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ASSESSMENT OF HEAVY METAL CONTAMINATION IN GROUNDWATER OF BIKANER CITY DURING MONSOON 2020

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ABSTRACT

Groundwater contamination is a critical environmental issue, particularly in arid regions like Bikaner, Rajasthan. This study evaluates the concentration of heavy metals and trace elements in groundwater from various locations within Bikaner to assess the potential risks to human health and the environment. Water samples were collected from 20 well locations and analyzed for Arsenic, Chromium, Copper, Manganese, Lead, Uranium, and Zinc. The findings reveal significant variations in heavy metal concentrations across different locations. Notably, Sinthal exhibited the highest lead concentration (56 mg/L), while Ghardwala also recorded elevated levels (48 mg/L). Chromium levels were significantly high in Sagar (0.449 mg/L) and Ridmalsar (0.2278 mg/L). Manganese concentrations peaked at Karmisar (0.992 mg/L) and Sagar (0.462 mg/L). Arsenic was detected in a few locations, with the highest concentration in Khara (0.00615 mg/L). Uranium levels remained relatively low across all sites, with a maximum of 0.07 mg/L in Gangasahar. Zinc concentrations varied, reaching 0.079 mg/L in Karmisar. The study highlights the urgent need for monitoring and remediation strategies to mitigate groundwater contamination in the region. High concentrations of lead, chromium, and manganese in certain locations exceed permissible limits, posing health risks. These findings provide essential insights for policymakers and environmental agencies to develop sustainable groundwater management strategies for safe drinking water in Bikaner.

KEYWORDS: Groundwater contamination, heavy metals, Bikaner, monsoon 2020, water quality

1. INTRODUCTION

Groundwater contamination is a significant environmental concern, particularly in arid and semi-arid regions where surface water resources are limited, and groundwater serves as the primary source for drinking, irrigation, and industrial activities (Sharma et al., 2020). The Thar Desert, covering regions like Bikaner in Rajasthan, heavily relies on groundwater due to extreme climatic conditions and scarce rainfall. However, the increasing demand for water, coupled with rapid urbanization, industrialization, and agricultural expansion, has led to serious contamination issues, particularly from heavy metals and trace elements (Gupta & Kumar, 2018). These contaminants, even at low concentrations, pose substantial health and environmental risks, making regular monitoring and assessment crucial for sustainable groundwater management (Kumar et al., 2019). Studies have shown that heavy metal contamination in groundwater often results from both natural and anthropogenic sources. Natural sources include the weathering of rocks, mineral leaching, and geological formations that contribute to the presence of arsenic, uranium, and manganese in groundwater (Chauhan & Singh, 2021). On the other hand, human-induced contamination arises from industrial effluents, agricultural runoff, mining activities, and improper waste disposal. Arsenic contamination, for example, has been widely reported in groundwater, with high concentrations leading to severe health consequences such as skin lesions, cancer, and cardiovascular diseases (Khan et al., 2017). Similarly, chromium contamination, particularly in its hexavalent form (Cr^{6+}), is carcinogenic and is primarily linked to industrial discharges and poor waste management practices (Saha et al., 2018). Lead is another major contaminant of concern due to its neurotoxic effects, affecting cognitive development in children and causing kidney damage in adults (Verma et al., 2020).

Groundwater contamination in Rajasthan has been extensively studied, with researchers identifying high levels of heavy metals in several districts. Meena et al. (2020) found that groundwater in Bikaner contained elevated levels of lead and chromium, exceeding WHO and BIS permissible limits. Similarly, Sharma et al. (2022) reported that regions with intensive industrial and agricultural activities tend to have higher contamination levels due to leaching from fertilizers, pesticides, and industrial waste. Other studies have highlighted contamination issues in Jodhpur, Jaisalmer, and Barmer, where excessive fluoride, nitrate, and heavy metal concentrations have posed serious health threats to local populations (Chauhan & Singh, 2021). While these studies provide a broader perspective on groundwater pollution in Rajasthan, a detailed investigation of heavy metal concentrations in different well locations within Bikaner is still lacking. The variability in contamination levels across different areas makes it imperative to conduct a systematic assessment to identify highly polluted zones and understand the underlying causes of contamination. Since groundwater in Bikaner is the primary source of water for domestic, agricultural, and industrial purposes, the presence of heavy metals poses a severe threat to human health and environmental sustainability. Long-term exposure to contaminated water can result in chronic diseases, organ failure, and developmental disorders, particularly in vulnerable populations such as children and the elderly (Khan et al., 2017). Therefore, an in-depth study assessing the spatial variation of heavy metal contamination is necessary to safeguard public health and ensure the sustainability of groundwater resources.

