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Assessment Of Physio-Chemical And Microbial Tests Of Water In Selected Districts Of Chhattisgarh: A Comprehensive Analysis

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Abstract

Access to clean, safe water is essential for human health and well-being. Water quality in Chhattisgarh, a state in central India, has been a source of worry owing to industrial activity, agricultural runoff, and poor sanitation. This project will investigate the physiochemical and microbiological quality of water in various areas throughout Chhattisgarh, giving critical information on the overall water quality state. Physiochemical parameters such pH, turbidity, TDS, DO, BOD, COD, and heavy metal concentrations were investigated. Microbial tests were also performed to detect the presence of *coliforms*, *Escherichia coli*, and other infections. Water samples were collected, kept, and tested using predetermined processes. To capture water quality oscillations, samples were gathered from a range of sources, including rivers, ponds, wells, and tap water, throughout various seasons. Preliminary studies show considerable differences in physiochemical parameters and microbiological contamination levels between locales. Industrial and agricultural regions are highly polluted, including high levels of heavy metals and microbiological pollutants. These findings have significant consequences for both human health and the environment. Contaminated water sources increase the risk of waterborne infections, compromising community health and economic output. This comprehensive study of water quality in Chhattisgarh provides a foundation for policymakers, environmental agencies, and community stakeholders to develop targeted activities for water quality management and pollution reduction. Watershed management, industrial effluent treatment, and public awareness campaigns are essential measures for conserving water resources and ensuring that all Chhattisgarh residents have access to clean drinking water.

Keyword: Wastewater, Physiochemical, Concentrations

Chapter-I IntroductionGeneral Background

Water quality studies are crucial for community health and environmental sustainability (Francis et. al., 2015). Water resources in Chhattisgarh, central India, are in high demand from industry, agriculture, and urbanization. Water quality in some areas of Chhattisgarh has worsened, causing concern for human health and the environment (Ruhela et. al., 2022; Bajpai et. al., 2019). This study examines the physiochemical and microbiological properties of water in specific locations in Chhattisgarh to determine pollution levels and their consequences for human health and the ecosystem. Access to clean and safe water is a basic human right, yet millions of people worldwide, including those in Chhattisgarh, do not have access to potable water sources (Dharminder et. al., 2019; Pink, 2016; Mishra, 2023). Water quality deterioration is typically caused by anthropogenic activities such as industrial discharge, agricultural runoff, poor waste management, and insufficient sanitation measures (Akhtar et. al., 2021; Khatri & Tyagi, 2015). These factors cause the existence of various toxins in water sources, providing serious health risks to those who drink, cook, and use them for other household uses. Physiochemical considerations play a significant influence in determining water quality and suitability for diverse purposes (Abbasnia et. al., 2019; Li et. al., 2018). pH, turbidity, TDS, DO, BOD, COD, and heavy metal concentrations are all indicators of water's physical and chemical qualities (Patil et. al., 2012; Sharma et. al., 2015; Nayar, 2020; Bakar et. al., 2020). Elevated values for numerous indicators indicate pollution and the presence of potentially harmful substances, which endanger both human health and aquatic wildlife (Zaghloul et. al., 2020). Microbial contamination is another significant concern in water quality assessment. Pathogenic bacteria, such as *coliforms* and *Escherichia coli*, can grow in faeces-contaminated water and cause waterborne diseases such diarrhoea, cholera, and typhoid fever (Fasunwon et. al., 2008; Okon et. al., 2022; Phiri et. al., 2023; Lightfoot, 2003; Simoes & Simões, 2013). Monitoring microbiological indicators is crucial for identifying pollution sources and taking corrective action to avoid waterborne illnesses.

.1. Wetland

Wetlands are important ecosystems that serve as natural water purifiers, flood control systems, and biodiversity hotspots (Kingsford et. al., 2016; Zhang et. al., 2020). These various ecosystems, characterized by varying water levels, support a wide diversity of moist- adapted plant and animal species. Wetlands, including marshlands, swamps, bogs, and mangroves, provide a range of ecological services (Balwan & Kour, 2021; Nayak & Bhushan, 2022; Maltby, 2009). They absorb excess rainwater, lowering flood danger, and improve water quality by filtering poisons and silt before it enters other bodies of water. Wetlands are biodiversity hotspots for a variety of species, including plants, birds, animals, fish, and amphibians (Berde et. al., 2022; Gopal, 2009; Arya & Syriac, 2018). They are critical for reproduction, raising young, and maintaining migratory routes. Wetlands also help humans by supporting fishing, agriculture, and tourism. They also help to mitigate climate change by sequestering carbon in their soil (Were et. al., 2019; Mitsch et. al., 2013; Lolu et. al., 2020; Moomaw et. al., 2018). Despite their importance, wetlands are under threat from habitat loss, pollution, and climate change. To protect and restore these diverse ecosystems, conservation efforts must include long-term land management, effective policies, community engagement, and international collaboration (Gann et. al., 2019; Berkes, 2007; Mansourian & Vallauri, 2014). Wetland's protection helps to ensure the continued availability of ecosystem services and biodiversity, while also promoting sustainability for both nature and humans.

.2. Role of Wetland

Wetlands are important ecosystems that assist to maintain ecological balance while also supporting animal and human populations (Assessment, 2005; Mitsch & Gosselink, 2000). These varied ecosystems, which include marshes, swamps, bogs, and mangroves, provide a number of important services. Initially, wetlands operate as natural water cleaners, collecting sediments and impurities while increasing water quality (Scholz, 2023; Vigil, 2003). They help regulate water flow, lowering flood risk after large rains and regulating water levels during dry spells. Furthermore, wetlands serve as biodiversity hotspots, providing habitat for a diverse range of plant and animal species (Gopal, 2009; Kingsford et. al., 2016; Mittermeier et. al., 2011). They offer habitat for migratory birds, serve as breeding grounds for fish and other aquatic life, and sustain a diverse range of animal species. Aside from their ecological importance, wetlands provide valuable resources and services to human societies (Silvius et. al., 2000; Horwitz & Finlayson, 2011). They support fishing, agriculture, and tourism, which all create jobs and economic opportunities. Wetlands assist to reduce climate change by storing carbon in soil. Nonetheless, wetlands are under threat from human activities such as habitat loss, pollution, and climate change (Mitchell, 2013; Erwin, 2009; Sievers et. al., 2018). As a result, conservation activities are critical for preserving and rebuilding these vital ecosystems.

.3. Distribution of wetland in India

Wetlands may be found all throughout India, contributing considerably to the country's ecology, biodiversity, and socioeconomic fabric. Here's a quick breakdown of their distribution: **Northern Plains:** The Indo-Gangetic plains, which encompass states like Uttar Pradesh, Bihar, and West Bengal, are home to vast wetlands created by rivers like the Ganges, Yamuna, and their tributaries (Sen, 2019; Bharati et. al., 2016). Examples include the Sundarbans, Keoladeo National Park (Bharatpur Bird Sanctuary), and a number of oxbow lakes and floodplain wetlands.

1.3.1. Eastern and Northeastern India: States like Assam, Manipur, and Tripura contain large wetlands, including the Brahmaputra and Barak River floodplains, seasonal beels, and the huge Loktak Lake, northeastern India's largest freshwater lake (Sarkar et. al., 2020; Chatterjee et. al., 2006; KOSYGIN; Biswas & Boruah, 2000).

1.3.2. Western India: Gujarat, Maharashtra, and Rajasthan have a broad range of wetlands, including coastal lagoons, estuaries, and interior lakes (Singh, 2005; Chaudhuri & Sarkar, 1998; Chakraborty et. al., 2023). Examples include Nalsarovar Bird Sanctuary, Thol Lake, and the Rann of Kutch.

1.3.3. Southern India: Wetlands of ecological importance may be found in the Western Ghats and coastal parts of Kerala, Karnataka, and Tamil Nadu, including backwaters, mangrove forests, and estuaries such as the Vembanad-Kol wetland system, Pulicat Lake, and Point Calimere Wildlife Sanctuary (Nazneen et. al., 2022; DasGupta & Shaw, 2013; Divinia Juanita et. al., 2023).

1.3.4. Central India: Wetlands generated by rivers, lakes, and reservoirs may be found in states such as Madhya Pradesh and Chhattisgarh in central India (Bassi et. al., 2014; Chandra et. al.). Examples are

Bhoj Wetland (Upper Lake) in Bhopal and Dalpat Sagar Lake in Chhattisgarh.

