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Ground Water Quality Assessment for Sustainable Drinking Purpose

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Abstract

Ground water is the purest form of water that can be in used agriculture and consumption purposes. Several factors have an impact on the quality of groundwater, including seasonal changes, the composition of dissolved salts, the water table's elevation, and the geology of a particular location. The dumping of unexpurgated factory waste directly through watercourses, which results in substantial pollutants level in underground water as well as the surface, is the primary cause of groundwater contamination. As the human population increases, the groundwater becomes even more important for economic and social activity. The study conducted in the Bhubaneswar region of Orissa, India focused on assessing the water quality suitability of groundwater for drinking purposes. The research found that microorganisms had contaminated the groundwater. The study collected 40 water samples from four selected localities, and various analysis methods were conducted to assess the physico-chemical and microbiological parameters of the collected samples. The physico-chemical parameters studied included total dissolved solids (TDS), pH, turbidity, total hardness, and chloride. The microbiological parameters studied were F. coliform and E. coli. The research found that some regions had TDS and total hardness levels below acceptable limits, according to IS 10500:2012. The chloride concentration was below the desired limit. However, the pH in some locations was much lower than acceptable. Overall, this study highlights the importance of regularly monitoring and assessing the quality of groundwater in different regions to ensure that it is safe for human use. The findings of this study can help policymakers and local authorities to develop effective strategies to protect groundwater resources and ensure that they remain safe for future generations.

Keywords: Groundwater; Water Quality; Total Coliforms; Physico-Chemical Parameters

Abbreviations: TDS: Total Dissolved Solids; WHO: World Health Organization; WQI: Water Quality Index; CPCB: Central Pollution Control Board; CGWB: Central Ground Water Board; BIS: Bureau of Indian Standards; NCR: National Capital Region; TH: Total Hardness.

Introduction

Water is a crucial natural resource and is essential for sustaining life on earth. Groundwater is considered the purest form of water that can be utilized in various industrial, agricultural, and domestic applications. However, groundwater contamination is a major environmental concern and can be caused by various anthropogenic activities such as agricultural practices, industrial activities, and urbanization [1].

Agriculture is indeed a major consumer of water worldwide, utilizing approximately 70% of the global water supply [2]. The demand for freshwater has significantly increased due to various factors such as population growth, urbanization, industrialization, and agricultural activities.

As a result, surface water, which includes rivers, lakes, and reservoirs, plays a crucial role in fulfilling the water requirements for irrigation, drinking, and fisheries [3].

Overutilization, pollution, and other factors have posed significant challenges to maintaining the quality of water resources [4]. Water, being a universal solvent, is susceptible to pollution from various sources, including industrial discharges, domestic waste, and agricultural runoff. These pollutants can include chemicals, pathogens, and other contaminants that pose health hazards when consumed or used for various purposes [5,6].

Waterborne diseases are a common consequence of polluted water sources. Contaminated water can lead to illnesses such as typhoid, diarrhea, cholera, skin diseases, vomiting, kidney disorders, and gastrointestinal disorders [5,6]. Therefore, monitoring and assessing water quality on a regular basis are essential due to the spatial and temporal variations in water quality [7]. Organizations like the World Health Organization (WHO) have established permissible values and guidelines for potable water safety to ensure the well-being and safety of human health [8].

The FAO statistics indicate that 20 percent of the irrigated land is responsible for producing 40 percent of the crops. However, irrigation practices come with certain risks that can affect water quality, such as water stagnation and increased salinity caused by irrigation return flows [9,10]. The suitability and quantity of water required for irrigation depend on factors such as soil type and cultivated crops [11].

Given the importance of water quality in determining its suitability for various purposes, continuous monitoring of physical, chemical, and biological parameters is necessary. This monitoring generates a large amount of data, and to make sense of it, the water quality index (WQI) is used. The WQI provides a single numerical expression that summarizes the data, enabling a better understanding of water quality for different purposes [12]. The concept of using WQI for water quality assessment, considering multiple variables and deriving a single value, was initially described by Horton in 1965 [13]. The resulting value helps determine the overall quality and suitability of water, making the WQI a valuable tool for assessing water quality [14].

In the case of assessing irrigation water quality in India, several criteria provided by the Central Pollution Control Board (CPCB) and the Central Ground Water Board (CGWB) are generally followed [15]. These criteria serve as guidelines for evaluating the quality of water intended for irrigation purposes. By adhering to these criteria, it becomes possible to assess the suitability of water for irrigation in India.

