Analysis of Water Quality Based on Atomic Absorption Spectroscopy and Its Impact on Fish Diversity

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***Abstract*—Atomic Absorption Spectroscopy (AAS) is utilized to measure trace amounts of heavy metals present in water contaminated by geochemical composition, and agricultural and mining activities waste. This leads to a decline in fish diversity and, while severely impacting the aquatic ecosystem, enhances the bioaccumulation of heavy metals-substances that foster the development of serious diseases in fish. Consequently, it has become imperative to prioritize water quality monitoring and assessment for the purposes of environmental conservation, agriculture, fisheries management, and comprehensive sustainable development. Traditional water analysis techniques are of limited utility due to their laborious nature and lengthy processing times. Spectroscopic techniques, when combined with chemometric analyses and advanced technical systems, enable the comprehensive quality assessment of water. In the present study, the Govind Sagar Dam in Lalitpur served as the study site. An assessment was conducted-utilizing spectroscopic techniques-to analyse the accumulation of toxic substances (such as pesticides, urea, and other chemicals used in agricultural fields) within the aquatic organisms and fish inhabiting the area, specifically examining how these substances enter their systems and accumulate within their organs. The objective of this study was to examine the water quality data and heavy metal analysis results of the Govind Sagar Dam using multivariate statistical analysis methods. Various water samples were collected from the dam, and the levels of heavy metals-such as Pb, Cd, Cr and Hg were analysed.**

***Index Terms*—Heavy Metals; Pollutants; Atomic Absorption Spectroscopy; Fish; water quality assessment**

I. INTRODUCTION

Water is the most vital resource on Earth, and it is indispensable for sustaining life. It covers approximately 71% of the planet's surface and plays a crucial role in climate regulation and ecological balance[1-3]. In the human body, it constitutes about 60–65% and facilitates biochemical reactions, temperature regulation, and metabolic functions. Approximately 97% of Earth's water is saline, leaving only 3% available as freshwater for consumption and other anthropogenic uses[4, 5]. However, only 0.06% of this freshwater exists in accessible reservoirs such as lakes and rivers, while the remaining 99.4% is found in underground aquifers, glaciers, and wetland ecosystems-highlighting the reliance on groundwater resources for potable and agricultural water supplies[6-9].

The universal dependence of all living organisms on Earth underscores the critical role of water in maintaining biological equilibrium and ecosystem stability[10-14]. Today, the "One Health" approach emphasizes the interdependence of human, animal, and environmental health, incorporating water security as a fundamental component. Spectroscopy-based methods can aid in achieving this objective by enabling the rapid, on-site detection of water pollutants, enhancing water quality monitoring, and facilitating data-driven decision-making aimed at ensuring safe and more equitable water access for all[15-19].

Various factors-including natural disasters, seasonal variations, and fluctuations in water availability-can bring about rapid or gradual changes in water quality regarding its potability, and in some instances, may

also alter its suitability for other applications. Spectroscopy has emerged as a versatile and efficient tool for water quality assessment across diverse applications[20, 21]. Spectroscopic techniques are widely employed across nearly all technical and scientific disciplines, enabling the determination of the composition, structural properties, and physicochemical characteristics of substances and materials; furthermore, their applications in agriculture and animal husbandry are of paramount importance, as reliable and accurate water quality monitoring is essential for optimizing productivity[22], enhancing animal health and welfare, and maintaining sustainable resource management.

The objective of this article focused on assessing water quality using spectroscopic techniques and studying the effects of heavy metals on freshwater fish. Specifically, Ultraviolet-Visible (UV-Vis) and Infrared (IR) spectroscopy were the primary subjects of study.

II. MATERIALS AND METHODS

Study Area

The water in dams-which are rapidly being subjected to the use of agricultural chemicals, industrialization, and urbanization-is becoming polluted, leading to environmental challenges such as habitat degradation and biodiversity loss[22]. Govind Sagar Dam has been a center of study in Lalitpur (**Figure 1**). The Govind Sagar Dam is an impressive and vast reservoir situated on the Shahzad River in the Lalitpur district of Uttar Pradesh, established as a vital hub for water storage, local irrigation, migratory birds, urban drinking water supply, and the fisheries industry.

