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Determination of heavy metals in drinking water collected from different sites of Bisalpur dam during different seasons

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Abstract
Heavy metal contamination of drinking water poses a serious threat to human health due to their toxicity, persistence, and bioaccumulative nature. The present study evaluates the concentration of selected heavy metals—lead (Pb), copper (Cu), nickel (Ni), iron (Fe), chromium (Cr), cadmium (Cd), and zinc (Zn)—in drinking water collected from three different sites of the Bisalpur Dam, Rajasthan, during summer, winter, and rainy seasons over the period 2021–22 and 2022–23. Water samples were analyzed using Atomic Absorption Spectroscopy (AAS) following standard procedures. The results revealed noticeable seasonal and site-wise variations in heavy metal concentrations; however, all analyzed metals were found to be within the permissible limits prescribed by the World Health Organization (WHO) and Bureau of Indian Standards (BIS). Higher concentrations of certain metals such as iron, nickel, and zinc were observed during the rainy season, likely due to runoff and sediment mixing. Overall, the findings indicate that the drinking water supplied from the Bisalpur Dam is safe with respect to heavy metal contamination, though continuous monitoring is recommended to ensure long-term water quality sustainability.

Keywords: Bisalpur dam, drinking water, heavy metal analysis, seasonal variations etc

Introduction

Safe drinking water is a fundamental requirement for human health and sustainable development. Contamination of water resources by heavy metals has emerged as a major environmental and public health concern due to rapid industrialization, urban expansion, agricultural runoff, and natural geological processes. Heavy metals such as lead, cadmium, chromium, and nickel are non-biodegradable and can accumulate in living organisms, causing severe toxicological effects even at low concentrations (Rahmanian *et al*., 2015; WHO, 2021) [10, 14].

Surface water reservoirs used for drinking water supply are particularly vulnerable to seasonal variations and anthropogenic pressures. Seasonal changes influence metal concentrations through rainfall-induced runoff, erosion, dilution, evaporation, and biochemical processes (Akter *et al*., 2016) [1]. Metals like iron and chromium may originate from natural weathering of rocks, whereas lead and cadmium often arise from anthropogenic sources such as plumbing materials, fertilizers, industrial effluents, and domestic wastewater (Kumar and Puri, 2012) [6].

In India, several studies have reported heavy metal contamination in drinking water sources, emphasizing the need for regular monitoring to prevent long-term health risks (Nazir *et al*., 2015; Radulescu *et al*., 2016) [7, 9]. The Bisalpur Dam, constructed across the Banas River in Rajasthan, is a major source of drinking water for Jaipur, Ajmer, and surrounding rural areas. Considering its critical role in supplying potable water to a large population, systematic assessment of heavy metals in its water is essential.

The present study aims to determine the seasonal and spatial variation of selected heavy metals in drinking water collected from different sites of the Bisalpur Dam using Atomic Absorption Spectroscopy. The results are evaluated against WHO and BIS standards to assess the suitability of water for drinking purposes and to provide baseline data for effective water resource management.

Materials And Methods

Methodology

The Study Area

The Bisalpur Dam across Banas river, a tributary of Chambal river was constructed in the year 1999 to create irrigation and drinking water supply capacity. The dam is located in Tehsil Toda Raisingh, near Bisalpur in Tonk district of Rajasthan. The dam supplies drinking water to the tune of 11.1 TMC to Jaipur city and en-route villages and 5.1 TMC to Ajmer city and en-route villages. Besides, irrigation supplies from the dam is of the order of 8 TMC to 81000 ha command area in Tonk, Todaraisingh, Uniyara and Deoli tehsils through 51 Km long right main canal and 18.65 km long left main canal. The nearest town is Deoli which is situated on Jaipur-Kota NH-12. Nearest airport is Jaipur, which is 185 km away from Dam and nearest Railway station is Bundi, which is 85 km from Dam. Distance of Bisalpur Dam from district Headquarter Tonk is about 72 km. Nearest Highway to Project is Jaipur-Kota State Highway (SH 52). The Project site is 19 km from Santhali village on SH 52 and 25 km from Deoli Tehsil.

Collection of Water Samples

Water samples were collected during 3 seasons of year 2021-22 and 2022-23. Seasons for sampling were divided as summer (March to June), Rainly/Monsoon (July to october) and winter (November to february). The water samples were obtained using sanitized sampling vials with a volume of 250 ml, which were labelled with stickers. The specimens were transported to the laboratory under refrigerated conditions and afterwards stored at a temperature of 4°C until they were to be utilized for further experimentation.

