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Assessment of Physicochemical Properties of Upper Lake, Bhopal: A Comprehensive Literature Review

Prasanta Ghadei[1*], Sujit Kumar Jally[2]
[1,2] School of Geography, Gangadhar Meher University, Sambalpur- 768004, Odisha, India

Abstract

Lake degradation is a critical global issue, with human activities having a significant negative impact on lakes and reservoirs. Eutrophication, the process of adding nutrients, silt, and other organic material to a lake, can result in increased algal and rooted aquatic plant production, altering the biological stability of the lake and tank ecosystems. Water pollution is a big issue in developing countries, with 35% of urban and 65% of rural Indians drinking polluted water, which leads to health issues like diarrhea, cholera, dysentery, typhoid, amoebiasis, jaundice, and Enterobacteriaceae. The Upper Lake in Bhopal, India, is facing severe threats from various anthropogenic activities, such as deforestation, intensive agricultural practices, industrial growth, and sewage. The health of the lake water can be assessed using various physicochemical characteristics. However, literature reviews have found that most variables are not at a standard level, indicating a need for proper attention and management of lake water.

Keywords: Physicochemical Parameters, Water Quality, Pollution, Upper Lake

1. Introduction

A lake is a huge body of water surrounded by land that was once a highly productive ecosystem and an important habitat for aquatic life. Lakes are exposed to a variety of natural processes, including the hydrological cycle that happens in the environment. Salt marshes, tropical mangroves, swamps, and deltas, which make up 15% of the world's coastal zone, combine to provide sheltered habitation areas. Many key factors contribute to changes in the lake ecology, including deforestation, intense agricultural activities, unsustainable use of lake resources, industrial expansion, and sewage. Natural changes are caused by physical, chemical, geological, and biological forces. Climate change has an impact on the key properties of a lake and, by extension, the ecosystem. Lake deterioration is a significant global issue. Human activity in the surrounding drainage basins is the primary source of lake and reservoir degradation (Rast, 2009). Eutrophication is a concern in the decline of health of the lake water. Eutrophication refers to the addition of nutrients, sediment, and other organic matter from the surrounding environment to a lake, which increases the formation of rooted aquatic plants and algae. Phosphorus and nitrogen additions may increase algal growth. This result could be harmful to the ecological stability of the lake ecosystems, disrupting nearly all species. Many

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developing countries have experienced water contamination in recent decades as a result of industrialization and high population increase (Singh et al. 2013; Thakur et al. 2015). Surface and subsurface water sources are being polluted as urbanization, industrial activity, and agricultural production increase. Such undesired changes in lake water qualities have an adverse effect on water quality and aquatic life. The World Health Organization (WHO) reported in 2003 and 2006 that around 65% of Indians living in rural areas and 35% of those living in urban areas drink contaminated water. Water contamination can lead to a variety of ailments, including diarrhea, cholera, dysentery, typhoid, amoebiasis, jaundice, and Enterobacteriaceae. Every year, around 5 million children, or almost one-sixth of the global population, become ill as a result of a shortage of safe drinking water.

The Upper Lake, Bhopal, was formed by King Bhoj in the early 11th century. It provides potable water to the city's rising population, meeting 40% of its drinking water demand (29 million gallons per day). It is also an important supply of water for wildlife and fisheries. The Bhopal Municipal Corporation (BMC) has granted a long-term lease to a fishermen's cooperative of 500 households. The BMC is the lakes' custodian and has the jurisdiction to oversee land use on the lakes' outskirts because it awards building authorization sanctions. The Upper Lake's catchments are both rural and urban. As the city grew in the late twentieth century, numerous areas of the lake were encircled by ecosystems. These advances have increased human pressures on the water body, hastening its eutrophication and microbiological pollution and rendering the water unsafe for human consumption unless properly treated. However, the Upper Lake's water quality has continuously worsened owing to contamination and ecological harm resulting from expanding settlements and various anthropogenic activities in the nearby region (Thakur et al. 2015). This resulted in lake water pollution caused by the entry of untreated sewage and other human activity (Misra et al. 2001). The reason of water contamination is (a) sewage, (b) agricultural pollution, (c) industrial waste, and (d) physical contaminants. The pollution of lake water endangers the health of the city's residents. In 1995, the Madhya Pradesh government collaborated with the Government of India to develop a conservation strategy, which was sponsored by JBIC.

