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RESEARCH ARTICLE

ASSESSMENT OF PHYSICOCHEMICAL PROPERTIES OF GROUNDWATER IN BHUBANESWAR, EASTERN INDIA

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ABSTRACT

Odisha's capital, Bhubaneswar, has been named a leading smart city and is rapidly becoming more urbanized. Significant changes in the city's geographic footprint are being brought about by unplanned, uncontrolled, and unrestrained urban expansion brought on by the growing population of the city and an immense number of migrants.Despite having three river borders, the city depends on groundwater for residential, commercial, and agricultural uses because many areas of the city and its suburbs lack a piped water delivery infrastructure. A significant volume of municipal solid waste is produced due to several human activities and is disposed of at various BMC dumping locations. Rainfall, water existing in the trash, and water produced by biodegradation all contribute to the leachate leaving the disposal site and seeping into the groundwater, which contaminates it. Approximately 60% of the city residents currently rely on ground water, which is becoming more and more contaminated every day. The priceless groundwater supply has been severely strained by the city's quick growth, which has led to a drop in both its quantity and quality. Given this, it is thought to be essential to assess the condition of the ground water quality in Bhubaneswar. Numerous human activities generate a sizable amount of municipal solid trash, which is dumped at different BMC dumping sites. Leachate leaves the disposal site and seeps into the groundwater, contaminating it. This process is facilitated by rainfall, water found in the waste, and water generated by biodegradation. The city's rapid growth has put a great deal of strain on the precious groundwater supply, causing both its quantity and quality to decline. In light of this, evaluating the state of the ground water quality in Bhubaneswar is deemed crucial.

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INTRODUCTION

Water constitutes the basic element of life and plays a vital role in determining the quality of the human life. Climatic changes such as change in rainfalls, temperatures as well as moisture content of soil represent a direct impact on thequality andobtainability of water to drink, feed animals, farm, and other demands. Groundwater is the primary agricultural,industrial and domesticwatersource in many countries, and water pollution has been regarded as one of the greatest problems in India.According to the recent research, there has been a steady decline in groundwater reserves with high-levels of water quality degradation in most parts of the world (Scanlon *et al*., 2007; Sinha *et al*., 2019; Lapworth *et al*., 2023; Mishra *et al*., 2023). This increasing water shortage has very intense socio-economic environmental issues. The lack of access to freshwater sources within certain regions is forcing communities to travel long distances in order to get water to be used at home. In addition, poor water supply limits farming production, threat of food security and sustainable lives. In addition to the quantitative losses in water availability, the pollution of water resources aggravates even further the crisis through adding pressure on already scarce freshwater resources (Singh *et al*., 2021; Mishra *et al*., 2023). The quality of water is controlled by the concentration and composition of dissolved solutes and gases, suspended and floating particulates (Levay *et al*., 2001; Bilotta and Brazier, 2008). It is a manifestation of the intrinsic physical and chemical properties of the water, which are determined by natural processes, and can be seriously altered by human-made activities. Water quality is an important factor to consider during the evaluation of water resource to be used in domestic purposes, irrigation and industry. Several studies conducted around the globe have analyzed the geochemical characteristics of ground water that are affected by human anthropological processes such as sewage disposal and use of agricultural fertilizers (Wali *et al*., 2024; Akhtar *et al*., 2021). Moreover, natural geochemical reactions include ion exchange, evapotranspiration, water-rock interactions, etc. that greatly alter the chemistry of groundwater and can often increase the ionic content of the water and make it undrinkable and non-agriculturally acceptable (Subramani *et al*., 2010; Khan *et al*., 2021).