1.3.5. Islands: India's island territories, which include the Andaman and Nicobar Islands and Lakshadweep, include distinct wetland habitats such as coastal mangroves, coral reefs, and saltwater marshes.

.4. Water parameters studied in wetlands

The physiochemical and microbiological features of water in certain parts of Chhattisgarh need a thorough approach to determining the quality and safety of water sources (Shrivastava et. al., 2014; Dewangan et. al.,). Several key indicators are crucial for assessing the health of water bodies and identifying potential hazards to human health and the environment. Here's an overview of the parameters usually used in such assessments:

pH is a measure of how acidic or alkaline the water is. It is crucial to monitor pH levels because they can affect mineral solubility and the effectiveness of chemical reactions in water (Brown et. al., 1970; Kaszuba et. al., 2013).Turbidity refers to the cloudiness or haziness of water caused by suspended particles. High turbidity levels may indicate pollution, rendering water unsafe for drinking and aquatic life (Tarzwell, 1956; Ntengwe, 2006).

Total dissolved solids (TDS) are the concentration of dissolved inorganic substances in water. Elevated TDS levels can reduce taste and odour while also indicating the presence of contaminants such salts, metals, and chemical substances (Marcussen et. al., 2013; Nayar, 2020; Sheibani & Mohammadi, 2018).

Dissolved oxygen (DO) is necessary for aquatic animals' existence because it promotes aerobic respiration. Pollution, organic matter decomposition, or thermal pollution can all contribute to low DO levels, which create hypoxic conditions that are detrimental to aquatic life (Gray et. al., 2002; Gobler & Baumann, 2016; Laws, 2000; Mateo-Sagasta et. al., 2018). Biochemical Oxygen Demand (BOD) is a measure of how much dissolved oxygen microbes need to degrade organic molecules in water. High BOD levels indicate organic pollution, which can deplete oxygen and harm aquatic ecosystems (Sharma & Gupta, 2014; Zaghloul et. al., 2019; Cooper, 1993; Kanu & Achi, 2011).

Chemical Oxygen Demand (COD) is the quantity of oxygen required to oxidize organic and inorganic molecules in water. Elevated COD levels indicate the presence of contaminants, which can contribute to poor water quality (Ntengwe, 2006; Akpor & Muchie, 2011; Edokpayi et. al., 2017).

Heavy metals such as lead, mercury, cadmium, and arsenic are harmful to human health even in trace concentrations. Monitoring heavy metal concentrations in water is crucial for establishing pollution levels and potential health hazards (Fernandez-Luqueno et. al., 2013; Zamora-Ledezma et. al., 2021; Mishra et. al., 2019).

Microbial Contamination: Microbial testing detects dangerous microorganisms such as coliform bacteria, *Escherichia coli* (*E. coli*), and other illnesses. A high microbial count indicates faecal contamination and the potential for waterborne disease (Ashbolt, 2004; Leclerc et. al., 2002; Ottoson & Stenström, 2003).

Researchers can gain valuable insights into water quality trends, identify sources of contamination, and inform pollution control and water resource management strategies by studying physiochemical and microbial parameters in water samples collected from various sources such as rivers, ponds, wells, and tap water in selected districts of Chhattisgarh. This multifaceted strategy is critical for providing safe and clean water to populations while maintaining the natural integrity of water bodies in Chhattisgarh.

Chapter-II Review of Literature

Pre-existing reports on Water Quality in Chhattisgarh

Water quality evaluation is an important facet of environmental monitoring, especially in areas experiencing problems from industry, agriculture, and urbanization. Chhattisgarh, a central Indian state, is known for its diversified habitats and abundant water resources. However, growing industrialization and urbanization have created worries about the region's water quality (Wang et. al., 2008; Duh et. al., 2008; Zehnder et. al., 2003). Several research have focused on analysing the physiochemical and microbiological characteristics of water in Chhattisgarh in order to better understand the level of pollution and its consequences for human and environmental health. These investigations emphasized the following significant conclusions and trends:

Table 1: Literature Review of Different studies done in Chhattisgarh

Citation	Location	Parameters Used	Analytical Methods	Result
Gupta, 2016	Durg-Rajnandgaon	pH, DO, heavy metals	Collected samples will be transferred to suitable culture medium like BG-11 medium for isolation and incubated for about two weeks in culture room at 25 ± 1˚C under controlled continuous illumination. Standard plating / streaking techniques will be used for purification of cyanobacterial strains. The plates will be examined and the best colonies will be	Higher number of phosphates and nitrates, with sufficient amount of oxidizable organic matter and limited DO contents played a vital role in their distributional pattern. Metal binding properties of pure isolates in terms of effect of pH, time dependency and metal binding capacity of biomass and compared over control for loss during incubation. The physio-chemical characterization of the study samples will help in determining the supportive or affective conditions for growth of the species. Possibility of heavy metal resistance of isolates may lead to selection of a judicious species or consortium of

			selected, picked up and re-streaked to new agar plates to obtain mono algal cultures. Total chlorophyll content will be measured according to Jeffrey's equation. Total carbohydrate content will be measured by phenol – sulphuric acid method. Total protein contents will be measured using BCA method. Five replicates will be maintained throughout the studies and the observations recorded will be analysed for Relative abundance,	metal-resistant cells, which may ensure better removal of toxic contaminants from environment.
Singh et. al., 2014	Korba, Chhattisgarh	pH, EC, Turbidity, TDS, DO, BOD, COD, Hardness, Conc. of Sulphate, Fluoride, Chloride, Ammonia, Phosphate	After sieving stones, parts of plants sediments were dried at 100 to 105˚ C for 4-5 hours and cooled in desiccator. Dried samples were grinded by rolling gently with a Mortar and converted into fine powder. By weight 1gm of	pH was found high due to mixing of hot waste water from industrial units. The electrical conductivity was found high. The high value of turbidity was due to the mixing of water-soluble wastes discharged by motor vehicles and industrial units. Higher TDS indicates the salinity behaviour of water and contains higher quantity of minerals. DO was found low in summer

			sediment was digested with mixture of Conc. H_2O_2, HCl, HNO_3 and then added 10ml of distilled water and filtered by using Whatman filter paper no. 41 in a 100 ml volumetric flask.	season while higher in winter season. BOD indicates microbial pollution in water. COD were found normal. The hardness of water was recorded high. Conc. Of Sulphate: 34 – 123 mg/L. (Max. 250 mg/L) Conc. Of Fluoride:0.1 – 0.7 mg/L. (Max250 mg/L) Conc. Of Chloride: 19 – 78 mg/L. (Max 250 mg/L) Conc. Of Ammonia: 0.04 – 0.08 mg/L. (Max 0.02 mg/ L) Conc. of Phosphate: 0.3 – 2.7 mg/L (Max 0.1 mg/L) [Phosphate increases the growth rate of blue green algae causing the water unsuitable for bathing and reduces dissolved oxygen levels in water.

Kumar et. al., 2023	Raipur district's Kharun River	pH, EC, TDS, turbidity, BOD, COD, Heavy metals	Using a spectrophotometer, the concentration of metals, including Cu, Cr, Zn, Pb, Mn, As, Cd, Co, Ni, Sn, and Fe, has been determined. On a hot plate, samples of water and sediment were digested with an acid solution (10 ml HNO3	Water of Kharun river was somewhat alkaline, with the monsoon season having the highest pH level of 7.9 and the summer season having the lowest pH level. The summer saw the highest EC value of river water, which was higher than the permitted maximum value of 993.43 S/cm. The monsoon season saw the lowest EC value. Lower values were reported during the monsoon season apparently owing to dilution of river water, and

			+ 5 ml HCl4). The samples were prepared in 25 ml of deionized water and maintained at 40°C. Metal standard solution calibration curves were used for metal quantification.	greater values of EC in the summer season region are plainly impacted by the industrial municipal effluents released, which may contain various ions like OH, CO32-, Cl-, Ca2+, K+, Na+, SO42+, etc. The Kharun River's water had a maximum TDS value during the summer that was greater than the allowable limit of 603.15 mg/L and a minimum TDS value during the winter. The fact that there are more chemicals, minerals, and wastewater released from industries during the summer is clearly the cause of the higher TDS readings in that area. The turbidity of the water in the Kharun River was found to be at its highest through the summer and at its lowest through the monsoon season. The biological aerobic breakdown of huge amounts of organic material causes a significant amount of dissolved oxygen to be rapidly consumed, affecting the water quality and aquatic life. Every season, it is discovered that the BOD and COD values are significantly higher than the thresholds. the seasonal standard concentration

				of heavy metals dropped in the following order: Zn > Cr > Sn > As > Cu > Cd > Pb > Co > Ni > Fe > Mn. This metal mostly enters the environment through anthropogenic activities including mining, industrial wastewater runoff from agriculture, and urban wastewater, as well as usual activities such as soil corrosion.