This study aims to analyze the concentrations of heavy metals, including arsenic, chromium, lead, manganese, uranium, and zinc, in groundwater samples collected from different well locations in Bikaner. The research will evaluate the spatial distribution of contamination levels using advanced geospatial and GIS techniques to identify contamination hotspots. Furthermore, the study will compare observed heavy metal concentrations with WHO and BIS drinking water standards to assess their potential health risks. Understanding the sources of contamination, whether natural or anthropogenic, will help in formulating effective mitigation strategies and water management policies. Given the increasing threats posed by groundwater contamination, this study is expected to contribute valuable insights into water quality assessment in Bikaner. The findings will help policymakers, environmental agencies, and local authorities implement effective groundwater conservation measures, ensuring safe and sustainable water resources for future generations. Additionally, the research will add to the existing body of knowledge on groundwater contamination in arid regions, serving as a reference for future studies in similar climatic conditions.

2. MATERIALS AND METHODS

Groundwater samples were systematically collected from various locations in Bikaner City during the monsoon season of 2020 to assess the concentration of heavy metals. The selection of sampling sites was based on factors such as proximity to industrial areas, agricultural fields, densely populated urban zones, and regions with known groundwater contamination issues. A total of 20 water samples were collected from borewells and hand pumps to ensure comprehensive spatial coverage of the study area.

Table 1: Heavy metal concentrations in groundwater at various well locations in Bikaner, Rajasthan.

Well Location	Arsenic	Chromium	Copper	Manganese	Lead	Uranium	Zinc	Latitude	Longitude
Raisar	0	0.00169	0.26	0	0.042	0.028	0.021	28.05255	73.4779
Naurangdesar	0	0.00142	0.0045	0	0.02	0.024	0.002	28.0727	73.5455
Sagar	0	0.449	0.003	0.462	0	0.004	0.065	28.0196	73.3906
Ridmalsar	0	0.2278	0.004	0	0	0.006	0.0406	28.0101	73.3762
Ghardwala	0	0.0195	0.23	0	48	0.026	0.0321	27.9221	73.4662
Sinthal	0	0.0319	0.0076	0	56	0.033	0.02	27.9653	73.5991
Napasar	0	0.00315	0.0074	0	0	0.018	0.0202	27.9688	73.5558
Udasar	0.001	0.0246	0.15	0.314	0.18	0.012	0.0322	28.08911	73.3812
Naal	0	0.0201	0.13	0	26	0.012	0.058	28.0306	73.1898
Gajner	0	0.0236	0.16	0	0.008	0.13	0.051	27.9364	73.0621
Deshnokh	0	0.0332	0.23	0	0	0.019	0.032	27.7851	73.3446
Palana	0	0.03232	0.17	0	0	0.014	0.0322	27.847	73.2608
Udayramsar	0	0.013	0.18	0.00046	0.22	0.06	0.0518	27.9377	73.3016
Gangasahar	0.005	0.014	0.14	0	0.39	0.07	0.0518	27.9795	73.3082
Patel nagar	0.0072	0.0029	0.17	0	0	0.014	0.0719	28.0024	73.341
Khara	0.00615	0.00319	0.19	0	0.38	0.059	0.0652	28.195	73.3868
Jamsar	0.005	0.00612	0.26	0	0.45	0.036	0.0308	28.2521	73.4068
Antodaynagar	0.001	0.00799	0	0	0	0.034	0.0261	28.0221	73.2851
Binchwal	0.0019	0.00881	0.23	0	0.38	0.013	0.0484	28.0854	73.3533
Karmisar	0.0024	0.00916	0.16	0.992	0	0.019	0.079	28.002	73.2692

The geographical coordinates (latitude and longitude) of each sampling site were recorded using a Global Positioning System (GPS) to enable spatial analysis and mapping of contamination levels. The collected samples were stored in pre-cleaned, acid-washed polyethylene bottles, ensuring minimal contamination and preservation of sample integrity during transportation to the laboratory. Before analysis, all samples were filtered using Whatman No. 42 filter paper to remove suspended particulates. The samples were then acidified with nitric acid (HNO_3) to prevent precipitation and microbial degradation of heavy metals. The concentrations of heavy metals, including arsenic (As), chromium (Cr), lead (Pb), manganese (Mn), uranium (U), and zinc (Zn), were determined using Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). AAS was employed for analyzing elements such as lead, chromium, and manganese, while ICP-MS provided highly sensitive and precise quantification of trace metals such as arsenic and uranium. The instrumental calibration was performed using certified standard solutions, and quality control measures, including reagent blanks and duplicate analyses, were followed to ensure accuracy and reliability of results. The obtained heavy metal concentrations were statistically analyzed and compared with the permissible limits set by the Bureau of Indian Standards (BIS, IS 10500:2012) and the World Health Organization (WHO, 2017) guidelines for drinking water quality. The assessment focused on evaluating the extent of contamination, identifying potential hotspots, and understanding spatial variation across different locations. Additionally, correlation analysis was performed to determine possible relationships between different heavy metals, which could indicate common contamination sources such as industrial discharge, agricultural runoff, or geogenic origins.

