparing them with BIS/WHO limits this paper highlights chemical speciation sources and toxicity mechanisms that are pertinent to an audience interested in advanced chemistry.

Materials And Methods

Sampling: Drinking-water samples (primarily hand-pump or borewell) in the Dada Nagar area are collected following APHA standard procedures. Bottles are acid-washed and rinsed with sample water, then preserved (usually by acidification) to stabilize trace metals. Sampling is done in different seasons to capture variations. Where available, piped water sources are also sampled. Sample locations include points near industrial drains, waste-disposal sites, and residential zones of Dada Nagar. GPS coordinates are recorded for mapping.

Analysis:

Conventional analytical methods are used to quantify the amount of heavy metals in water. For Pb Cd As (often with hydride generation for As) and Cu Atomic Absorption Spectroscopy (AAS) is commonly used. For the analysis of multiple elements such as Cr Ni Zn and others ICP-OES or ICP-MS are utilized. For instance, Gupta et al. (2022) employed ICP-OES for river and sediment samples and AAS for Kanpur groundwater (drinking water samples). For AAS detection limits are typically in the low µg/L range. Reagent blanks duplicates and standard reference materials are all part of quality control. Water chemistry is also evaluated by measuring pH conductivity and anions/cations (using titration or ion chromatography).

Standards

Regulations are compared with the measured concentrations of heavy metals. Maximum limits for drinking water are specified by BIS (IS 10500:2012) as follows: 0. 01 mg/L for Cr (total) 0. 05 mg/L for Pb 0. 01 mg/L for Cd and 0. 001 mg/L for Hg. The WHOs provisional guidelines also set 10 µg/L for As and Pb 50 µg/L for Cr 3 µg/L for Cd and 6 µg/L for inorganic mercury (with 1 µg/L for total mercury) [63]. Additionally we observe that the strict limit is 0. 01 mg/L while the BIS specifies a permissive limit of 0. 05 mg/L (50 µg/L) for As in emergency. These guidelines act as standards by which to measure contamination.

Results

The reported heavy metal concentrations in the drinking water of the Dada Nagar/Kanpur area are listed in Table 1 which is a summary of the literature. There are few direct published data for Dada Nagar however regional studies shed light on the area. Chauhan and colleagues. (2012) discovered that groundwater in Shuklaganj close to Kanpur had As levels ranging from 0 to 448 µg/L which is above the WHO limit of 10 µg/L at numerous locations. Gupta and others. found that groundwater samples from Kanpur had isolated levels of Cr and Pb in addition to detectable levels of Fe Cu and As (2023). Two wells had Pb detected in that study and one well close to an industrial zone had Cr (19. 8 µg/L). In contrast the river water near Kanpur had significantly higher metal loads (Cu 32–125 µg/L Cr 19–725 µg/L Pb 37–163 µg/L and As 32–153 µg/L) which were indicative of untreated effluent inputs.

Our main conclusions from the literature are as follows: Many Kanpur wells have been found to contain arsenic frequently in excess of recommended levels. Chauhan and associates. found As(III) and As(V) species in water geogenic mobilization (Fe-oxyhydroxide reductive dissolution) was suggested. The stated maximum As was 448 µg/L which is significantly higher than the recommended threshold of 10 µg/L. Near tanneries there is severe chromium contamination: CPCB (1997) found that the groundwater in Kanpur had Cr(VI) levels as high as 6. 2 mg/L. While not all sites are that bad many wells in the Dada Nagar area have Cr levels higher than 50 µg/L. Kanpur groundwater has been found to contain lead (e. g, Some wells have levels between 20 and 80 µg/L which is above the 10 µg/L limit. Although cadmium levels are typically lower (few µg/L) they can occasionally surpass 3 µg/L. Groundwater rarely contains mercury but sludge can leach mercury. Some wells have high levels of iron and zinc (Zn up to mg/L in previous surveys).

In conclusion measured concentrations frequently exceed Indian/WHO standards in the Dada Nagar area: e.g. As opposed to 0. 01 mg/L WHO and 0. 05 mg/L BIS. Cr(VI) up to approximately 0. 45 mg/L detected 0. 05 mg/L BIS vs. Pb (0. 01 mg/L) versus multi-mg/L present. detected in the tens of µg/L.

Metal	**Reported Concentration Range (µg/L)**	**Maximum Reported Value (µg/L)**	**BIS Limit (µg/L)**	**WHO Guideline (µg/L)**	**Major Source**
Arsenic (As)	0 – 448	448	10 (desirable), 50 (permissible)	10	Geogenic leaching,

Metal	**Reported Concentration Range (µg/L)**	**Maximum Reported Value (µg/L)**	**BIS Limit (µg/L)**	**WHO Guideline (µg/L)**	**Major Source**
					industrial discharge
Chromium (Total/Cr(VI))	19 – 6200	6200	50	50	Tanneries, electroplating
Lead (Pb)	20 – 80	~80	10	10	Batteries, metal industries
Cadmium (Cd)	1 – 10	~10	3	3	Electroplating, industrial waste
Copper (Cu)	32 – 125	125	50 (acceptable), 1500 (permissible)	2000	Industrial effluent
Zinc (Zn)	Up to 1000+ (mg/L levels in some surveys)	>1000	5000	No health-based guideline	Industrial discharge
Mercury (Hg)	Rarely reported in groundwater; trace levels detected	<10 (limited data)	1	6 (inorganic)	Industrial sludge

Table 1. Reported Heavy Metal Concentrations in Groundwater and Surface Water Near Kanpur Industrial Regions in Dada Nagar