Sahu et. al., 2018	Rajnandgaon, Chhattisgarh	pH, DO, ORP, EC, Conc. of F, Cl, NO_3, SO4, Na, K, Mg, Ca	Physical parameters, such as DO, pH, ORP, EC were measured at the spot. The Met Rohm ion meter -720 was used for the monitoring of F^- in the presence of buffer. TISAB – III buffer (300 g sodium citrate, 22 g 1,2-cyclohexanediamine- N, N, N, N-tetra acetic acid and 60 g NaCl in a volume of 1 L with the deionized Water) was used to make a subsequent adjustment of pH value at 5.0 – 5.5.	Value of pH: 6.5-8.1 Value of DO: 6.6-8.3 mg/L Value of ORP: 176- 251 mV Value of EC: 212- 599 µS/ cm. Conc. of F^-: 1.6- 5.5 mg/ L Conc. of Cl^-: 15- 51 mg/ L Conc. of $NO3^-$: 11- 51 mg/ L Conc. of $SO4^{2-}$: 24- 88 mg/ L Conc. of Na^+: 14- 64 mg/ L Conc. of K^+: 11- 23 mg/ L Conc. of Mg^{2+}: 12- 71 mg/ L Conc. of Ca^{2+}: 14- 78 mg/ L Conc. of metals are present in the order: U < Cd < Th < Pb < Sb < As < Cu < Cr <Zn < Mn < Fe < F– < K < Cl– < $NO3^-$ < Na < Ca < Mg < $SO4^{2-}$. The concentration of F–, As, Mn and Fe in the pond water was found above the recommended value of 1.5, 0.01, 0.05 and 0.30 mg/L, respectively.

				High amount of F^- results in the appearance of diseases i.e., lesion of teeth, skin, hair and nails and skeletal fluorosis.
Shankar et. al., 2021	Raipur, Chhattisgarh	pH, DO, Cl content		A low number of pH below 4.0, on the other hand, indicates a sour flavour, while a higher value beyond 8.5 indicates an alkaline taste. The alkalinity of Methyl Orange was measured between 240 and 440 mg/l, indicating the lack of Hydroxyl and Carbonate and the presence of Bicarbonate. Water with a dissolved solid content of less than 500 mg/l is typically suitable for household and industrial usage. Water with more than 1000 mg/l dissolved solids generally contains minerals that give it a particular flavour or render it unfit for human consumption. The high chloride concentration in water might be attributed to contamination from sewage and municipal waste chloride affluent effluent. DO levels below 1 mg/L are insufficient to maintain fish, while values below 2 mg/L may result in the death of most fish. DO concentration should be over 6.0 mg/L for drinking water, and more than 5.0 mg/L is advised for

				fisheries, recreation and irrigation.

Objective of the study

The research on the Assessment of Physiochemical and Microbial Tests of Water in Selected Districts of Chhattisgarh aims to conduct a comprehensive analysis of water quality indicators in order to:

Evaluate the physio-chemical characteristics of water

Determine the microbial contamination levels

Identify variations in water quality

Assess the impact of anthropogenic activities

Provide recommendations for water quality management

Chapter-III Methods and Methodology

Chhattisgarh, located in Central India between latitudes 17°46'N to 24°8'N and longitudes 80°15'E to 84°24'E, is the ninth largest state by geographical area and the seventeenth most populous, with about 30 million people. Chhattisgarh was once a part of Madhya Pradesh until becoming a separate state on November 1, 2000, with Raipur as its capital (Bhatti et al., 2018). The state's topography is diverse, with steep hills to the north and south and a fertile plain in the middle. Gaurlata, the highest peak in Samri's Balrampur-Ramanujganj district, is a notable landmark. The Eastern Highlands of the state are covered with deciduous trees, accounting for around 44%. To the north, the Rihand River, a Ganges tributary, drains the huge Indo-Gangetic plains (Asriansyah et al., 2021). Other prominent rivers are Jonk, Kelo, Udanti, Indrawati, Sheonath, Hasdeo, Mand, Eeb, Pairi Arpa, and Maniyari. Chhattisgarh is divided into three major regions: northern, middle plains, and southern.

1. Study Area

The current study focuses on aquatic ecosystems, namely ponds (wetlands) in Raipur, Chhattisgarh. Because to its closeness to the Tropic of Cancer, Chhattisgarh has a primarily tropical environment with high temperatures and humidity (Wu et. al., 2011)). The monsoon season generates the majority of the region's precipitation. The summer season, which runs from April to June, may be warm, with temperatures reaching the mid-40s. The monsoon season, which lasts from late June to October, provides relief from the harsh summer heat by covering the whole state in lush greenery and culminates in a series of waterfalls. Winter in Chhattisgarh is pleasant, with lower temperatures and less humidity. Summer temperatures normally range from 30 to 47°C (86 to 117°F), whereas winter temperatures range from 5 to 25°C (41 to 77°F). The climate may be dramatic, with temperature changes ranging from 0°C to 49°C. The Mahanadi River is significant in that it is the state's principal river (Sellami et. al., 2010).

2. Data Collection

The survey was conducted during the summer months of April and May in the ponds of Raipur District villages Dhamni, Kotni, Kuhera, Palaud, and Sector-27. Hand pumps, bore wells, and surface water bodies such as rivers and ponds will be sampled (Tiwari et al. 2016). Two liters of water were collected from each site and stored in a clean plastic container for future investigation (APHA).

Table 2: Locations of different sampling points

Location	Latitude	Longitude	Altitude
Dhamni	21.1691086	81.8520626	293.06
Kotni	21.1617256	81.8357516	290.78
Palaud	21.8213387	81.8213387	301.02
Kuhera	21.15496	81.80877	310
Sector-27	21.164993	81.775307	308

3. Data Analysis

1. Physio-Chemical Analysis

A range of physio-chemical parameters will be analyzed, including:

i. pH: measured using a calibrated pH meter.
ii. Temperature: measured using a thermometer.
iii. Electrical Conductivity (EC): measured using a conductivity meter.
iv. Total Dissolved Solids (TDS): measured using a gravimetric method or a conductivity meter.
v. Turbidity: measured using a nephelometer. Reference:
vi. Major ions (e.g., Calcium, Magnesium, Chlorides, Nitrates, Sulphates): measured using titrimetric or spectroscopic methods.

2. Microbial Analysis

Microbial Contamination: The presence and levels of fecal coliform bacteria will be determined using the Most Probable Number (MPN) technique or membrane filtration methods**.**

Chapter-IV Results

Physio-Chemical Parameter Analysis

Table 3: Physio-Chemical Parameters of different Locations

Parameter	Dhamni	Kotni	Palaud	Kuhera	Sector-27
pH	7.2	7.0	7.5	7.3	7.1
Temperature (°C)	29.5	30.0	29.8	29.7	29.9
EC (µS/cm)	650	620	630	640	660
TDS (mg/L)	300	310	320	330	290
Turbidity (NTU)	5.2	5.0	5.5	5.3	5.1
Calcium (mg/L)	50	52	48	51	49

Magnesium (mg/L)	30	28	32	29	31
Chlorides (mg/L)	100	98	102	99	101
Nitrates (mg/L)	5.5	5.3	5.7	5.6	5.4
Sulphates (mg/L)	40	42	38	41	39

- **pH Level:** The pH values range from 7.0 to 7.5 across the sampled locations, indicating slightly alkaline to neutral conditions.
- **Temperature (˚C):** Temperature measurements range from 29.5°C to 30.0°C, suggesting relatively consistent water temperatures among the sampled locations.
- **Electrical Conductivity (EC) (µS/cm):** EC values vary from 620 to 660 µS/cm, indicating differences in the conductivity of water samples, which may reflect variations in dissolved mineral content.
- **Total Dissolved Solids (TDS) (mg/l):** TDS concentrations range from 290 to 330 mg/L, indicating differences in the amount of dissolved substances present in the water samples.
- **Turbidity:** Turbidity values range from 5.0 to 5.5 NTU, suggesting relatively low levels of suspended particles in the water samples.
- **Calcium (mg/l):** Calcium concentrations range from 48 to 52 mg/L, indicating variations in the calcium content of the water samples.
- **Magnesium (mg/l):** Magnesium concentrations range from 28 to 32 mg/L, reflecting differences in the magnesium content across the sampled locations.
- **Chlorides (mg/l):** Chloride concentrations range from 98 to 102 mg/L, indicating variations in the chloride content of the water samples.
- **Nitrates (mg/l):** Nitrate concentrations range from 5.3 to 5.7 mg/L, suggesting similar levels of nitrate contamination across the sampled locations.
- **Sulphates (mg/l):** Sulphate concentrations range from 38 to 42 mg/L, indicating differences in the sulphate content of the water samples.