Thus, proper identification and analysis of groundwater composition are necessary in order to assess its applicability to different end uses. The quality of groundwater is mostly assessed by measuring the concentration of the major ions and trace elements to measure the suitability of groundwater to its use as drinking, agricultural, and industrial water. Although some trace elements are important in the human body, their high levels can be very dangerous to the human health. Specifically, the presence of heavy metals and pesticide residues in groundwater is problematic because of their insubordination and inability to breakdown (Pérez-Lucas *et al*., 2018; Acharya *et al*., 2025). Many papers and reports have been conducted on the distribution and effects of heavy metal contamination in ground water in various parts of the world (Sankhla *et al*., 2019; Nouri *et al*., 2008; Sankhla and Kumar, 2019), The current paper is going to measure the levels of major and trace elements in the ground water of the Bhubaneswar area, compare the findings against the standards of drinking water as stipulated by WHO (1993) and ISI (1991), and find out the main causes that lead to the high levels of dissolved constituents. The paper also aims at recommending suitable actions to reduce the decline in groundwater quality in the region.

Study Area: Bhubaneswar is situated in the Khurda district of eastern Odisha and encompasses the municipal limits along with its adjoining peri-urban areas, covering approximately 233 km². The study area is between latitudes 20°09′46″ N and 20°21′36″ N, and longitudes 85°43′51″ E and 85°52′32″ E. The average annual rainfall is predominantly received during the monsoon months (June–September), which significantly influences groundwater recharge and hydrological dynamics.

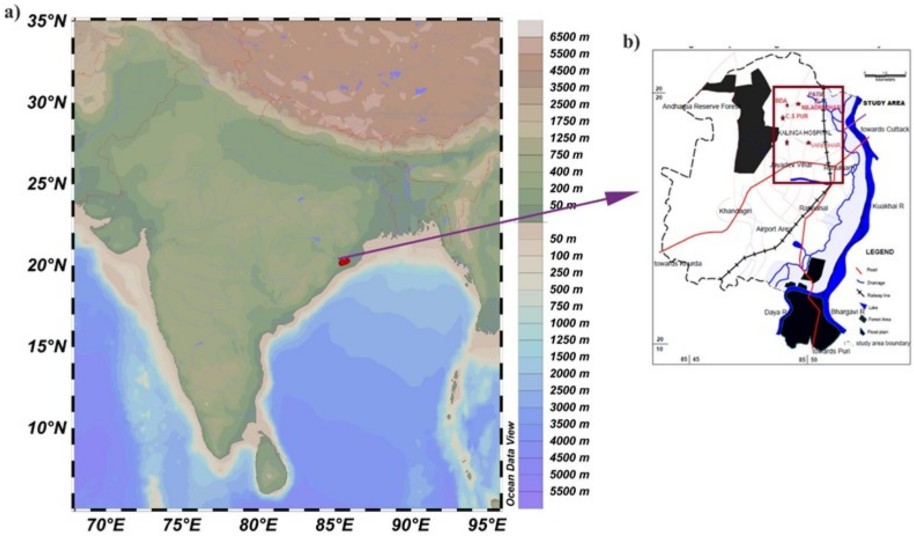

Figure 1. Location Map of the Study Area Showing Ground Water Sampling points. The base map is prepared by following Mohanty *et al*., 2025 and by using ODV Software (Schlitzer, 2022)

Geologically, the area is underlain by the Athgarh Formation of Lower Cretaceous age, belonging to the Upper Gondwana Group (Mishra *et al*., 2004; Goswami *et al*., 2010; Chakraborty *et al*., 2021). The Athgarh Basin mainly comprises sandstones, grits, conglomerates, and clay horizons, which exhibit variable permeability and porosity. Lateritic formations commonly cap the underlying consolidated rocks, particularly over elevated terrains (Ghosh and Sanat, 2015). In contrast, Quaternary alluvial deposits are extensively developed in the eastern and southeastern parts of the study area, consisting of unconsolidated sands, silts, and clays.

