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Geospatial analysis of industrial and agricultural pollution impact on pond water quality in Raipur district, central India

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ABSTRACT

This study attempts to fill the critical need for comprehensive data on pond water quality in the central region of rural India, with an emphasis on the industrial and agricultural zone of Chhattisgarh's Raipur district. Geospatial tools were used to map pollution distribution and identify contamination hotspots across the district. The study employs geospatial analysis and mapping methods to assess physicochemical factors, such as pH, EC, TDS, DO, and concentrations of metals, alongside the Water Quality Index (WQI) and other water quality indicators to evaluate the overall impact of industrial and agricultural pollution on pond water quality. Ponds are increasingly in danger due to pollution from domestic waste, industrial discharge, and agricultural runoff, even though they are essential for everyday tasks like irrigation and drinking. Twenty ponds were selected for analysis based on their proximity to industrial zones and agricultural activities. Water samples were collected and analysed for key physicochemical parameters and specific metal contaminants for WQI. The total WQI score was 115.74, indicating severe contamination across the sampled ponds. This high WQI score underscores the urgent need for remediation efforts to address pollution and protect public health. The results offer insightful information about the declining condition of pond water quality, emphasizing the need for prompt action and long-term sustainable management strategies. Bioremediation methods such as phytoremediation, microbial treatment, and adsorption techniques (e.g., activated carbon) can effectively remediate water contaminated by industrial and agricultural pollutants, improving water quality sustainably and cost-effectively.

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1. Introduction

Water covers almost two-thirds of the earth's surface, yet 96.5% is kept in saline water reserves that are unfit for domestic, commercial, or agricultural use. On the other hand, groundwater makes up about 1.7% of the water [1]. In ponds, lakes, rivers, dams, and other bodies of water used for domestic, commercial, and agricultural purposes, there is less than 1% of water [2]. An estimated 70% of the water in these ponds is contaminated due to the effluents from residential, commercial, industrial, and agricultural drainage systems being released into the water [3]. Ponds are essential for supporting biodiversity by providing habitats for various plants, animals, and microorganisms. They act as natural water reservoirs, storing rainwater and helping to regulate water flow; this helps prevent soil erosion and reduces the risk of flooding by controlling runoff during heavy rains. The urban and rural ponds exhibit heterogeneous conditions, frequently symbolizing the more extensive issues confronting water bodies nationwide [4,5]. Some ponds are neglected, polluted, and overrun by encroaching, while others are carefully preserved as ecological and cultural treasures that serve as hubs for neighbourhood events [6,7]. Furthermore, ponds are a crucial water source for local communities, supplying water for drinking, domestic use, and irrigation, especially in rural areas where alternative water sources may be limited [8–10]. Ponds are essential ecological features on a global scale [11], providing a home for a variety of aquatic species, such as fish, amphibians, and invertebrates [12–16].

Indian ponds confront several difficulties, such as siltation, neglect, encroachment for development in urban areas, and pollution from agricultural and industrial runoff [17,18]. The ecological health and water quality of many ponds have declined, which has harmed ecosystem services, reduced water availability, and resulted in biodiversity loss [19,20]. The developing state of Chhattisgarh, known for its rich water and mineral resources, has experienced substantial growth in both the agricultural and industrial sectors. This development has driven economic progress and has led to significant environmental challenges. The pond water quality varies significantly, with some areas experiencing dangerously elevated levels of contamination. To preserve these vital water resources and ensure their sustainability for future generations, close monitoring, strict regulations, and active community involvement are essential [21-23]. Raipur, the state capital, serves as a major centre for rapid industrialization and agricultural expansion, which has exacerbated water pollution in the region [24-27]. The urban development has also intensified stress on local water resources, while inadequate wastewater treatment facilities further exacerbate contamination issues [28,29]. The increasing discharge from industries and runoff from agricultural lands have severely impacted pond water quality, introducing contaminants such as heavy metals and chemicals [30-32]. Understanding current water quality conditions is critical to forming policy decisions, prioritizing sustainable management strategies, and protecting community well-being [33]. These pollutants pose severe environmental and public health risks, highlighting Raipur's struggle with water pollution as a growing concern in Central India [34]. Small ponds have historically been an essential domestic water source and have significantly impacted the availability of fish for human consumption [35,36]. Many people in these cities are under the poverty line and still depend on pond water for bathing, brushing, washing, and other daily needs [37].

Several prior studies (Singh et al., 2020; Shakar et al.,2021; Tamrakar et al., 2022; Jaiswal et al., 2023; Swarnkar et al., 2024) [38-42] have used multivariate statistical techniques to study the quality of surface water, with a focus on physicochemical characteristics, pond toxicity, and water quality parameters[43]. Accurate evaluation requires ongoing updates due to the dynamic nature of water quality. These water quality indices are established by evaluating the physicochemical characteristics of pond water, which provides vital information on the state and compatibility of these aquatic ecosystems [44,45]. Examining variables like pH, dissolved oxygen content, turbidity, temperature, and amount of salt allows scientists and environmental experts to assess the general condition of pond water and identify possible causes of pollution or degradation [46-48].