1. Variation of the pH of the water tested

These pH values enable one to deduce that the water samples are often found to be neutral to somewhat alkaline. While less than 7.0 pH values point to acidity, more than 7.0 pH readings imply alkalinity. Seven pH is regarded to be neutral.

Given their pH values of 7.2 and 7.2, respectively, Dhamni and Kuhera point to a moderately alkaline environment.

Palaud, with its pH of 7.5, indicates that the water is somewhat alkaline. Pavlova is the water with the highest acidity.

Kotni and Sector-27 are characterized by conditions that range from neutral to fairly alkaline. Its pH values are what characterize them; they are 7.0 and 7.1, respectively.

The variations in pH levels are most likely the result of geological characteristics, land use patterns, and human activity in the various locations (Balstrøm et. al., 2013; Pouvat et. al., 2007). It is crucial to monitor pH because it influences the availability of nutrients, the solubility of minerals, and the general state of aquatic ecosystems (Boyd et. al., 2016). More study on the elements generating pH changes may shed significant insight on the dynamics of water quality and provide appropriate management techniques.

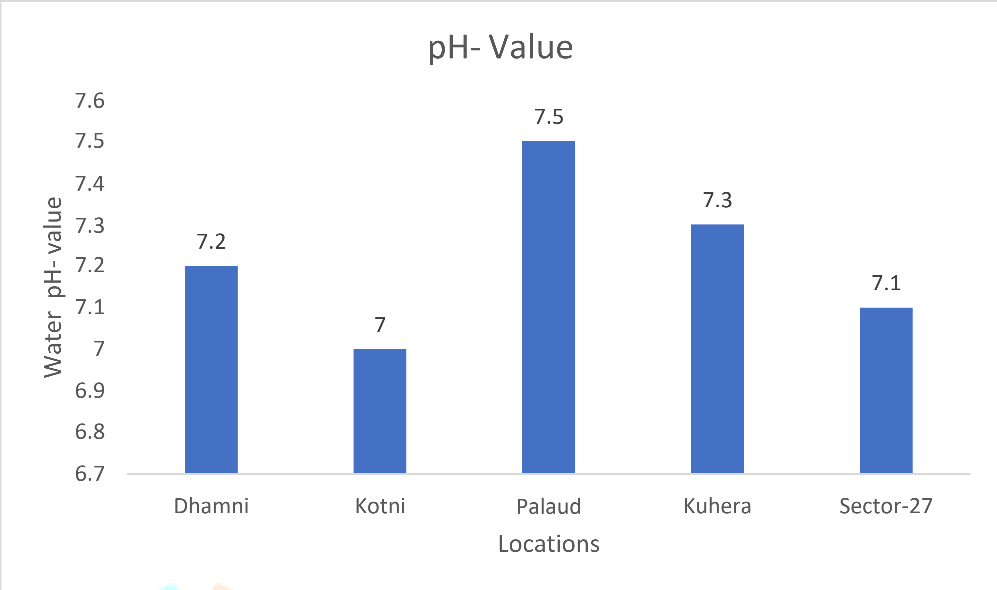

Fig 1: pH value of waterbodies of different sites

2. Variation of the EC of the water tested

At 660 µS/cm, Sector-27 has the highest EC value, indicating somewhat greater dissolved solid concentrations than other sites.

With an EC of 650 µS/cm, Dhamni shows somewhat lower but still high quantities of dissolved solids.

With a 640 µS/cm EC value, Kuhera follows closely. Palaud has the lowest EC value of all the sites—630 µS/cm.

With 620 µS/cm, Kotni's EC value is the second lowest.

The causes of these changes in EC values might include industrial operations, agricultural runoff, geological formations, and human inputs (Artiola et. al., 2019). High EC values have an effect on the flavor, irrigation appropriateness, and health of aquatic ecosystems of water (Arshad & Shakoor, 2017; Ali & Ali, 2010). Evaluation of water quality, detection of pollution sources, and use of suitable management strategies to guarantee the sustainability of water resources depend on an understanding of EC fluctuations.

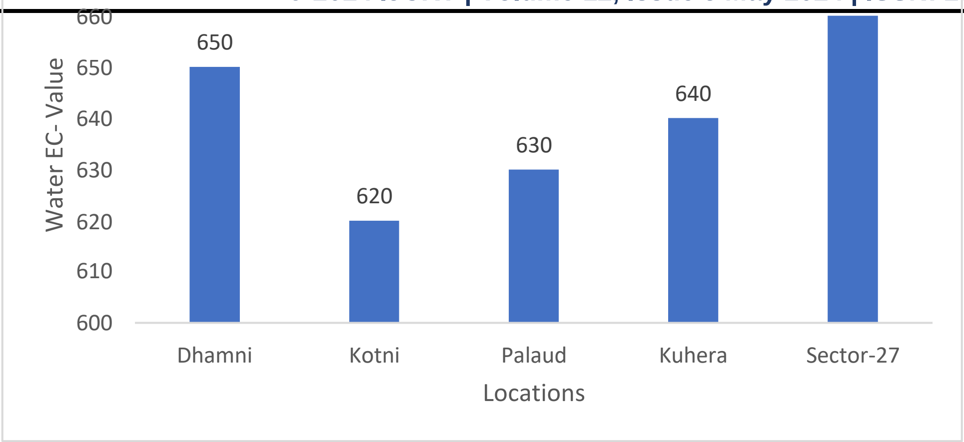

Fig 2: EC of waterbodies of different Locations

3. Variation of the TDS of the water tested

From the above readings, we can say that,

The 330 mg/L greatest TDS result at Kuhera points to somewhat greater dissolved solid concentrations than at other sites.

At 320 mg/L, Palaud takes second position.

A TDS value of 310 mg/L for Kotni indicates somewhat lower but still noteworthy amounts of dissolved solids.

At 300 mg/L, Dhamni has the second-lowest TDS value among the sites. Sector-27 has the lowest TDS reading—290 mg/L.

The natural weathering processes, land use patterns, industrial activities, agricultural runoff, and geological features may all affect these differences in TDS levels. Aside from taste, scaling in pipes and appliances, and appropriateness of water for industrial, irrigation, and drinking purposes, high TDS levels may also impact water quality (DeZaune, 1997); Frimpong, 2019). To evaluate water quality, identify causes of pollution, and put in place suitable management strategies, TDS levels must be monitored.

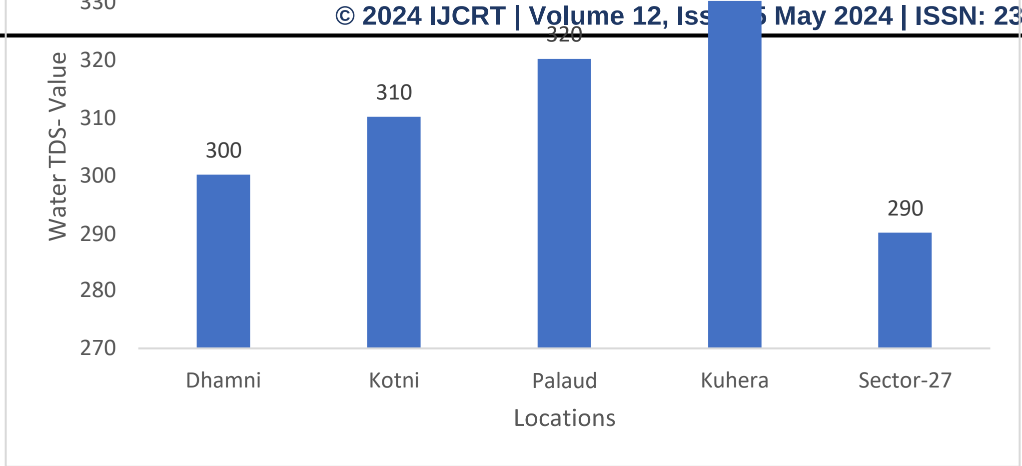

Fig 3: TDS value of waterbodies of different sites

4. Variation of the Turbidity of the water tested

The measurement of turbidity is the degree of haziness or cloudiness in water brought on by suspended particles like plankton, silt, clay, and organic debris (Adjovu et. al., 2023). More suspended particles in the water are indicated by higher turbidity readings, which may have an impact on its cleanliness, appeal, and effectiveness of water treatment methods (Gumbi, 2020).