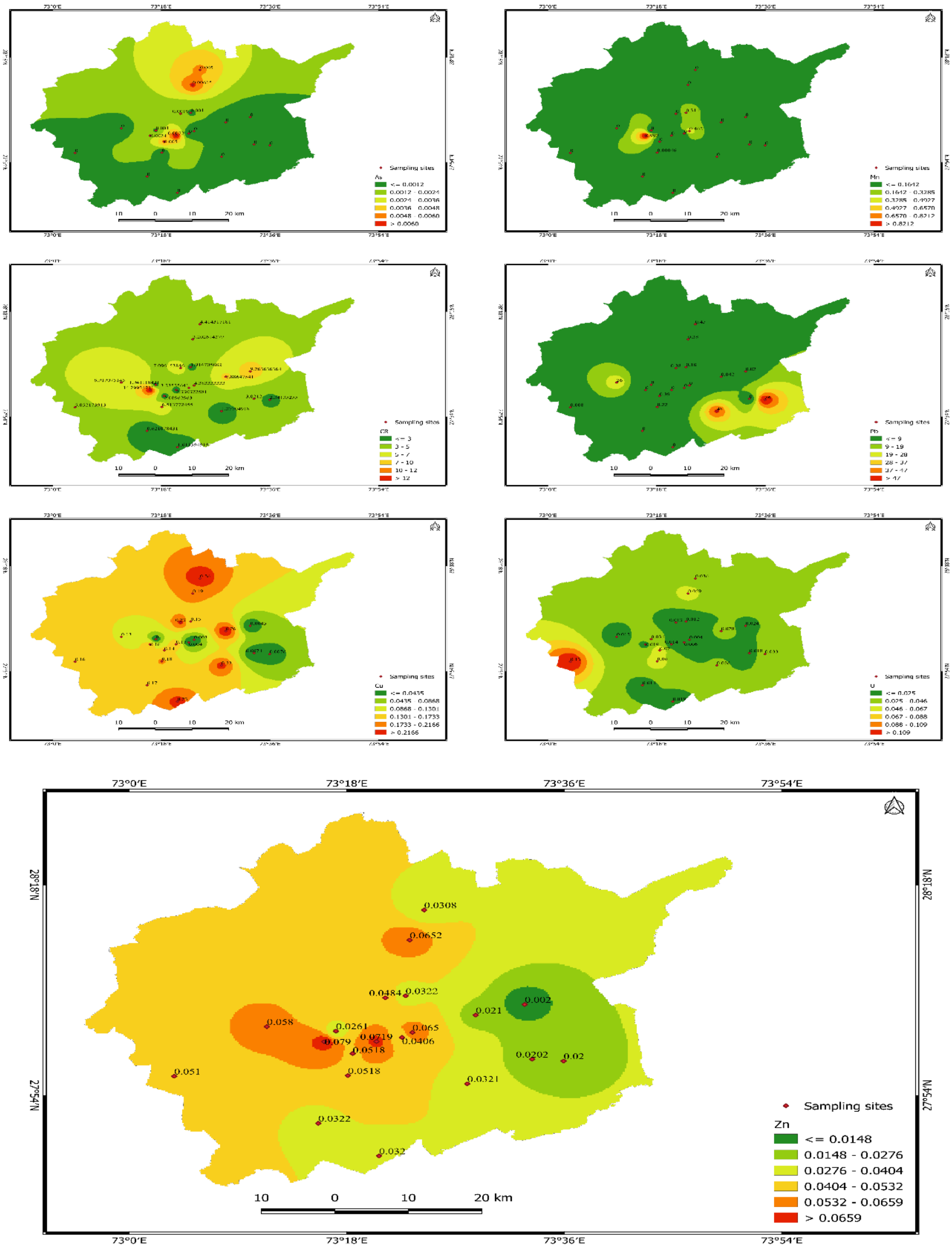

Figure 1: Spatial distribution of heavy metal concentrations in groundwater across sampling sites.