The present study aims to evaluate the physico-chemical properties of water from twenty different ponds in the Raipur District to assess the suitability of these water bodies for various purposes, including drinking, agriculture, recreational activities, and the preservation of aquatic ecosystems. These evaluations are essential for determining water quality and forming sustainable water management practices. To achieve this goal, the research evaluated each of the 15 key water quality parameters individually, identifying their relationships and correlations and providing insights into how these parameters relate to each other and their sources. This study revealed widespread pollution in all the sampled ponds, making the water unsafe for drinking and irrigation. This result highlighted the severity of contamination and the urgent need to address water quality issues in the region.

2. Study area

The capital of Chhattisgarh state is Raipur City (Figure 1), which is situated in central India (22◦33′N to 21◦14′N and 82◦6′E to 81◦38′E) with a population of two million (According to Census 2011) [49]. The city has several ponds that are used for drinking, bathing, washing, and fishing. Raipur's tropical climate is categorized as sub-humid, with annual precipitation ranging from 1300 to 1400 mm. Most of the rain falls during the rainy season (June to early October) [40]. The 20 ponds selected for this study are primarily located near major industrial and agricultural areas of the district. These ponds were chosen to evaluate the impact of both industrial activities and agricultural runoff on local water quality. Proximity to these key sectors was considered crucial, as they are likely to contribute significantly to variations in pollution levels.

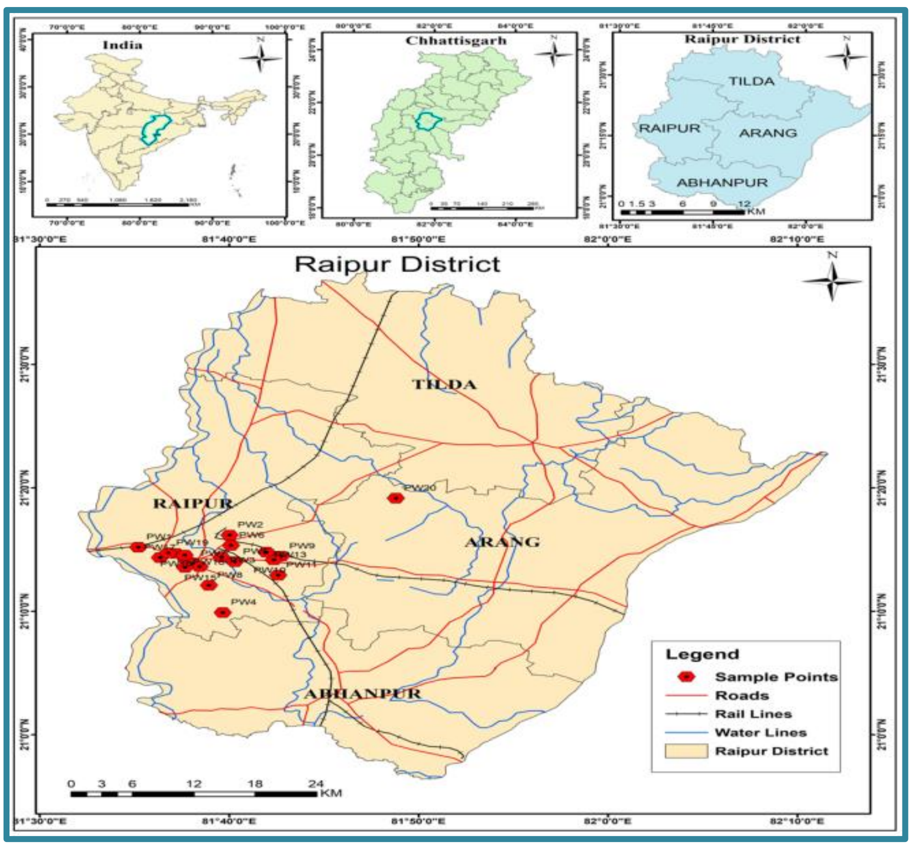


Fig. 1. A geographical depiction of Raipur showcasing the spatial

3. Materials and methods

3.1. Sample Collection and Geo-Statistical Approach

In this study, 20 ponds were selected based on industrial and agricultural lands near Raipur district, as shown in Table 1. Figure 1 depicts a map of sampling locations from February 2023. Metal contamination, such as calcium, magnesium, sodium and potassium, can be high near industrial and agricultural areas. Mapping of sampling points of the pond for geospatial analysis was done using ArcGIS software (version 10.5), which is well known for the Inverse Distance Weighted (IDW) method used for the geographical study; the software helps to create, manage, and analyze spatial data [50]. A 500ml sample bottle was used to collect the water samples. One-time water sampling was done for each pond during the pre-monsoon season, with each sample taken at a depth of 1 to 2 feet. The samples were labeled, sealed, and stored in a refrigerator until analysis. Figure 2 depicts images of ten sampling locations. All parameters were determined using the American Public Health Association (APHA) standard procedures, and all results were evaluated by comparing them to the World Health Organization (WHO) and Bureau of Indian standard (BIS) standards [51-55].

3.2. Methodology

A Hanna multiparameter instrument (model HI98194) was used for analyzing pH, electrical conductivity (EC), total dissolved solids (TDS), temperature, and dissolved oxygen (DO) to ensure accurate and reliable measurements for these key water quality parameters [56]. Sodium (Na) and potassium (K) were analyzed using an ESICO microprocessor flame photometer (model 1385), providing precise measurements of these metal ions [57]. Turbidity was measured with a Turbidity Meter (model HI98703-01) [58]. Chloride (Cl), Calcium (Ca), magnesium (Mg) hardness, and alkalinity were determined through the titration method, ensuring accurate water quality assessments [59].