At 5.5 NTU of turbidity, Palaud seems to have a bit more suspended particles than the surrounding areas.

The turbidity readings show a bit lower but still substantial number of suspended particles at
5.2 NTU for Kuhera and 5.2 NTU for Dhamni, respectively.

At only 5.1 NTU, Sector-27 is the least turbid.

Kotni, with its 5.0 NTU, is the second lowest in turbidity.

Various turbidity readings may result from natural sedimentation processes, industrial discharges, urban runoff, agricultural runoff, and soil erosion (Shen et. al., 2018; Hart, 2006). High turbidity levels may negatively affect aquatic ecosystems, microorganism habitat, photosynthetic suppression, and decreased light penetration among other aspects of water quality (Bilotta & Brazier, 2008; Dunlop et. al., 2005). To evaluate the quality of water, identify sources of pollution, and carry out suitable management strategies to guarantee the longevity and security of water resources, turbidity levels must be monitored.

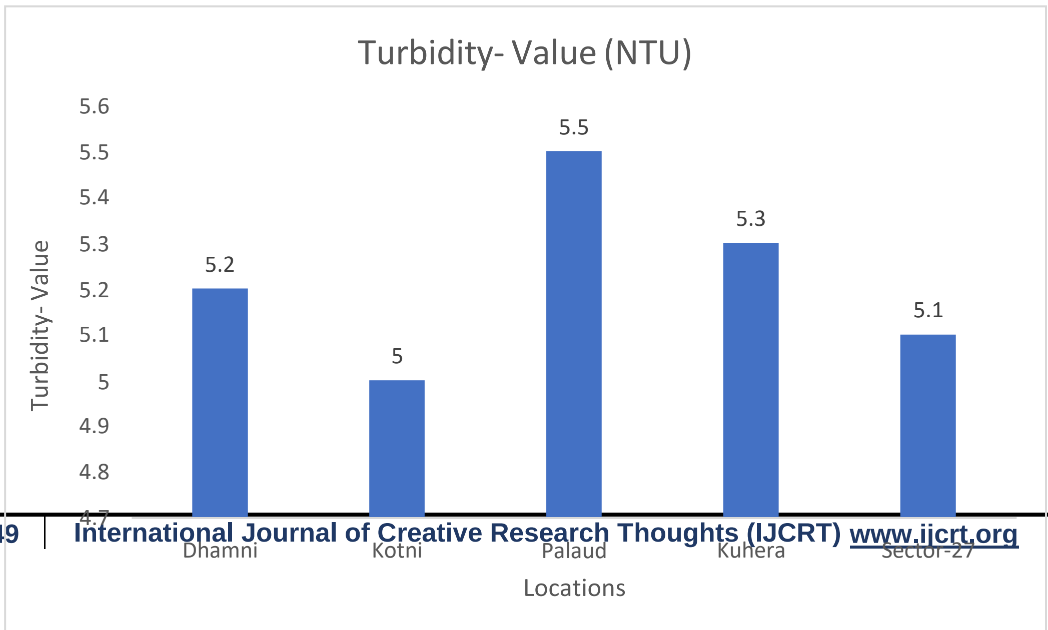

Fig 4: Turbidity value of waterbodies of different sites

5. Variation of the Calcium ion content in the water tested

A vital element of water, calcium is mostly derived from the disintegration of limestone and other calcium-containing rocks in geological formations (Ali & Hascakir, 2017; Saad et. al., 2023). Being an important part of water hardness, it is necessary for many physiological and biological functions.

The greatest calcium content of 52 mg/L in Kotni indicates that the area has considerably higher calcium levels than other places.

Second place goes to Kuhera with 51 mg/L of calcium.

Dhamni and Sector-27 have calcium contents of 50 mg/L and 49 mg/L, respectively. Palaud has the lowest calcium content—48 mg/L—of all of the locations.

These variations in calcium concentrations may be caused by the local geology, groundwater flow patterns, and the breakdown of minerals in the aquifer that contain calcium (Razowska- Jaworek, 2014; Schot & Wassen, 1993). They must be monitored because calcium levels influence water hardness, which in turn affects water taste, the effectiveness of water treatment methods, and the formation of scale in pipes and appliances. Calcium is also very important to the ecology and aquatic life.

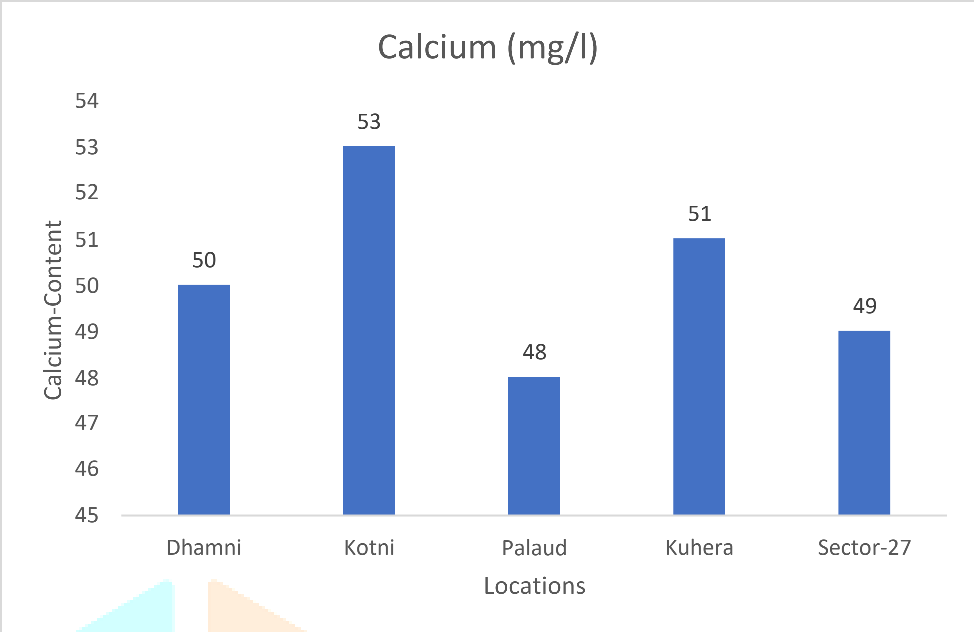

Table 5: Calcium content of waterbodies of different sites

6. Variation of the Magnesium ion content in the water tested

Usually acquired via the disintegration of magnesium-containing rocks in geological formations, magnesium is a crucial component of water (Shand, 2006; MacAdam & Jarvis, 2015). Together with calcium, it increases the hardness of water and functions in several physiological and biological processes.

Among all the locations, Palaud has the greatest magnesium content—32 mg/L. Closely behind with 31 mg/L of magnesium is Sector-27.

A thirty milligramme magnesium is present in Dhamni.

The magnesium concentrations in Kuhera and Kotni are 29 mg/L and 28 mg/L, respectively.

Different magnesium concentrations may be influenced by human activities, patterns of groundwater migration, and the composition of geological formations (Liu et. al., 2022; Ahmed et. al., 2013). Monitor magnesium levels since they impact water hardness, which in turn determines whether water is fit for drinking, irrigation, and industrial usage (Patil et. al., 2012; Sappa et. al., 2014). Living creatures and aquatic ecosystems also need magnesium.