Groundwater contamination has become a significant environmental problem globally, with a substantial impact on human health and the environment [16]. In many regions, water scarcity is a severe challenge, and the groundwater is the primary source of drinking water. In India, nearly 50% of urban residents and 80% of rural residents rely on contaminated groundwater, particularly in the state of Orissa, where the scarcity of pure drinking water is particularly acute [17]. Therefore, it is imperative to evaluate the quality of groundwater to determine its suitability for domestic use.

The research study conducted in Bhubaneswar, India focuses on evaluating the extent of groundwater pollution and determining its suitability for domestic use, specifically for drinking purposes. Bhubaneswar, being the capital of Odisha with a rapidly growing population, faces the challenge of meeting the water demands of its residents, and a significant portion of the population relies on groundwater as a source of drinking water. The study's objectives are:

- Assess groundwater quality by analyzing variations in physicochemical parameters to identify contamination levels, including pH, electrical conductivity, heavy metals, and nitrates.
- Identify factors influencing water quality using geochemical plots and statistical analysis, examining industrial, agricultural, sewage, and natural impacts.
- Determine the suitability of Bhubaneswar's groundwater for drinking purposes by comparing measured values with Bureau of Indian Standards (BIS) benchmarks, aiming to provide insights into water quality, influencing factors, and drinking water safety measures.

Materials and Methods

Bhubaneswar, the capital of Orissa, lies at 20°12'N to 20°25'N and 85° 'E to 85°55'E, on the western edge of the coastal plain opposite the main axis of the Eastern Ghats in Kurda district (Figure 1). The Bhubaneswar region is a part of the ancient and most sustainable mainland in the world, Gondwana, according to geological data. The rocks range from Archean to recent. Most of the area is covered by quarterly alluvial and lateritic soils. Groundwater depth varies from 5 to 12 m in laterite and weathered sandstone. 0–50 m crushed brittle sandstone forming deeper aquifers in semi-restrictive to limited conditions. Rock formations in and around the western part of the city store water replenished by rainfall. The maximum depth is 6 m bgl in December and decreases to 8 m bgl in May.

Study Area

Assurance of groundwater quality for domestic and drinking water supply has become necessary in the National Capital Region (NCR) of New Delhi, India, due to diverse geological and topographical settings, growing population, and anthropogenic factors [1]. Anim Gyampo M, et al. [18] conducted research to assess the suitability of groundwater for irrigation and drinking, as well as the potential health risks to the population in Ghana's Atankwidi basin. The city is on the northern bank of the River Daya and to the west of the River Kuakhai. The Kuakhai and Daya rivers can be found to the east and south, respectively, on the sloping land surrounding the city. Bhubaneswar city gets most of its water from the River Kuakhai, the River Daya, and the Spring Tanks, as well as from groundwater sources. The primary sources of surface water are the Rivers Daya and Kuakhai. Both domestic and industrial discharges reach the rivers.

Figure 1: Bhubaneswar map.

The topology of the city is one of undulating ridges and valleys, and it is drained by numerous natural drainage channels. The Kuakhai and Daya rivers, which encircle the city on its north and south sides, respectively, control the drainage. Aside from that, the city is crisscrossed by a number of open drains that run west to east, some of which eventually join to form Gangua Nallah. The distributaries of the River Kuakhai, the Gangua Nallah, meet the River Daya.

Methodology

There are total 40 samples of ground water were collected from four different locations of Bhubaneswar in 2019 and segmented as per postal pin codes (Table 1). The sampling methods were maintained as per Indian Standard IS: 3025 & IS: 1622 – 1981 (Techniques for Sampling and Testing Physical and Chemical Parameters for Water and Wastewater). All the samples were collected in a clean 250 ml sterilized bottles and the bottles were rinsed thoroughly prior to sampling and sealed tightly post samples collection. Further the analysis of water samples are being done by the testing method as per BIS: 10500:2012 (2nd Revision). Analytical methods for 7 investigated water quality indicators has been summarized in Table 2. All the samples are analysed at Department of Biotechnology Labs of Ravenshaw University.

S. No	Sampling Sites	Name of Locality	Postal Pin Code
1	L-01	Old Town	751002
2	L-02	Laxmi Sagar	751006
3	L-03	Aiginia	751019
4	L-04	Chandrasekharpur	751024

Table 1: Locations of the four sampling sites.

