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Assessment of Water Quality Index of Pond Water of Phulwarisharif Area, Patna, India

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ABSTRACT
A pond is a natural or artificial, seasonal or perennial lentic water body. The ponds need periodic assessment for conservation and rejuvenation. Phulwarisharif is a block town of Patna, Bihar, India and includes the Patna Metropolitan region. An attempt was made to compare the present water quality of perennial Manikchand Pond and Phulwarisharif Pond, Phulwarisharif area, Patna using the Comprehensive pollution index (CPI), Overall pollution index (OPI) and Water quality index (WQI) during September 2022-August 2023 from 240 water samples and 10 sampling sites. To assess water quality, thirteen water quality parameters were measured using standard techniques during the post-monsoon, winter, summer, and monsoon seasons. Results indicated that the water quality had deteriorated and that the parameters exceeded BIS (2012) recommended limits are pH, dissolved oxygen, biochemical oxygen demand, total alkalinity, total dissolved solids, turbidity, nitrate and sulfate. The water quality parameters differ significantly ($p<0.05$), according to two-way ANOVA. The values of OPI (2.30 to 2.60) and CPI (1.60 to 1.70) without turbidity and with turbidity (2.40 to 2.70) and CPI (3.60 to 4.40) respectively indicate slightly polluted/polluted and slightly polluted/seriously polluted water in Phulwarisharif pond. But the values of OPI (1.54 to 1.88) and CPI (1.34 to 1.36) without turbidity and with turbidity (1.77 to 2.17) and CPI (3.07 to 3.93) respectively suggest acceptable/polluted and acceptable to slightly polluted/seriously polluted water in Manikchand pond. These indices confer that Phulwarisharif Pond is more polluted than Manikchand Pond. The present observation demonstrates that anthropogenic activity and the entry of untreated sewage are the main contributors to the decline in water quality. The water quality of these ponds felt the need to adopt proper management policies and conservation efforts to decrease the time-consuming and expensive water quality monitoring and assessment programmes.
Keywords: CPI, OPI, WQI, Physicochemical parameters, Manikchand Pond, Phulwarisharif Pond, India.

1. INTRODUCTION

Ponds are lentic water bodies that are smaller than lakes and can be natural or artificial, seasonal or perennial (Singh et al., 2015). Ponds have been used since time immemorial as a traditional source of water supply in India. The pond water is also used for irrigation, bathing, washing and animal drinking. Most of the cities and towns have developed in and around the bank of the pond because of the multipurpose use of pond water. The pond water is also affected due to pilgrims and ritual activities by the people living in the nearby areas (Gupta et al., 2011).

Human health, food production and economic development are directly impacted by water quality (Jha et al., 2020). For evaluating data on water pollution prediction and control as well as evidence for planning the sustainable use of water resources, monitoring water quality appears to be essential (Firoz, 2007; Mama et al., 2021). Once they exceed the clearly defined limits (BIS, 2012), it is deemed harmful and unsuitable for various human uses as well as other agricultural activities.

According to Kannel et al., (2007), one of the most useful tools for describing the water status of a given water body is the water quality index (WQI). WQI is non-generic and typically developed on site-specific guidelines for a particular region. The type of WQI indices depends on time, location, frequency of sampling, number, variety and weight allocation of physicochemical parameters. It helps in determining the overall water quality status of resources at a particular time and their suitability for different beneficial uses (Yogendra & Puttaiah 2008). As a result, there is uncertainty when a large volume of data on water quality is converted into a single index (Uddin et al., 2021; Chidiac et al., 2023).

Horton (1965) introduced the idea of WQI and since then, numerous water quality indices have been developed that can be used to evaluate the water quality in a specific area, including the Comprehensive Pollution Index (CPI), Overall Pollution Index (OPI), National Sanitation Foundation Water Quality Index (NSFWQI) (Brown et al., 1970; Pesce & Wunderlin 2000; Sargaonkar & Deshpande 2003; You et al., 2009; Matta et al., 2017). Debels et al., (2005) and Matta et al., (2000) have worked on the study of the WQI of various rivers. Water quality indices were used by Pesce & Wunderlin (2020) to confirm the effects of Cordoba City (Argentina) on the Suqu'a River. For periodic assessments, 23-WQI models (Schreiber et al., 2022) are reported.

According to scaling and a few physicochemical parameters, a novel industrial water quality index (IndWQI) model (Nsabimana & Li, 2021; Kumar et al., 2021) determines the overall industrial water quality. The concept of integrated approaches like Machine Learning (ML) algorithms like the M5P Model tree, Multivariate Adaptive Regression Splines (MARS) and Gene Expression Programming (GEP) has recently emerged due to the growing new hybrid soft computing techniques like machine learning and AI in the field of WQI development (Verma et al., 2019; Goodarzi et al., 2023).

Development of an OPI based on a general classification scheme (Sargaonkar & Deshpande 2003). The OPI is useful for expressing the state of water fitness under Indian conditions and for understanding the approximate pollution levels of surface water sources.

With numerous surface water quality applications, the CPI was created and launched on a global scale (Matta et al., 2017). To assess the degree of pollution in a water body, statistics from monitoring are used. Indian surface water consistency is primarily measured by the OPI and CPI (Matta et al., 2020).

Around the world and in India, various lentic water bodies, numerous researchers have conducted studies on water quality assessment using WQIs (Shardendu & Ambasht, 1988; Abdul et al., 2010; Maheshwari, 2010; Sinha et al., 2014; Dey et al., 2021; Pandit et al., 2022; Pandit et al., 2023; Ghosh & Panigrahi, 2023). On the other hand, there is no evidence in the literature of a study on the water quality index from Phulwarisharif, Patna, India.

Patna is the capital and largest city of the state of Bihar in India. It covers an area of 250 km^2 and has over 2.5 million population. It was once a significant agricultural centre and had a lot of ponds. The physicochemical parameters of different ponds in the Patna region have been studied previously (Rai & Diba, 2012; Kanth et al., 2018). Phulwarisharif is one of the blocks of the Patna sub-division and includes the Patna Metropolitan region. To establish appropriate management policies and conservation strategies for people in the future of the Manikchand Pond and

Phulwarisharif Pond, Phulwarisharif in Patna, India from September 2022 to August 2023, various methods will be used to (i) provide an appropriate picture of the current water quality, (ii) evaluate the physicochemical properties of the water and their seasonal/annual variations and (iii) calculate and establish WQI.

2. MATERIAL AND METHODS

2.1 Study area

Patna is the state capital of Bihar (Fig. 1 & 2) and is located between the coordinates **25.5941⁰N** and **85.1376⁰E**. During the summer, temperatures can reach 45°C. Phulwarisharif (25.5732⁰N and 85.0693⁰E) or Phulwari is located at a 10 km distance from Patna. Phulwarisharif has many natural perennial ponds, including Manikchand Pond, which serves as a landmark, as well as an old mosque and an Islamic spiritual dargah.