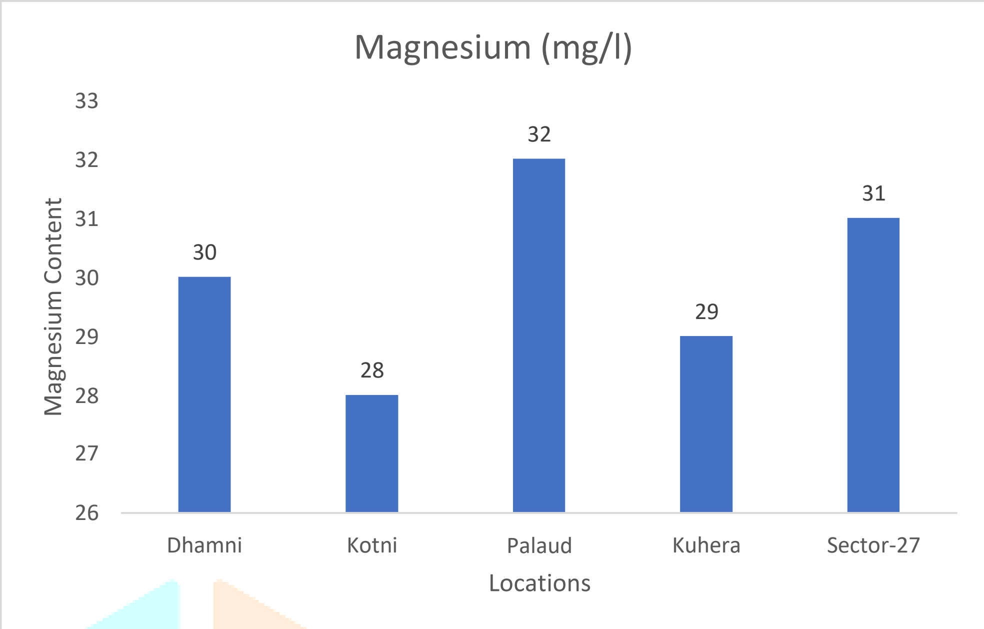

Table 6: Magnesium content of waterbodies of different sites

7. Variation of the Chloride ion content in the water tested

Commonly occurring ions in water, chlorides come from both natural sources such road salts, industrial discharges, and sewage effluents as well as from the breakdown of minerals containing chloride in geological structures (Granato et. al., 2015; Novotny et. al., 2009).

With a value of 102 mg/L, Palaud has the highest chloride content among all the places. Following closely with a chloride content of 101 mg/L is Sector-27.

Chloride content of Dhamni is 100 mg/L.

With chloride levels of 99 mg/L in Kuhera and 98 mg/L in Kotni, respectively.

Hydrological processes, proximity to pollution sources, land use patterns, and geological features may all affect these fluctuations in chloride concentrations (Jiang & Yan, 2010; Ledford et. al., 2016). Because they may impact the taste, corrosiveness, and quality of water as well as the health of aquatic ecosystems and species, chlorine levels should be closely monitored (Dietrich & Burlingame, 2015; Bozorg-Haddad et. al., 2021). High chloride levels in drinking water may also be harmful to health, especially for those with certain medical issues.

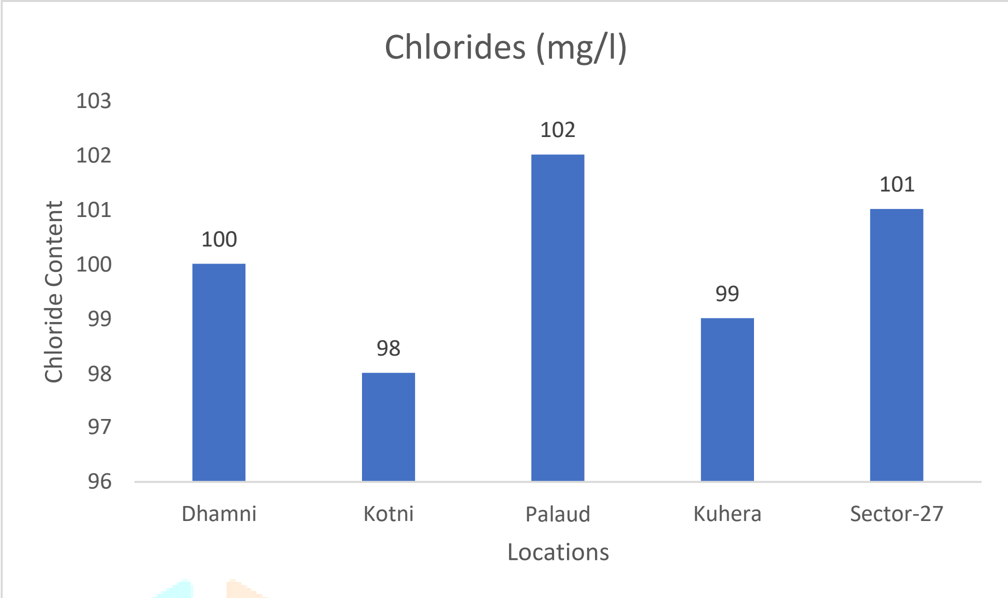

Fig 7: Chloride content of waterbodies of different sites

8. Variation of the Nitrate ion content in the water tested

Common in water, nitrates are nitrogen-containing compounds originating from, among other natural and man-made sources, fertilizer applications, agricultural runoff, and sewage effluents (Viets Jr, 1974; Bellingham, 2012).

Palaud has somewhat greater nitrate levels than other locations, peaking at 5.7 mg/L. Just behind with 5.6 mg/L is Kuhera.

Dhamni has 5.5 mg/L of nitrate.

Sector 27's is 5.4 mg/L, whereas Kotni's is 5.3 mg/L.

Variations in nitrate levels may be brought on by soil characteristics, land use activities, natural processes, and agricultural practices. High nitrate content in water may be harmful for infants and expecting women in particular because too much of it may produce methemoglobinemia, sometimes referred to as "blue baby syndrome" (Johnson, 2019; Gehle, 2013; Brender, 2020). Moreover, eutrophication brought on by nitrates in aquatic settings may cause algal blooms and worsening water quality (Wurtsbaugh et. al., 2019; Khan & Mohammad, 2014; Ansari et. al., 2011). Monitoring nitrate levels thus becomes essential to the assessment of water quality as well as the preservation of the environment and human health.

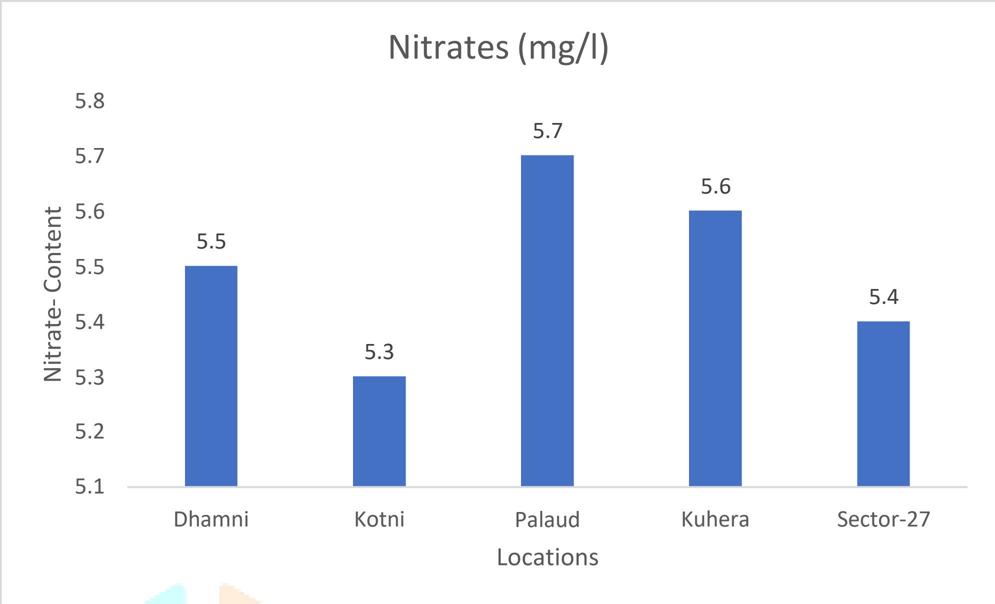

Fig 8: Nitrate content of waterbodies of different sites

9. Variation of the Sulphate ion content in the water tested

Sulphates are substances that consist of atoms of sulphur and oxygen that are often found in water sources as a result of both natural processes like the weathering of rocks and minerals and human activities like industrial discharges and agricultural runoff (Zak et. al., 2021; Akhtar et. al., 2021; Tiwari et. al., 2013).