2. Study Area

Upper Lake, locally known as Bhojtal, is located in the city of Bhopal in Madhya Pradesh, India (Figure 1). This historic lake is one of the oldest man-made waterbodies in the country, believed to have been constructed in the 11th century by Raja Bhoj by damming the Kolans River (Bashir & Samartha, 2022). Geographically, the lake lies between latitude 23°13′N to 23°16′N and longitude 77°18′E to 77°22′E, covering a surface area of approximately 31 square kilometers and a catchment area of 361 square kilometers (Singh et al., 2017). Upper Lake of Bhopal forms a crucial component of the Bhoj Wetland, which comprises both the Upper and Lower Lakes. The Upper Lake is relatively less polluted compared to the Lower Lake and is primarily used for consuming water supply, supporting nearly 40% of Bhopal's urban population (Mishra & Bhatt, 2020). In recognition of its ecological significance, the Bhoj Wetland was designated as a Ramsar Site in 2002, highlighting its importance as a wetland of international importance (Ramsar Sites Information Service, 2002). Ecologically, the lake hosts a variety of biodiversity including aquatic plants, plankton, fish species, and several resident

and migratory bird species (Chourasia & Adoni, 1985). It performs a crucial role in regulating the urban microclimate, supporting groundwater recharge, and serving as a hub for local livelihoods such as fisheries and tourism. Despite its ecological and socio-economic importance, Upper Lake faces multiple environmental threats such as eutrophication, siltation, wastewater discharge, and encroachment due to rapid urban expansion (Jain et al., 2021). Nutrient enrichment from untreated sewage and agricultural runoff has led to algal blooms and degraded water quality over time (Ahmad et al., 2019). These growing pressures necessitate continuous monitoring of the lake's physicochemical characteristics and trophic state to support its sustainable management.

