Spatial variation of Physico-chemical parameters and water quality assessment of urban ponds at Raipur, Chhattisgarh, India

Anjali Tamrakar¹, Kshitij Upadhyay² & Samir Bajpai²

1. Department of Environmental Science, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh
2. Department of Civil Engineering, National Institute of Technology, Raipur, Raipur, Chhattisgarh, India.

Corresponding author: Kshitij Upadhyay

Email: kshitij.upadhyay111@gmail.com

Abstract-

Water bodies, natural or man-made, are under threat due to rapid urbanization. This research paper assesses the water quality of 20 ponds located in the vicinity of urban habitats of Raipur district, Chhattisgarh (India) using the Water Quality Index (WQI). The samples were analyzed for 16 physicochemical parameters in the post-monsoon winter season. The parameters were used to calculate WQI and the ponds were categorized accordingly for end use purposes, that is, drinking, irrigation, industrial, or unfit for use without treatment. The WQI of post-monsoon samples resulted in that 75% of the total pond water samples are in excellent condition, & 25% of the samples are unfit for various activities like drinking, irrigation, industrial & domestic. A high value of nutrients was observed in all the ponds, suggesting that the nutrient entering through surface runoff, solid waste disposal, and wastewater is entering the ponds. Our results conclude that all ponds require interventional steps to restore pond water quality and stop it from further degradation, determining which trophic state of the ponds may change in the future. The spatial monitoring of physical and chemical properties of pond water helps to predict, identify, and assess the natural condition of the urban ponds and their relation with the surrounding (environment) and helps in adopting rejuvenation measures.

Keywords- Pond Water, Physicochemical Properties, Water Quality Index (WQI), Raipur, Chhattisgarh.

1. Introduction-

Ponds are described as a small area filled with water, natural or man-made. They are smaller than a lake and are the habitat of various aquatic plants and animals [1]. Ponds are important hotspots for biodiversity. Healthy ponds are an indicator of a healthy environment, they provide safe havens to native wildlife, and they also help in nutrient cycling and remove environmental pollution [2].

Compared to other water bodies (oceans, rivers, lakes) that flow in nature, many ponds are more prone to pollution due to their stagnant nature [3]. The stagnant nature of a water body with high temperatures or high concentrations of phosphate and nitrates fuels the bloom of algae. Algae are always present in the water. The harmful algae bloom (HAB) has a direct correlation with the trophic state of the pond [4]. Excess fertilizer runoff caused by rainfall to rural, urban, and natural environments can remove nutrients such as phosphorus, nitrogen, and potassium from the water [5]. Agricultural waste (containing animal waste, bird droppings), industrial waste (chemical discharge and waste), and urban life (raw untreated wastewater and waste) also carry these nutrients. These nutrients along with warm temperatures and
sunlight cause algal growth. Cyanobacteria is considered one of the HABs that releases toxins such as microcystin that enter the public drinking water system and kill the aquatic life [6]. Chlorophyll-a is also determined to know how much algae is present in the water source. Chlorophyll (a) is a pigment that is responsible for making plants and algae green in color. Chlorophyll (a) concentration can tell a lot about water quality, a water body with low productivity is deep and generally have good water quality and vice versa [7].

Hence, the productivity of the lake is used to make a quantitative and qualitative assessment of the water body based on the amount of biological activity happening in it. Trophic state index (TSI), a popular dimensionless parameter, is used to classify lakes or ponds individually based on the level of biomass and nutrients in the water body. Carlson proposed a widely used biomass-based TSI in 1977. It accounts for three important variables, chlorophyll-a, Secchi transparency depth, and total phosphorus concentration. The TSI value is calculated individually for each variable on a logarithmic scale and then averaged to give a final TSI value which indicates the level of biological activity in the particular water body. The TSI value is then used to label pond as oligotrophic (productivity level - less), mesotrophic (productivity level - moderate), and eutrophic (productivity level – very high) [8]. Many modifications have been proposed in the Carlson TSI by including or excluding other variables based on local geography [9, 10]. A major nutrient, Total Nitrogen (TN), is another key component that plays a vital role in the productivity of aquatic sources as it acts as a nutrient. The nutrient ratio (total nitrogen / total phosphorus) is used by the Florida TSI method to assess the limiting nutrient levels in the water body and TSI has been calculated accordingly [11, 12]. Long-term monitoring of biomass concentration, nutrient concentration is essential to establish levels of biological activity in the water bodies to ascertain their suitability to sustain aquatic life (plant, fish, wildlife) [13].

A safe water supply is essential for the survival of human species, still considered to be of least concern. Surface water bodies across the globe has shown a significant reduction in water quality since the last century [14]. Despite the ever-growing body of scientific findings that have established wastewater discharge (domestic, industrial), wastewater treatment plant effluent discharge, agricultural and surface runoff, and disposal of solid waste as the major drivers of surface water pollution, the condition of natural bodies continues to worsen. These anthropogenic activities lead to a change in the hydrological cycle and significantly affect the biogeochemical cycle in freshwater bodies [15, 16, 17].

Scientific findings suggest that loss of biodiversity due to changes in the landscape especially conversion of rural habitats, to urban habitats is directly responsible for ‘reduction of important ecosystem functions, such as productivity and material cycling’ [18].

The quality of the aquatic sources is interrelated with the variation in the land cover and associated land use in the respective watersheds. A good water quality lies in the vicinity of untouched forest watersheds. The water quality starts falling as the land use covers change. This has been observed as the rural landscapes’ changes from rural to urban through intense urbanization and industrialization. While the human endeavor and quest to advancement and pursuit of ease of life can’t be rationally stopped, the major task is balancing available and exploitable water resources and sustaining their quality [19].