Indicators of water quality	Abbreviation	Adopted analytical method	Analytical instruments/techniques
pH	–	IS 3025 (Part 11):1983, Reaffirmed, 2017	Electrometric method (Eutech pH 700)
Total Dissolved Solid	TDS	IS 3025 (Part 16):1984, Reaffirmed:2017	Gravimetric method
Turbidity	Turb.	IS 3025 (Part 10):1984, Reaffirmed, 2017	Nephelometric method (Lovibond TB 300 IR)
Total Hardness	TH	IS 3025 (Part 21):1983	EDTA Titrimetric Method
		Reaffirmed, 2014	
Chloride	Cl^-	IS 3025 (Part 32):1988	Argentometric method
		RA: 2014	
Faecal Coliform	FC	IS 1622:1981	MPN
		Reaffirmed:1993	
		Reprint (2003)	
E. coli	–	IS 1622:1981	MPN
		Reaffirmed:1993	
		Reprint (2003	

Table 2: Physico-chemical and microbiological water parameters and methods for analysis.

In factor analysis, the first step is to measure the relationship and strength between different chemical parameters. This is done using a "Pearson correlation matrix" Table 3 in an Excel sheet. The data used for the analysis comes from 40 sources and includes physio-chemical parameters for major elements and trace elements.

The correlation index is then classified into three categories based on their values:

- 95 to 99.9%: This indicates a very strong correlation between the parameters.
- 85 to 94.9%: This shows a strong correlation between the parameters.
- 70 to 84.9%: This indicates a moderate correlation between the parameters.
- Less than 70%: This suggests a weak or negative correlation between the parameters.

	TDS in PPM	pH	Turbidity (NTU)	Total Hardness (mg/l)	Chloride (mg/l)	Iron (mg/l)	Fluoride (mg/l)	Total Coliform (MPN/100ml)
TDS in PPM	1.00							
pH	-0.15	1.00						
Turbidity (NTU)	0.08	-0.18	1.00					
Total Hardness (mg/l)	0.98	-0.19	0.08	1.00				
Chloride (mg/l)	0.85	-0.05	0.21	0.86	1.00			
Iron (mg/l)	0.02	-0.19	-0.07	0.05	-0.13	1.00		
Fluoride (mg/l)	0.23	-0.15	0.11	0.32	0.27	0.06	1.00	
Total Coliform (MPN/100ml)	0.15	-0.45	0.18	0.2	0.17	0	0.08	1.00

Table 3: Groundwater quality parameters correlation matrix (Pearson).

Result and Discussion

pH

Bhat et al. proposed in 2022 that modifications to living thing and other bioactive compounds can cause pH readings to change. The pH level for drinking water should be between 6.5 and 8.5, according to IS: 10500. In this study pH varies between 4.6 to 7.5 during study period. It is further noted that the main source is acidic in character. Here in Figure 2 it shows the location wise pH range. According to the reference to Mandal SK, et al. [19], hydrolysis processes typically raise the pH level above 7, indicating alkaline conditions. Water with a pH above 7 is considered alkaline.

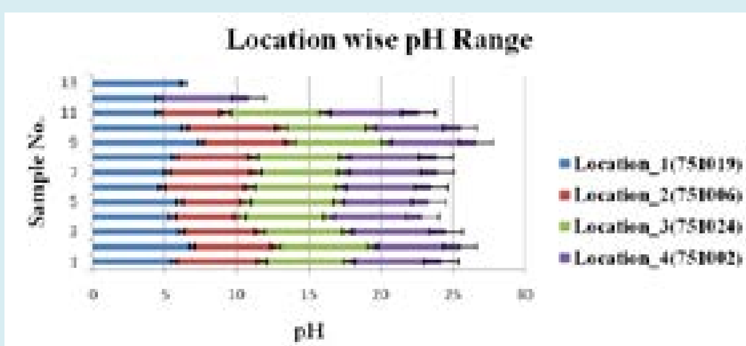

Figure 2: pH at different locations.

Turbidity

The range of turbidity was 2 to 5 NTU. There was no seasonal fluctuation in the samples. However, contaminated ground water may have a significant amount of high turbidity as a result of the action of subterranean soil and rock. The Figure 3 shows the turbidity range location wise.

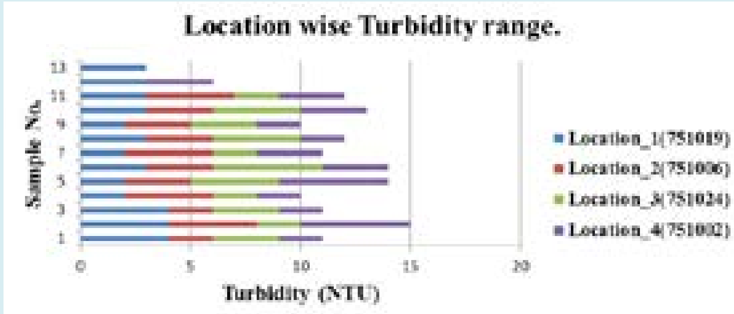

Figure 3: Turbidity at different locations.