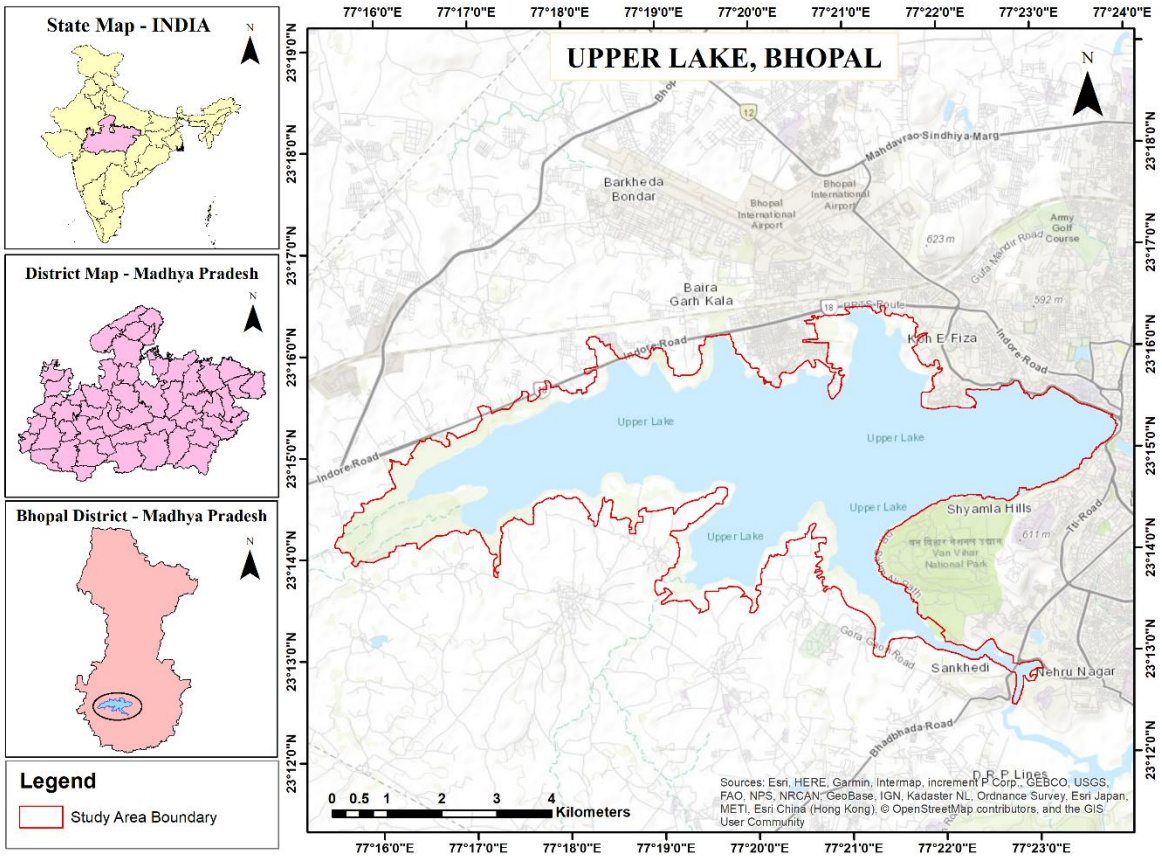

Figure 1. Location of the study area—The Upper Lake, Bhopal, India

3. Literature Review

Many researchers have evaluated the condition of the water of the Upper Lake in Bhopal. Some noteworthy contributions of this study are discussed below:

Iqbal et al. (1995) undertook a bacteriological analysis of lake water to evaluate the water quality of Bhopal's Upper Lake after the escape of methyl isocyanate gas from the Union Carbide factory in Bhopal, India. Water samples were taken from different sample sites on the lake's surface. The study discovered that coliform bacteria levels increased to 24000/mL during pre-monsoon and decreased to a minimum (120/mL) in the monsoon time, compared to the WHO's recommended limit of 100/mL for drinking water. According to the data collected, the Upper Lake's water quality has deteriorated and is gradually becoming dangerous to drink in the habitat.

Tripathi and Singh (2000) used satellite data in a GIS context to evaluate and construct a pollution zone map of Upper Lake, Bhopal. Spectral reflectance analysis was used to assess wavelength appropriateness for measuring chlorophyll-a (chl-a), suspended solid concentration (SSC), and Secchi depth (SD). Least-squares regression analysis was used to create empirical models. These models were determined to be valid for the unused samples. The suggested models generated Chl-a, SSC, and SD distribution maps, which were then used as data layers in GIS to analyze polluted zones. The pollution zone map provides spatial pollution information that can be used to identify sections of lakes with significant pollution loads. The methodology utilized in this study can be used to monitor pollution levels in surface water bodies on a regular basis, providing data for better water quality management.

Margade et al. (2006) discussed how one of the largest lakes in India is the Upper Lake of Bhopal, which provides a significant supply of drinking water for the city's residents. The study evaluated various water quality characteristics such as water surface temperature, pH, alkalinity, BOD, DO, heavy and hazardous metals, and total dissolved solids (TDS). The result indicates that the water of Upper Lake, Bhopal is partially contaminated and needs appropriate measures to prevent it.

Parashar et al. (2006) stated the water that is suitable for human consumption should be pleasant to taste, free of dangerous chemicals and pathogens, and suitable for residential use. Temperature, pH, DO, total hardness, total alkalinity, and turbidity measurements were used to evaluate the drinkable water health of the Upper Lake of Bhopal. It has been determined how much pollution has been caused by urbanization, human activity, and increased alterations to water bodies. This was unable to achieve the desired water quality standard.