Samples were collected at a distance of approximately two to three meters from the water's edge. The collection of water samples involved the utilization of pre-sterilized bottles, which were affixed to the distal end of an elongated bamboo pole. This procedure was conducted subsequent to the observation of visual cues on the water's surface,

indicating the potential existence of organic substances. Upon reaching its maximum capacity, the cap was tightly affixed to the bottle. The sample bottle was affixed with a label containing pertinent information. These samples were brought to the laboratory and analysed by standard methods. During study 3 sites of Bisalpur dam were selected for the sampling. Those were mentioned as site 1, site 2 and site 3.
Heavy metals like Lead, Copper, Nickel, Iron, Chromium, Cadmium[, Zinc were determined using atomic absorption spectroscopy (AAS).

Results And Discussion

Lead (Pb)

Lead, in rainy season, was recorded maximum as 0.004 mg/l at site 1 in year 2022 while minimum value was 0.002 mg/l for site 2 and 3 in 2021. Highest value in winter season was found to be 0.004 mg/l (site 3, 2022) and lowest was 0.001 mg/l (site 2, 2021). For summer these values were maximum 0.004 mg/l (site 2 and 3, 2022; site 3, 2021) and minimum 0.002 mg/l (site 1, 2021). Highest mean as calculated as 0.0040 mg/l for site 3 in summer and annual mean was 0.0026 mg/l. Results were under the limits of WHO and BIS guidelines showing good water quality for drinking purpose.

Copper (Cu)

Copper was recorded in varied range during study period. For rainy season, maximum value was recorded as 0.06 mg/l at site 3 in year 2022 while minimum value was 0.03 mg/l for site 2 in 2021. Highest value in winter season was found to be 0.06 mg/l (site 1, 2022) and lowest was 0.03 mg/l (site 3, 2021 and 2022). For summer these values were maximum 0.06 mg/l (site 1, 2021) and minimum 0.03 mg/l (site 3, 2022). Highest mean as calculated as 0.055 mg/l for site 3 in rainy season and annual mean was calculated 0.045 mg/l. All values were as per guidelines of WHO and BIS, indicating its good drinking water quality.

Nickel (Ni)

Nickel was found in varied range throughout study period. For rainy season, maximum value was recorded as 0.2 mg/l at site 3 in year 2021 and site 2 in year 2022 while minimum value was 0.1 mg/l for site 1 & 2 in 2021 and site 1 in 2022. Highest value in winter season was found to be 0.2 mg/l (site 2, 2021 & site 1, 2022) and lowest was 0.1 mg/l (site 3, 2021 & 2022). For summer these values were maximum 0.2 mg/l (site 1, 2021 & 2022) and minimum 0.1 mg/l (site 3, 2021 & 2022). Highest mean as calculated as 20 mg/l for site 1 in summer. All values are under permissible limits.

Iron (Fe) and Chromium (Cr)

Fe is the essential micronutrient for animals and plants. The permissible limit of Fe and Cr in drinking water is 0.3 ppm and 0.03 ppm respectively. The Concentration of Fe and Cr in ground water ranges from 0.12 to 0.23 ppm and 0.007 to 0.018 ppm respectively. The samples under investigation in the study area contain Fe and Cr content within the permissible limits as set by the WHO and BIS.

Cadmium (Cd)

Cadmium was recorded in varied range during study period. In rainy season, maximum value was recorded as 0.0003 mg/l at site 1 & site 3 in year 2021 and site 3 in year 2022 while minimum value was 0.0001 mg/l for site 2 in 2021. Highest value in winter season was found to be 0.0002 mg/l (site 2, 2021 and site 2 & 3, 2022) and lowest was 0.0001 mg/l (site 1, 2021). For summer these values were maximum 0.0004 mg/l (site 2, 2022) and minimum 0.0002 mg/l (site 2, 2021 and site 1, 2022). Highest mean was recorded as 0.0003 mg/l. Results were under the limits of WHO and BIS guidelines showing good water quality for drinking purpose.

Zinc (Zn)

Zinc, in rainy season reported with maximum value as 0.04 mg/l at site 2 in year 2022 while minimum value was 0.01 mg/l for site 1 & 3 in 2021. Highest value in winter season was found to be 0.03 mg/l (site 2 & 3, 2022) and lowest was 0.01 mg/l (site 1 & 2, 2021 and site 1, 2022). For summer these values were maximum 0.04 mg/l (site 3, 2022) and minimum 0.01 mg/l (site 2, 2021). Highest mean as calculated as 0.030 mg/l for site in rainy season and annual mean was 0.020 mg/l. All values were as per guidelines of WHO and BIS, indicating its good drinking water quality.