The continuous degradation of lakes and ponds presents major challenges for restoration and will have significant ecological and material costs. Due to global warming and world population rising, the polluted water bodies will require increased conservation efforts to improve their quality. [20]. In third world countries which are transitioning from developing to developed economies like India, there remains a large inequality in water supply and sanitation. Lack of systematic and planned potable forced rural populations to look for alternative sources, while lack of proper education and health infrastructure, and employment aspiration have forced people to migrate to urban centers. The rapid industrialization and commercialization of rural habitats recently are transforming them into semi-urban and urban habitats [21]. This shift in land use and land cover has put the aquatic sources in the urban vicinity at increased risk of contamination. The urban ponds are susceptible to wastewater discharge, surface runoffs, street washing, and solid waste disposal. These ponds are also used for bathing and laundry purpose. Cattle owners use urban ponds to wash and cool off the cattle which introduces nutrients to the pond. Few urban pond waterfronts is a popular recreational and tourist hotspot, making them more susceptible to pollution.
Recent studies have shown that the water quality of Chhattisgarh is deteriorating [22]. The Raipur city of Chhattisgarh state is known for its high quantity of natural and manmade ponds [1]. The city is recently witnessing a habitat transformation. The spatial distribution of the physical and chemical properties of the pond water is limited, but few studies have shown it to be high, considering that most ponds lie in urban vicinity with poor sanitation practices. The main objective of this study was to assess the surface water quality of various urban ponds in Raipur City, as well as categorize their suitability using WQI.

WQI (Water Quality Index) is a mathematical model which provides information about water quality. It provides a single value for variable values of water quality parameters. It makes understanding water quality easy. WQI is of two types: 1. Physicochemical indices, [2]. Biological indices. In this paper, we have used a physicochemical index to categorize ponds based on observed physical and chemical parameters. [23,24,25,26]. The study also examines the influence of land use patterns on the water quality of the ponds by collecting water samples from the ponds located in different land-use areas across Raipur city and making inter-comparison across the classified groups.

2. Materials and methods

2.1 Location and geology of study area

The 20 ponds studied here are located in heart of the industrial and residential area of Raipur city, which makes them prone to anthropogenic pollution. Raipur, the capital city of Chhattisgarh state, India falls under the Hirri sub-basin in the Chandi formation of Chhattisgarh basin. “The Chandi formation is further classified into two geological groups, the Raipur Limestone and the Deondongarh Shale. Raipur Limestone is known for grey, fine-grained, horizontally bedded, stromatolitic, massive limestone, high secondary porosity due to joints and karstification but with negligible primary porosity” [24, 25]. The tropical climate of Raipur city can be classified as sub-humid with average annual precipitation in range of 1300 to 1400 mm. Majority of the precipitation occurs in monsoon season (June to early October).
2.2 Land use and land cover information-
Apparent changes in the land use pattern from forest, rural to urban and semi-industrial land transformation of Raipur can be observed through land-use and land-cover (LULC) maps. The city still lacks a proper sewerage system. The Land use and land cover image of 2021 is shown in fig.1 while sampling locations are depicted in fig.2. A visible change in the land-use and land-cover (LULC) patterns can be deduced by comparing LULC 2013 to LULC 2021.

| Classification of ponds in various groups based on habitat, land use and gentrification | Sample location code | Ponds studied | Accessibility to the public and frequency of pond cleaning |
|---------------------------------|---------------------|--------------|------------------------------------------------------|
| [A] Commercial / Industrial     | P1                   | Vyas pond    | Accessible, no cleaning                              |
|                                 | P2                   | Sarona pond  | Accessible, no cleaning                              |
|                                 | P3                   | Kari pond    | Accessible, monthly cleaning                         |
|                                 | P4                   | Khamtarai pond | Accessible, no cleaning                             |
|                                 | P5                   | Pandri pond  | Accessible, no cleaning                              |
| [B] Recreational                | P6                   | Budha pond   | Accessible, daily cleaning                           |
|                                 | P7                   | Katora pond  | Not accessible, no cleaning                          |
|                                 | P8                   | Narheshwar pond | Accessible, no cleaning                             |
|                                 | P9                   | Telebandha pond | Accessible, periodic cleaning                      |
|                                 | P10                  | Danganiya pond | Accessible, no cleaning                           |
| [C] High-income group           | P11                  | Raja Pond    | Accessible, no cleaning                              |
|                                 | P12                  | Pahadi pond  | Accessible, no cleaning                              |
|                                 | P13                  | Karbala pond | Accessible, no cleaning                              |
|                                 | P14                  | Kho kho pond | Accessible, no cleaning                              |
|                                 | P15                  | Dalal seoni pond | Accessible, no cleaning                           |
| [D] Low-income group            | P16                  | Ayappa pond  | Accessible, no cleaning                              |
|                                 | P17                  | Chironji pond | Accessible, no cleaning                             |
|                                 | P18                  | Macchhi pond | Accessible, no cleaning                              |
|                                 | P19                  | Macchhi taraiya pond | Accessible, no cleaning                           |
|                                 | P20                  | Mahrajbandh pond | Accessible, no cleaning                           |

The 20 ponds considered in this study is divided into 4 category – High-Income group, Low-income group, Recreational/tourist, and the Commercial/Industrial zones. The detail of each pond with accessibility to general public, pond cleaning, and categorization is enlisted in [Table 1]. The classification and the selection of the ponds was done after preliminary survey of the ponds. Based on the reconnaissance survey a total of 5 ponds were selected from each category for this study.

A multitude of sources including unrestrained industrial growth, lack of wastewater collection infrastructure, gentrification, rapid urban migration, ineffective implementation of environmental and sanitation laws & practices, and lack of motivated participation from all the stakeholders involved in water quality management lead to have adverse impact on aquatic sources of Raipur city. Categorization of the pond is done based on the habitat and gentry surrounding the pond location, variations in the quality of
water depend on the population living around it and the end use of the pond be the people living around it. Higher income groups are having different uses as compared to low-income group. As water bodies near low income group are being used more vigorously for multiple uses (bathing, irrigation, washing etc) as compared to high income group. This is the reason why we get different quality of water body when we studied those for this research.