Vyas et al. (2006) stated that the Upper Lake, Bhopal water was used to drown Lord Ganesh and Durga statues at the time of the festivals, which is a main cause of pollution. The Upper Lake and the Lower Lake of Bhopal serve as the main cause of drinkable water for the city's population. Water contamination is induced by idol immersion, a practice peculiar to India due to its vast Hindu population. The idol is made of clay, but non-biodegradable thermocol and paints containing dangerous pollutants are also utilized. Immersion reduces water adequacy and promotes siltation. Thus, turbidity, total hardness, DO, BOD, COD, oil, and grease do not meet the standard level.

Bajpai et al. (2008) conducted a project called the "Bhoj Wetland Project" (financed by JBIC) to conserve the Upper Lake in Bhopal. To undertake for conservation of the lakes of Bhopal various steps can be like desilting, preservation of Takia Island, catchment area treatment, construction of floating fountains, elimination of weed sewerage systems, and other efforts were. After the project was successfully implemented, it was evident that the lake's water quality had significantly improved; meanwhile, carrying capacity also increased. As a result, ecotourism has expanded. The major water quality indicators were taken into account. It was found that the dissolved oxygen content increased significantly over the decade, but BOD, COD, and other nutrient inputs decreased dramatically.

Parashar et al. (2008) discussed one of the very major concerns of environmentalists: contamination of water bodies. Urbanization, industrialization, and modern farming practices

all directly impact water resources. The city of Bhopal relies heavily on freshwater from the Kolar reservoir, often known as Kolar, and the Upper Lake. In an effort to evaluate the condition of water, major physicochemical characteristics were evaluated, which do not meet the standard criteria.

Shrivastava and Joshi (2008) stated that the Upper Lake is very important for the city of Bhopal, but the quality has deteriorated over time due to trash and sewage imports. The goal of this research was to assess the major physicochemical characteristics of water samples taken throughout the summer season at the Prempura site in the Upper Lake during 2005. To ensure the health of lake water, the standard desirable limit for each characteristic in drinking water was compared with each parameter by several agencies.

Vyas et al. (2008) stated that the religious activities in India have a close relationship with water bodies; nevertheless, many aquatic features have now get decreases for garbage disposal, causing in degradation of their water condition due to fast urban expansion. The Upper Lake, Bhopal is a great example of an urban water feature that also provides as an important source of drinkable water for the inhabitants of Bhopal. Until the mid-twentieth century, the water from Upper Lake did not need to be treated before being consumed. However, due to pollution and other toxins in modern times, the need for treatment is obvious.

Rao et al. (2009) conducted a comprehensive study with the primary aim of utilizing spatial simulation techniques to analyze the morphology of Upper Lake in Bhopal. The study focused on understanding the link between suspended sediment concentration and satellite-based remote sensing data. It also involved the development of an updated elevation-capacity relationship, formulation of an elevation–water spread area curve, and estimation of sediment load using ground truth observations and GIS tools. Upper Lake, recognized as a major wetland by India's Ministry of Water Resources, served as the research site. To achieve these objectives, a high-resolution digital elevation model (DEM) was generated based on bathymetric contour data collected at 0.5-meter intervals. GIS-based spatial simulations of water spread areas under various water levels were carried out using a neighborhood connectivity approach. For sediment analysis, water samples were taken from various georeferenced points across the lake using a GPS device. These samples were analyzed in a laboratory to determine suspended sediment concentrations. Digital data from the LANDSAT 5 Thematic Mapper (TM), excluding the thermal band, were processed using image analysis techniques. A positive linear relationship was got between suspended sediments and radiance values in band 2. This regression model was then applied to a radiance image of the lake to map the spatial distribution of suspended sediments across the water body.

Margade et al. (2011) conducted a limnological study of Upper Lake, Bhopal by evaluating water quality data from four independent sites at the top and bottom levels of the lake in 2008. The physicochemical characteristics of water samples were also investigated. Major physicochemical properties were statistically examined to evaluate the relationship between various water quality variables such as chloride, sulfate, nitrate, and nitrite. Based on these findings, the selected parameters were not found to be at the standard level.