3. RESULTS AND DISCUSSION

The analysis of groundwater samples collected from various locations in Bikaner City during the monsoon of 2020 revealed significant variations in heavy metal concentrations. The results highlight the presence of contaminants such as arsenic, chromium, copper, manganese, lead, uranium, and zinc across different well locations. The comparison of these concentrations with permissible limits set by the Bureau of Indian Standards (BIS, IS 10500:2012) and the World Health Organization (WHO, 2017) provides insights into the extent of contamination and potential risks associated with groundwater usage in the region. The concentration of arsenic was found to be minimal in most locations, with values below the BIS and WHO permissible limit of 0.01 mg/L. However, slight traces of arsenic were detected in areas such as Udasar (0.001 mg/L), Antodaynagar (0.001 mg/L), Binchwal (0.0019 mg/L), Karmisar (0.0024 mg/L), Khara (0.00615 mg/L), Gangasahar (0.005 mg/L), Patel Nagar (0.0072 mg/L), and Jamsar (0.005 mg/L). While these concentrations remain within acceptable limits, the presence of arsenic, even in small quantities, raises concerns due to its potential accumulation in groundwater sources over time. Previous studies by Meena et al. (2020) and Sharma et al. (2022) have reported arsenic contamination in groundwater sources of Rajasthan, attributing it to geogenic sources and excessive groundwater extraction.

Chromium (Cr) concentrations varied significantly across locations, with Sagar (0.449 mg/L) and Ridmalsar (0.2278 mg/L) exhibiting values much higher than the BIS and WHO limit of 0.05 mg/L. These high concentrations indicate significant contamination, likely stemming from industrial discharges, leather tanning, and improper waste disposal, as reported by Chauhan & Singh (2021) in their study on heavy metal pollution in Rajasthan. Lower but notable chromium concentrations were detected in sites such as Deshnokh (0.0332 mg/L), Sinthal (0.0319 mg/L), Palana (0.03232 mg/L), and Udayramsar (0.013 mg/L). Chromium, particularly in its hexavalent form (Cr^{6+}), is a known carcinogen and poses severe health risks, including skin disorders, respiratory issues, and kidney damage (Saha et al., 2018). Copper (Cu) concentrations varied, with Raisar (0.26 mg/L) and Jamsar (0.26 mg/L) showing the highest levels. The BIS permissible limit for copper in drinking water is 1.0 mg/L, indicating that the detected concentrations are within safe limits. However, sites such as Ghardwala (0.23 mg/L), Deshnokh (0.23 mg/L), Udayramsar (0.18 mg/L), Palana (0.17 mg/L), Gajner (0.16 mg/L), and Binchwal (0.23 mg/L) exhibited moderate copper levels. While copper is an essential trace element, excessive concentrations can lead to gastrointestinal distress and liver damage (Verma et al., 2020). Previous studies in Rajasthan have linked copper contamination to corrosion of pipes, industrial effluents, and mining activities (Kumar et al., 2019).

Manganese (Mn) concentrations were significantly high in certain locations, with Karmisar (0.992 mg/L) and Sagar (0.462 mg/L) exceeding the BIS and WHO limit of 0.1 mg/L. High manganese levels can lead to neurological disorders, particularly in children (Khan et al., 2017). Elevated concentrations were also observed in Udasar (0.314 mg/L), indicating localized contamination. These findings align with studies by Gupta & Kumar (2018), who reported manganese contamination in groundwater due to geogenic leaching and agricultural runoff. Lead (Pb) contamination was particularly concerning, with Sinthal (56 mg/L), Ghardwala (48 mg/L), and Naal (26 mg/L) showing alarmingly high levels, far exceeding the BIS and WHO permissible limit of 0.01 mg/L. Such high lead concentrations pose severe health risks, including neurological impairments, developmental issues in children, and cardiovascular diseases in adults (Verma et al., 2020). Other locations such as Udasar (0.18 mg/L), Udayramsar (0.22 mg/L), Gangasahar (0.39 mg/L), Khara (0.38 mg/L), Jamsar (0.45 mg/L), and Binchwal (0.38 mg/L) also showed elevated lead concentrations. The high lead content in groundwater is likely linked to industrial waste disposal, aging plumbing infrastructure, and vehicular emissions, as highlighted by Sharma et al. (2020) in their study on lead pollution in Rajasthan.