There are probably higher Sulphates in Kotni than elsewhere, based on the highest Sulphate level of 42 mg/L.

Next with 41 mg/L of Sulphate is Kuhera.

Sector-27 has 39 mg/L of sulphate while Dhamni has 40 mg/L.

Palaud has the lowest Sulphate content—38 mg/L—of all the locations.

Sulphate concentrations may alter in response to geological characteristics, industrial activities, agricultural practices, and proximity to pollution sources (Zak et. al., 2021; Jakóbczyk-Karpierz et. al., 2017). Sulphate levels should be regularly checked as they may affect the flavour, odour, and quality of the water as well as how corrosive it is to plumbing systems (Dorman, 1992; Dietrich & Burlingame, 2015; Suffet et. al., 1995). Additionally contributing to scale build-up in pipes and appliances might be high Sulphate levels. Monitoring Sulphate levels, therefore, is necessary to assess the quality of the water and to ascertain the safety and sustainability of water resources.

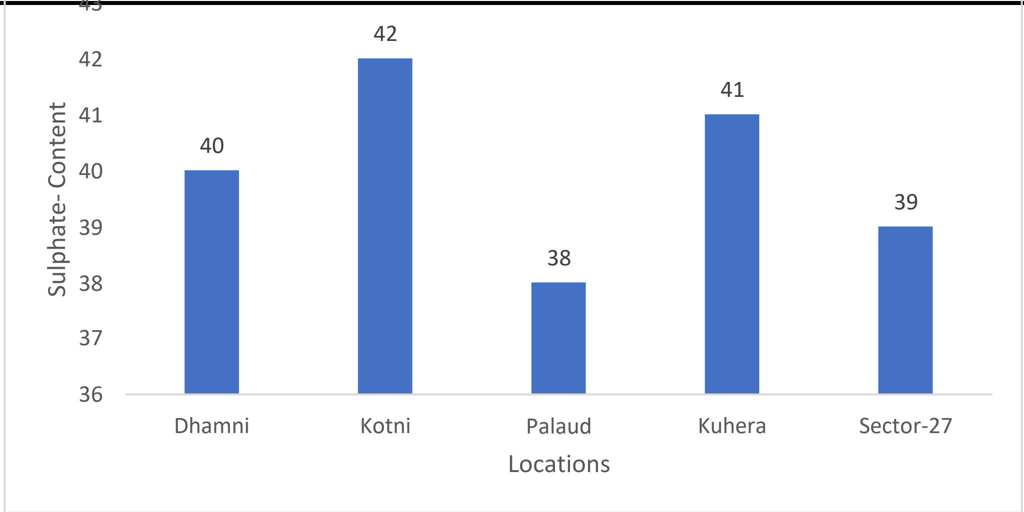

Fig 9: Sulphate content of waterbodies of different sites

2. Microbial Test Analysis

Table 4: Microbial Test analysis of different Locations

Location	Fecal Coliform Bacteria
Dhamni	100
Kotni	50
Kuhera	150
Palaud	75
Sector-27	30

Microbial analysis indicated the presence of fecal coliform bacteria in all samples. However, the levels varied considerably, with Kuhera exhibiting the highest count (150 MPN/100mL) and Sector-27 showing the lowest (30 MPN/100mL). It is important to note that the acceptable limit for fecal coliform bacteria in drinking water is 0 MPN/100mL.

3. Impact of Anthropogenic Activities

1. Agricultural Runoff

Fertilizers and pesticides are only two examples of agricultural practices that add to the nutrient load in water systems. Eutrophication, brought on by high concentrations of nutrients from fertilizers like phosphates and nitrates, may result in algal blooms, oxygen depletion, and water quality deterioration (Wurtsbaugh et. al., 2019; Khan & Mohammad, 2014; Ansari et. al., 2011; Smith et. al., 1999; Mishra, 2023; Pathak & Pathak, 2012; Purohit).

Agricultural methods that cause soil erosion may cause sedimentation in aquatic bodies to rise, which raises turbidity and reduces light penetration (Oschwald, 1972; Boyd & Boyd, 2020; 2015; Wantzen & Mol, 2013; Rickson, 2014; Ekholm & Lehtoranta, 2012; Singh & Gupta, 2016). Aquatic environments may be impacted, photosynthesis hampered, and aquatic life's health may suffer. Pesticide and herbicide residues in runoff from agricultural fields may pollute water supplies and endanger aquatic ecosystems as well as human health (Ali et. al., 2021; Kaur & Sinha, 2019; Anju et. al., 2010; Tudi et. al., 2021; Zahoor & Mushtaq, 2023; Rad et. al., 2022).

2. Urban Wastewater Discharge

Human and animal waste are often found in urban wastewater, introducing illnesses including bacteria, viruses, and parasites. The release of untreated or badly treated wastewater into bodies of water may cause microbial contamination, increasing the risk of waterborne infections such diarrhoea, cholera, and typhoid fever (Tariq & Mushtaq, 2023; Fazal-ur- Rehman, 2019; Akpor & Muchie, 2011; Rath, 2021; Agarwal et. al., 2022; Okereke et. al., 2016; Ali et. al., 2021). Contaminants in urban wastewater include heavy metals, pharmaceuticals, and industrial chemicals (Teijon et. al., 2010; Shraim et. al., 2017; Margot et. al., 2015; Williams et. al., 2019; Ahmed et. al., 2021). These toxins have the potential to pollute bodies of water, bioaccumulate in aquatic species, and jeopardize human and environmental health. When wastewater is deposited into bodies of water, nutrients such as nitrogen and phosphorus may contribute to eutrophication (Khan & Mohammad, 2014; Carey & Migliaccio, 2009; Le et. al., 2010). Excessive nutrient enrichment may promote algal growth, causing water quality degradation and ecological imbalances.

3. Public Health Risks

Waterborne pathogens, such as bacteria, viruses, and parasites, may cause illness and even death, particularly in vulnerable populations such as children, the elderly, and people with compromised immune systems. Long-term exposure to water pollutants, such as heavy metals, pesticides, and industrial chemicals, may result in cancer, neurological disorders, reproductive issues, and developmental defects (Rehman et. al., 2018; Shetty et. al.,2023; Ojha & Tiwary, 2021; Babuji et. al., 2023). These health impacts may emerge gradually and have far-reaching implications for public health and well-being. Communities that use polluted water for drinking, cooking, and sanitation are more likely to develop water-borne diseases (Zahid, 2018; Hamner et. al., 2006; Ntajal et. al., 2022). Lack of access to safe and clean water exacerbates health disparities and socioeconomic inequalities, disproportionately affecting vulnerable groups such as rural areas, indigenous communities, and low-income households (Levy & Patz, 2015; Smith et.al., 2022). Waterborne infections and chronic health conditions have a significant financial effect on individuals, families, healthcare systems, and the whole economy (Malik et. al., 2012; Pathak, 2015; Butt & Khair, 2016). Treatment costs, productivity losses, and healthcare expenditures associated with water- related diseases may put a burden on limited resources and stymie economic development (Hansen & Bhatia, 2004; Lall et. al., 2017; House, 2005). Contamination of water sources affects not only human health, but also the ecology and ecological integrity. Pollutants injected into bodies of water may harm aquatic life, disrupt ecosystems, degrade water quality, and endanger biodiversity, culminating in a cascade of ecological consequences (Chakraborty et. al., 2023; Gonçalves & Summers, 2024; Kennish & Paerl, 2010). Empowering people and communities to advocate for safe water access, sanitation infrastructure, and environmental stewardship is essential for addressing water-related health challenges (Jiménez et. al., 2019; Ajith et. al., 2022; Herrera, 2019). Raising public awareness and education on water quality issues, health risks, and preventative measures is crucial for encouraging informed decision-making, behaviour change, and community empowerment (Blackstock et. al., 2010; Gram, 2018; Yigitcanlar, 2009; Bullard & Johnson, 2000).