Table 1. The names of ponds, along with their corresponding geographical positions and local landmarks.

Serial No.	Pond Name	Given Name	Latitude	Longitude	Landmark Area
1	Doomar Pond	PW1	21.2531632°	81.5866798°	Amanaka
2	Mova Pond	PW2	21.2694980°	81.6671122°	Dubey Colony
3	Telibandha Pond	PW3	21.2397853°	81.6600278°	Telibandha
4	Sejbahar Pond	PW4	21.1649265°	81.6610903°	Sejbahar
5	Purena Pond	PW5	21.2335132°	81.6717672°	Purena
6	Khamardih Pond	PW6	21.2554926°	81.6682085°	Khamardih
7	Swami Vivekanand Sarovar	PW7	21.2307559°	81.6345150°	Budhapara
8	Boriyakhurd Pond	PW8	21.2016386°	81.6490244°	Boriyakhurd
9	Zora Pond	PW9	21.2409353°	81.7125662°	Zora
10	IGKV Pond	PW10	21.2360968°	81.7059724°	Zora
11	Dharmpura Pond	PW11	21.2153490°	81.7098093°	Dharmpura
12	Narhareswar Pond	PW12	21.2269753°	81.6408591°	Janta Colony
13	Labhandih Pond	PW13	21.2463648°	81.6994067°	Labhandih
14	Kankalimata Pond	PW14	21.2363771°	81.6287479°	Kankali Para
15	Maharajbandh Pond	PW15	21.2259167°	81.6279674°	Mahamai Para
16	Ramkund Pond	PW16	21.2446752°	81.6195070°	Samta Colony
17	Dangniya Pond	PW17	21.2390002°	81.6058086°	Danganiya
18	Handi Pond	PW18	21.2423840°	81.6274836°	Mominpara
19	Karbala Pond	PW19	21.2455027°	81.6131270°	Geeta Nagar
20	Kausaliya Mata Mandir Pond	PW20	21.3192864°	81.8135357°	Chandkhuri

Fig. 2. The images represent the specific sampling sites meticulously selected for the collection of specimens as part of this study.

3.3. Water Quality Index

WQI denotes an index number indicating the general water quality for any intended use [60]. The rating reflects the composite influence of various parameters for estimating the WQI [61]. It is the most impactful method for conveying information on water quality trends to ordinary people, policymakers, and quality management. Different parameters in the formula of a water quality index are essential based on the intended use of water. It is primarily done to determine its suitability for human consumption.

WQI was computed by following these steps in the weighted arithmetic index method:

$$WQI = \frac{\Sigma qnWn}{\Sigma Wn} \quad (1)$$

$$qn = \frac{100.(Vo-Vio)}{Vs-Vio} \quad (2)$$

Where qn = Quality rating of the nth water quality parameter, Vn = Estimated value of the nth parameter of a given water, Sn = Standard permissible value of the nth parameter, Vio = Ideal value of the nth parameter of pure water (i.e., 0 for all other parameters except pH and Dissolved Oxygen (7.0 and 14.6 mg/L), respectively), and Wn = Unit weight for the nth parameter.

The WQI for the particular pond was determined using the previously mentioned equations, and the result was compared to the standard WQI values shown in Table 2. These values presented an idea of the general state of the pond water and recommended possible uses for it. In this paper, the following physicochemical parameters have been examined: pH, electrical conductivity (μS/cm), total dissolved solids (mg/L), total alkalinity (mg/L), total hardness (mg/L), calcium hardness as $CaCO_3$ (mg/L), magnesium hardness as $CaCO_3$ (mg/L), and turbidity (NTU).

4. Results and discussion

4.1. Physical Parameters of Pond Water

The concentrations of 14 physical and chemical parameters in the 20 ponds analyzed are displayed in Figure 3-10. Tables 3 and 4 show the results of the physicochemical interpretation.

4.1.1. pH

The pH value of 20 pond water samples was summarized and shown in Figure 3. With constant temperature, the pH value varied from 5.65 to 9.21. Among all the ponds, the pH of the Kaushilya Mata Mandir Pond was the highest and can be attributed to its proximity to agricultural land, where the extensive use of fertilizers, particularly potash, may contribute to the increased alkalinity of the water. However, the Labhandih pond's pH was the lowest due to the influence of nearby steel and cement industries, which contribute to acidification through the release of acidic emissions, dust, and industrial runoff. According to another study, the pH of rainfall gathered downstream from roofs is frequently acidic [62]. The permissible limit for pH in drinking water is typically within the range of 6.5 to 8.5. In the present study, six samples showed pH values outside this permissible range, as shown in Table 3. Nonetheless, the high pH levels following a runoff could be explained by the presence of calcium and magnesium ions in atmospheric deposits dissolved by rainwater [63].