MATERIALS AND METHODS

A total of 22 groundwater samples were collected from various borewellsin the study area. The water was left to run for 5 minutes before collection. The samples were then subjected to physical and chemical analysis, including pH, EC, TDS, CI, CO_3, HCO_3, SO_4, Ca, Mg, Na, K, and trace elements like Fe, Mn, and Cu. Major cations and anions were analyzed using standard methods. Trace elements like Fe, Mn, and Cu were measured using Atomic Absorption spectroscopy.Samples of 22 groundwater were taken in one-litrepolyethylene bottles. The concentration of the hydrogen ions (pH) and electrical conductivity (EC) was determined on-site using a portable pH and conductivity meter. The samples obtained were then examined on the basis of major ion chemistry as per the ordinary water quality analysis standards. It was determined that EC values of the sample were used to estimate total dissolved solids (TDS) with a conversion factor of 0.64, which varies depending on the relative ionic composition of the water per the approach of Hem (1991). The standard EDTA titration was used to determine the total hardness (TH) in terms of $CaCO_3$ and the concentration of calcium (Ca^{+2}). The total calcium and hardness were used to obtain Magnesium (Mg^{+2}). A flame photometer was used to measure sodium (Na^{+}) and potassium (K^{+}). Standard methods of acid titration were used to determine carbonate (CO_3^{-2}) and bicarbonate (HCO_3^{-2}) (APHA, 1985), and chloride (Cl^{-}) was determined using silver nitrate ($AgNO_3$). The concentration of sulphate (SO_4^{-}) was determined through a spectrophotometric process. All chemical parameters are in the form of milligrams per litre (mg/l), with an exception of pH that is expressed in standard units. The error calculated in ionic balance per complete chemical analysis was also below the acceptable limit of 5 percent which also means good accuracy in the analysis.

RESULT AND DISCUSSION

Rapid industrialization and human activities are altering the quality of both surface and groundwater, with subsurface water contamination being a greater challenge to detect and control. Groundwater quality, which varies depending on location, should be verified before use, as it is a crucial requirement and should be represented by physical and chemical properties.

Evaluation of physical parameters

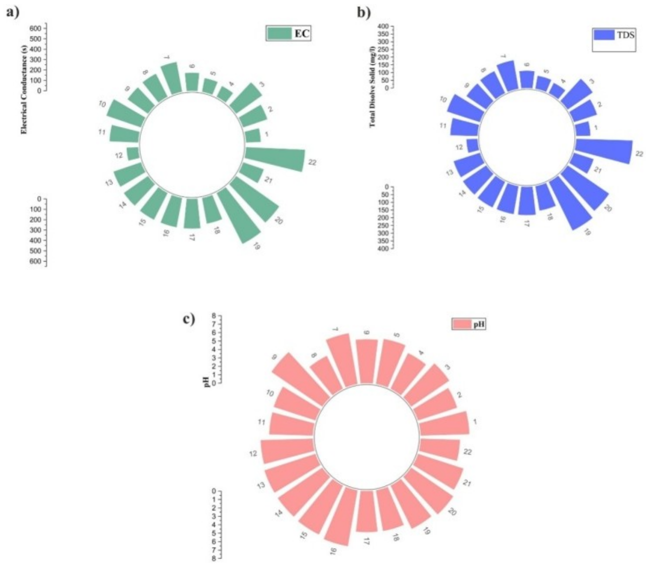

Figure 2. Concentration of Physical parameters EC, TDS and pH

The physical properties of water including electrical conductance (EC), total dissolve solid (TDS) and pH, vary significantly. Figure 2 shows that electrical conductivity from 115 to 555 Siemens, and TDS values from 73.6 to 355.2 mg/L and pH samples range from 4.2 to 7.8.

Evaluation of chemical parameters: The study area's water samples show varying levels of common cations (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}), and common anions (Cl^{-}, CO_3^{2-}, HCO_3, SO^{4-}). The calcium content varies from 5 to 42 mg/L, while the Mg^{+2} content ranges from 3.7 to 29.3 mg/L. The Na^{+} content ranges from 6.61 to 44.91 mg/L, and the K^{+} content ranges from 0.14 to 12.6 mg/L. The chloride content ranges from 10 to 182 mg/L. The CO_3^{2-} of the ground water sample is nil, the HCO_3 content varies from 21.96 to 146.4 ppm, SO^{-4} varies from 5.1 to 30 mg/L. The variation of all these parameters are shown in the figure 3.