Discussion

Sources and Speciation

Both anthropogenic and geogenic sources contribute to the presence of heavy metals in Dada Nagar drinking water. Among the geogenic sources are naturally occurring minerals in the Ganga alluvium that contain arsenic and dissolve in reducing conditions. The Chauhan group. In reducing aquifers As is primarily found as As(III) and As(V) in low-oxygen environments the more hazardous As(III) predominates. Anthropogenic/industrial sources predominate for Cr Pb Cd and so forth. Chromium salts are used for tanning in Kanpur's 350 tanneries (in Jajmau and the surrounding areas) resulting in waste that is rich in Cr(VI). Cr(VI) has contaminated groundwater as a result of these wastes discharge or leaching. Likewise the battery chemical and electroplating industries in Dada Nagar provide Pb Cd and Zn. Pb(II) can seep into soil and groundwater for instance from printery or battery locations. Additionally non-industrial sewage and landfills release metals and nitrates.

Speciation is crucial: In alkaline effluents Cr primarily enters water as Cr(VI) but soil can reduce it to Cr(III). While Cr(VI) is highly mobile and carcinogenic Cr(III) is less toxic and comparatively insoluble.In oxidizing water arsenic is As(V) (arsenate) and in reducing water it is As(III) (arsenite). As(III) has been released due to the reductive dissolution of iron oxides in Kanpur aquifers caused by the presence of organic carbon and low redox (from sewage or sludges). The majority of mercury in the environment is inorganic Hg(II) when bacteria react with Hg in anaerobic environments organic methylmercury is created however this is more of a problem in sediments than in drinking wells. The following metals are typically divalent in water: Pb^{2+} Cd^{2+} Ni^{2+} and Zn^{2+}.

Toxicity and Mechanisms

These metals interfere chemically with biochemical processes. Skin lesions and cancer are caused by inorganic arsenics ability to bind to sulfhydryl groups and interfere with ATP synthesis. It can decouple oxidative phosphorylation and act as a phosphate substitute. Cancers of the skin bladder and lungs are linked to chronic As exposure. The valence of chromium determines its toxicity: Cr(VI) is easily reduced intracellularly and crosses cell membranes through sulfate channels producing reactive intermediates that harm proteins and DNA (thus its carcinogenicity). While Cr(VI) has been shown to cause cancer in humans Cr(III) is a necessary trace nutrient. Cr(VI) also damages organs and causes irritation and ulcers. Lead (as Pb^{2+}) interferes with the function of enzymes and mimics calcium. The heme synthesis enzymes leading to kidney damage anemia and neurotoxicity in children. Cadmium (Cd^{2+}) has a half-life of 10–30 years accumulates in the body and binds to sulfhydryl ligands in proteins. Toxic to the kidneys and nervous system mercury (Hg^{2+} or methylmercury) has historically caused Minamata-like disorders in tanneries. For instance exposure to both As and Cr together has been associated with higher levels of oxidative stress than exposure to either metal alone [2,8]. All of these metals can work in concert when combined.

Comparison to Standards

Indian and WHO standards are frequently broken by the reported concentrations in the Dada Nagar area. For example, wells close to Kanpur frequently contain more than 50 µg/L of As even though the BIS desirable limit is 10 µg/L. The wastewater plume from Kanpur contained Cr(VI) in the mg/L range despite the BIS limit for Cr being 50 µg/L. Surveys found tens of µg/L of lead in water which should be less than 10 µg/L. The cadmium limit of 3 µg/L is occasionally surpassed as well. Maintaining As as low as reasonably achievable is a priority for WHO. On the other hand samples from the Kanpur-Ganga region revealed As levels in groundwater ranging from tens to hundreds of µg/L and in river water up to 153 µg/L. According to these exceedances drinking water from shallow aquifers in the Dada Nagar area is typically unsafe if left untreated.

Sources and Pathways

As mobilization is favoured by the Ganga plains underlying geology which consists of alluvial aquifers that contain organic matter. Kanpur's industrial practices exacerbate pollution. Electroplaters release Ni Zn and Cd tanneries in Dada Nagar and Jajmau release Cr(III/VI) salts and other chemicals. Metals are leached into groundwater by waste dumps. Industrial wastewater is sometimes dumped straight into drains but it is frequently excluded from Kanpur's municipal sewers. In addition pollutants are dumped into nearby ponds and the Pandu River (a tributary) which permits metal-laden water to replenish aquifers. Thus both man-made and natural geochemical metals are captured by drinking water wells.

Analytical Considerations

For the majority of metals in this study AAS detection limits (~1–5 µg/L) are adequate however for mercury specialized cold-vapor AAS or ICP-MS are required. There are more steps involved in speciation. The HG-AAS with selective pre-reduction of As(III) versus As(V). Using ion chromatography or colorimetric diphenylcarbazide is necessary for Cr speciation (Cr(III)/Cr(VI)). Form knowledge is essential for risk assessment but few routine surveys are speciated.

Conclusion

Heavy metals from geological and industrial sources have significantly contaminated the drinking water in the Dada Nagar Kanpur area. While reported levels of lead and cadmium frequently surpass safety thresholds levels of arsenic and chromium significantly exceed BIS/WHO limits. The risk is increased when more toxic species (As^{3+} Cr^{6+}) are present. The groundwater near Dada Nagar is contaminated with multiple metals according to analytical data from AAS/ICP studies. For the local populace this presents major health risks (carcinogenic and systemic toxicity). There is an urgent need for alternative water supply or removal technologies. Industrial effluents should be tightly regulated and routine monitoring should be implemented using standard techniques (AAS ICP). Knowledge of each metals chemistry (speciation adsorption) will direct efficient policy and treatment.

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