![Study Area Map](image)

**Figure 2.** A map of the Raipur city depicting the location of the 20 ponds sampled in this study.

### 2.3 Sample collection–

Sample collection was done from 20 November to 10 December 2021 in the winter season. The average temperature during the sampling was 28°C. A total of 20 samples were collected and transported back to the laboratory for analysis. The images of 10 sampling location are shown in fig.3. The sample collection, preservation, and transportation were done strictly as described in the APHA manual. The collection of samples was done using plastic bottles. All the parameters are determined using standard procedures described in APHA [27]. All the results were collated with the WHO norms. Every sample was collected by taking all the necessary precautions. Every sample has been analyzed for 16 different physicochemical parameters for this research work and interpreted accordingly. All the samples were analyzed using standard methods as given in APHA manual. Samples were bought from the locations and were stored at below 4 degrees in deep refrigerator.
2.4 Water Quality Index (WQI)-

Here, we have used a mathematical model called water quality index (WQI) based on the discrete parameter value of the water quality component. The quality of the water depends upon many variables which is commonly referred as water quality parameters whose values are compared with the standard permissible values prescribed by the governmental agency. A qualitative assessment and inter comparison of water sources become challenging due to the large numbers of involved water quality variables, and lack of uniform measurement units and relative importance of few variables like MPN, BOD, COD and nutrients etc. over others. The WQI address these challenges and provides a single value that represents the overall quality of the aquatic body at a certain location and time by incorporating all the variables that affects the water quality. With the central purpose of simplifying the complex datasets into an easily comprehensible and comparable value, the WQI is a very useful tool for all the stakeholders. In this paper we have studied the physicochemical parameters (pH, Conductivity (µs/cm), Turbidity (NTU), Total Dissolved Solids (mg/L), Total Hardness as CaCO₃ (mg/L), Calcium Hardness as CaCO₃ (mg/L), Magnesium Hardness as CaCO₃ (mg/L), TKN (mg/L), Nitrate Nitrogen (mg/L), Phosphorus as PO₄³⁻ (mg/L), Chlorophyll-a (mg/m3), COD (mg/L), BOD (mg/L), Total Alkalinity (mg/L), Chlorides (mg/L), and DO (mg/L) [23].

Here we used Horton’s WQI method which is discussed below.

\[
WQI = \frac{\sum q_n \ W_n}{\sum W}
\]

Where, \(q_n\) = quality rating assigned to the \(n^{th}\) water quality parameter

\(W_n\) = unit weight of \(n^{th}\) water quality parameter

**Quality Rating:**

Quantity rating can be expressed by using the formula given below-

\[
q_n = \left( \frac{V_n - V_{id}}{S_n - V_{id}} \right) \times 100
\]

Where,

\(V_n\) = Estimated value of the \(n^{th}\) water quality parameter at a given sample location
Vid = Ideal value for nth parameter in pure water. (Vid for pH = 7 and 0 for all other parameters)

Sn = Standard permissible value of nth water quality parameter

**Unit weight**

Unit weight can be calculated using the formula given below –

\[ W = \frac{k}{Sn} \]

Where,

\[ k = \frac{1}{Sn} \]

Sn = Standard permissible value of nth water quality parameter

The individual pond is rated using the WQI values created using equations discussed above and the value is compared with the standard WQI values, which gives us the overall status of the pond water and also suggest the possible usage of the pond water [Table. 2].

| S.No. | WQI  | Status    | Possible Usage                                      |
|-------|------|-----------|-----------------------------------------------------|
| 1     | 0-25 | Excellent | Drinking, Irrigation, Industrial                     |
| 2     | 25-50| Good      | Domestic, Irrigation, Industrial                     |
| 3     | 51-75| Fair      | Irrigation And Industrial                            |
| 4     | 76-100| Poor      | Irrigation                                           |
| 5     | 101-150| Very Poor | Restricted Use for Irrigation                        |
| 6     | Above 150| Unfit For Drinking | Proper Treatment Required Before Use. |

**Table 2.** Categorization of WQI value, the corresponding status of water body, and suggestions for the possible usage of water. [58]

3. Results

3.1 Physico-chemical parameters of the pond water

The concentration of 16 physical and chemical parameters of 20 ponds studied here 9 is shown in fig 4, 5 & 6. All the ponds can be easily compared. Location variations in water revealed all the maximum and minimum values of all the physicochemical parameters which have been studied and calculated for this research. The results obtained from the physiochemical analysis are discussed below.

Ph values (Fig.4(a)) of these ponds were alkaline which is relatable with biological activity in each pond. Mahrajbandh pond showed the highest pH value, as the pond receives a constant influx of domestic wastewater, there is a good amount of phytoplankton population. Algal growth means higher photosynthesis, CO₂ depletion due to increased photosynthetic activities, and interaction with continuous vehicular emissions so these can be a very reason for higher ph. It has been observed that the average pH value in the commercial and industrial zone is more alkaline as compared to the other subgroups which were expected as these ponds are prone to deposition of vehicular emissions and atmospheric fallouts containing emissions from the industries.
The clarity of the water is very important, as it is the very first sign of good water. According to International Standard Organization (ISO) turbidity is caused due to the presence of suspended and colloidal matter, inorganic or organic in nature which reduces the transparency of liquid. Turbidity was measured by using the instrument called Nephelometer for this study. The range varies from 1.4 NTU (Kari Pond) to 20.8 NTU (Narheshwar pond) (Fig.4(b)). Ponds under the recreational group are more turbid, having a value of 15.38 NTU which is quite higher and the reason which has been observed is the aesthetic implications of the water supplies in those locations. Turbidity >5 NTU is usually acceptable for consumers. Raipur pond locations result in a higher average turbidity value of 9 NTU which is very high and it needs to be monitored as it indicates pollution triggered by environmental events (eg. Earthquakes, flood, fire, etc.) or anthropogenic activities or ingress of contamination due to infrastructures (Fig.4(b)) [31,32].

Dissolved oxygen concentration (mg/l) followed throughout the investigation period as it is a direct indicator of an aquatic resources’ ability to support aquatic life. Low DO level in water leads to the death of aquatic organisms. The lower the concentration the higher the stress. If DO value of the water falls below 4mg/l, the survival chances of organisms will reduce. It was analyzed by using Winkler’s method. The DO values of the samples varied from minimum (Mahrajbandh pond) – 1.7 mg/l to maximum (KhoKho pond)- 10.7 mg/l (Fig.4(c)). Higher values of phosphorus and nitrogen in Mahrajbandh pond supported the conclusion about its lower DO value. As high nutrients can lead to excessive plant growth and result in a decline in DO. Mainly phosphorus and nitrogen are responsible for the lower DO value. Uncontrolled plant growth leads to algal bloom, is often due to fertilizer run-offs causing a phenomenon called eutrophication. Eutrophication is mainly due to heavy nitrogen-enriched fertilizer runoffs leading to imbalance causing the death of aquatic life and creation of zones where survival of aquatic life is not possible. So, it can be reduced by taking preventive methods to reduce fertilizers or prevention of any type of plantation near highly eutrophic water bodies such as Mahrajbandh pond (Fig.4(c)).