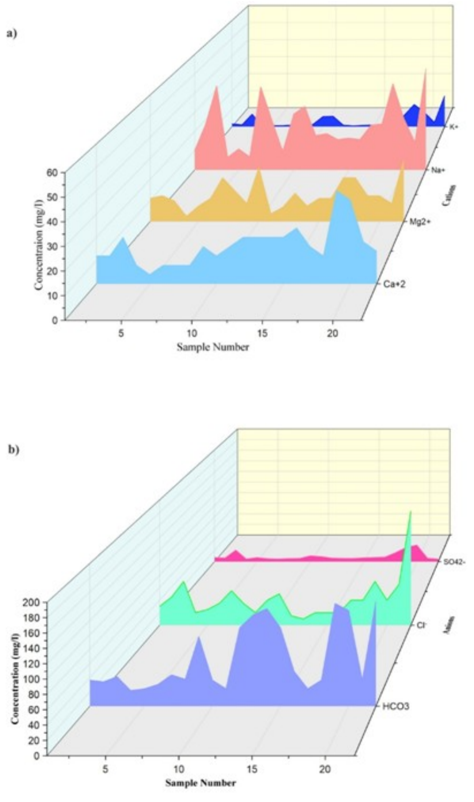

Figure 3. Distribution of major cations concentration in mg/l including Ca^{+2}, Na^{+}, Mg^{+2}, and K^{+}; b) Distribution of major anions concentration in mg/l like HCO_3, Cl^{-}, SO_4^{-2}

TRACE ELEMENTS

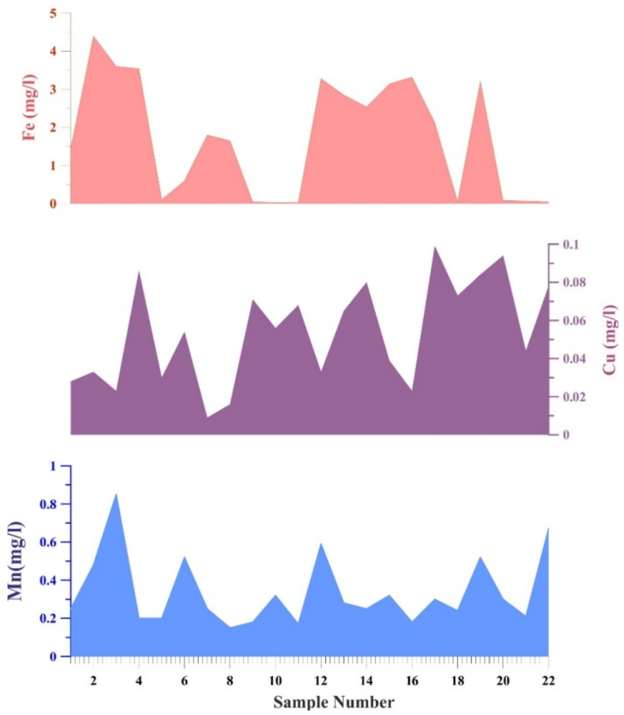

Figure 4. Concentration of trace element Mn, Cu and Fe

The ground water's Fe content, ranging from 0.105 to 4.7 mg/L, does not meet the 0.3mg/L standard, possibly due to lateritic soil and leaching from municipal solid waste. The Mn content ranges from 0.15 to 0.85 mg/L, with most locations slightly exceeding the prescribed value of 0.1 to 0.3 mg/L. The Cu content ranges from 0.008 to 0.098 mg/L, with copper content slightly higher than the prescribed value of 0.05 mg/L.

