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International Journal of Basic and Applied Sciences
(ISSN: 2277-1921) (Scientific Journal Impact Factor: 6.188)

UGC Approved-A Peer Reviewed Quarterly Journal

<u>**Full Length Research Paper**</u>

Monitoring of Water Parameters of Two Major Ponds in The Vicinity of Birkona in Bilaspur District, Chhattisgarh

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ARTICLE DETAILS

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Key words:
Water Quality, Birkona Village, Pond Water, Drinking Water Safety, Pretreatment

ABSTRACT

This study provides a comprehensive evaluation of the drinking water quality in Birkona village, focusing on the suitability of pond water for domestic use and consumption. Water samples were systematically collected from several key ponds during three distinct seasons—winter, pre-monsoon, and post-monsoon—to capture seasonal variations in water quality. The analysis centered on critical physicochemical parameters, including pH, Total Dissolved Solids (TDS), hardness, and Dissolved Oxygen (DO), which are vital indicators of water quality. The results revealed that, while parameters like TDS and DO generally adhered to World Health Organization (WHO) guidelines, the hardness of the water consistently exceeded recommended levels across all seasons. This elevated hardness poses potential health risks, suggesting that the pond water is not safe for direct consumption without undergoing pretreatment processes, such as water softening. These findings underscore the importance of regular monitoring to identify and address seasonal fluctuations in water quality that could compromise the safety of these water sources. The study also highlights the need for proactive management and the implementation of precautionary measures to protect these essential water resources from further degradation. By addressing these issues, the Birkona village community can ensure the long-term sustainability and safety of its drinking water, ultimately safeguarding the health of its residents.

1. Introduction

The primary sources of water pollution in rural India include sewage discharge, industrial effluents, agricultural runoff, urban runoff, and a general lack of awareness among the populace. The most prevalent chemical pollutants in rural India's water are fluoride and arsenic, which can lead to severe health issues such as dental fluorosis, skeletal fluorosis, skin lesions, cancer, and neurological disorders. Iron has also emerged as a significant concern in recent years due to its potential to cause aesthetic and operational issues such as staining, clogging, corrosion, and taste alterations (Jhingran et al., 1989). Despite various government initiatives since independence aimed at providing safe drinking water to the rural population, the coverage and quality of water supply remain inadequate. Water pollution harms not only human health but also aquatic ecosystems and biodiversity (Alvarez et al., 2018). It alters the physico-chemical parameters of water, affecting the metabolism and reproduction of aquatic organisms. Excessive nutrients from sewage and fertilizers can lead to eutrophication, a process characterized by an overgrowth of algae and aquatic plants that reduce the dissolved oxygen in water, creating hypoxic or anoxic conditions. This can result in fish kills, loss of biodiversity, and deterioration of ecosystem services (Bakker, 2012).

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Received: 01-August-2024; Sent for Review on: 05-August -2024; Draft sent to Author for corrections: 12-August -2024; Accepted on: 24- August-2024
Online Available from 28-August-2024
DOI: 10.13140/RG.2.2.31153.60007

Surface water pollution is more likely than groundwater pollution, and climate change has a major impact on surface water quality (Uhl et al., 2022). Human activities are the main reason for the decline of surface water quality in many countries and regions around the world in the past few decades (Zheng et al., 2022). To determine the water quality grade, the surface water environmental quality standards are used to select the worst monitoring indicators among all the monitoring indicators. This technique makes it easier to estimate the water quality risk level, as it is fast and simple but gives cautious evaluation results (Xia and Chen, 2015). Water quality of surface water affects the natural vegetation (Taniwaki et al., 2019) and urban and agricultural areas contribute to the global increase in nutrients and sediments in freshwater ecosystems (de Mello et al., 2022). Considering these challenges, the current study aimed to analyse water quality and environmental pollution in stagnant surface water in the rural area of Birkona in Bilaspur, Chhattisgarh.