Total Hardness

Total Hardness (TH) in water is primarily attributed to divalent cations, particularly calcium and magnesium. TH is a measure of the concentration of these cations in water and is used to assess water hardness. Based on the TH value, water can be classified into moderately hard to hard categories, as stated in Sarath Prasanth SV, et al. [20]. The hardness of the water causes the boiling point of the liquid to rise and prevents soap from lathering [21]. Total Hardness is permitted up to a maximum of 600 mg/l. Total hardness as CaCO3 ranged between 34 to 268 mg/l in water samples. High concentrations were found in the samples from the Aiginia and old town areas. The range location-wise is shown in Figure 4, and all samples fall below the permitted limits.

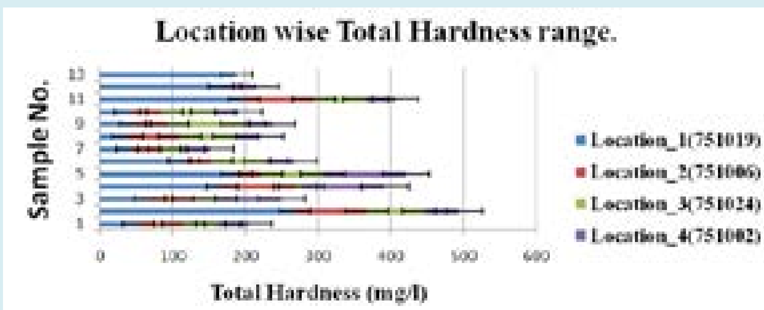

Figure 4: Total hardness at different locations.

Chloride

Chloride is naturally present in all types of water. Its concentration remains relatively low in naturally occurring fresh waters [21]. Here in Figure 5, show that the Chloride concentrations are below the desired levels. Water samples range in chloride level from 09 to 72 mg/l. Higher concentrations were observed in the Samantarapur area, but the remaining samples were determined to be beneath the BIS-acceptable level of 250 mg/l.

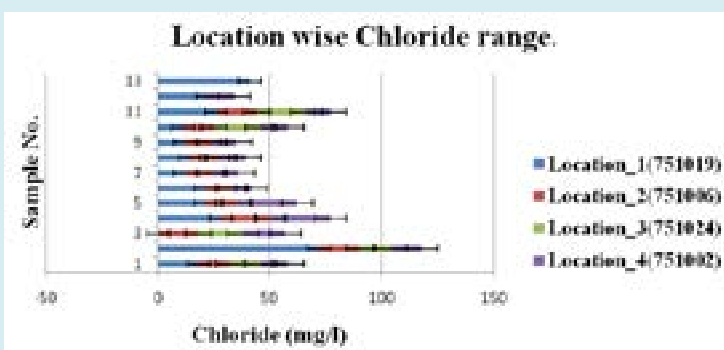

Figure 5: Chloride concentrations at different locations

Total Dissolved Solid

Acharya S, et al. [22] analyzed various parameter of water and among them TDS value is major indicator for ground water quality of Delhi. TDS (Total Dissolved Solids) refers to the collective concentration of dissolved ions, including cations, anions, trace metals, organic matter, and dissolved gases in water [23]. TDS is often used as an indicator of water quality. TDS of sample varied from 71 to 622mg/l. Sample drawn from Aiginia & Old town area record high value of TDS as compared to the desirable limit of BIS. Here in Figure 6 represents TDS range location wise. 96 % of TDS values were well within the permissible limit of 500 mg l−1 WHO [24] and can be classified as desirable for drinking type water [20].

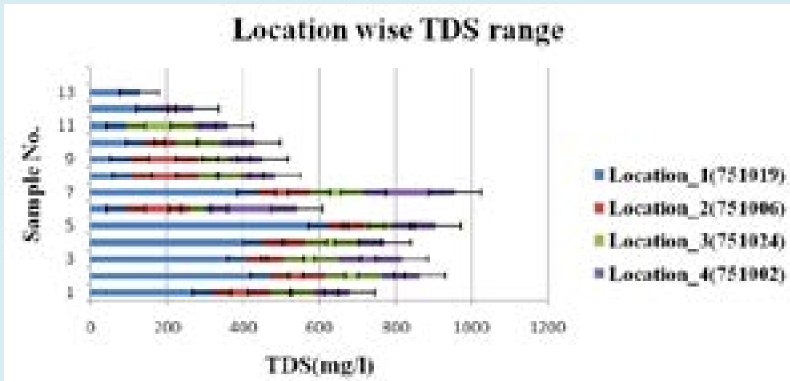

Figure 6: TDS at different locations.