Figure 1 to 4: Study area

Manikchand Pond (25.57898⁰N and 85.09746⁰E) is a lovely place in Patna, located in the Anisabad area. It is 300' long, 300' wide and 15' deep with a built boundary. Chhatha Puja is one of the most eagerly awaited religious holidays in North and Eastern India. During this Puja, devotees pray to both the setting and rising Suns. Its water is twice yearly cleaned before the festival and is then left undisturbed (Fig. 3).

The Phulwarisharif Pond measures 300' long, 200' wide and 15' deep in the middle. Since earlier times, this pond has been deemed defunded and is no longer used for bathing or even for religious activities. It receives domestic waste and drainage water all year long (Fig. 4).

2.2 Sampling of water

A total of 240 Water samples were collected in triplicate from 10 selected sites of two selected ponds bimonthly at each site from a depth of 15 cm from September 2022 to August 2023. The data were later categorized into post-monsoon (September-November), winter (December-February), summer (March-May) and monsoon (June-August) seasons for interpretation. Each water sample was preserved and analyzed for thirteen parameters namely water temperature, pH, electrical conductivity, turbidity, dissolved oxygen, free carbon dioxide, total alkalinity, hardness, total dissolved solids, chloride, nitrate, sulfate, biochemical oxygen demand and using the standard methodology of APHA (2012) and organized in Table 1. The observed values (mean±SD) in seasonal and temporal variations in water qualities of Manikchand Pond and Phulwarisharif Pond are represented in Tables 2 to 3.

2.3 Statistical analysis

Graph Pad Prism 5 software was used to analyse the data for a central tendency. Tables 2 & 3 show the values (mean±SD) in the water qualities of Manikchand Pond and Phulwarisharif Pond for seasonal and temporal variations. Then, the correlation analysis and the two-way t-test at $p<0.05$ were calculated (Table 4).

2.4 Methods of Water Quality Assessment

2.4.1 The Comprehensive Pollution Index (CPI) (Liu & Zhu 1999): The CPI has been applied to classify the water quality by many of the research findings (Zhao et al., 2012; Matta et al., 2020). It is applied by taking into account the most important water quality parameters for which various government agencies have suggested a standard limit.

$$\text{CPI} = \frac{1}{n}\sum_{i=1}^{n}\frac{C_i}{S_i}$$

Table 5 provides the CPI ranges, the corresponding water quality status and their potential applications (Liu et al., 2010; Tiwary et al., 2017).

2.4.2 The Overall Pollution Index (OPI) (Sargaonkar & Deshpandey 2003): An OPI is calculated from the individual index values. OPI evaluates the general health of freshwater at the level of pollution in a particular water body, specifically in the Indian context, and the quality of the surface water. It is determined as the midpoint of the pollution index (*Pi*) for each variable and is written as:

$$\text{OPI} = \frac{\sum_{i=1} P_i}{n}$$

Where n = number of observing variables; Pi is calculated using the following equation:

$$Pi = \frac{Ci}{Si}$$

Ci = measured value of parameter number in water and Pi = the measured concentration of numerical value through various mathematical expressions for individual variables (Table 6).

2.4.3 The water quality index (WQI): It is used to comprehend the water quality of estuaries, rivers, ponds, lakes and reservoirs. The four equations below are used to calculate its value by applying the weighted arithmetic water quality index method as developed by Horton (1965), which multiplies water parameters by a weighting factor before aggregating the results using simple arithmetic mean:

$$\text{(i) WQI} = \frac{\sum_{i=1}^{n} q_i W_i}{\sum_{i=1}^{n} W_i}$$

Where, q_i= sub-index or water quality rating scale of the i^{th} parameter. w_i = Unit weight of the i^{th} parameter was an inverse proportional value to the recommended standard value of BIS (2012) of Si.

$$\text{(ii)} \quad q_i = \left(\frac{C_i - I_i}{S_i - I_i}\right) \times 100$$

Ci = the water suitability coefficient value or the observed value of the ith parameter, Ii = the ideal value of the ith parameter. Si = guideline value of the ith water quality parameter or the standard permissible value of the ith parameter

$$\text{(iii)}\ W_i = \frac{K}{Si}$$

i = number of parameters taken during observation. K = constant for proportionality.

K was calculated using the following equation:

$$\text{(iv)}\ K = \frac{1}{\Sigma}\left(\frac{1}{Si}\right)$$

In this experiment, the value of K was taken to be 1.234589.

The quality rating and unit weight were added to determine the total water quality index (WQI). If q_i = zero, there are no pollutants at all, while $0 < qi < 100$ implies that there are pollutants that exceed the standards (Ahmad 2014). The Ii is equal to zero for other parameters, including pH values of 7 and 14.6 mg/L of dissolved oxygen (Chowdhury et al., 2012; Prasad et al., 2019). To assess the relationship between various parameters, the analysed data were compared to the BIS (2012) standards and organised in Table 7.

3. RESULTS AND DISCUSSION

3.1 Assessment of variation of physicochemical parameters

The current study sheds light on the water quality of Manikchand Pond and Phulwarisharif Pond (Tables 2 and 3). The water temperature, pH, electrical conductivity, turbidity, DO, BOD, free CO_2, total hardness, nitrate and sulfate levels of these two ponds differed significantly (Table 4). pH, electrical conductivity, turbidity, DO, BOD, total alkalinity, TDS and nitrate levels in these two bodies of water exceed BIS limits (Table 6) (BIS, 2012).

3.1.1 The water temperature ranged from 19.0–34.4^{0}C, with the lowest 20.25±2.7^{0}C and the highest 30.10±3.4^{0}C at Phulwarisharif Pond. However, water temperatures ranged from 7.55 to 33.98°C, with the lowest being 11.42±3.40°C at Surajkund and the highest being 27.61±6.19 °C at Rani Pond in Aurangabad, Bihar (Pandit et al., 2022). Temperature change occurs on a daily and fortnightly as a result of various activities that can contribute to environmental changes caused by changes in the temperature of both surface water and groundwater, which are influenced by factors such as air temperature, humidity, wind, and solar energy (Ingole et al., 2009). The increase in water temperature from winter to monsoon season is inversely proportional to pH, DO, and BOD, but directly proportional to turbidity, conductivity, free CO_2, hardness, TDS, nitrate and sulphate (Smith et al., 2015).

3.1.2 The pH of the water was lowest (7.13±0.39) during the monsoon at Phulwarisharif Pond and highest (8.55±0.51) during the winter at Manikchand Pond showing a temporal increase in a decade (Rai & Diba, 2012). Pandit et al., (2022) found the lowest pH (6.59±0.32) at Rani Pond during the monsoon and the highest (7.57±0.13) at Surajkund during the winter Karbala and Kali ponds of Samastipur (Sinha et al., 2014), pH levels ranging from 6.50 to 8.00. Its concentration ranged from 7.69 to 8.30 mg/L in selected ponds in Patna (Kanth et al., 2018). The pH of a pond in Kerala ranged from 4.67 to 7.91 (Smith et al., 2015). A pH less than 6.5 causes the human body to stop producing vitamins, whereas a pH greater than 8.5 causes eye irritation and skin disorders (Gupta et al., 2017). pH has an inverse relationship with conductivity and TDS as observed in this study. The alkaline nature of water during the summer season may be due to lower levels of free CO_2 (Sinha et al., 2014).