Electrical conductivity reflects the ability of water to conduct electricity. This electrical conductivity is due to the substances dissolved in the water which breaks down into positively and negatively charged ions. Electrical conductivity varies from 361µs/cm (Telebandha) to 922 µs/cm (Vyas) (Fig.4(d)). Vyas pond being on the commercial/ industrial location is having interaction with industrial runoffs that means dissolved salts and inorganic chemicals, conductivity increases. The electrical conductivity of low-income group ponds - (721 µs/cm) is much higher than other subgroups. Ponds in this group have access to many agricultural run-offs, i.e dissolved chemicals summarizing the very reason for higher electrical conductivity. Raipur ponds are having electrical conductivity of 634 µs/cm which is double the standard electrical conductivity value. Higher electrical conductivity is not a necessarily cause of concern due to its lack of direct health impact but dissolved insoluble solids may lead to higher water hardness and alkalinity (Fig.4(d)).

Total Dissolved Solids of water is the amount of dissolved inorganic salts and organic matter present in water. The major constituents dissolved in water are calcium, magnesium, sodium, potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. Total Dissolved Solids range from 232 mg/l (Telebandha pond) – to 922 mg/l (Vyas Pond). Total dissolved solids in ponds in commercial/ industrial groups have higher TDS values as compared to other subgroups (Fig.5 (a)).

Alkalinity is the capacity to neutralize the acid present in water. Alkalinity in water sources is basically due to carbonates, bicarbonates, and hydroxide so it is considered as a sign of the presence of these constituents in the water body. (American Public Health Association, 1995). Water sources studied for this research range from Chironji pond (40 mg/l) to Raja Pond (304 mg/l) (Fig. 5 (b)).
Figure 4. Spatial distribution of (a) pH, (b) Turbidity, (c) Dissolved oxygen, and (d) Conductivity in the surface water of urban ponds.

Phosphate measurements showed the recorded minimum value of 1.70 mg/l in (Telebandha pond) and a maximum value of 22.62 mg/l (Mahrajbandh pond). Phosphorus is an important nutrient for the growth of organisms. It is a growth-limiting nutrient so if the amount of phosphate speeds up due to continuous discharge from agricultural runoff, industrial wastes, or raw or treated wastewater it will lead to eutrophication. Ponds in the high-income group have the highest phosphorus value as compared to other subgroups. Proving the very reason for higher phosphorus concentration i.e runoff from urban areas & lawns, leaking septic systems, etc. (Fig.5(c)).

High chloride concentration in water or wastewater causes harm to metallic pipes and structures, and plants. It is increasing due to an increase in the number of industries. It varies from 46 mg/l (BudhaPond) to 378 mg/l (MacchiTaraiyya) (Fig.5(d)).

Nitrogen-Nitrate concentration is normally in trace amount in surface and groundwater but it can reach to higher concentration due to agricultural runoff, industrial waste, human & animal waste discharge. It varies from 8.20 mg/l (Macchi pond) to 51.20mg/l (Mahrajbandh pond) (Table2). The maximum nitrogen nitrate value was of ponds under the low-income group. TKN was measured from 1.20 mg/l (Kho Kho pond) to 28 mg/l (Mahrajbandh pond) (Fig.6(a)) [37].
Figure 5. Spatial distribution of (a) TDS, (b) TA, (c) Phosphate, and (d) Chloride in the surface water of urban ponds.

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are the major physicochemical parameters measured for the evaluation of organic contamination pollution in water. The minimum COD value estimated is 36 mg/l (Kho Kho pond) and the maximum is 240 mg/l (Pandri pond). Higher values of COD mean a greater amount of oxidizable organic material in the water body which will reduce DO level. Pandri being in the commercial/industrial location has higher industrial run-offs leading to an increase in COD values. The maximum COD and BOD values are of ponds that are under the low-income group. BOD5 value estimated is a minimum of 10 mg/l (Telebandha pond) and the maximum is 142 mg/l. The COD/BOD ratio is a very crucial parameter which tells us about the nature and draggability of the organic matter present in the water body. A high COD value reflects that major portion of the organic matter is better suited for chemically oxidation rather than biological oxidation. This organic matter often involves organic chemicals which are very toxic to the aquatic organisms. Thus, COD test is very essential to get a comprehensive picture on the nature of organic matter which otherwise left unaccounted for in BOD test. (Fig. 6(b)) [35,36].

Hardness is observed to be higher in ponds of low-income groups. according to industries, a good water hardness level should not increase above 100 mg/l but these water sources have higher values of total hardness which is making the water unfit for consumption (fig.6(D)) [23].
Figure 6. Spatial distribution of (a) Nitrogen species, (b) BOD & COD, (c) Chlorophyll-a, and (d) Hardness in the surface water of urban ponds.

3.2 Water quality assessment of 20 ponds using Horton’s WQI -

16 Physicochemical parameters that were analyzed for 20 different ponds during the post-monsoon season were used to calculate WQI using Horton’s method. Our investigations during post monsoon winter season shows that 75% of the pond water samples are in excellent condition, & 25% of the samples are unfit for various activities like drinking, irrigation, industrial & domestic. The index result constitutes the water quality status of the water samples [23,24].

Table 3. WQI values of the pond water of 20 ponds, the corresponding status of water body, and suggestion for the possible usage of water.

| Sample Location Code | Wn*Qn   | Water Quality Status     | Possible Usage                        |
|----------------------|---------|--------------------------|---------------------------------------|
| P1                   | 120.087976 | Unfit for consumption    | Proper treatment required before use  |
| P2                   | 60.57507927 | Poor                    | Irrigation                            |
| P3                   | 78.63236564 | Very Poor               | Restricted use for irrigation         |
| P4                   | 51.29076094 | Poor                    | Irrigation                            |
According to WQI calculated for various ponds, Mahrajbandh pond, Ayappa pond, Narheshwar pond, Tanzania, Raja Pond, Vyas Pond, Kari Pond, Sarona Pond, and Khamtarai Pond have water quality index above 100; they come under category – unfit for drinking according to the WQI ranges [table(3)]. The very reason behind the value being this high is that they are in industrial location & near high way having continuous exposure to chemicals, dust & waste disposal. This leads to an increase in nutrient concentration, toxicant concentration making them unfit for various activities.