TC & FC

The research area's ground water proved safe as none of the locations were above desirable limit of BIS for TC & FC. Here the Figure 7 shows the location wise Total coliform range. The research conducted by Atta SA, et al. [25] indicates that the higher levels of Fe, Mn, and Zn in the groundwater are natural and attributed to geogenic factors, not pollution sources. In line with this, the studies conducted by Khalil JB, et al. [26] and Awad SR, et al. [27] also highlight that the groundwater in the area is significantly impacted by freshwater seepage from canals and excessive irrigation.

In our study, we found that the contamination level of the groundwater is remarkably low, which indicates that it is safe for use, especially when compared to the standards set by the Bureau of Indian Standards (BIS). This finding suggests that the groundwater in the area is suitable for various purposes without posing any health risks to users.

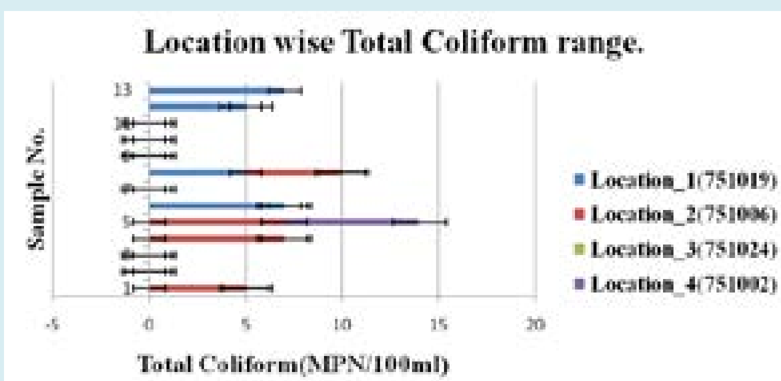

Figure 7: Total coliform at different locations.

Ground water is becoming more and more contaminated every day, according to the physico-chemical and microbiological parameters. Humans must raise public knowledge of the importance of maintaining the maximum level of water purity for a healthy lifestyle. Here in Table 4 shows the average range of all the parameters with respect to locations.

Locations	Source	Average of TDS in mg/l	Average of Input-pH	Average of Turbidity (NTU)	Average of Total Hardness (mg/l)	Average of Chloride (mg/l)	Average of Total Coliform (MPN/100ml)	Average of Fecal Coliform (MPN/100ml)	Count of E Colli (MPN/100ml)
L-01	Bore Well	123.67	6.35	2.92	57	14.75	0.58	0	0
L-02	Bore Well	130	5.62	3.18	62.18	15.27	2.18	0	0
L-03	Well Water	92	7.5	2	48	12	0	0	0
	Bore Well	287.33	5.64	3	128.33	25.33	2	0	0
L-04	Well Water	120	6.1	3	48	14	0	0	0
	Bore Well	147	6.55	3	71.5	21.5	0	0	0

Table 4: Physico–Chemical and microbiological Characteristics of ground water.

Conclusion and Suggestions

The study found that groundwater in the Bhubaneswar region, the main source of irrigation and drinking water, has very low pH levels, indicating acidity. It needs pH correction to be safe for drinking. Human activities may harm groundwater quality, emphasizing the need for monitoring and environmental assessments in future projects to ensure safe and sustainable groundwater use.

In summary, the study highlights the need to rectify the extremely low pH levels in the groundwater of the Bhubaneswar region before it can be used for drinking purposes. It suggests that human intervention may be contributing to the degradation of groundwater quality, emphasizing the importance of continuous groundwater monitoring. However, further research is necessary to draw specific conclusions and evaluate potential clinical implications. My recommendation is that for all future development projects in the area of Bhubaneswar, it is essential to conduct a full environmental impact assessment. This assessment will help us understand the potential effects of the projects on groundwater resources. By doing so, we can take necessary measures to ensure the sustainable and responsible use of groundwater as a valuable resource in the region. This will help protect our environment and guarantee a reliable source of water for both present and future generations.

Ethical Responsibilities of Authors

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

Declaration of Competing Interest

The authors whose names are recorded certify that they have no affiliation with or connection to any organization or substance with financial interests (e.g. fascinated (such as individual or professional connections, affiliations, information or beliefs) relating to the Topics or materials discussed in this original copy.

Data availability statement

All the facts generated throughout and/or analyzed throughout the modern examination are to be had from the corresponding writer on affordable request.

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