4.1.2. Turbidity and Color

The clarity of the water is critical because it is the first indication of good water. The permissible limit for color in drinking water is typically 5 TCU (True Color Units). In this study, all twenty samples exceeded this permissible limit. Turbidity is caused by suspended and colloidal matter, either inorganic or organic, which reduces a liquid's transparency [64]. Turbidity value varies from 2- 12NTU. Among all the ponds, the turbidity of the Dharampura Pond was the highest, and the Kaushilya Mata Mandir Pond was the lowest. Turbidity and colour are shown in Figure 4, according to the International Standard Organization (ISO). Turbidity was measured in this study using a Nephelometer. Sixteen samples exceeded the permissible limit for turbidity, which could indicate the presence of suspended particles, microorganisms, or pollutants in the water. High turbidity levels could pose health risks and affect the water's aesthetic quality.

Table 2. Classification of WQI values, delineation of water body status, and formulation of recommendations for water usage (Aher et al., 2016; Haingotseheno et al., 2020).

S. No.	WQI	Water Quality Status	Possible usage
1	0-25	Excellent	Drinking
2	26-50	Good	Domestic
3	51-75	Poor	Irrigation and Industrial
4	76-100	Very poor	Irrigation
5	Above100	Unfit for consumption	Before being used, appropriate treatment is required.

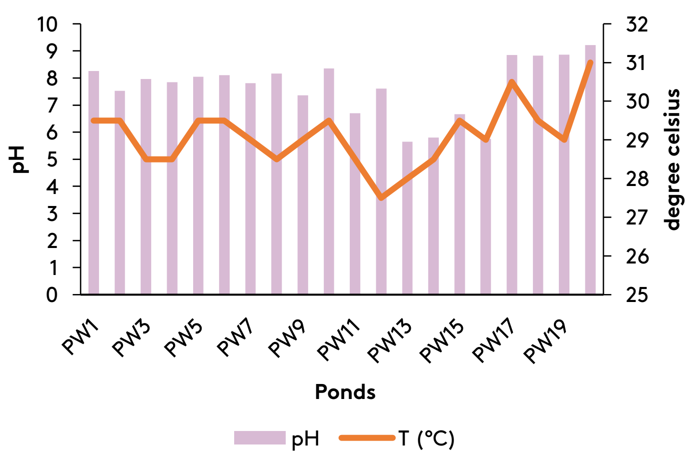


Fig. 3. Variation of pH and Temperature

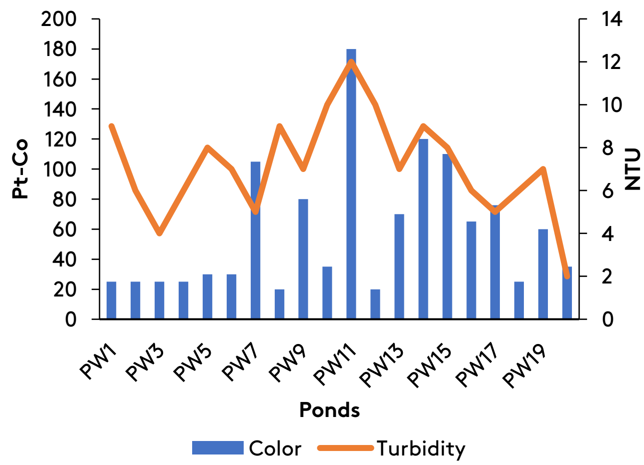


Fig. 4. Variation of Color and Turbidity

4.1.3. Alkalinity

The capacity of water to counteract acids is measured by its alkalinity, ranging from 180 to 450 mg/L in the IGKV and Zora ponds, respectively (Figure 5). Nineteen samples exceeded the permissible limit for alkalinity, which could cause the water to be less palatable and affect its suitability for industrial and agricultural use. However, excessive alkalinity levels can lead to a bitter taste in water [65].

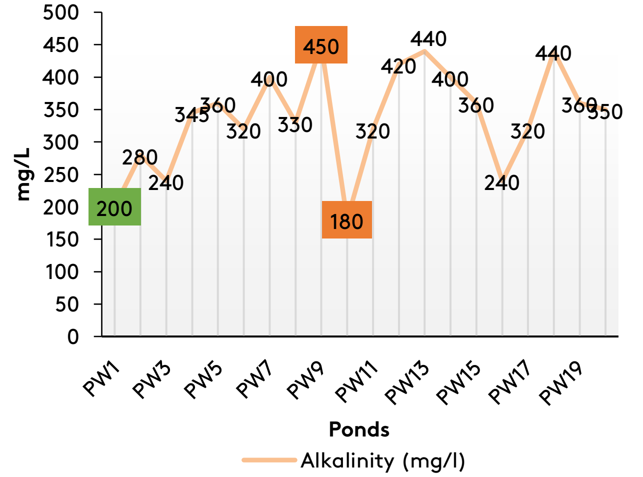


Fig. 5. Variation of Alkalinity

4.1.4. Total Dissolved Solids

The composition of dissolved solids in natural water bodies is determined by the types of bedrock and soil in the surrounding environment. As water interacts with these geological materials, it dissolves minerals and nutrients, which then contribute to the specific chemical makeup of the water. The decomposition of organic matter in water causes an increase in solids [66]. The decomposition of organic matter in the water causes an increase in solids. The total dissolved solids in the Doomar Pond and Swami Vivekanand Sarovar were in the range of 432 to 928 mg/L, as shown in Figure 6. Eighteen samples exceeded the permissible limit for Total Dissolved Solids (TDS), which could negatively affect the taste, appearance, and safety of the water. High TDS levels may indicate the presence of salts, metals, or other contaminants.