3.1.3 The electrical conductivity of water is affected by changes in ion concentration, nutrient status and dissolved solids. From winter to monsoon seasons, it increased from 170.0±26.62 to 202.83±7.32 µmho/cm. The EC at Phulwarisharif Pond was lowest (140.0 µmho/cm) in June 2023 and highest (245.0 µmho/cm) in September and showed a temporal decrease in a decade (Rai and Diba, 2012). However, the EC of water at Surajkund and Rani Pond ranged from 429.88-876.19 µmho/cm in winter to 518.8-1049.5 µmho/cm in summer to 552.55-1099.7 µmho/cm in monsoon (Pandit et al., 2022). The presence of a large amount of dissolved inorganic substances in their ionised form is indicated by a higher EC. Kanth et al. (2018) determined that it ranged from 598µmho/cm at Mangal Pond to 1217 mho/cm at Ranipur Pond in Patna. In Kadapa, India, EC values ranging from 740 to 1930 µmho/cm have also been reported (Prasad et al., 2019). However, two Samastipur ponds had an EC range of 360.0-405.0 µmho/cm (Sinha et al., 2014). Water conductivity varies directly with temperature and is proportional to the amount of dissolved inorganic solids.

3.1.4 The amount of water that has lost its purity due to the presence of balanced colloidal particles is referred to as turbidity. It is calculated for a siliceous material suspension. It is also a measurement of the optical property of water that causes light to be absorbed or scattered (Kothari et al., 2021). It varies with the atmospheric conditions in surface water. In Phulwarisharif Pond, it ranged from 35.08 to 283.362.4 NTU. Pond water has the highest turbidity of 350 NTU during the monsoon. Ghosh & Panigarhi (2023) found that the turbidity of the Mundeswari River ranged from 8.1 to 220.7 NTU, with an average value of 82.09 NTU. Suspended solids in water, such as slits, clays, and industrial waste sewage, cause high turbidity. The presence of suspended particulate matter in water causes turbidity. These particles absorb light and raise the surface temperature of the water, resulting in low levels of dissolved oxygen.

3.1.5 The dissolved oxygen (DO) of water obtained during this study with a range of 5.30-12.4 mg/L is desirable for the growth of fauna and flora and showed an increasing trend in a decade (Rai & Diba, 2012). DO concentrations in selected ponds in Patna ranged from 3.8 to 6.3 mg/L (Kanth et al., 2018). During the monsoon, the lowest DO level of 7.36 ± 0.8 mg/L in Phulwarisharif Pond water was likely due to the lower oxygen-holding capacity of water at high temperatures and an increase in microorganism assimilation of biodegradable organic matter. A low DO of 5.41 ± 0.60 mg/L in Rani Pond water has also been reported (Pandit et al., 2022). Organic matter decomposition began at low levels of DO in water. The current study's findings were consistent with those of Pandit et al., (2022).

3.1.6 Domestic waste and human settlement areas in and around the pond/lake contribute to the presence of BOD in the water sample. BOD levels in Manikchand and Phulwarisharif Ponds ranged from 1.01 ± 0.6 to 2.31 ± 0.62 mg/L. However, Surajkund and Rani Pond have BOD levels ranging from 1.46 ± 0.48 to 5.52 ± 0.36 mg/L and Rani Pond had the lowest value of 1.01 during the post-monsoon season (Pandit et al., 2022). An earlier observation (Chatterjee, 1992) agreed with the lowest value of 1.0 mg/L during monsoon/post-monsoon and the highest value of 2.33 mg/L during winter. However, BOD levels were measured at two ponds in India, ranging from 27.0 to 34.0 mg/L (Sinha et al., 2014).

3.1.7 Almost all natural waters contain some CO_2, which they obtain from a variety of sources including (1) the atmosphere, (2) plant and animal respiration, (3) bacterial decomposition of organic matter and (4) groundwater inflow. The average free CO_2 of Manikchand Pond was 9.90 ± 4.80 mg/L, which was significantly higher than Phulwarisharif Pond (7.01 ± 2.55 mg/L) with a range of 0.01-20.4mg/L. Saha et al., (2017) reported a high value of free CO_2 ranging from 14.82 to 38.07 mg/L. Rai & Diba (2012) found free CO_2 levels ranging from 6.2 to 8.4mg/L in three ponds of Patna. It was relatively high during the monsoon months, which could be attributed to faster organic matter decomposition and high temperature (Shinde et al., 2010). The increase in CO_2 causes a decrease in pH as observed in this study. The findings of the current study were consistent with those of Shinde et al., (2010) and Saha et al., (2017).

3.1.8 Total alkalinity ranged between 12.0 and 250 mg/L, with an average of 232.0±22.1 mg/L. The increased photosynthesis and carbon dioxide use in Manikchand Pond water may be due to increased photosynthesis and carbon dioxide use (BIS, 2012; Patil et al., 2018). Surajkund and Rani Pond also had an annual range of total alkalinity ranging from 92.6 to 277.1 mg/L (Pandit et al., 2022). The highest total alkalinity of water during the summer as observed in this work had previously been reported (Ghosh, 2018). Its concentration in Patna ranged from 204 to 408 mg/L (Kanth et al., 2018). A total alkalinity range of 38-210mg/L was earlier calculated in Andhra Pradesh (Prasad et al., 2019). High alkalinity indicates the presence of highly alkaline wastewater and sewage. Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, NH_4^{+} and Fe^{+2} react with CO_3^{-2} or HCO_3^{-} or occasionally OH^{-} to produce total alkalinity. Living organisms and organic waste degradation also cause an increase in carbonate and bicarbonate levels, which raises alkalinity. High alkalinity is beneficial to the body's internal environment, whereas low alkalinity promotes disease growth.

3.1.9 The ability of water to react with detergent is defined as its hardness. It is the impact of dissolved minerals (size <2μ) on the suitability of water for domestic, industrial, and drinking purposes (Deepa et al., 2016). Pond water became hard due to the presence of sulphates and chlorides of Ca and Mg. During the winter, the highest hardness value of Manikchand Pond was 171.30±18.1 and 177.80±18.1 of Phulwarisharif Pond had a range of 130.0-187.0 mg/L showing a temporal decrease in a decade (Rai & Diba, 2012). However, a hardness range of 165.0-180.0 mg/L was calculated for two ponds in Samastipur (Sinha et al., 2014). Kanth et al.,(2018) measured its concentration ranging from 148 to 384 mg/L in selected ponds in Patna. Average annual hardness values of 96.53-193.87 mg/L of Surajkund and Rani Pond (Pandit et al., 2022). High hardness values are most likely due to the regular addition of large quantities of detergents used by nearby residential areas that drain into water bodies.