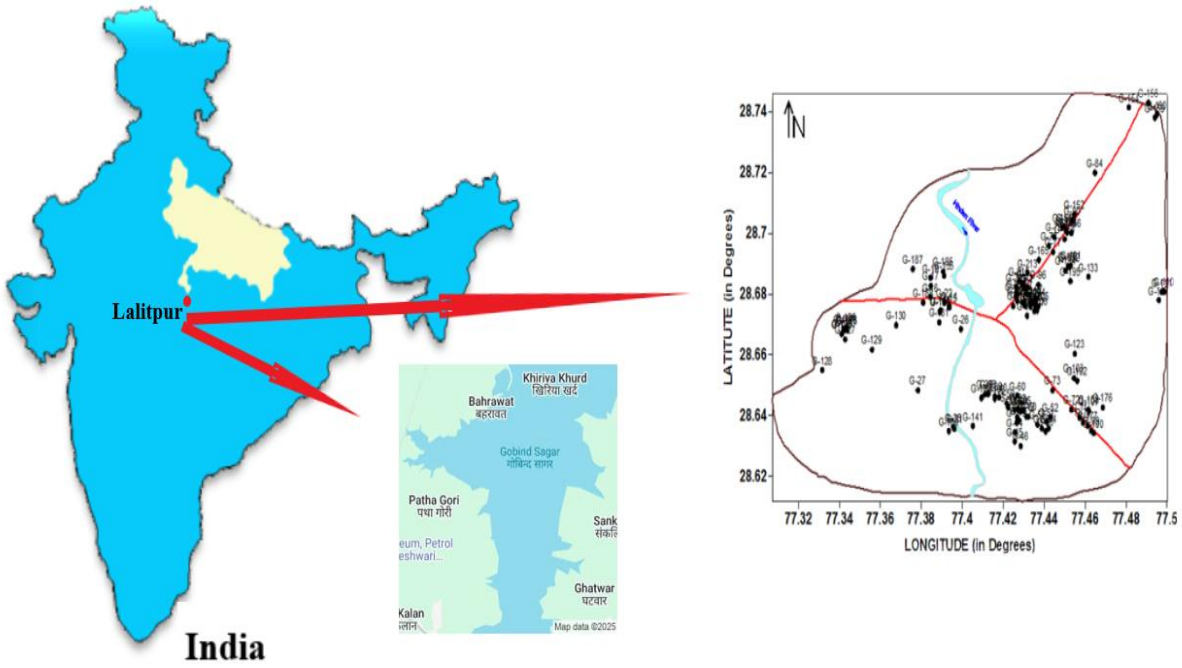

Figure: 1 Site location map of study area

The Govind Sagar Dam is situated at 24°40'27" N latitude and 78°25'25" E longitude. From social, economic, and environmental perspectives, it is proving to be highly beneficial. An ichthyological study at the Gobind Sagar Dam was conducted during the period spanning from July 2022 to June 2023. This study was carried out during specific time slots: in the summer, from 06:00 to 10:00 AM and from 16:30 to 18:30 PM; and in the winter, from 07:00 to 11:00 AM and from 15:00 to 17:30 PM.

Sample Collection and Preparation

Water samples from the Govind Sagar Dam in Lalitpur were collected in accordance with the quality sampling protocols and recommendations prescribed by Indian Standards (IS 3025 Part-1) and the 22nd edition of APHA. Water samples were collected with due

precautions from the study areas. First, the collection containers were filled with nitric acid and left to stand for 24 hours. Subsequently, the containers were rinsed twice with water and then dried. The sampling container was rinsed two or three times with water from the collection site itself before the samples were collected, ensuring that the results obtained through duplicate measurements would be optimal. Subsequently, 0.5 ml of pure-grade nitric acid was added to these samples[23, 24]. All samples, having been collected with the utmost care, were preserved at the collection site itself at a temperature of 4°C using a Styrofoam box packed with ice.

The procedure for the digestion of water samples was carried out in the following manner:
First, 50 mL of a well-mixed and acid-preserved water sample was taken in a 250 mL conical flask. Next, 5 mL of concentrated nitric acid (Conc. HNO_3) was added to the flask very slowly and carefully, drop by drop. Using a hot plate, this mixture was heated to its boiling point. The mixture was then evaporated until its volume was reduced to between 10 and 20 mL. While continuing the heating process, concentrated nitric acid was added until the digestion of the sample was complete; this completion was indicated by the solution in the conical flask becoming pale in color and clear. Subsequently, the mixture was rinsed with distilled water and filtered. The filtered mixture was then transferred into a 10 mL volumetric flask. The 250 mL conical flask was rinsed twice with 5 mL of water, and these rinsings were also added to the volumetric flask. In accordance with the guidelines of Brooks et al., the solution was allowed to cool and was then diluted to the volume mark by adding water. Finally, adhering to APHA guidelines, an aliquot of the sample solution was taken for the determination of the required metals.