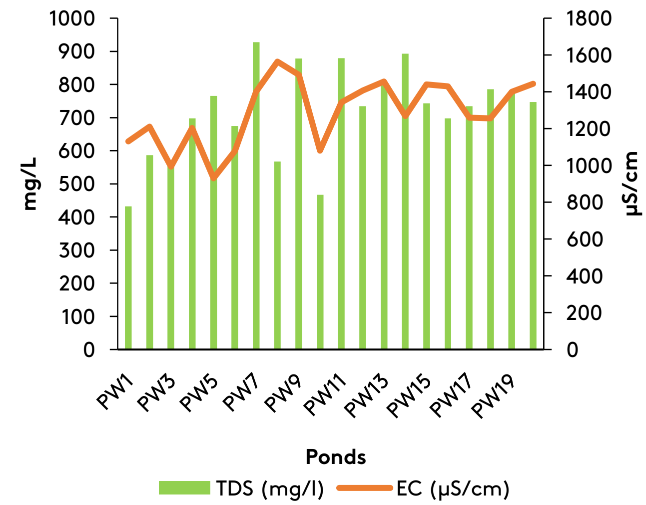


Fig. 6. Variation in TDS, EC

4.1.5. Electrical Conductivity

The ability of water to conduct electricity can be determined using conductivity. Indeed, it enables the measurement of the amount of salt dissolved in water and the determination of pollution in the water [67,68]. The minimum and maximum EC values of all collected pond water samples were 930 μS/cm and 1564 μS/cm, respectively, as shown in Figure 6. Some of the samples collected were above this limit. As a result, these ponds were not suitable for aquaculture. As per the results, all 20 samples showed very high Electrical Conductivity (EC) levels, which was a strong indication of the presence of a significant amount of dissolved salts or minerals in the water. High EC could be caused by various factors, such as industrial discharges by sponge iron and the steel industry. Agricultural runoff from fertilizers and pesticides adds more minerals to the water, while wastewater contamination introduces excess ions, both of which contribute to water pollution and affect its quality.

4.2. Chemical Parameters of Pond Water

4.2.1. Dissolved Oxygen and Biological Oxygen Demand

Dissolved oxygen is one of the most crucial components for an aquatic organism's survival in water [69]. During the sampling, the dissolved oxygen levels were between 5.65 and 7.8 mg/L at Dharampura and Purnena, respectively, while Khamardih had a 7.8 mg/L level, as shown in Figure 7. According to this study, some ponds have a high concentration of dissolved oxygen in their water, which benefits aquatic life.

4.2.2. Biochemical Oxygen Demand (BOD)

BOD represents the amount of dissolved oxygen required by microorganisms to break down organic matter in water, serving as an indicator of water quality and pollution levels [70]. The BOD and DO correlation graph for the pond water samples revealed an inverse relationship between these parameters [71]. A sample with a 5-day BOD between 1 and 2 mg O/L indicated immaculate water, 3.0 to 5.0 mg O/L indicated moderately clean water, and >5 mg O/L indicated a nearby pollution source [72]. The BOD of the fourteen ponds ranged from a minimum of 3.1 mg/l in the Zora Pond to a maximum value of 7.3 mg/l in the Dharampura Pond due to more agricultural activity. Figure 8 underscores the critical connection between BOD and DO in assessing water quality, showing that high BOD levels often correlate with low oxygen levels, which could be detrimental to aquatic ecosystems.

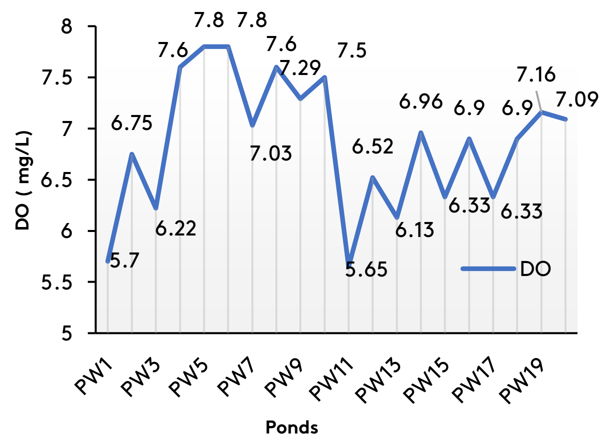
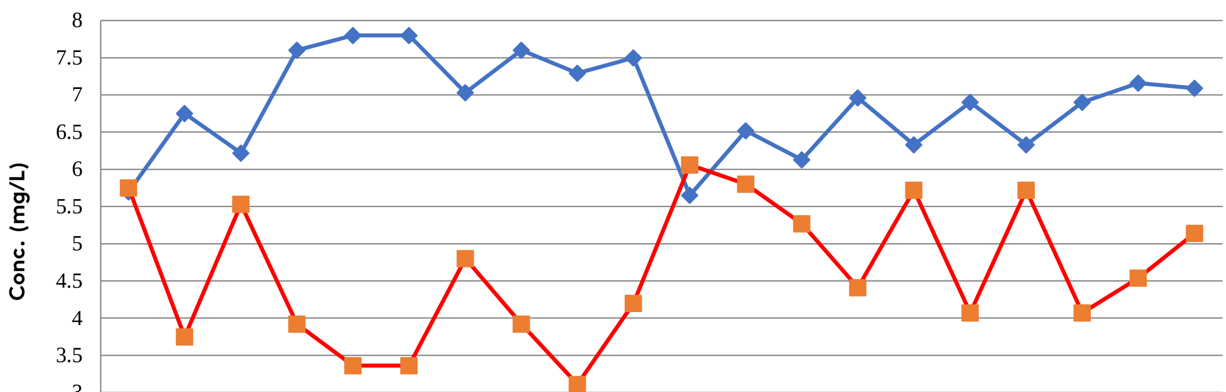