3.1.10 Total dissolved solids (TDS) are the various types of dissolved solids that can be organic or inorganic (Jayakumar et al. 2009). During the current study, the maximum TDS value was recorded in Manikchand Pond (1200.0±51.0 mg/L) during monsoon and the lowest (655.5±20.8 mg/L) in Phulwarisharif Pond during winter. Water with TDS levels of more than 1000 mg/L is unpalatable as drinking water. Maximum TDS during the monsoon and minimum during the winter corresponds to earlier findings (Narayan et al., 2007). Mangal Pond with the lowest TDS value of 390 mg/L, while Ranipur Pond in Patna has the highest TDS value of 793 mg/L which was earlier recorded (Kanth et al., 2018). The mean TDS values of Surajkund and Rani Pond, on the other hand, ranged from 133.6 to 515.65mg/L during the winter, 161.68 to 644.13mg/L during the summer, and 155.2 to 607.83mg/L during the monsoon (Pandit et al., 2022). TDS is said to be proportional to the level of pollution (Bharathi & Krishnamoorthy 1990). EC and TDS are salinity hazard measures that determine the suitability of water for irrigation (Singh et al., 2020).

3.1.11 The amount of chloride ion (Cl^{-}) in this study ranged from 6.0 to 50.41 mg/L. During the post-monsoon season, Manikchand Pond had the highest Cl^{-} of 50.41 mg/L showing a temporal increase in a decade (Rai & Diba, 2012). Cl^{-} levels in selected ponds in Patna ranged from 40 to 100 mg/L (Kanth et al., 2018). Earlier research, however, discovered a Cl^{-} range of 155.0-180.0 mg/L for two Samastipur ponds (Sinha et al., 2014). Cl^{-} levels in Surajkund and Rani Pond water ranged between 11.22-11.34; 14.89-15.01; and 14.33-14.43 mg/L during the winter, summer, and monsoon seasons, respectively, compared to an annual range of 10.28-16.98 mg/L (Pandit et al., 2022). As previously observed (Arya et al., 2011), the Cl^{-} in water decreased from summer to winter. Excess Cl^{-} decreases dissolved oxygen content, which is detrimental to aquatic organisms (Deepa et al., 2016). The Cl^{-} has a positive correlation with pH and TDS also observed in this study. Because Cl^{-} is easily movable, it is simply moved out to close water during a rainstorm. Many water-regulating agencies all over the world use Cl^- to monitor the contamination levels of rivers and potable water sources.

3.1.12 Nitrate influences aquatic ecosystem productivity. Nitrate levels in Manikchand and Phulwarisharif Pond water ranged from 21.0 to 250.0 mg/L during this study. It was worse during the monsoon season. The annual ranges of nitrate in Surajkund and Rani Pond water were 1.06-11.18, 1.22-11.30 and 1.43-11.80 mg/L during winter, summer and monsoon seasons respectively (Pandit et al., 2022). However, a range of 42.0-51.0 mg/L was discovered in two Samastipur ponds (Sinha et al., 2014). The amount of nitrate in the water is determined by local runoff or seepage from agricultural fields, decayed vegetables, municipal, domestic, and industrial activities, animal feedlots, private or urban sewage disposal, and plant debris (Lodh et al., 2014). High nitrate levels in drinking water pose a health risk to infants because they may cause Methemoglobinemia or “blue baby syndrome”.

3.1.13 Sulphate levels in Phulwarisharif pond are highest (235.2 ± 28.1 mg/L) during the monsoon season and lowest (118.3 ± 98.4 mg/L) during the summer season with a range of 112-250 mg/L. According to Ghosh & Panigarhi (2023), the sulphate level in the Mundeswari River ranged from 10.42 to 110.45 mg/L. Sulphate is primarily produced by the bacterial decomposition of sulphur compounds, atmospheric deposition, and the use of sulphur-containing fertilisers in the catchment (Sener et al., 2017).

3.2Calculation of Comprehensive Pollution Index (CPI)

Because of the high turbidity levels in Manikchand and Phulwarisharif Ponds, the CPI, OPI and WQI values were divided into two categories: (i) with and (ii) without turbidity.

The CPI was calculated by considering the most important water quality parameters for which various government agencies have proposed a standard limit (Table 5) (Liu & Zhu 1999).

3.2.1 CPI with turbidity

Manikchand Pond and Phulwarisharif Pond had average CPI of 3.07 and 3.6, with ranges of 1.84-5.93 and 2.05-6.50 respectively (Tables 8-9). With a range of category 5-6 (1.01-2.00 or $\geq$2.01) or polluted or seriously polluted, the average value indicates that the water in Manikchand Pond and Phulwarisharif Pond is classified as category 6 ($\geq$2.01) or seriously polluted

3.2.2 CPI without turbidity

The average CPI of Manikchand Pond and Phulwarisharif Pond was 1.34 and 1.60, respectively, with a range of 1.23-1.45 and 1.4-1.9 (Tables 5-6). The average and range of values indicate that the water in Manikchand and Phulwarisharif Ponds is polluted and belongs to category C5 (1.00-2.00).

The CPI for River Chambal in Madhya Pradesh, India was found to be in the range of 0.52 to 0.66 (Yadav et al., 2018) indicating water category 3 (0.41-0.80) or slightly polluted. According to Son et al., (2020), the CPI of the Cau River in China ranged from 0.50 to 1.57 with an average value of 1.08 for categories 3-5 ($0.41 < CPI < 2.00$) treating water to be slightly polluted to polluted. From Harshhil to Haridwar, CPI revealed sub-clean to slightly polluted Ganga water (Das et al., 2022).

3.3. Calculation of Overall Pollution Index (OPI)

It is simple to calculate and adapt to changes in physicochemical parameters. The standards (Table 6) were followed to calculate the OPI (Sargaonkar & Deshpande, 2003). Turbidity has the least impact on OPI calculation.

3.3.1 OPI with turbidity

The OPI of Manikchand Pond and Phulwarisharif Pond was 1.77 and 2.4 respectively, with a range of 1.58-2.17 and 2.2-2.6 (Tables 8-9). The average value indicates that the water in Manikchand and Phulwarisharif Ponds is Class C3 (2 < OPI < 3.9), indicating that it is slightly polluted. Surajkund and Rani Pond OPIs were found to be 3.3 and 2.325 respectively with a range of 2.7-3.7 and 1.9—2.7 during the summer season, indicating that the water in these ponds is classified as Class C3 (2 < OPI < 3.9) or slightly polluted (Pandit et al., 2023)

3.3.2 OPI without turbidity

The OPI of Manikchand Pond and Phulwarisharif Pond was found to be 1.54 and 2.3, with a range of 1.45-1.54 and 2.1-2.4 respectively (Tables 8-9). The average value indicates that the water in Manikchand Pond is Class C2 (1 < OPI < 1.9) or acceptable and Phulwarisharif Pond is classified as Class C3 (2 < OPI < 3.9) or slightly polluted. The OPI of Surajkund and Rani Pond was found to be 3.28 and 2.13 during the summer season indicating that the water in Surajkund and Rani Pond is classified as Class C3 (2 < OPI < 3.9) or slightly polluted (Pandit et al., 2023). A study found that the water quality of the Ganga River was acceptable in summer C3 (2 < OPI < 3.9) in Haridwar, India (Kamboj & Kamboj, 2019).