In this study analyzed the water quality and environmental pollution of stagnant surface water in the rural area of Birkona, focusing on two specific ponds: Sontariya and Tikari in Bilaspur District (Chhattisgarh). They measured the physical characteristics of water, including parameters such as transparency, temperature, and specific conductivity of the water. They assessed the chemical characteristics of water, covering total solids, total dissolved solids, pH, electrical conductivity, total hardness, alkalinity, nitrates, phosphates chloride, calcium, sulphate, and fluoride. They evaluated the biological characteristics of water, focusing on parameters such as BOD (Biochemical Oxygen Demand), DO (Dissolved Oxygen), and COD (Chemical Oxygen Demand). All these parameters with seasonal variations in the period of three years from 2021 to 2023 were examined. Water samples at all sites were collected at the margin in the four directions North, South, East and West as well as at the center of the ponds.

1.1 Objectives

To conduct a study of water quality with the goal of determining suitability of Birkona pond water for drinking and domestic use.

2. Method and Materials

2.1 Sampling Site and Collection Method

Birkona, a rural area situated 5 km from Bilaspur city in Chhattisgarh, was selected as the primary site for this study due to its high population density and reliance on surface water for various domestic purposes. The area has achieved notable water system coverage, yet challenges persist in maintaining water quality, as evidenced by our preliminary observations.

Water samples were systematically collected from two major ponds identified as critical water sources for the local population (Table 1). Sampling was conducted at various points around each pond, including both margins and centers, to ensure comprehensive coverage. These locations were strategically chosen to represent the North, South, East, West and Inner directions, aiming to capture any potential spatial variations in water quality.

Table 1: Sampling locations at different ponds

Pond name	Sampling location
Sonatariya	S-1
Tikari	S-2

2.2 Analysis of Water Quality

The collected samples underwent a thorough analysis for both chemical and biological characteristics. Chemical parameters assessed included total solids, dissolved solids, pH, electrical conductivity, hardness, alkalinity, and the concentrations of nitrate, chloride, calcium, sulfate, phosphate and fluoride (Trivedi and Goel, 1986). Biological parameters focused on Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), and Chemical Oxygen Demand (COD).

2.3 Seasonal Variation and Sample Collection

The study was meticulously designed to assess a wide range of water quality parameters across three distinct seasons: winter, pre-monsoon, and post-monsoon. This approach enabled a comprehensive understanding of seasonal impacts on water quality. Throughout the year, surface water samples were systematically collected to analyze an array of parameters including pH, temperature, transparency, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness (TH), and the concentrations of calcium, magnesium, alkalinity, conductivity, fluoride, nitrate, sulfate, phosphate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD).

To ensure the integrity of the samples, the collection was performed using specially prepared plastic (polyethylene) bottles. These bottles were secured with tight-fitting caps and underwent a rigorous cleaning process, initially with a Chromic acid mixture ($K_2Cr_2O_7$ + conc. H_2SO_4), followed by multiple rinses with distilled water. Prior to collecting each sample, the bottles were twice rinsed with the pond water to maintain sample consistency.

2.4 Methodological Approach

In conducting this study, we adhered to the methods and techniques established by the American Public Health Association (APHA, 2023; NEERI, 2002), ensuring that our data collection and analysis procedures met the highest standards of scientific accuracy and reliability (Table 2). A correlation analysis was also incorporated to examine the relationships between the physico-chemical parameters of the water samples.