Fig. 7. Variation of DO



	PW1	PW2	PW3	PW4	PW5	PW6	PW7	PW8	PW9	PW10	PW11	PW12	PW13	PW14	PW15	PW16	PW17	PW18	PW19	PW20
DO	5.7	6.75	6.22	7.6	7.8	7.8	7.03	7.6	7.29	7.5	5.65	6.52	6.13	6.96	6.33	6.9	6.33	6.9	7.16	7.09
BOD5	5.75	3.75	5.53	3.92	3.36	3.36	4.8	3.92	3.11	4.2	6.06	5.8	5.27	4.41	5.72	4.07	5.72	4.07	4.54	5.14

Fig. 8. Correlation graph of BOD and DO.

Table 3. Comparative study of physicochemical parameters (Temp., pH, Colour, Turbidity, EC, TDS, and Alkalinity) with BIS and WHO Standard.

S.No.	Pond Name	Temp (°C)	pH	Colour (TCU)	Turbidity (NTU)	EC (μS/cm)	TDS (mg/L)	Alkalinity (mg/L)
1	PW1	29.5	8.26	25	9	1131	432	200
2	PW2	29.5	7.53	25	6	1210	587	280
3	PW3	28.5	7.96	25	3	994	565	240
4	PW4	28.5	7.84	25	6	1203	698	345
5	PW5	29.5	8.04	30	8	930	765	360
6	PW6	29.5	8.1	30	7	1079	675	320
7	PW7	29	7.81	105	5	1400	928	400
8	PW8	28.5	8.16	20	9	1564	567	330
9	PW9	29	7.36	80	7	1492	878	450
10	PW10	29.5	8.35	35	10	1080	467	180
11	PW11	28.5	6.7	180	12	1343	879	320
12	PW12	27.5	7.61	20	10	1407	734	420
13	PW13	28	5.65	70	7	1456	797	440
14	PW14	28.5	5.8	120	9	1268	893	400
15	PW15	29.5	6.66	110	8	1440	743	360
16	PW16	29	5.75	65	6	1429	698	240
17	PW17	30.5	8.85	76	5	1259	734	320
18	PW18	29.5	8.83	25	6	1256	786	440
19	PW19	29	8.86	60	7	1401	778	360
20	PW20	31	9.21	35	2	1444	747	350
BIS STANDARD		10-25	6.5-8.5	5-15	5	300	500	200
WHO STANDARD		12-25	6.5-8.5	15	5	400	300	200

Table 4. Comparative study of physicochemical parameters (DO, TH, Ca-H, Mg-H, Salt, Na+, K+) with BIS and WHO Standard.

S. No.	Pond Name	DO (mg/L)	TH (mg/L)	Ca-H (mg/L)	Mg-H (mg/L)	Salt (mg/L)	Na+ (mg/L)	K+ (mg/L)	BOD_5 (mg/L)
1	PW1	5.7	120	60	60	532	56.89	18.19	5.75
2	PW2	6.75	160	48	112	458	36.2	13.58	3.75
3	PW3	6.22	240	100	140	612	38.27	21.88	5.53
4	PW4	7.6	200	120	80	365	23.79	12.655	3.92
5	PW5	7.8	200	100	100	289	87.93	37.56	3.36
6	PW6	7.8	240	140	100	345	42.41	12.65	3.36
7	PW7	7.03	320	140	180	368	69.31	35.71	4.8
8	PW8	7.6	120	60	60	129	25.86	0.66	3.92
9	PW9	7.29	356	160	196	368	48.62	12.65	3.11
10	PW10	7.5	80	40	40	249	13.44	4.35	4.2
11	PW11	5.65	280	180	100	265	98.27	99.36	6.06
12	PW12	6.52	160	60	100	365	56.89	26.49	5.8
13	PW13	6.13	240	100	140	456	81.72	19.11	5.27
14	PW14	6.96	320	180	140	694	85.86	83.68	4.41
15	PW15	6.33	280	180	100	327	56.89	27.41	5.72
16	PW16	6.9	272	140	132	625	110.68	63.39	4.07
17	PW17	6.33	220	120	100	283	69.31	29.266	5.72
18	PW18	6.9	168	80	88	286	50.68	56.93	4.07
19	PW19	7.16	320	180	140	264	54.82	36.64	4.54
20	PW20	7.09	240	140	100	133	30	13.58	5.14
	BIS STANDARD	6	200	75	30	200	200	10	
	WHO STANDARD	6	500	100	50	200	200	20	

4.2.3. Total Hardness

Calcium and magnesium carbonates, bicarbonates, sulfates, and chlorides cause water hardness. It restricts soap lather formation and raises the boiling point of water [73]. The TH in pond water samples collected from different locations ranged from 80 to 356 mg/L, as in the IGKV and Zora Ponds shown in Figure 9. However, a water sample with a maximum hardness of 356 mg/L could not be used for washing. Fourteen samples exceeded the permissible limit for total hardness, which can lead to scaling in pipes, boilers, and other water infrastructure, affecting the water's suitability for industrial use.