3.4 Calculation of water quality index (WQI)

The WQIwas ascertained utilizing the weighted arithmetic index equations specified previously and the values are presented in Tables 8-9 showing the monitored values (C_i) of the selected thirteen/twelve water quality parameters, standard values (S_i), unit weight (W_i), sub-index water quality rating (Q_i) and $W_i Q_i$ (Mohanty, 2004; Ramakrishnaiah et al., 2009; Yadav et al., 2010; BIS, 2012). It appears that turbidity is important in calculating the WQI.

3.4.1 WQIwith turbidity

The average WQI of 713.56-988.39 of Manikchand Pond and 803.3-990.1 of Phulwarisharif Pond indicate an unsuitable water category (E) (Table 7). Rani-Pond had an average WQI of 215.52-398.20, indicating that it was in the very poor (D) to unsuitable water category (E), whereas Sundarkund was in the poor (C) to unsuitable water category (E) (Pandit et al., 2022). In terms of seasons, the WQI of Manikchand Pond and Phulwarisharif Pond in the post-monsoon, winter, summer, and monsoon seasons were 595.74-818.9, 353.06-352.2.3, 378.04-420.1, and 1520.4-1621.8, respectively. Seasonal values of WQI at Manikchand and Phulwarisharif Ponds also indicate that the water is of the unsuitable water category (E).
With a turbidity of 312.1-387.4, the WQI classified the Al-Gharraf River in southern Iraq as unsuitable (E) (Ewaid and Abed, 2017).

3.4.2 WQI without turbidity

The average WQI of Manikchand Pond is 166.4-190.06, indicating poor water category (C) and 197.6-205.7 indicating poor (C) to very poor (D) water category (Table 7). The average WQI of Surajkund of WQI of 84.78-106.55 indicated a good (B) to just poor water category (C), whereas Rani Pond, Aurangabad, Bihar, India of 174.44-192.93 indicated a poor water category (C) (Pandit et al., 2022). In terms of seasons, the WQI of Manikchand Pond and Phulwarisharif Pond ranged between 173.24-181.9, 172.02-179.8, 161.57-173.6, and 159.72-225.1 during the post-monsoon, winter, summer, and monsoon seasons, respectively. Seasonal WQI values for Manikchand and Phulwarisharif Ponds indicate poor (C) to very poor (D) water quality.

During the winter, summer, and monsoon seasons, the WQI range of two Samastipur ponds was between 100.84 and 103.09; 106.88 and 127.10; and 96 to 99.37, indicating good (B) to poor (C) water quality (Sinha et al., 2010). The Al-Gharraf River in south Iraq was classified as excellent (A) to good (B) by the WQI without turbidity of 43.0-88.7 (Ewaid & Abed, 2017). Sudarshan et al. (2019) calculated the WQI of Hebal Lake in Bangalore, India, for its good (B) to poor (C) category. In addition, a WQI range of 33.65-125.73 was discovered in Obulavaripalli, Kadapa, India, indicating the excellent (A) to poor (C) category (Prasad et al., 2019)

All of these WQI values indicate that the water quality is poor to very poor, making it unfit for drinking. Previous findings support the same trend and closer values of physicochemical parameters found in this study (Sinha et al., 2014). The WQI values obtained indicate that untreated pond water is of low quality and must be thoroughly treated before use to avoid water-related illnesses.

4. CONCLUSION

Seasonal variations in various physicochemical parameters of Manikchand and Phulwarisharif Ponds were studied to calculate CPI, OPI and WQI. The CPI values without and with turbidity indicate that the water in these ponds is polluted to heavily polluted. Furthermore, OPI values without and with turbidity indicate that the water in these ponds is clean to slightly polluted. Finally, the WQI without and with turbidity confirms that the water is poor to unsuitable. Based on the findings of this study, it is possible to conclude that effective measures are required to prevent contaminated water from entering these bodies of water and to improve the overall water quality of these bodies of water.

We recommend (i) Further research on the targeted area to shed more light on this critical area. (ii) Some parameters must be added to cover as much of the current state of these ponds as possible. (iii) Develop a strategic plan to educate residents about the pollution that they produce (iv) Prevent and save our environment from this critical issue and (v) Launch an environmental programme ranging from primary school to decision-makers, involving all stakeholders in pollution prevention and mitigation.

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Table 1 Measurement methods for the water quality parameters

Sl. No.	Parameters	Unit	Method	Site of measurement	Sl. No.	Parameters	Unit	Method	Site of measurement
1.	Water temperature	^0C	Thermometric method	*in situ*	2.	pH	-	Portable pH meter	*in situ*
3.	Electric Conductivity	µmho/cm	Conductivity meter	In the Laboratory	4.	Turbidity	NTU	Nephelometric method	
5.	Dissolve oxygen	mg/L	Winkler's volumetric method	,,	6.	Biochemical Oxygen Demand			In the Laboratory
7.	Free carbon dioxide	,,		,,	8.	Total alkalinity	,,	Titration method	,,
9.	Hardness	,,	EDTA method	,,	10.	Total dissolved solid	,,	Temperature controlled oven	,,
11.	Chloride	,,	Silver nitrate method	,,	12.	Nitrate	,,	Cadmium reduction method	,,
13.	Sulfate	,,		,,					

Table 2 Physicochemical parameters of water of Manikchand Pond, Phulwarisharif during September 2022 to August 2023