Table 4. WQI values of the pond water of 20 ponds, the corresponding status of the 20 ponds

| S.no. | WQI    | Status          | Ponds                  |
|-------|--------|-----------------|------------------------|
| 1     | 0-25   | Excellent       | P14, P9                |
| 2     | 26-50  | Good            | P17, P13, P6, P7       |
| 3     | 51-75  | Fair            | NIL                    |
| 4     | 76-100 | Poor            | P19, P18, P2, P4       |
| 5     | 101-150| Very poor       | P15, P3, P5            |
| 6     | 157    | Unfit for drinking | P20, P16, P1, P8, P10, P11, P12 |
4. Discussion-

The stagnant inland surface water sources are frequently subjected to an abrupt change in various environmental stressors due to changes in anthropogenic activities like habitat change, gentrification, industrialization, commercialization, or recreational activities. Urban ponds in Raipur city are facing immense pressure from increasing population density and gentrification which directly affects the pond water quality. The urban population of Raipur city increased from 1,139,172 in 2011 to 1,702,000. The population is increasing from an average rate of 3.5 % annually since 2010 [41].

A detailed study on the spatial and temporal variation of pond water quality is pertinent for conservation and rejuvenation efforts. Moreover, qualitative assessment of the pond water quality using WQI and TSI presents a summarised overview of the current status of the ponds which helps the authorities and masses for planning water quality management efforts. The present study is a part of a project where the long-term assessment of the inland water quality of Raipur city is being carried out. Here we present the physiochemical assessment of pond water in the post-monsoon winter season. Our findings confirm that the ponds lying in low-income group gentry, where the wastewater effluent is being discharged in the ponds are exhibiting high levels of nutrients, BOD, and COD. This is in line with the findings of earlier studies that have attributed the indiscriminate release of wastewater in the inland surface water body to their failing water quality [42, 43, 44].

The aesthetic and intrinsic value of the overall pond ecosystem decreases when the wastewater is discharged into the pond. Recreational ponds like Telebandha Pond which used to receive wastewater went through a restoration process. When the wastewater drains were stopped entering the pond, the water quality improved, thereby improving the aesthetic value. Now the pond serves as a waterfront and major recreational hotspot for the people of the entire city.

Variations in turbidity values followed variation in land use pattern with the maximum average value obtained in the vicinity of the recreational zone and minimum in the industrial and commercial zone. This variation may probably occur due to the direct disposal of solid waste and food waste by tourists. A slight high value of TH, MH, and CH was observed which can be explained by the dissociation of calcium carbonate, the release of calcium and magnesium from aquatic biota, and the use of calcium in aquaculture. The Calcium ion was observed to be higher than magnesium which can be attributed to the difference between the chemistry of calcium and magnesium mainly water solubility and precipitation rate. Further, the variation in the divalent cation species can be attributed the fact that aquatic flora have different utilisation rate for them.

The positive correlation between chlorophyll-a and dissolved oxygen suggests one possibility that increased chlorophyll-a values and related photosynthesis activities play a crucial role in the measured values of dissolved oxygen, particularly during winters. Significant increases in DO of surface water bodies are the result of phytoplankton growth activities. The low DO values in the LIG ponds can be attributed to wastewater discharge where older ponds still receive wastewater from the closed wastewater drains through seepage. The outlet drains are connected to the ponds at the bottom level which is manually not possible to observe [43].

A significant spatial variation in the nutrient levels exists within the subgroup and across the subgroup which is very alarming. The average nitrogen concentration in the ponds of LIG gentry is higher than others, however, ponds in the recreational zones have somewhat lower values. Maharajbandh pond is showing high nutrient values as the pond is constantly receiving sewage discharge from the Raipur city (Table 6). The Raja Pond in the HIG gentry is also exhibiting higher nutrient values still when compared with Maharajbandh Pond, the latter is greater which can mainly be attributed to factors such as difference in sewage discharge volumes, and quality of the wastewater.
Table 5. Nutrient and Chlorophyll-a value (average) across 4 pond categories.

| Pond Classification | TKN (mg/L) | Nitrate Nitrogen (mg/L) | Total Nitrogen (mg/L) | Phosphorus as PO43- (mg/L) | Chlorophyll-a (mg/m^3) |
|---------------------|------------|-------------------------|-----------------------|-----------------------------|------------------------|
| Commercial/Industrial | 15.2       | 17                      | 32.2                  | 7.662                       | 0.996                  |
| Recreational        | 5.708      | 17.4                    | 23.108                | 6.18                        | 0.628                  |
| High Income Group   | 10.674     | 19.86                   | 30.534                | 9.146                       | 1.008                  |
| Low Income Group    | 14.78      | 24.94                   | 39.72                 | 8.778                       | 1.076                  |

The increase in the nutrient levels especially nitrate could be due to occasional additions of the organic manure and other fish foods that are added to the ponds by fishermen or by the fish waste product discharged by them into the water. The decrease or low nutrient values reflect the possibility that these ponds are not receiving any form of sewage or receiving waste that have less concentration of nutrients [46,47].

The high value of the phosphate that is observed in all 3 pond groups except those in recreational habitat could be due to fertilizers, manure, street washing, and runoffs. Groundwater table polluted with phosphate could also be responsible for elevated phosphate values (Table 5). Ponds like Pahadi Pond are recharged by pumping groundwater which may contain phosphorus. The excessive use of fertilizers in urban habitats in public and private parks and gardens is introducing phosphorus to the groundwater. Another possibility for the elevated phosphorus might be due to a process called sediment reflux which is very high during the winter season. The sampling was carried out at the onset of the winter season so were through the process known as ‘winter stratification’ where the water in the ‘hypolimnion layer’ with high phosphorus content may get mixed with the ‘epilimnion layer’.