Table 2. Standard methods for analysis of physicochemical parameters

SN	Parameter	Method
1	Transparency	Measured by secchi disc.
2	Temperature	Measured with a mercury the thermometer
3	pH	Measured with the help of a digital pH meter
4	Conductivity	Measured by digital Conductivity meter
5	Total solids	Measured by Gravimetric method.
6	Total Suspended Solids	Measured by Filtration method.
7	Total Dissolved Solids	Measured by Gravimetric method.
8	Total Alkalinity	Measured by Titration methods.
9	Total Hardness	Measured by EDTA Titrimetric method.
10	Calcium Hardness	Measured by EDTA Titrimetric method.
11	Magnesium Hardness	Measured by EDTA Titrimetric method.
12	Chloride	Measured by Argentometric method
14	Fluoride	Spectroscopy Method
13	Sulphate	Measured by turbid metric method
14	Phosphate	Measured by Stannous chloride solution method
15	Nitrate	Measured by phenoldisulphonic Acid method
16	Dissolved Oxygen	Measured by Winkler method
17	Biochemical Oxygen Demand	Measured by dilution method
18	Chemical Oxygen Demand	Measured by Potassium dichromate method.

Field measurements of pH, temperature, conductivity, TDS, and dissolved oxygen were conducted on-site using a state-of-the-art portable water quality analyzer kit. The transparency of each pond was meticulously measured using a Secchi disk, a simple yet effective tool for assessing water clarity. For the determination of additional parameters such as alkalinity, hardness, total solids, total suspended solids, DO, BOD, COD, chloride, sulfate, fluoride, phosphate, and nitrate, we employed standard methods as prescribed by authoritative sources including APHA (2023), and the NEERI manual (2002) on water and wastewater analysis as well as related literature (Jadhav, 1992; Vogel, 2008; Sinha, 1995; Manivasakam, 2018). The reagents used in our investigation were of Analytical Reagent (A.R.) grade, and double distilled water was utilized for the preparation of all solutions, ensuring the highest level of accuracy and consistency in our findings.

3. Results and Discussions

Sewage and fertilizers are some of the causes of pollution that contain nutrients like nitrates and phosphates. At high levels, nutrients stimulate the excessive growth of aquatic plants and algae. These organisms clog our waterways, consume dissolved oxygen as they decay, and block light to deeper waters. This harms aquatic organisms as it affects their breathing ability and other invertebrates that live in water.

In the current investigation, 02 ponds were chosen for seasonal monitoring of the physico-chemical characteristics of water samples. This monitoring was carried out every three months (quarterly) over a span of 3 years (2021, 2022, and 2023). The water samples were analyzed for 19 crucial physico-chemical parameters. The observed analytical results of the different physico-chemical parameters of water samples from different sampling stations are presented in Table 3 to 8. Figures 1 to 6 show spatio-temporal variations of different physico-chemical parameters for different water samples in all directions such as North, South, East, West and Inner surface for the assessment year 2021-2023. The temperature of water bodies is subject to a range of influencing factors, including seasonal shifts, ground temperature, subsurface heat dynamics, and geophysical reactions. In our study, temperature variations across two distinct sampling stations in the region were meticulously recorded, observing significant fluctuations influenced by various environmental factors. The temperature of water bodies is subject to a range of influencing factors, including seasonal shifts, ground temperature, subsurface heat dynamics, and geophysical reactions. In our study, temperature variations across two distinct sampling stations in the region were meticulously recorded, observing significant fluctuations influenced by various environmental factors.

At Station S-1 (Sontariya), temperature readings ranged from 21°C to 38°C, with the lowest on the inner surface in January 2021 and the highest in the west in April 2022. Lastly, Station S-2 (Tikari) exhibited temperatures between 21°C and 36°C, with the minimum in the south in January 2023 and the maximum on the inner surface in April 2022.The pH level is a critical indicator of water quality, influencing the health of aquatic ecosystems and its suitability for human use. It measures water's acidity or alkalinity on a scale from 0 to 14, where 7 is neutral. Values below 7 are acidic, while those above are alkaline. In aquatic environments, pH is crucial as it affects nutrient solubility, mineral availability, and biological and chemical processes.