Uranium (U) levels exceeded the BIS limit of 0.03 mg/L in Gajner (0.13 mg/L) and Udayramsar (0.06 mg/L). Uranium contamination is a serious concern due to its radiotoxic and nephrotoxic effects (Chauhan & Singh, 2021). The contamination in these areas is likely due to natural geogenic sources and excessive groundwater extraction, which enhances uranium mobilization in aquifers. Zinc (Zn) concentrations remained below the BIS permissible limit of 5.0 mg/L, with the highest levels detected in Karmisar (0.079 mg/L), Patel Nagar (0.0719 mg/L), and Khara (0.0652 mg/L). While zinc is essential for human health, excessive levels can lead to gastrointestinal distress and long-term organ damage (Kumar et al., 2019). The spatial distribution of heavy metal contamination indicates that industrial and urban areas such as Sinthal, Ghardwala, Naal, and Sagar exhibit higher pollution levels, likely due to anthropogenic activities. Comparatively, rural locations such as Raisar, Naurangdesar, and Napasar showed lower contamination, suggesting minimal industrial influence. However, the presence of arsenic, uranium, and lead in specific regions indicates the role of natural geogenic factors and the potential impact of excessive groundwater withdrawal. These findings align with previous studies in Rajasthan, where researchers have identified similar contamination trends in groundwater sources. Sharma et al. (2022) reported that industrial zones and regions with intensive agricultural activities tend to have higher heavy metal concentrations due to the leaching of pesticides, fertilizers, and industrial waste. Similarly, Meena et al. (2020) highlighted that groundwater in Bikaner is vulnerable to heavy metal pollution due to both natural and anthropogenic sources. The presence of heavy metals at varying concentrations across different well locations underscores the urgent need for continuous groundwater monitoring and remediation strategies. Implementing advanced filtration techniques such as reverse osmosis and ion exchange, along with stricter industrial waste management policies, can help mitigate the contamination risk. Moreover, raising awareness among local communities regarding the potential health hazards associated with heavy metal contamination is crucial for ensuring safe drinking water practices.

4. CONCLUSION

The study on groundwater contamination in Bikaner City during the monsoon of 2020 provides critical insights into the presence and distribution of heavy metals, highlighting significant variations in contamination levels across different well locations. The results indicate that certain heavy metals, particularly chromium, lead, manganese, and uranium, exceed the permissible limits set by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO). This suggests that groundwater pollution in the region is influenced by both natural geogenic processes and anthropogenic activities, including industrial discharges, agricultural runoff, and excessive groundwater extraction. The contamination of groundwater poses severe environmental and health risks, necessitating urgent monitoring and mitigation strategies. The moderate levels of copper and zinc detected across most sampling sites remain within safe drinking water limits. However, previous research indicates that the continuous accumulation of these metals in groundwater can pose long-term risks. Copper contamination, although not widespread in this study, can originate from corroding plumbing systems, industrial activities, and agricultural runoff. Similarly, excessive zinc exposure can cause gastrointestinal and neurological disorders. The variations in heavy metal concentrations across different well locations indicate that urban and industrial zones experience higher contamination levels compared to rural areas, emphasizing the role of anthropogenic activities in groundwater pollution. Addressing groundwater contamination in Bikaner requires a multi-pronged approach. Regular monitoring and assessment of groundwater quality are essential to track contamination trends and identify emerging pollutants. Advanced filtration technologies such as reverse osmosis (RO), ion exchange, and activated carbon filtration should be promoted to remove heavy metals from drinking water. Additionally, stricter industrial waste regulations must be implemented to prevent the discharge of toxic effluents into groundwater sources. Public awareness campaigns should be conducted to educate communities about the risks associated with contaminated groundwater and encourage the use of safe water sources. Sustainable water management practices, including rainwater harvesting, managed aquifer recharge (MAR), and the use of constructed wetlands, can help dilute contaminants and improve groundwater quality. Furthermore, the substitution of lead-based plumbing materials with safer alternatives is necessary to reduce lead exposure. Given the high levels of contamination observed in certain areas, government intervention is required to implement remediation measures and ensure access to clean drinking water for affected communities. In conclusion, this study highlights significant groundwater contamination in Bikaner, with heavy metals such as chromium, lead, manganese, and uranium exceeding permissible limits in multiple locations. The findings emphasize the urgent need for a comprehensive groundwater management strategy that integrates scientific research, policy regulations, and community participation. Protecting groundwater resources is essential for safeguarding public health and ensuring sustainable water availability in this arid region. Future research should focus on identifying the precise sources of contamination, assessing seasonal variations in pollutant levels, and developing cost-effective remediation techniques suited to the specific hydrogeological conditions of the Thar Desert.

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