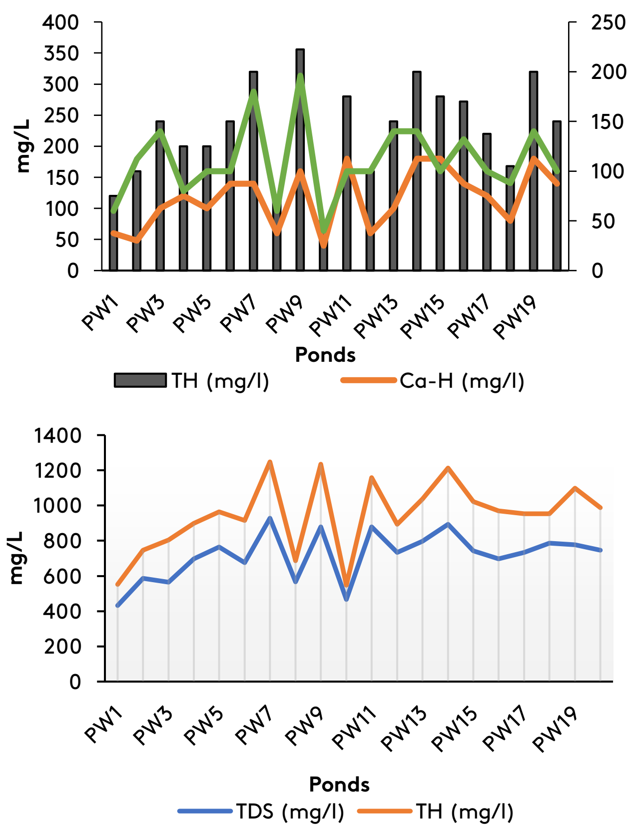


Fig. 9. Variation of TH with Ca-H, Mg-H and TDS

4.2.4. Sodium and Potassium

The primary source of sodium in natural aquatic habitats is rock erosion and decomposition. However, industrial waste and municipal wastewater have a high sodium content, which causes them to accumulate in natural waters after disposal [74]. During the current investigation, the sodium level was found to vary between a minimum of 13.44 mg/L for the IGKV pond and a maximum of 110.68 mg/L for the Ramkund pond. Sodium (Na) levels were below the permissible limit, indicating that sodium contamination was not a concern for these samples. Furthermore, the potassium concentration in Boriyakhurd and Dharampura ponds ranged from 0.66 mg/L to 99.36 mg/L, as shown in Figure 10. Potassium (K) levels exceeded the permissible limit in 15 samples, which could have implications for plant growth and other ecological factors if the water is used for irrigation.

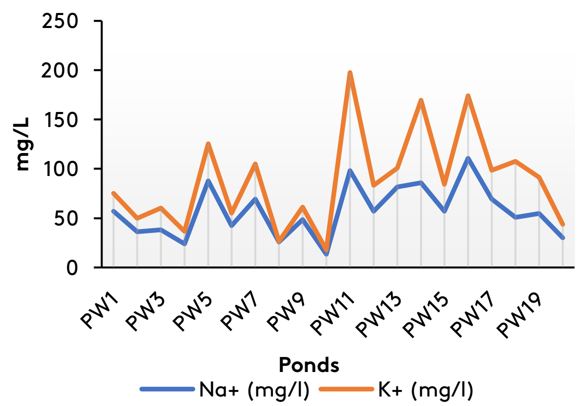


Fig. 10. Variation of Na ions and K ions.

4.3. Correlation matrix

The correlation matrix for all the parameters of pond water is shown in Table 5. Here TDS is strongly positively correlated with TH, Ca, Mg, Alka, Na, K, and EC, meaning that as the level of dissolved solids increased, these related parameters also increased because they contributed to the total mineral content and ionic balance in the water. On the other hand, there was a negative correlation with pH, indicating that higher pH could reduce the solubility of specific ions, decreasing their concentrations. This relationship showed how pH affected water chemistry, including mineral levels and conductivity, and impacted overall water quality.

4.4. Water Quality Index

The water quality index of pond water samples used in this investigation ranged from 86.78 to 138.35, as shown in Table 6; Figure 11 displays the water quality in all water samples. This demonstrated that the water samples were unfit for consumption.