Virha et al. (2011) stated that the biggest environmental risk for the future is freshwater contamination by heavy metals. One of Bhopal City's main sources of drinking water is the manmade freshwater lake known as the Upper Lake. However, this lake is becoming poisoned as a result of numerous human activities. The lake's seasonal water quality in 2006 and 2007 was assessed by the experiment's analysis of heavy metals and physicochemical parameters. Every physicochemical parameter was below the recommended level. The outcome shows that there is some heavy metal pollution in the upper lake's water. This research also suggested that rigorous attention to detail and ongoing monitoring are necessary to preserve the lake's water quality, which is a significant supply of drinkable water of Bhopal.

Kumar and Chaudhary (2013) stated that the Bhoj wetland, which includes the Upper Lake and the Lower Lake, is dealing with serious environmental issues such as changing land use patterns around lakes, polluted land and macrophyte development, and eutrophication. It supplies roughly half of Bhopal's drinking water. The preservation of Bhopal lakes has received widespread attention. In addition to de-weeding, aquaculture, and floating fountain installation, these operations comprise catchment area treatment, sewage treatment programs, and solid waste management. However, an overall lack of biodiversity has been noted.

Upadhyay et al. (2013) discussed that many artificial and natural lakes, wetlands, and reservoirs can be found inside the boundaries of India's largest cities. Although these limited water supplies objectively provide a number of human needs, numerous water bodies are progressively suffering from severe degradation due to various anthropogenic activities and widespread urbanization. The water quality of these urban lakes is being impacted by the combined effects of human pressure and the pollution load imposed by point and non-point sources. The Upper Lake, Bhopal is the prime source of drinking water supply for Bhopal city. The primary aim of this study was to evaluate the water quality of Upper Lake, Bhopal using the trophic status index and Palmer to gain an improved understanding of limnetic chemistry. The results depicted that the concentration of key parameters that primarily control the chemistry of lakes was determined to be over the threshold level of eutrophication and above allowable limits. By reviewing the Palmer Index data, 12 genera were identified with a total index value of 27, indicating organic pollution in the lake, but the trophic state index results show that the Upper Lake is in a greater stage of eutrophic because of significant nutrient loading.

Shameem et al. (2014) conducted a study on the effect of lake sediment chemistry on water quality in the Upper Lake, Bhopal. The analysis revealed that there is a rise in the pollution status of the lake. The varied land use and land cover in the lake's catchment area contribute to nitrate and reactive phosphate changes. The lake was found to be hypertonic between June and August. It was also noticed that greater concentrations of nutrients were caused by their release from sediments into the water column as a result of the decreased oxygen level in lake water.

Goyal (2016) conducted a study of the condition of the Upper Lake water, Bhopal, analyzing monthly average of various physicochemical properties in water samples obtained from various places in the Upper Lake. Water quality characteristics were examined and assessed in accordance with WHO standards. The results show that the lake's water quality is polluted. Heavy metals, including Cr, Cd, Ni, and Pb, are the primary cause of water pollution.

Singh et al. (2016) evaluated several physicochemical parameters of Upper Lake, Bhopal to determine its water quality condition. Various physicochemical properties were examined throughout the investigation. The general water quality of the Upper Lake was found to be between 'Fair' and 'Poor' at all sampling points. Sewage, agricultural runoff, and other anthropogenic activities are the lake's primary causes of contamination.

Singh et al. (2016) examined water samples from the Upper Lake in Bhopal. The Water Quality Index (WQI) was used to classify lake water. The average WQI values for the pre-monsoon, monsoon, and post-monsoon periods were measured to be 64.52, 52.23, and 42.45, respectively. However, there are more polluted samples during the pre-monsoon season; thus, a multivariate statistical technique is used to handle vast and complicated datasets and acquire better information regarding lake water quality. The total investigation found that agricultural runoff, waste dumping, leaching and irrigation with wastewater, and land transformation in the surrounding areas are the primary reasons for lake water contamination. As a result, there is an immediate requirement to focus on and manage water resources properly.