Analysis of Heavy Metals via Atomic Absorption Spectroscopy: This is the most widely utilized analytical technique for detecting trace and heavy metals-down to parts-per-billion levels-within samples. It is a highly effective technique for easily detecting trace levels of multiple elements in a single aspiration. For heavy metal analysis, the AA-6800 AAS was employed in conjunction with the GFA-EX7 Graphite Furnace Atomizer and the ASC-6100 Auto Sampler from Shimadzu (Kyoto, Japan). A high-density graphite tube was utilized for atomization, while a standard single hollow cathode lamp was used for irradiation.

Data Analysis

Table 1: Mean Concentrations of Heavy Metals in Fish Tissues (mg/kg, N = 150)

Metal	Gills (Mean±SD)	Liver (Mean±SD)	Muscle (Mean±SD)	FAO Permissible Limit (mg/kg)
Lead (Pb)	1.38 ± 0.61	2.33 ± 0.66	1.05 ± 0.23	1.5
Cadmium (Cd)	0.31 ± 0.18	1.02 ± 0.22	0.33 ± 0.14	0.4
Chromium (Cr)	1.07 ± 0.25	1.28 ± 0.21	1.03 ± 0.11	0.9
Mercury (Hg)	0.12 ± 0.07	0.47 ± 0.01	0.23 ± 0.03	0.2

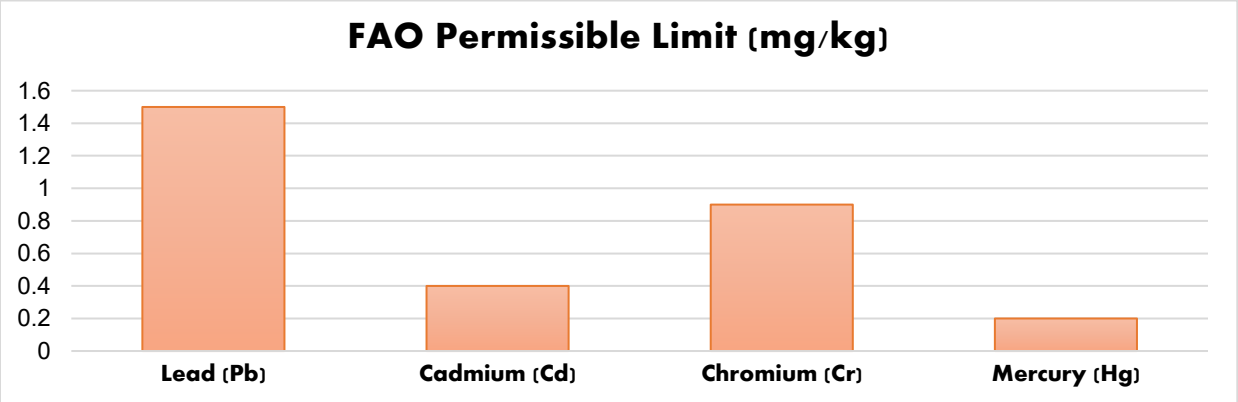

Figure 2: Showing the bar Graph of Heavy Metals in water samples

Interpretation and their result

Analysis of water samples collected from the vicinity of the Govind Sagar Dam reveals that the water is neither colorless nor odorless. Analytical results regarding the metal content of the samples indicated that the concentrations of certain heavy metals-specifically Pb, Cd, Cr, and Hg were observed to be slightly above the permissible limits. The analysis reveals that the accumulation of heavy metals in the bodies of fish occurs at various levels, with concentrations closely approaching and, in some instances, slightly exceeding the permissible limits established by the FAO. In this context, the liver was found to be the most significantly affected organ. It was followed by the gills and muscle tissues, a pattern that underscores the central role played by the liver in detoxification and metal sequestration. Levels of lead and cadmium were found to be notably elevated in the liver samples, pointing toward the process of bioaccumulation in fish through trophic transfer. In conclusion, these findings underscore the persistent presence of heavy metal pollution within aquatic ecosystems and highlight the potential risks posed to both ecological integrity and public health through dietary exposure.

XRD analysis

Water flowing through agricultural fields traverses various pathways before eventually discharging into water bodies; this process leads to a significant increase in the concentration of toxic heavy metals within the aquatic organisms inhabiting these water sources. Atomic Absorption Spectroscopy proves to be highly versatile in detecting and quantifying trace metal levels. It holds immense significance in water analytical studies and in the qualitative assessment of environmental toxicology. The study of the presence of metals within the tissues-specifically the livers of aquatic organisms further substantiate these findings.