Figure 7. Correlation between Chlorophyll-a and (a) Phosphorus, (b) TKN, (c) Nitrate-Nitrogen, and (d) Total Nitrogen in the surface water of urban ponds.
On the contrary, the depletion of phosphate concentration could be due to its consumption by the phytoplankton family or due to the introduction of different particles having a high affinity for phosphorus, promoting phosphorus accumulation in the bottom sediments. Phosphate in freshwater habitats is correlated with dissolved oxygen and phytoplankton. A significant negative correlation between phosphate and chlorophyll-a was observed in this study which confirms that phosphorus concentration decreased with an increase in the phytoplankton family [48-51].

As far as the correlation between Chlorophyll-a value with the nutrient is concerned, a high correlation was observed. A significant correlation between TN and Chlorophyll-a is also observed which indicates that the ponds are receiving fresh sewage and high decay of the organic matter is happening in the ponds (Fig. 7). The ponds lying in the recreational zones are showing low nutrient value when compared with other groups. However, when compared with WHO standards for surface water, they are significantly higher. These ponds are tourist hotspots where people spend a considerable amount of time.

During sampling, a high volume of MSW was observed floating in surface water. Further, these ponds are prone to receiving kitchen waste from the food stalls catering the tourists which plausibly may introduce nutrients in the pond. One key point the authors would like to mention is that the ponds with a high recreational value that remains in the center of attraction receive much attention from municipal authorities where ponds like Budha and Telebandha enjoy periodic cleaning of the floating solid waste.

All the ponds except those in the recreational zone receive runoffs from street washing. These contain a high level of nutrients and organic matter. The street cattle and those from dairy farms discharge excreta and urine on the road surface which along with the organic matter in form of food waste discarded on the street gets mixed with street washing and enter the ponds.

Many criteria have been established that aid in classifying ponds and lakes using water transparency (turbidity, Secchi depth) algal biomass (chlorophyll-a), and nutrients (nitrogen and phosphorus species). The nutrient ratio (Total-N/Total-P) is widely used to elucidate the concentration of phytoplankton and nutrient availability. Total Phosphorus act as a limiting nutrient in ponds and lakes where TN/TP value is greater than 7, whereas below 7 indicates total nitrogen as a limiting factor for algal growth. For general use, TN/TP value less than 10 indicates a nitrogen shortage, and higher than 20 a phosphorus shortage. Lower TN/TP ratios occur in eutrophic lakes and are higher in mesotrophic and oligotrophic lakes. The urban ponds of Raipur city are showing a large variation in nutrient value. The TN/TP ratio varies between 1.62 and 10.50, while the average ratio is 5.02 which indicates TN to be the limiting nutrient. The algal blooms which signify eutrophication was observed in many ponds during sampling which was further confirmed using Chlorophyll-a value [52-57].

The quality of surface water is affected by many physical and chemical variables and rating the ponds mathematically which reflects overall water quality by combing all the relevant variables of concern helps scientists to communicate the complex findings to the stakeholders. During the present study, sixteen parameters were studied out of which 15 parameters were considered for calculation of WQI of the pond water using Horton’s method. The results indicate that the water quality of the pond ranged between Excellent (19.23%) at Telebandha pond and unfit for consumption (217%) at Mahrajbandh pond waters with being average of 86%.

The average WQI values of all the ponds were collectively classified as Poor and only fit for agriculture and irrigation purposes. The WQI allowed us to report and communicate our findings in a single number which enable stakeholders, policymakers, and even the public to evaluate the water quality and adopt preventive measures.

5. Conclusion-

In this study, variations in the water quality of different ponds in Raipur, Chhattisgarh, were examined in the post-monsoon winter season to observe and analyse the extent of water pollution. A successful attempt
was made to identify the ponds that are most affected by the anthropogenic activities and then correlated with the habitats where they are located. It was observed that most of the water pollution is caused by human-induced sources. This conclusion was made as it has been analysed that ponds near service roads, industries, agricultural fields, (Maharajbandh pond, Vyasa pond, Kari pond, Khamtari pond, Sarona pond) are more polluted and this was supported by the Water Quality Index (mathematical model) used for this study. Long-term monitoring of the water quality and trophic level of the urban pond is of utmost importance to adopt a comprehensive rejuvenation and conservation strategy. It was confirmed that ponds are having high pH and algal bloom, many ponds with acidic pH didn’t show any alarming situation as they are in the range of pH 6.5 which is ok with pond water. For majority of ponds turbidity was found about 5 NTU and above which shows presence of phytoplankton and other suspended solids in water indicating the increased nutrient inflow. DO is another parameter showing the health of pond, majority of ponds showed DO above 3 which is acceptable and is due to presence of phytoplankton due to higher photosynthetic activity as most of the samples were taken during the day time. Conductivity is also high showing substantial number of dissolved solids. TDS is in the range 300-500 which is acceptable above that will be an issue showing higher amount of suspended dissolved solid which can be a reason for salinity in pond water. Some of the pond water showed low level of alkalinity consuming the acidic effluent coming from industries. Phosphorus and nitrogen concentration is also high in majority of ponds showing continuous flow of detergent, or fertilizers used in gardens etc shows higher growth of phytoplankton. This conclusion showed the continuous anthropogenic activities are the very reason for this state of ponds. Long-term monitoring of the water quality and trophic activity of urban ponds is of utmost importance to adopt a comprehensive rejuvenation and conservation strategy.