Table 1: Water parameters (Bisalpur dam) at different sites in Summer Season in the year 2021-22 and 2022-23

	2021-22			2022-23		
	Site 1	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Pb (mg/l) or (ppm)	0.002	0.003	0.004	0.003	0.004	0.004
Cu (mg/l) or (ppm)	0.06	0.04	0.05	0.05	0.04	0.03
Ni (mg/l) or (ppm)	0.2	-	0.1	0.2	-	0.1
Fe (mg/l) or (ppm)	0.18	0.21	0.15	0.20	0.20	0.16
Cr (mg/l) or (ppm)	0.015	0.016	0.009	0.016	0.018	0.010
Cd (mg/l) or (ppm)	-	0.0002	0.0003	0.0002	0.0004	0.0003
Zn (mg/l) or (ppm)	0.03	0.01	0.02	0.02	0.02	0.04

Table 2: Water parameters (Bisalpur dam) at different sites in Winter Season in the year 2021-22 and 2022-23

	2021-22			2022-23		
	Site 1	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Pb (mg/l) or (ppm)	0.002	0.001	0.003	0.003	0.002	0.004
Cu (mg/l) or (ppm)	0.04	0.05	0.03	0.06	0.05	0.03
Ni (mg/l) or (ppm)	-	0.2	0.1	0.2	-	0.1
Fe (mg/l) or (ppm)	0.14	0.16	0.12	0.16	0.16	0.15
Cr (mg/l) or (ppm)	0.013	0.009	0.008	0.016	0.010	0.010
Cd (mg/l) or (ppm)	0.0001	0.0002	-	0.0002	0.0002	-
Zn (mg/l) or (ppm)	0.01	0.01	0.02	0.01	0.03	0.03

Table 3: Water parameters (Bisalpur dam) at different sites in Rainy Season in the year 2021-22 and 2022-23

	2021-22			2022-23		
	Site 1	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Pb (mg/l) or (ppm)	0.003	0.002	0.002	0.004	0.003	0.003
Cu (mg/l) or (ppm)	0.05	0.03	0.05	0.05	0.04	0.06
Ni (mg/l) or (ppm)	0.1	0.1	0.2	0.1	0.2	-
Fe (mg/l) or (ppm)	0.21	0.20	0.18	0.23	0.21	0.19
Cr (mg/l) or (ppm)	0.013	0.016	0.007	0.014	0.018	0.009
Cd (mg/l) or (ppm)	0.0003	0.0001	0.0003	-	0.0002	0.0003
Zn (mg/l) or (ppm)	0.01	0.02	0.01	0.02	0.04	0.02

Discussion

Water quality index (WQI) reflects the composite influence of different water quality parameters. Calculated value of WQI describes the suitability of water for drinking and providing overall water quality information of water sources. The WQI was first developed by Horton in 1965 [5] and then this technique was subsequently modified by several experts (Akter *et al.,* 2016) [1]. The WQI is used to investigate contamination level of drinking water and is a comprehensive guideline for water resources management and policymaking (Saha *et al.,* 2018) [11].

Lead (Pb): From a drinking water perspective, the almost universal use of lead compounds in plumbing fittings and as solder in water distribution systems is important. Lead pipes may be used in older distribution systems and plumbing. Lead is present in tap water to some extent as a result of its dissolution from natural sources but primarily from household plumbing systems in which the pipes solder, fittings, or service connections to homes contain lead. PVC pipes also contain lead compounds that can be leached from them and result in high lead concentration in drinking water. According to India standard drinking water specification 1991, highest desirable limit of lead in drinking water is 0.05 ppm and no relaxation for maximum permissible limit. Lead is a cumulative general poison and associated with several health hazards like anemia, reproductive effects (Kumar and Puri, 2012) [6]. During present study, lead wad found under the permissible limit i.e. 0.001-0.004 mg/l.

Copper (Cu): Copper is an essential micronutrient. Acute ingestion of excess copper in drinking water can cause gastrointestinal (GI) tract disturbances and chronic ingestion can lead to liver toxicity in sensitive populations. The concentrations of copper in drinking water can be greatly increased during the distribution of drinking water. Many pipes and plumbing fixtures contain copper, which can leach into the drinking water. Characteristics of the water that can increase the leaching of copper include low pH, high temperature, and reduced hardness (NRC, 2000) [8]. During present study the range of copper in different water sites were found as 0.03- 0.06 mg/l with annual mean 0.045 mg/l. All values were as per guidelines of WHO and BIS, indicating its good drinking water quality. Similar results were obtained by Nazir *et al.,* (2015) [7].