The X-ray diffractogram of the scale powder is shown in Figure 3. The composition of the scale sample is characterized by the use of a carbonate mixture composed of Mg-calcite and aragonite. This is determined using a qualitative and semi-quantitative method based on X-ray diffraction of the scale powder.

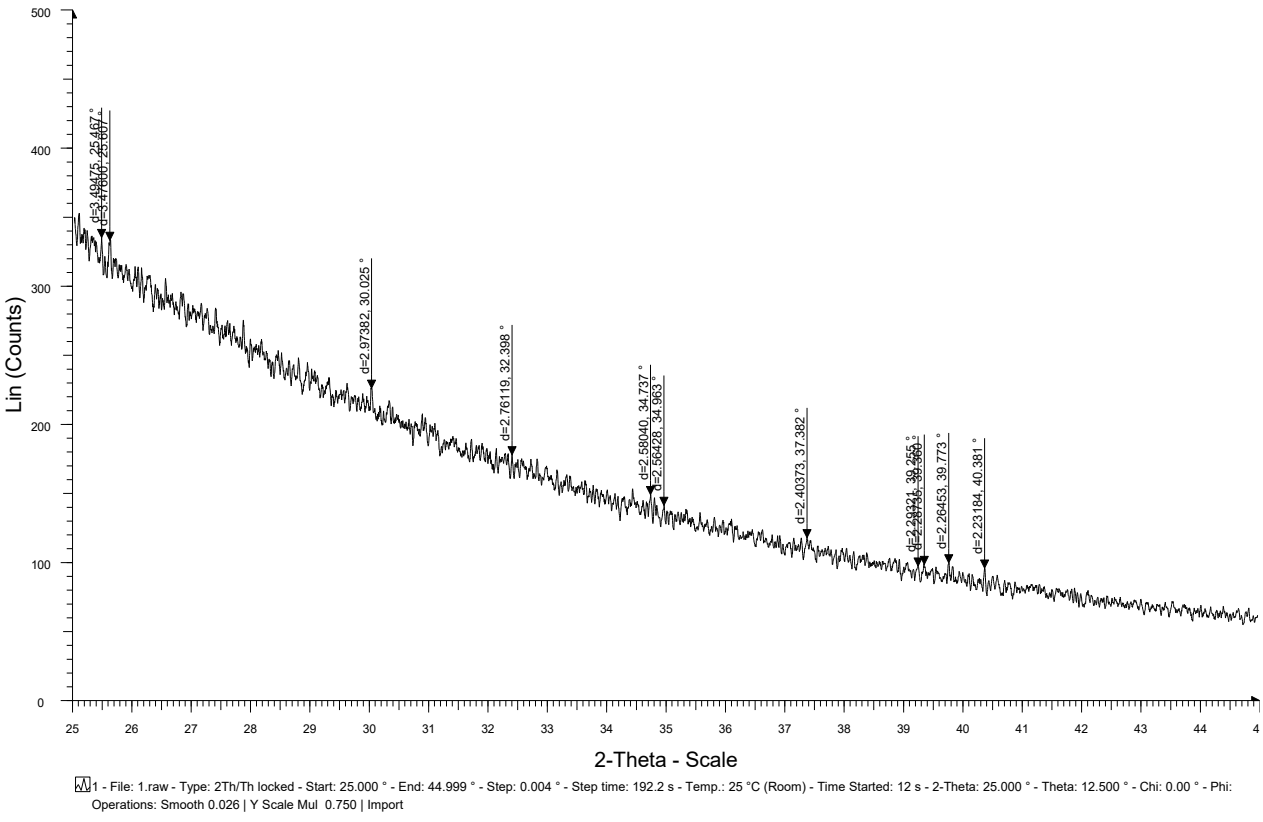

Figure 3: Showed the XRD Spectra of Heavy Metals in the Water of Govind Sagar Dam, Lalitpur

III. CONCLUSION

Environmental parameters of water can be adversely affected by heavy metal toxicity. These substances impact the physiological functions of aquatic organisms, including fish. Furthermore, they play a role in altering the chemical speciation of metals within the water. In the aquatic environment, elevated concentrations of heavy metals—along with certain toxic agrochemicals lead to their bioaccumulation within the tissues of commercially important food fish and shellfish, thereby compromising their health.

The inherent risk associated with this high level of toxic bioaccumulation poses serious health hazards to consumers, particularly humans. It is evident from this study on heavy metals in the waters of the Govind Sagar Dam (Lalitpur, Uttar Pradesh) that such toxic metal contamination in dam waters can be mitigated through the application of effective heavy metal removal techniques.

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