Singh and Shrivastava (2016) investigated monthly changes of various physicochemical characteristics such as, transparency, conductivity, pH, chloride, total hardness, and total suspended particles from March to May 2007. The study reveals that these physicochemical characteristics fluctuated throughout the research period. Previous investigations have found that the water in this lake is safe for both residential and drinking purposes.

Bhattacharya and Shandilya (2017) conducted a study to assess the pollution level of the Upper Lake, Bhopal and the extent of remediation needed to make it safe to drink. A number of tests were performed on Upper Lake water samples. The extent of water hygiene delivery was analyzed by comparing the recorded values of major physicochemical parameters and other microbiological tests for the presence of bacteria before and after the water purification. The detrimental impacts of lake water contamination on the environment and the local community, as well as the quality of the water following treatment, were also noted.

Khan (2020) conducted a study of physicochemical and statistical analysis of the Upper Lake water in the Bhopal region of Madhya Pradesh, India. He evaluated the lake's many physicochemical characteristics to present the current state of lake water quality. The positive co-relationship that existed between the traits was discovered to be independent of one another, and it varied depending on location.

Farooq et al. (2021) did a study to analyze the health state of the Upper Lake, Bhopal. Water samples were obtained at two distinct locations for physicochemical analysis. The examined samples were matched to the standards established in BIS-10500 and WHO. The results revealed that high bacteriological pollution was caused by sewage discharge from catchment regions. Furthermore, it is proposed that frequent evaluations and control of water quality are required to protect water from low quality, which is harmful to human health and aquatic life.

Singh and Samantha (2021) conducted a study to assess the water quality of the Upper Lake, Bhopal. Water samples were taken from the Upper Lake surface water from March 2019 to February 2020 during the pre-monsoon, monsoon, and post-monsoon seasons. Standard methods were used to calculate the degree of degradation in water quality using various

physico-chemical factors. The findings revealed that various physicochemical properties change slightly during the three different seasons, and the majority of water quality characteristics are favorable for the existence of fish development and health but unsuitable for human use.

Singh and Samartha (2021) stated that the Upper Lake, also known as Bada Talab, is a man-made lake in Bhopal. Household runoff into the Upper Lake causes massive fertilizer input and the highest phosphate and nitrogen concentrations, proving that the water is eutrophic. In this study, the seasonal availability of particular zooplankton in the Upper Lake of Bhopal was determined. The zooplankton abundances during pre-monsoon, monsoon, and post-monsoon were examined.

Bashir and Samartha (2022) analyzed several physicochemical parameters of water samples obtained from four different places in the Upper Lake, Bhopal. The findings revealed that Site 1 had significant variances in several metrics. However, there were no major changes in temperatures among the four test sites. The pH at sampling site 1 was lower than at site 2, site 3, and site 4. Dissolved oxygen (DO) levels were consistent across every site, while free carbon dioxide levels differed somewhat at site 1, where they were greater than at site 2, site 3, and site 4.

4. Conclusion

The health of the Upper Lake water, Bhopal may be assessed using a number of physicochemical characteristics. Finally, it was determined that the majority of the parameters exceeded the legal limit. As a result, it should be sought to raise these parameters to the study's benchmark level while also removing the foul odor emanating from specific aquatic locations. Lake water is more affected in the summer than in the winter. This could be because cold suppresses microbial activity, keeping the DO level within a reasonable range throughout the winter. Several different characteristics have been shown to increase during the summer and decrease during the wet season as a result of toxins detected in the lake. As a result, these changes would have an impact on the aquatic ecosystem since increased feeding would produce eutrophication, lowering the level of oxygen in the water. Without consistent availability of bottom-level oxygen, the organic waste cannot be biodegraded by beneficial bacteria or insect silt at lake bed level. Filtration operations should be employed as purification approaches before introducing any foreign objects into the water body. A few toxins were released into the lake. To improve the quality of such water, proper bioremediation techniques should be used.

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