References-

1. Swarnakar, A. K., & Choubey, S. (2016). Testing and analysis of pond water in Raipur City, Chhattisgarh, India. International Journal of Science and Research, 5(4), 1962-1965.
2. Nag, A. (2014). Physicochemical analysis of some water ponds in and around Santiniketan, West Bengal, India. International journal of environmental sciences, 4(5), 676-682.
3. Gupta, N., Yadav, K. K., Kumar, V., & Singh, D. (2013). Assessment of physicochemical properties of Yamuna River in Agra City. International Journal of ChemTech Research, 5(1), 528-531.
4. Hecky, R. E., & Fee, E. J. (1981). Primary production and rates of algal growth in Lake Tanganyika. Limnology and Oceanography, 26(3), 532-547.
5. Lu, H., Yin, C., Wang, W., & Shan, B. (2007). A comparative study of nutrient transfer via surface runoff from two small agricultural catchments in north China. Environmental Geology, 52(8), 1549-1558.
6. Fried, S., Mackie, B., & Nothwehr, E. (2003). Nitrate and phosphate levels positively affect the growth of algae species found in Perry Pond. Tillers, 4, 21-24.
7. Björn, L. O., Papageorgiou, G. C., & Blankenship, R. E. (2009). A viewpoint: why chlorophyll a? Photosynthesis research, 99(2), 85-98.
8. Fairchild, G. W., Anderson, J. N., & Velinsky, D. J. (2005). The trophic state ‘chain of relationships’ in ponds: does size matter?. Hydrobiologia, 539(1), 35-46.
9. Crossetti, L. O., & de M Bicudo, C. E. (2008). Phytoplankton as a monitoring tool in a tropical urban shallow reservoir (Garças Pond): the assemblage index application. Hydrobiologia, 610(1), 161-173.
10. Sharma, M. P., Kumar, A., & Rajvanshi, S. (2010). Assessment of trophic state of lakes: a case of Mansi Ganga Lake in India. Hydro Nepal: Journal of Water, Energy and Environment, 6, 65-72.
11. Kratzer, C. R., & Brezonik, P. L. (1981). A carlson-type trophic state index for nitrogen in Florida lakes. JAWRA Journal of the American Water Resources Association, 17(4), 713-715.
12. Sigua, G. C., Williams, M. J., Coleman, S. W., & Starks, R. (2006). Nitrogen and phosphorus status of soils and trophic state of lakes associated with forage-based beef cattle operations in Florida. Journal of environmental quality, 35(1), 240-252.
13. Bhateria, R., & Jain, D. (2016). Water quality assessment of lake water: a review. Sustainable Water Resources Management, 2(2), 161-173.
14. Gupta, A. P., Ranga, M. M., & Banerjee, A. Physico-chemical Properties of MouliBandh, Ambikapur, Sargujawith reference to Water Quality.
15. Keller, C., Guntzer, F., Barboni, D., Labreuche, J., & Meunier, J. D. (2012). Impact of agriculture on the Si biogeochemical cycle: input from phytolith studies. Comptes Rendus Geoscience, 344(11-12), 739-746.

16. Chen, B., Zhang, X., Tao, J., Wu, J., Wang, J., Shi, P., ... & Yu, C. (2014). The impact of climate change and anthropogenic activities on alpine grassland over the Qinghai-Tibet Plateau. Agricultural and Forest Meteorology, 189, 11-18.

17. Doi, H., Katano, I., Negishi, J. N., Sanada, S., & Kayaba, Y. (2013). Effects of biodiversity, habitat structure, and water quality on recreational use of rivers. Ecosphere, 4(8), 1-11.

18. Hill, M. J., Biggs, J., Thornhill, I., Briers, R. A., Gledhill, D. G., White, J. C., ... & Hassall, C. (2017). Urban ponds as an aquatic biodiversity resource in modified landscapes. Global change biology, 23(3), 986-999.

19. Balvanera, P., Pfisterer, A. B., Buchmann, N., He, J. S., Nakashizuka, T., Raffaelli, D., & Schmid, B. (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecology letters, 9(10), 1146-1156.

20. Jenny, J. P., Amnéville, O., Arnaud, F., Baulaz, Y., Bouffard, D., Domaizon, I., ... & Weyhenmeyer, G. A. (2020). Scientists’ warning to humanity: rapid degradation of the world’s large lakes. Journal of Great Lakes Research, 46(4), 686-702.

21. Rahman, A., Jahana, I., & Jolly, Y. N. (2021). Assessment of physicochemical properties of water and their seasonal variation in an urban river in Bangladesh. Water Science and Engineering.

22. Dixit, A. K. (2015). Study of physico-chemical parameters of different pond water of Bilaspur District, Chhattisgarh, India. Environmental Skeptics and Critics, 4(3), 89.

23. Akhtar, N., Ishak, M. I. S., Ahmad, M. I., Umar, K., Md Yusuff, M. S., Anees, M. T., ... & Ali Almanasir, Y. K. (2021). Modification of the water quality index (WQI) process for simple calculation using the multi-criteria decision-making (MCMD) method: a review. Water, 13(7), 905.

24. Adelagun, R. O. A., Eitim, E. E., & Godwin, O. E. (2021). Application of Water Quality Index for the Assessment of Water from Different Sources in Nigeria. Promising Techniques for Wastewater Treatment and Water Quality Assessment, 267.

25. Haingotseheno, R., Chrysostome, R. J., Robert, R., & Tojonirina, A. R. WATER QUALITY INDEX (WQI) CALCULATION FOR THE EVALUATION OF PHYSICO-CHEMICAL QUALITY OF RAINWATER COLLECTED IN RESERVOIRS FULL OF SAND (RFS).

26. Suneetha, M., Sundar, S. B., & Ravindranath, K. (2015). Calculation of water quality index (WQI) to assess the suitability of groundwater quality for drinking purposes in Vinukonda Mandal, Guntur District, Andhra Pradesh, India. Journal of Chemical and Pharmaceutical Research, 7(9), 538-545.

27. Bodhankar, N., & Chatterjee, B. (1994). Pollution of limestone aquifer due to urban waste disposal around Raipur, Madhya Pradesh, India. Environmental Geology, 23(3), 209-213.

28. Dar, F. A., Arora, T., Warsi, T., Devi, A. R., Wajihuddin, M., Grutzamer, G., ... & Ahmed, S. (2017). 3-D hydrogeological model of limestone aquifer for managed aquifer recharge in Raipur of central India. Carbonates and Evaporites, 32(4), 459-471.

29. Mukherjee R, Sahoo M, Naik KC (2011) Hydrogeological model of limestone aquifer for managed aquifer recharge in Raipur of central India. Journal of Che.

30. W.E.F. American Public Health Association (APHA) (2017). Standard Methods for the Examination of Water and Wastewater (23rd edition), Ameri.