Table 5. Correlation matrix of all pond water parameter.

	pH	TDS (mg/l)	T (°C)	Salt (mg/l)	TH (mg/l)	Ca-H (mg/l)	Mg-H (mg/l)	Alk (mg/l)	Na+ (mg/l)	K+ (mg/l)	Colour (TCU)	DO (mg/l)	EC (µS/cm)	Turbidity
pH	1.00													
TDS (mg/l)	-0.32	1.00												
T (°C)	0.55	-0.15	1.00											
Salt (mg/l)	-0.62	-0.03	-0.36	1.00										
TH (mg/l)	-0.37	0.79	-0.07	0.24	1.00									
Ca-H (mg/l)	-0.31	0.71	0.06	0.08	0.91	1.00								
Mg-H (mg/l)	-0.36	0.68	-0.20	0.37	0.85	0.55	1.00							
Alk (mg/l)	-0.15	0.80	-0.26	-0.17	0.48	0.35	0.51	1.00						
Na+ (mg/l)	-0.62	0.54	-0.20	0.41	0.48	0.45	0.39	0.20	1.00					
K+ (mg/l)	-0.45	0.56	-0.19	0.31	0.44	0.52	0.22	0.17	0.77	1.00				
Color (TCU)	-0.32	0.56	0.10	0.02	0.54	0.62	0.30	0.17	0.56	0.58	1.00			
DO (mg/l)	0.29	0.02	0.14	-0.33	-0.05	-0.04	-0.04	0.13	-0.38	-0.35	-0.43	1.00		
EC (µS/cm)	-0.26	0.41	-0.18	-0.24	0.35	0.31	0.31	0.48	0.12	0.05	0.26	-0.12	1.00	
Turbidity	-0.33	-0.04	-0.47	-0.06	-0.22	-0.07	-0.35	-0.04	0.22	0.31	0.17	-0.13	0.03	1

Table 6. Computation of WQI for all 20 pond water samples.

S. No.	Pond Names	WQI	Water Status
1.	PW1	128.4129	Unfit for consumption
2.	PW2	104.2697	Unfit for consumption
3.	PW3	97.78565	Very poor
4.	PW4	101.8968	Unfit for consumption
5.	PW5	120.547	Unfit for consumption
6.	PW6	115.799	Unfit for consumption
7.	PW7	117.469	Unfit for consumption
8.	PW8	121.696	Unfit for consumption
9.	PW9	128.386	Unfit for consumption
10.	PW10	125.37	Unfit for consumption
11.	PW11	141.11	Unfit for consumption
12.	PW12	133.015	Unfit for consumption
13.	PW13	96.36	Very poor
14.	PW14	111.391	Unfit for consumption
15.	PW15	110.699	Unfit for consumption
16.	PW16	86.789	Very poor
17.	PW17	117.167	Unfit for consumption
18.	PW18	118.674	Unfit for consumption
19.	PW19	138.356	Unfit for consumption
20.	PW20	99.699	Very poor

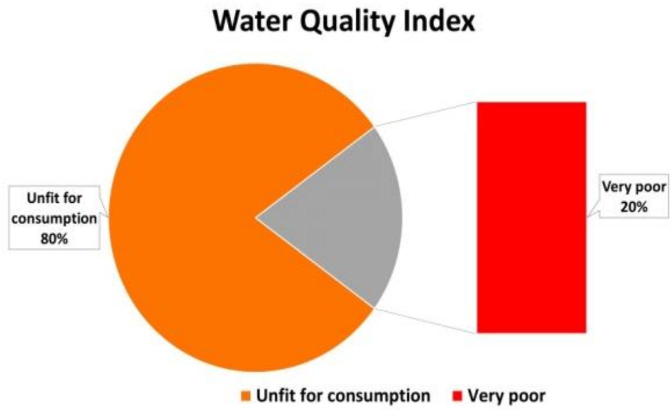


Fig. 11. Pie chart illustrating the quality levels of pond water based on water quality index (WQI) Distribution.

WQI significantly reduced the pollution issues that are frequently present in various surface water bodies. According to the investigation, pond water must be protected from sewage and agricultural wastewater. The WQI is used to simplify the assessment of water quality by combining multiple parameters like pH, DO, BOD, TDS, turbidity, hardness, and alkalinity into a single value. It helps assess water suitability for drinking, agriculture, and aquatic life and supports regulatory compliance and monitoring trends. Assumptions made during the calculation included fixed weightage for parameters, which may not always reflect local conditions, and the normalization of values against standards, which could vary regionally. These assumptions can impact the final WQI result, especially if local environmental factors are not considered.

5. Conclusions

This study aimed to evaluate the water quality of the Raipur ponds before the pre-monsoon season. In 2023, the overall water quality was evaluated by utilizing the water quality index to analyze the physicochemical parameters, including pH, temperature, electrical conductivity, total dissolved solids, dissolved oxygen, total hardness, total alkalinity, calcium hardness, magnesium hardness, turbidity, salt content, water color, oxygen, sodium, and potassium. The findings indicated that the water quality of ponds in Raipur varied significantly, with many requiring extensive treatments to make them safe for human consumption. Ponds situated in industrial, agricultural, and densely populated areas were found to be heavily contaminated, rendering them unsuitable for human use. This study highlights the urgent need for effective water management strategies and mitigation measures to address the deteriorating water quality in the region. While the focus of this study was on the physicochemical analysis of pond water, it is important to recognize that poor water quality, as reflected by the analysed parameters, could pose risks to local ecosystems and communities. Contaminated water can negatively impact aquatic life and create unsafe conditions for activities such as irrigation, drinking, and recreation. The results of this study provide valuable insights for policymakers and water management authorities, helping them implement the necessary measures to improve water quality and ensure a healthy, sustainable environment for both current and future generations.

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