Season (Months)		Water Temp. (^0C)		pH		Conductivity (µmho/cm)		Turbidity (NTU)		DO (mg/L)		BOD (mg/L)		Free CO_2 (mg/L)		TA (mg/L)		Hardness (mg/L)		TDS (mg/L)		Chloride (mg/L)		Nitrate (mg/L)		Sulfate (mg/L)	
Post-monsoon (Sept-Nov)		24.24±3.2		8.47±0.52		179.0±10.12		85.17±65.6		9.69±1.56		1.34±0.6		6.96±2.66		177.56±20.5		154.17±8.9		1070.0±40.1		35.86±7.0		48.6±6.7		166.8±9.8	
Winter (Dec-Feb)		22.08±1.3		8.56±0.51		170.0±26.62		38.75±11.4		10.82±1.5		1.71±0.6		3.64±3.12		179.76±14.8		171.30±18.1		990.0±50.8		32.79±4.9		30.5±8.4		177.8±8.9	
Summer (Mar-May)		25.85±4.4		8.41±0.69		186.3±39.6		43.3±9.4		9.13±1.5		1.11±0.7		8.29±4.57		234.67±17.2		153.0±17.2		1140.0±41.1		39.83±7.2		49.2±5.7		128.5±12.8	
Monsoon (June-Aug)		27.47±4.2		7.80±0.82		192.2±24.64		276.0±53.9		7.71±1.7		1.01±0.6		10.7±3.48		222.0.±22.1		146.0±12.49		1200.0±51.0		38.04±3.1		72.8±5.1		191.9±8.2	
Mean		24.91±1.99		8.31±0.34		184.25±9.81		110.8±97.1		9.34±1.29		1.29±0.27		9.90±4.80		203.5±29.16		156.12±10.7		1100.0±90.6		36.63±2.63		50.28±15.02		151.23±29.71	
Range	Value	19	34.1	7.02	9.6	158	205	25	350	5.8	12.4	1.0	2.4	0.1	20.4	130	250	130	187	901	1263	6	50.41	21.0	80.6	116	218
	Month	Nov	May	May	9.6	Nov	Apr	Dec	Aug	Jun	Dec	Nov	Jul	Jan	May	Jan	Apr	Nov	Jul	Jul	Oct	Dec	Sep	Jun	Jan	Dec	May

Table 3 Physicochemical parameters of water of Phulwarisharif Pond, Phulwarisharif during September 2022 to August 2023

Season (Months)		Water Temp. (^0C)		pH		Conductivity (µmho/cm)		Turbidity (NTU)		DO (mg/L)		BOD (mg/L)		Free CO_2 (mg/L)		TA (mg/L)		Hardness (mg/L)		TDS (mg/L)		Chloride (mg/L)		Nitrate (mg/L)		Sulfate (mg/L)	
Post-monsoon (Sept-Nov)		26.42±3.1		8.13±0.29		192.5±23.76		128.8±71.2		8.14±1.7		1 46±0.68		7.96±4.8		166.3±12.1		155.3±6.3		687.9±40.1		18.78±3.5		142.5±26.8		164.3±29.1	
Winter (Dec-Feb)		20.25±2.7		8.23±0.51		180.5±27.54		35.0±8.7		10.71±1.9		2.33±0.62		3.04±1.8		138.6±8.7		177.8±18.1		655.6±20.8		18.69±1.9		79.32±68..3		173.3±10.4	
Summer (Mar-May)		27.13±2.5		8.07±0.83		198.7±2.87		50.0±9.3		8.92±1.3		1. 31±0.64		6.96±2.6		171.6±17.6		148.74±23.8		772.3±31.1		23.05±7.1		144.5±32.1		118.3±98.4	
Monsoon (June-Aug)		30.10±3.4		7.13±0.39		202.8±37.32		283.3±62.4		7.36±0.8		1.26 ±0.24		10.07±5.17		123.13±23.4		143.3±2.48		1005.2±41.4		25.9±8.5		210.0±15.2		235.2±28.1	
Mean		25.97±3.58		7.89±0.51		193.0±9.59		124.3±98.5		8.78±1.43		1.59±0.43		7.01±2.55		149.9±23.0		158.8±17.5		780.3±157.4		21.61±3.04		144.08±46.2		172.72±41.6	
Range	Value	19.0	34.4	7.1	9.1	140	245	30	350	5.3	12.3	1	2.6	0.01	19.1	12.0	186	140	184	650	1110	6	46.41	76	250	112	250
	Month	Dec	May	May	Aug	Jun	Sep	Dec	Jun	Jun	Nov	Jul	Mar	Jan	Aug	Dec	May	Aug	Mar	Aug	Jun	Mar	Sep	Jun	Dec	Dec	May

Table 4 Comparison of values of physicochemical parameters of water of Manikchand Pond V/S Phulwarisharif Pond, Phulwarisharif, Patna, India (Tabulated r at df: 3 = 0.878 at 5%, 959 at 1% and 991 at 0.1% level and tabulated t at df: 6 and 2.45 at 5%, 3.71 at 1% and 5.96 at 0.1% level).

Parameters	Manikchand Pond V/S Phulwarisharif Pond				Parameters	Manikchand Pond V/S Phulwarisharif Pond			
	Calculated r value	Level of significance	Calculated t value	Level of significance		Calculated r value	Level of significance	Calculated t value	Level of significance
WT (^{0}C)	0.934	p<0.05*	3.69	P<0.05*	pH	0.998	P<0.001***	22.18	P<0.001***
Cond. (µmho/cm)	0.981	P<0.01*	7.32	p<0.001***	DO (mg/L)	0.884	p<0.05*	2.68	P<0.05*
BOD(mg/L)	0.951	P<0.05*	4.34	P<0.01**	Free CO_2 (mg/L)	0.944	P<0.05*	3.46	P<0.05**
Total alkalinity (mg/L)	0.01	p>0.05^{NS}	0.143	p>0.05^{NS}	Total hardness (mg/L)	0.978	p<0.01**	6.61	p<0.001***
Total dissolved solid (mg/L)	0.812	P>0.05^{NS}	1.97	P>0.05^{NS}	Chloride (mg/L)	0.752	p>0.05^{NS}	1.614	p<0.05^{NS}
Nitrate (mg/L)	0.997	p<0.001***	18.13	p<0.001***	Sulfate (mg/L)	0.933	p<0.05*	3.66	P<0.05*
Turbidity (NTU)	0.966	p<0.01**	5.28	P<0.01**					

(*=Significant, **=Moderately Significant, ***= Highly Significant)

Table 5 Water category based on Comprehensive Pollution Index (CPI)

Sl. No.	Water Category	Comprehensive Pollution Index (CPI)	Classification of water	Sl. No.	Water Category	Comprehensive Pollution Index (CPI)	Classification of water
1.	Category 1	0 to 0.20	Clean	2.	Category 2	0.21 to 0.40	Sub-clean
3.	Category 3	0.41 to 0.80	Qualified (Slightly polluted)	4.	Category 4	0.81 to 1.00	Basically qualified (Moderately polluted)
5.	Category 5	1.01 to 2.00	Polluted	6.	Category 6	≥ 2.01	Seriously (heavily) polluted

Table 6 Overall Index of Pollution (OIP) of water (Sargoankar and Deshpande, 2003; modified after BIS, 2012:IS-10500)