The combined consequences of agricultural runoff, urban wastewater discharge, and public health threats need integrated approaches that include water resource management, pollution control, public health interventions, and community engagement (Hanjra et. al., 2012; Volenzo & Odiyo, 2018; Scheierling et. al., 2010; Rauh & Hughes, 2024; Zahoor & Mushtaq, 2023). Implementing pollution-reduction measures, improving wastewater treatment facilities, promoting sustainable farming practices, and raising public awareness and education are vital for maintaining water quality, human health, and developing resilient communities in Chhattisgarh and elsewhere.

Chapter-V Discussion

Insights into Water Quality

A detailed analysis of several parameters, ranging from pH levels to microbial makeup, has provided important insights into water quality.

First, the physiochemical analysis revealed considerable disparities among several areas of Chhattisgarh. pH, electrical conductivity, total dissolved solids, turbidity, and ion concentrations such as calcium, magnesium, chlorides, nitrates, and sulphates all exhibit broad ranges, illustrating the complex interplay of natural and anthropogenic elements that influence water quality. These variations underscore the need of localized monitoring and management operations that are tailored to each district's specific environmental conditions and water use patterns (Cleland et. al., 1997).

Moreover, microbiological testing confirmed the presence of potentially harmful microorganisms in water samples. The discovery of microbiological contaminants highlights the need of stringent water quality regulations and proper sanitation practices in limiting the spread of waterborne infections and protecting public health (Agbasi et. al., 2024;

Daud et. al., 2017; Schwarzenbach et. al., 2010). Understanding the microbial composition and dynamics of water sources is crucial for recognizing pollution sources, assessing health risks, and carrying out targeted activities to ensure community drinking water safety (Holcomb & Stewart, 2020; WHO, 2016; Zhang & Liu, 2019; Szewzyk et. al., 2000).

Overall, the results of this extensive study provide the framework for informed decision- making and action to address water quality challenges in Chhattisgarh. Using these insights, stakeholders may develop evidence-based strategies for water management, pollution prevention, and public health protection. Collaboration among government agencies, research institutions, local communities, and civil society organizations is critical for translating these insights into actionable steps to protect water resources, promote environmental sustainability, and improve the well-being of Chhattisgarh residents.

1. Implication for water management

The analysis of many criteria and their interrelationships has yielded some significant implications for water management.

The investigation discovered contaminants in water sources from a variety of districts, including fertilizers, sediments, pesticides, and microorganisms. These studies provide light on the causes and channels of pollution, which include agricultural runoff, urban wastewater discharge, industrial operations, and natural processes (Khatri & Tyagi, 2015; Akhtar et. al., 2021; Tariq & Mushtaq, 2023; Wato et. al., 2020). Identifying these pollution sources is critical for carrying out targeted management activities that reduce pollutants and improve water quality.

By recording changes in physiochemical and microbiological markers over time, the study allows determining water quality trends and environmental changes easier. Monitoring long- term trends enables water managers to identify potential issues, regions of degradation or improvement, and assess the efficacy of management actions (Vaughan et. al., 2001; Behmel et. al., 2016). This information is critical for adaptive management and making educated decisions about water resources.

The study's findings help to shape particular management plans and methodologies for addressing specific water quality concerns in each region. These strategies could include implementing best management practices in agriculture to reduce runoff, improving wastewater treatment infrastructure to remove pollutants, establishing buffer zones to protect water bodies from contamination, and encouraging sustainable water use practices in both urban and rural areas.

The results emphasize the need of incorporating comprehensive water quality monitoring tools into current water management regimes. Coordinated monitoring operations including government agencies, research institutions, and local stakeholders are critical for gathering standardized data, detecting pollution hotspots, and prioritizing management solutions (Adekugbe & Ibeh, 2024; Shepherd et. al., 2015; Stephenson et. al., 2022). Collaborative monitoring initiatives improve data consistency, reliability, and comparability, allowing for evidence-based decision-making and resource allocation.

Water management objectives include ensuring safe drinking water and improving public health (Bereskie et. al., 2018; Edition, 2011; Hasan, 2019; Krewski et. al., 2004). The discovery of microbiological pollutants emphasizes the need of rigorous water quality legislation, frequent monitoring, and good sanitation in preventing waterborne infections (Habtu et. al., 2024; Joseph et. al., 2023; Dura et. al., 2010). Water management must prioritize public health protection by taking actions to limit microbiological pollution and mitigate health hazards from waterborne pathogens (Bartram et. al., 2001; WHO, 2016; Bichai & Ashbolt, 2017; Alegbeleye & Sant'Ana, 2020).

Water managers in Chhattisgarh may utilize these insights and collaborate with stakeholders to create evidence-based initiatives to safeguard water resources, enhance public health, and promote sustainable water use practices.

5.2. Public Health Considerations

This assessment of many factors and their implications for human well-being identifies three key health concerns:

Microbial pollutants in water, including bacteria, viruses, and parasites, pose a serious health danger to the population (Kristanti et. al., 2022; Saxena et. al., 2015; Akpor et. al., 2014). These microorganisms may cause a variety of watery ailments, including diarrhoea, cholera, typhoid fever, and hepatitis (Ashbolt, 2004; Fazal-ur-Rehman, 2019; Pal et. al., 2018). Prevention of aquatic infections is critical for sustaining public health and lowering the prevalence of avoidable illnesses.

Exposure to chemical pollutants in water, such as heavy metals, pesticides, and industrial chemicals, may have long-term health consequences (Rehman et. al., 2018; Nadal et. al., 2011). These might include neurological diseases, reproductive problems, developmental anomalies, and a higher risk of cancer (Sabarwal et. al., 2018; Kumar et. al., 2020; Dolk & Vriheid, 2003). To mitigate long-term health consequences, it is critical to address the sources of chemical pollution and limit human exposure to hazardous compounds (Naidu et. al., 2021; Balbus et. al., 2013; Villanueva et. al., 2014).

Children, the elderly, pregnant women, and others with weakened immune systems are particularly exposed to the health effects of low water quality. The health of disadvantaged groups needs targeted interventions such as safe drinking water, sanitation facilities, and hygiene education (Ezbakhe et. al., 2019; Unicef & Unicef, 2016; Chirgwin et. al., 2021; Hutton & Chase, 2018; Unicef, 2018).

Equal access to clean, safe water is critical for achieving health equity and eliminating health disparities. Water quality concerns often affect disadvantaged groups, such as those in rural regions, informal settlements, and undeveloped metropolitan areas (Dos Santos et. al., 2017; Williams et. al., 2018; Bosch et. al., 2001). To address health inequalities, health equality must be prioritized in water management policies and practices, as well as the underlying socioeconomic determinants of health.

Rapid reaction methods and emergency preparation plans are critical for dealing with waterborne disease outbreaks and other public health problems caused by poor water quality (Chan et. al., 2021; Craun et. al., 2001; WHO, 2016). Timely diagnosis, monitoring, and reaction are crucial for controlling outbreaks, providing medical treatment to those afflicted, and limiting the spread of waterborne infections (WHO, 2019; Bisen & Raghuvanshi, 2013).

Raising public knowledge and education on water quality problems, health hazards, and preventative measures is critical for empowering people and communities to preserve their own health (Nutbeam & Kickbusch, 1998; WHO, 2022; Frumkin et. al., 2008; Kumar & Preetha, 2012; Petersen, 2003). Health education campaigns, community outreach programs, and school-based efforts may all help to increase awareness of safe water practices, good cleanliness, and the value of clean water to one's health and well-being (Anthoni et. al., 2021; WHO, 2003; 2019; 2000).

By incorporating health concerns into water quality monitoring, management, and policy frameworks, stakeholders may collaborate to guarantee that all communities have access to clean, safe water while also lowering the health risks associated with poor water quality.

Chapter- VI Conclusion

Conclusion

The findings of physiochemical and microbiological testing in many districts of Chhattisgarh provide a clear picture of the region's water quality. The rigorous investigation of several parameters, such as pH, conductivity, turbidity, and microbial composition, has revealed important information about water resource health and management. This research found considerable differences in water quality between places, indicating a broad variety of natural conditions and human activities. Agricultural runoff and urban wastewater discharge seem to be important sources of pollution, emphasizing the need of tailored management approaches to prevent contamination and safeguard water quality.

Moreover, the presence of microbiological pollutants emphasizes the need of strict monitoring and sanitation measures to safeguard public health and avoid waterborne infections. By addressing these challenges and adopting future measures like as greater monitoring, community engagement, and policy change, stakeholders may work together to provide clean, safe, and sustainable water supplies to all Chhattisgarh citizens.

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