Nickel (Ni): Nickel is a naturally occurring, lustrous white, hard, ferromagnetic metal that is ubiquitous in the environment. Metallic nickel is not affected by water, but is slowly attacked by dilute hydrochloric or sulfuric acid and is readily attacked by nitric acid. Several nickel salts, including the acetate, chloride, nitrate and sulfate salts, are soluble in water. Carbonates and hydroxides of nickel are far less soluble, and sulfides, disulfides, subsulfides and oxides are practically insoluble in water (WHO, 2021) [14]. Nickel was found in range (0.1-0.2 mg/l) throughout study period and under the permissible limits.

Heavy Metals (Iron- Fe and Chromium- Cr): The presence of heavy metals in drinking water higher than a certain concentration can cause detrimental impacts on human health. Therefore, the analysis of heavy metals in drinking water is an important parameter **(**Rahmanian *et al.,* 2015) [10]. Iron in water may be present in varying qualities depending upon the geological area and other chemical component of the water way. Iron in domestic water supply system, stains laundry and porcelain. It appears to be more of a nuisance than a potential health hazard. Taste thresholds of iron in water 0.1 mg/l for ferrous iron and 0.2 mg/l ferric Iron, giving a bitter or an astringent taste (Kumar and Puri, 2012) [6]. Water containing iron does not show deleterious effect on human health, its presence in drinking water is not desirable for various reasons. Excessive iron content makes the water turbid, discolored and imparts an astringent taste to water. Chromium also occurs naturally in small amounts in rocks and soils, from where it can be released into groundwater through weathering and erosion processes. Background levels of chromium in surface water and groundwater aquifers are determined by regional geology, mineral weathering processes, sediment loading rates and precipitation patterns. High concentrations of chromium may occur naturally in groundwater in areas with mafic or ultramafic volcanic or metamorphic rocks (WHO, 2020) [13]. The permissible limit of Fe and Cr in drinking water is 0.3 ppm and 0.03 ppm respectively. The samples under investigation in the study area contain Fe and Cr content within the permissible limits as set by the WHO and BIS. Results were in accordance with the study of Radulescu *et al.,* (2016) [9].

Cadmium (Cd): Contamination of drinking-water may occur as a result of the presence of cadmium as an impurity in the zinc of galvanized pipes or cadmium-containing solders in fittings, water heaters, water coolers and taps (WHO, 2004) [12]. Cadmium is a heavy metal that is often referred to as the metal of the 20th century. In the general population, exposure to cadmium occurs primarily through dietary sources, cigarette smoking, and, to a lesser degree, drinking water. Although the metal has no known physiological function, there is evidence to suggest that the cadmium is a potent metallohormone (Byrne *et al.,* 2009) [3]. As per present study, results were under the limits of WHO and BIS guidelines showing good water quality for drinking purpose with range of 0.0001-0.0004 mg/l.

Zinc (Zn): The importance of micronutrients in health and nutrition is undisputable, and among them, zinc is an essential element whose significance to health is increasingly appreciated and whose deficiency may play an important role in the appearance of diseases. Zinc is one of the most important trace elements in the organism, with three major biological roles, as catalyst, structural, and regulatory ion (Chasapis *et al.,* 2012) [4]. Recent investigations indicate that water containing 1.5-50 ppm zinc can be safely consumed. The presence of 2 ppm causes slight and 5 ppm great opalescence in the water, which exhibits a greasy film on boiling. Results of present study showed the range of Zn concentration 0.01-0.04 mg/l with annual mean 0.020 mg/l. All values were as per guidelines of WHO and BIS. Nazir *et al.,* (2015) [7] was carried out similar study with results under permissible limits.

Conclusion

The present study provides a comprehensive evaluation of heavy metal concentrations in drinking water collected from different sites of the Bisalpur Dam during summer, winter, and rainy seasons over two consecutive years. The concentrations of lead, copper, nickel, iron, chromium, cadmium, and zinc exhibited minor seasonal and site-wise variations, with relatively higher values observed during the rainy season, likely due to surface runoff and increased sediment interaction.

Importantly, all analyzed heavy metals were found to be within the permissible limits recommended by WHO and BIS standards, indicating that the drinking water supplied from Bisalpur Dam is safe with respect to heavy metal contamination. Essential metals such as iron, copper, and zinc were present in acceptable concentrations, while toxic metals like lead and cadmium were detected only in trace amounts.

Although the current status of water quality is satisfactory, increasing anthropogenic activities and environmental changes necessitate continuous monitoring. Regular assessment of heavy metals is crucial to prevent future contamination and to ensure long-term public health safety. The findings of this study contribute valuable baseline data and support sustainable management of surface water resources in semi-arid regions like Rajasthan.

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