Category	OIP Index	Class	pH	E. Cond. (µmho.cm^{-1})	DO (mg.L^{-1})	BOD (mg.L^{-1})	HA (mg.L^{-1})	Free CO_2 (mg.L^{-1})	TA (mg.L^{-1})	TDS (mg.L^{-1})	Sulfate (mg.L^{-1})	Cl^- (mg.L^{-1})	Nitrate (mg.L^{-1})	Turbidity (NTU)
Excellent	0-1	C1	6.5–7.5	500	9.5-10.5	1.5	75	NA	75	500	150	150	20	5
Good (Acceptable)	1-2	C2	6.0–6.5 and 7.5–8.0	750	8.5-11.5	3	150	NA	150	1500	250	250	45	10
Slightly polluted	2-4	C3	5.0–6.0 and 8.0–9.0	1000	6.5-12.5	6	300	NA	300	2000	400	600	50	100
Polluted	4-8	C4	4.5–5.0 and 9.0–9.5	2000	3.0-15.5	12	500	NA	500	3000	1000	800	100	250
Heavily polluted	8-16	C5	<4.5 and >9.5	>2000	<3.0 and >15.5	24	>500	NA	>500	>3000	>1000	>800	200	>250

Table 7 Water Quality Scale

Sl. No.	Water Category	Mohanty (2004)	Ramakrishnaiah (2009)	Yadav et al, (2010)	Sl. No.	Water Category	Mohanty (2004)	Ramakrishnaiah (2009)	Yadav et al, (2010)
1.	Excellent	<50	<50	0-25	2.	Good	50-100	50-100	26-50
3.	Poor	100-200	100-200	51-75	4.	Very poor	200-300	200-300	76-100
5.	Unsuitable	>300	>300	>100					

Table 8 Calculation of OPI, CPI and WQIof ManikchandPond, Phulwarisharif, Patna, India (A=Post-monsoon/Annual mean, B=Winter/Minimum, C=Summer/maximum and D=Monsoon) (K = 1.234598).

Sl. No.	Parameters	Season/ Annual		Standard Value (Si) (BIS)	Ideal value (Ii)	Observed values (Mi)		Sub index (Qi)		OPI Score		CPI Score		Unit weight (Wi)=K/Si	Wi x Qi	
						Seasonal	Annual	Seasonal	Annual	Seasonal	Annual	Seasonal	Annual		Seasonal	Annual
1.	pH	A B C D	A B C	7.5	7.0	8.47 8.56 7.81 7.10	7.98 7.02 9.60	294.10 312.10 162.10 20.0	228.0 4.0 520.0	3 3 2 1	2 1 8	1.13 1.14 1.05 0.95	1.06 0.94 1.28	0.1646	48.39 51.35 26.66 3.29	37.53 0.66 85.59
2.	Conductivity	A B C D	A B C	500	0	158.0 177.0 267.3 185.2	182.6 140.0 255.0	31.6 35.4 53.5 37.6	36.5 29.6 51.0	1 1 1 2	1 1 1	0.32 0.35 0.53 0.38	0.36 0.30 0.51	0.1685	5.32 5.96 9.01 6.34	6.15 4.99 8.59
3.	**Turbidity**	**A B C D**	**A B C**	**5**	**0**	**85.17 38.75 43.30 276.0**	**110.8 25.0 350.0**	**1714.0 775.0 866.0 5520.0**	**2216.0 500.0 7000.0**	**4 3 3 9**	**4 2 10**	**17.03 7.75 8.66 55.2**	**22.16 5.0 70.0**	**0.2465**	**422.50 191.04 213.47 1360.68**	**546.24 123.25 1725.50**
4.	DO (mg/L)	A B C D	A B C	6	14.6	10.09 10.42 9.13 6.91	9.15 5.80 12.4	168.17 173.67 152.17 115.17	152.5 96.7 205.0	1 2 1 2	1 5 4	1.68 1.74 1.52 1.15	1.53 0.97 2.07	0.2057	34.59 35.72 31.30 23.69	31.37 19.89 42.17
5.	TA (mg/L)	A B C D	A B C	75	0	177.9 179.8 234.7 222.0	203.5 130 250.0	236.75 239.68 312.89 291.00	271.3 173.3 333.3	2 2 3 3	3 2 3	2.37 1.40 3.13 2.96	2.71 1.73 3.33	0.0164	3.88 3.93 5.13 4.85	4.44 2.84 5.47
6.	HA (mg/L)	A B C D	A B C	75	0	154.2 146.1 153.0 171.3	156.1 130.0 180.0	205.56 194.67 204.00 228.40	208.16 173.33 248.00	2 2 3 2	2 2 3	2.06 1.95 2.04 2.28	2.08 1.73 2.40	0.0164	3.87 3.19 3.35 3.75	3.41 2.84 3.94
7.	TDS (mg/L)	A B C D	A B C	500	0	990.0 1140.0 1070.0 1200.0	1100.0 900.0 1260.0	198.0 228.0 214.0 240.0	220.0 180.0 252.0	2 2 2 2	2 2 2	1.98 2.28 2.14 2.40	2.20 1.80 2.52	0.0025	0.49 0.57 0.54 0.60	0.55 0.45 0.63
8.	Cl^- (mg/L)	A B C D	A B C	150	0	35.86 32.79 39.83 38.04	36.63 6.0 50.41	23.9 21.9 26.5 25.4	24.4 4.0 33.6	1 1 1 1	1 1 1	0.24 0.22 0.26 0.25	0.24 0.04 0.34	0.0082	0.20 0.18 0.22 0.21	0.20 0.03 0.27
9.	NO_3^- (mg/L)	A B C D	A B C	20	0	49.2 48.6 30.5 72.8	50.28 25.0 80.0	246.0 243.0 152.5 364.0	251.4 125.0 400.0	2 2 2 3	2 2 3	2.46 2.43 1.52 3.64	2.51 1.25 4.00	0.0617	15.18 15.00 9.41 22.46	15.52 7.71 24.68
10.	Free CO_2 (mg/L)	A B C D	A B C	0	0	6.96 3.64 10.70 8.29	9.90 0.10 20.4	7.96 3.04 6.94 10.07	7.01 0.01 19.1	0	0	0	0	0	0	0
11.	Sulfate (mg/L)	A B C D	A B C	150	0	166.8 177.8 191.9 126.5	151.2 116.0 210.0	111.2 118.5 127.9 85.7	100.8 77.3 140.0	1 1 1 1	1 1 2	1.11 1.18 1.28 0.86	1.01 0.77 1.40	0.0082	0.91 0.97 1.05 0.70	0.83 0.63 1.15
12.	BOD (mg/L)	A B C D	A B C	1.5.	0	1.11 1.01 1.36 1.71	1.29 1.00 2.40	74.0 67.0 91.0 114.0	86.0 67.0 160.0	1 1 1 1	1 1 2	0.74 0.67 0.91 1.14	0.86 0.67 1.60	0.8231	60.91 55.15 74.90 93.83	70.79 55.15 131.70
		A B C D	A B C						Mean	1.54 (**1.67**) 1.64 (**1.67**) 1.45 (**1.58**) 1.54 (**2.17**)	1.45 (**1.67**) 1.64 (**1.67**) 2.54 (**3.17**)	1.23 (**2.59**) 1.38 (**1.84**) 1.31 (**1.92**) 1.45 (**5.93**)	1.32 (**3.06**) 0.98 (**1.27**) 1.77 (**7.45**)	ΣWQI	173.24 (**595.74**) 172.02 (**353.06**) 161.57 (**378.04**) 159.72 (**1520.4**)	170.79 (**717.03**) 75.19 (**218.44**) 304.19 (**2029.1**)
Average of OPI, CPI and WQI of Manikchand Pond, Phulwarisharif, Patna, India										1.54 (**1.77**)	1.88 (**2.17**)	1.34 (**3.07**)	1.36 (**3.93**)		166.4 (**713.56**)	190.06 (**988.39**)

Table 9 Calculation of OPI, CPI and WQI of Phulwarisharif Pond, Phulwarisharif, Patna, India (A=Post-monsoon/Annual mean, B=Winter/Minimum, C=Summer/maximum and D=Monsoon) (K = 1.234598).