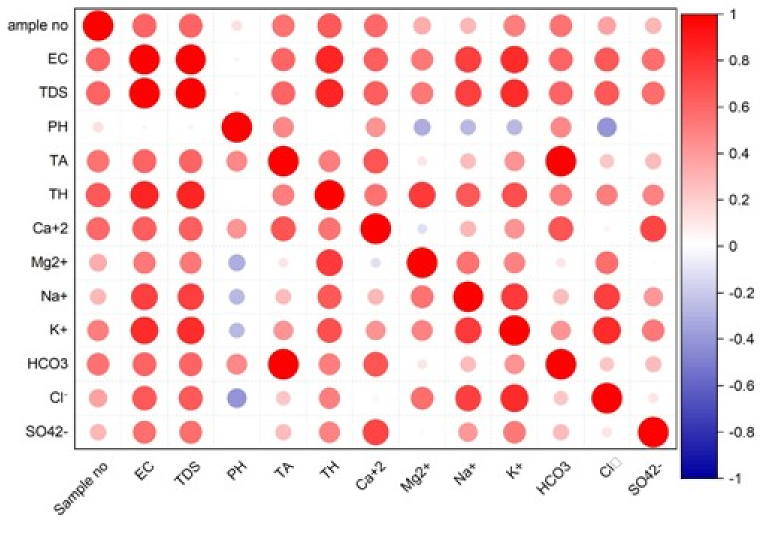

Figure 5. Corelation matrix analysis of parameters for 22 samples

Corelation matrix analysis: The heatmap of correlation indicates that the major water quality parameters would have strong interrelations throughout the analyzed samples. The strongest positive correlation between EC and TDSis observed as demonstrated by the strong red clustering around sample means as a resultant relationship between the two measures where higher concentrations of ions increase both measures. This trend has been consistent with existing hydrochemical processes in a water system, as the dissolved salts directly increase the EC and TDS levels pH demonstrates moderate negative relationships with the total alkalinity (TA) and total hardness (TH), as indicated by the darker blues, and this indicates that acid changes can lead to a decrease of buffering capacity via carbonates. Cations such as Ca2+, Mg2+ and Na + have positive relationship with other cations as well as with anions such as Cl^-, SO_4^{-2}, and exhibit trends that suggest typical anthropogenic or geogenic origins such as mineral dissolution or concentration by evaporation. Interestingly, the HCO_3^- appears to have lower or negative correlations with salinity indicators, which might reflect the effects of dilution or other sources of bicarbonates in the water matrix.The results point to sample-specific heterogeneity such as outliers of red in TDS-SO_4^{-2} or blue in pH-TA to emphasize the role of spatiotemporal factors in water chemistry, which may be useful in guiding more focused monitoring such as ground water systems. Generally, the heatmap validates the principal component clustering, PC1 is probably a model of salinity-based variance (EC, TDS, major ions) and PC2 distinguishes between acid-base equilibria, which aids in the apportionment of pollution sources.The process of urbanization adds increased correlations in the heatmap by enhancing the ion leaching to the ground water via the impervious surfaces, sewage intrusion, and runoff resulting in high levels of TDS, EC and major cations such as Na^{+}, Ca^{2+} and Mg^{2+}. In cities, the same trends are reflected by the rapidly growing regions where residential growth is associated with more chloride and sulfate by the wastewater, which directly reduces recharge to the lakes and aquifers.This is urban-induced salinization which degrade the groundwater drinking ability, as pH alterations and spikes in hardness foster scaling in infrastructure and health hazards of surplus minerals. In the case of lake-proximal systems, these contamination vectors also worsen the sample variability of the biplot, which supports the necessity of controlled urban buffers to reduce the stress of the aquifer in the long run.

CONCLUSION

This study demonstrates that there are strong correlations among the most important hydrochemical parameters of the lake water samples, and EC and TDS have the strongest positive correlations due to the dissolved ions effect, furthermore, there are moderate cation-anion correlations that indicate both the geogenic and anthropogenic factors. Urbanization promotes such trends by salinizing via runoffs and introducing pollutants into groundwater, which increases TDS, hardness, and major ions levels in near-surface groundwater, undermining the quality of potable water and recharge in the growing areas. Such insights highlight the need to adopt the integrated monitoring and land-use planning to protect aquatic resources.The introduction of the temporal sampling and isotopic tracers in future studies would help in de-polluting urban sources and natural sources, which would lead to sustainable management in the urbanizing lake catchments.

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