31. Lambrou, T. P., Anastasiou, C. C., & Panayiotou, C. G. (2011). RAINWATER COLLECTED IN RESERVOIRS FULL OF SAND (WQI) CALCULATION FOR THE EVALUATION OF PHYSICO-

32. World Health Organization. (2017). Water quality and health—regulators and water suppliers.

33. Garg, S. K., &Bhatnagar, A. (1996). Effect of varying closes of organic and inorganic fertilizers on plankton production and fish biomass in brackish water fish ponds. Aquaculture research, 27(3), 157-166.

34. Boyer, J. N., Kelble, C. R., Ortner, P. B., & Rudnick, D. T. (2009). Phytoplankton bloom status: Chlorophyll a biomass as an indicator of water quality condition in the southern estuaries of Florida, USA. Ecological indicators, 9(6), S56-S67.

35. Prambyud, H., Supriyatin, T., & Setiawan, F. (2019, October). The testing of chemical oxygen demand (COD) and biological oxygen demand (BOD) of river water in Cipagar Cirebon. In Journal of Physics: Conference Series (Vol. 1360, No. 1, p. 012010). IOP Publishing.
36. Lee, J., Lee, S., Yu, S., & Rhew, D. (2016). Relationships between water quality parameters in rivers and lakes: BOD5, COD, NBOPs, and TOC. Environmental monitoring and assessment, 188(4), 1-8.
37. Nordin, R. N., Pommen, L. W., & Meays, C. L. (2009). Water quality guidelines for nitrogen (nitrate, nitrite, and ammonia). Water Stewardship Division, Ministry of Environment, Province of British Columbia, Canada, 1-29.
38. Khan, R., &Jhariya, D. C. (2017). Groundwater quality assessment for drinking purpose in Raipur city, Chattisgarh using water quality index and geographic information system. Journal of the geological society of India, 90(1), 69-76.
39. Jena, V., & Sinha, D. (2017). Physicochemical analysis of ground water of selected areas of Raipur city. Indian J. Sci. Res, 13(1), 61-65.
40. Dwivedi, S. L., & Pathak, V. (2007). A preliminary assignment of water quality index to Mandakini River, Chitrakoot. Indian Journal of Environmental Protection, 27(11), 1036.
41. Web article https://www.census2011.co.in/census/city/280-raipur.html
42. Shiddamallayya, N., & Pratima, M. (2008). Impact of domestic sewage on fresh water body. Journal of Environmental biology, 29(3), 303.
43. Kotut, K., Krienitz, K., & Muthuri, F. M. (1998). Temporal changes in phytoplankton structure and composition at the Turkwel Gorge Reservoir, Kenya. Hydrobiologia, 368(1), 41-59.
44. Otokunefor, T. V., & Obiukwu, C. (2005). Impact of refinery effluent on the physicochemical properties of a water body in the Niger delta. Applied ecology and environmental research, 3(1), 61-72.
45. Kant, S., Mandal, N. K., & Dubey, M. K. (2019). Impact of anthropogenic activities on physicochemical properties of water and sediment soil of a perennial pond of Godda District (SantallPargana), Jharkhand. Indian J Environ Sci, 23(2), 69-74.
46. Morée, A. L., Beusen, A. H. W., Bouwman, A. F., & Willems, W. J. (2013). Exploring global nitrogen and phosphorus flows in urban wastes during the twentieth century. Global biogeochemical cycles, 27(3), 836-846.
47. Okuku, E. O., Ohowa, B., Mwangi, S. N., Munga, D., Kiteresi, L. L., Wanjeri, V. O., ... & Kilonzo, J. (2011). Sewage pollution in the Coastal waters of Mombasa City, Kenya: A norm Rather than an Exception. International Journal of Environmental Research, 5(4), 865-874.
48. Soltan, M. E., Moalla, S. M. N., Rashid, M. N., & Fawzy, E. M. (2005). Physicochemical characteristics and distribution of some metals in the ecosystem of Lake Nasser, Egypt. Toxicological & Environmental Chemistry, 87(2), 167-197.
49. Romo, S., Miracle, M. R., Villena, M. J., Rueda, J., Ferriol, C., & Vicente, E. (2004). Mesocosm experiments on nutrient and fish effects on shallow lake food webs in a Mediterranean climate. Freshwater Biology, 49(12), 1593-1607.
50. Wu, X. Y., & Yang, Y. F. (2010). Accumulation of heavy metals and total phosphorus in intensive aquatic farm sediments: comparison of tilapia Oreochromis niloticus× Oreochromis aureus, Asian seabass Lates calcarifer and white shrimp Litopenaeus vannamei farms. Aquaculture Research, 41(9), 1377-1386.
51. Elçi, Ş. (2008). Effects of thermal stratification and mixing on reservoir water quality. Limnology, 9(2), 135-142.
52. Attayde, J. L., & Menezes, R. F. (2008). Effects of fish biomass and planktivore type on plankton communities. Journal of Plankton Research, 30(8), 885-892.
53. El-Serehy, H. A., Abdallah, H. S., Al-Misned, F. A., Al-Farraj, S. A., & Al-Rasheid, K. A. (2018). Assessing water quality and classifying trophic status for scientifically based managing the water resources of the Lake Timsah, the lake with salinity stratification along the Suez Canal. Saudi Journal of Biological Sciences, 25(7), 1247-1256.
54. Garg, S. K., & Bhatnagar, A. (1996). Effect of varying closes of organic and inorganic fertilizers on plankton production and fish biomass in brackish water fish ponds. Aquaculture research, 27(3), 157-166.
55. Egberi, J. C. (2020). Groundwater quality assessment using pollution index of groundwater (PIG), ecological risk index (ERI) and hierarchical cluster analysis (HCA): a case study. Groundwater for Sustainable Development, 10, 100292.
56. El-Serehy, H. A., Abdallah, H. S., Al-Misned, F. A., Al-Farraj, S. A., & Al-Rasheid, K. A. (2018). Assessing water quality and classifying trophic status for scientifically based managing the water resources of the Lake Timsah, the lake with salinity stratification along the Suez Canal. Saudi Journal of Biological Sciences, 25(7), 1247-1256.
57. Daniel, T. C., Sharpley, A. N., Edwards, D. R., Wedepohl, R., & Lemunyon, J. L. (1994). Minimizing surface water eutrophication from agriculture by phosphorus management.
58. Abbasi T, Abbasi SA. Water quality indices. Elsevier; 2012 Jun 13.