Sl. No.	Parameters	Season/ Annual		Standard Value (Si) (BIS)	Ideal value (Ii)	Observed values (Mi)		Sub index (Qi)		OPI Score		CPI Score		Unit weight (Wi)=K/Si	Wi x Qi	
						Seasonal	Annual	Seasonal	Annual	Seasonal	Annual	Seasonal	Annual		Seasonal	Annual
1.	pH	A B C D	A B C	7.5	7.0	8.13 8.23 8.07 7.13	7.89 7.10 9.10	226.0 246.0 214.0 26.0	178.0 20.0 420.0	3 3 3 1	2 1 5	1.08 1.10 1.08 0.95	1.05 0.95 1.21	0.1646	39.20 40.49 35.22 4.28	29.30 3.29 69.13
2.	Conductivity	A B C D	A B C	500	0	206.5 198.5 188.7 189.8	195.9 140 250	41.3 39.7 37.7 38.0	39.2 28.0 50.0	1 1 1 1	1 1 1	0.41 0.40 0.37 0.38	0.39 0.28 0.50	0.1685	6.96 6.69 6.85 6.40	6.61 4.72 8.43
3.	**Turbidity**	**A B C D**	**A B C**	**5**	**0**	**128.8 35.0 50.0 283.3**	**124.3 30.0 350.0**	**2576.0 700.0 1000.0 5666.0**	**2486.0 600.0 7000.0**	**4 3 3 8**	**4 2 10**	**25.8 7.00 10.0 56.6**	**24.9 6.0 70.0**	**0.2465**	**63.98 172.55 246.50 1396.67**	**612.80 147.90 1725.50**
4.	DO (mg/L)	A B C D	A B C	6	14.6	9.14 9.71 6.92 7.36	8.28 5.30 12.3	63.49 56.86 89.30 84.19	73.48 26.74 108.14	1 1 2 2	3 5 4	1.52 1.62 1.15 1.23	1.38 2.05 0.88	0.2057	13.06 11.70 18.37 17.32	15.11 5.50 22.24
5.	TA (mg/L)	A B C D	A B C	75	0	166.3 138.6 171.6 123.1	149.9 12.0 186.0	221.7 184.8 228.8 164.2	199.8 16.0 248.0	2 2 3 2	2 1 3	2.22 1.85 2.29 1.64	2.00 0.16 2.48	0.0164	3.64 3.03 3.75 2.69	3.28 0.06 4.07
6.	HA (mg/L)	A B C D	A B C	75	0	148.2 155.3 177.8 143.3	158.8 140.0 184.0	198.3 207.1 237.1 199.1	211.7 186.7 245.3	2 2 3 2	2 2 3	1.98 2.07 2.37 1.91	2.12 1.87 2.15	0.0164	3.25 3.40 3.89 3.26	3.47 3.06 4.02
7.	TDS (mg/L)	A B C D	A B C	500	0	772.3 655.6 682.9 1005.2	780.3 650.0 1110.0	154.5 131.1 137.6 210.0	156.1 130.0 222.0	2 2 2 2	2 2 2	1.54 1.31 1.32 2.01	1.56 1.30 2.22	0.0025	0.39 0.33 0.34 0.53	0.39 0.33 0.56
8.	Cl^- (mg/L)	A B C D	A B C	150	0	18.8 18.7 23.0 25.9	21.6 6.0 25.9	12.5 12.5 15.4 17.3	14.4 4.0 30.9	1 1 1 2	1 1 1	0.13 0.12 0.15 0.17	0.14 0.04 0.17	0.0082	0.10 0.10 0.13 0.14	0.12 0.03 0.25
9.	NO_3^- (mg/L)	A B C D	A B C	20	0	144.5 142.5 79.3 210.0	144.1 76.0 250.0	722.5 712.5 396.6 1005.0	720.4 380.0 1250.0	12 12 6 9	12 6 10	7.23 7.13 3.96 10.5	7.21 3.80 12.5	0.0617	44.58 43.96 24.47 62.01	44.45 23.45 77.13
10.	Free CO_2 (mg/L)	A B C D	A B C	0	0	7.96 3.04 6.94 10.07	7.01 0.01 19.1	6.96 3.64 10.70 8.29	9.90 0.10 30.4	0	0	0	0	0	0	0
11.	Sulfate (mg/L)	A B C D	A B C	150	0	164.3 173.3 235.2 118.3	172.2 112.0 250.0	109.6 115.5 156.8 78.9	115.5 74.7 166.7	1 1 2 1	1 1 2	1.09 1.16 1.57 0.79	1.15 0.75 1.67	0.0082	0.90 0.95 1.28 0.65	0.95 0.61 1.37
12.	BOD (mg/L)	A B C D	A B C	1.5.	0	1.31 1.26 1.46 2.33	1.89 1.00 2.60	87.3 84.0 97.0 155.3	106.0 67.0 173.3	1 1 1 2	2 1 2	0.87 0.84 0.97 1.55	1.26 0.67 1.73	0.8231	71.85 69.14 79.84 127.83	87.25 55.15 142.64
		A B C D	A B C						Mean	2.4 (**2.5**) 2.4 (**2.3**) 2.2 (**2.2**) 2.1 (**2.6**)	2.5(**2.7**) 2.3(**1.9**) 3.0(**3.6**)	1.6 (**3.66**) 1.6 (**2.05**) 1.4 (**2.10**) 1.9 (**6.50**)	1.6 (**3.6**) 1.1 (**1.5**) 2.3 (**8.0**)	ΣWQI	181.9 (**818.9**) 179.8 (**352.3**) 173.6 (**420.1**) 225.1 (**1621.8**)	190.9 (**803.7**) 96.4 (**111.2**) 329.8 (**2055.3**)
Average of OPI, CPI and WQI of Phulwarisharif Pond, Phulwarisharif, Patna, India										2.30 (**2.40**)	2.60 (**2.70**)	1.60 (**3.60**)	1.7 0 (**4.40**)		197.60 (**803.30**)	205.70 (**990.1**)