Table 3: Physicochemical Characteristics of Sontariya (S-1) Pond for Year 2023

	N-Jan	N-Apr	N-Jul	N-Oct	S-Jan	S-Apr	S-Jul	S-Oct	E-Jan	E-Apr	E-Jul	E-Oct	W-Jan	W-Apr	W-Jul	W-Oct	I-Jan	I-Apr	I-Jul	I-Oct
Temp	23.0	36.0	26.0	24.0	22.0	34.0	26.0	24.0	24.0	33.0	25.0	24.0	24.0	37.0	27.0	26.0	25.0	37.0	27.0	26.0
pH	8.5	8.6	8.3	8.1	8.5	8.3	8.1	8.4	8.6	8.4	7.9	8.3	8.5	8.7	7.9	8.3	8.3	8.1	7.3	8.9
EC	190.0	194.0	197.0	194.0	186.0	189.0	197.0	189.0	193.0	196.0	185.0	183.0	187.0	190.0	194.0	191.0	194.0	197.0	188.0	193.0
Alk	197.0	219.0	183.0	211.0	171.0	200.0	182.0	185.0	200.0	224.0	198.0	226.0	214.0	227.0	218.0	216.0	187.0	194.0	188.0	184.0
TDS	255.0	167.0	259.0	179.0	258.0	264.0	245.0	201.0	257.0	268.0	262.0	183.0	246.0	276.0	258.0	244.0	245.0	247.0	248.0	236.0
TSS	58.0	65.0	55.0	61.0	63.0	67.0	58.0	54.0	73.0	75.0	64.0	49.0	65.0	78.0	65.0	61.0	55.0	57.0	48.0	45.0
TS	558.0	562.0	542.0	555.0	554.0	557.0	549.0	558.0	558.0	455.0	548.0	553.0	488.0	490.0	483.0	493.0	510.0	514.0	513.0	517.0
TH	246.0	223.0	238.0	231.0	237.0	234.0	235.0	226.0	238.0	246.0	241.0	239.0	238.0	243.0	246.0	225.0	207.0	220.0	224.0	226.0
Mg-H	82.0	81.0	76.0	79.0	78.0	87.0	81.0	76.0	74.0	75.0	79.0	76.0	65.0	74.0	59.0	65.0	68.0	75.0	63.0	65.0
Ca-H	116.0	140.0	126.0	122.0	116.0	135.0	125.0	118.0	120.0	131.0	127.0	129.0	110.0	132.0	137.0	126.0	98.0	110.0	116.0	102.0
DO	5.8	4.2	5.7	5.9	4.9	5.6	4.8	4.7	4.9	5.3	4.8	4.1	4.6	5.7	5.9	5.2	4.2	4.5	4.8	4.1
BOD	7.21	16.43	11.13	17.04	16.29	8.43	10.51	12.33	2.37	16.80	16.91	9.73	8.94	9.31	3.53	8.20	5.51	8.15	11.69	16.16
COD	39.0	34.0	36.0	31.0	43.0	47.0	33.0	39.0	34.0	38.0	35.0	39.0	33.0	36.0	31.0	33.0	34.0	35.0	37.0	29.0
Cl^-	173.0	191.0	193.0	185.0	179.0	190.0	193.0	182.0	158.0	163.0	156.0	151.0	163.0	167.0	159.0	155.0	189.0	201.0	196.0	185.0
F^-	0.0	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
SO_4^{2-}	40.0	42.0	45.0	41.0	38.0	45.0	44.0	34.0	33.0	43.0	35.0	33.0	38.0	47.0	44.0	49.0	56.0	61.0	55.0	49.0
PO_4^{2-}	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.2
NO_3^-	26.0	39.0	34.0	25.0	24.0	29.0	27.0	23.0	25.0	34.0	33.0	26.0	23.0	25.0	27.0	25.0	37.0	40.0	37.0	38.0
Transp	23.0	19.0	14.0	24.0	25.0	21.0	23.0	22.0	23.0	22.0	15.0	25.0	21.0	17.0	15.0	26.0	24.0	25.0	16.0	20.0

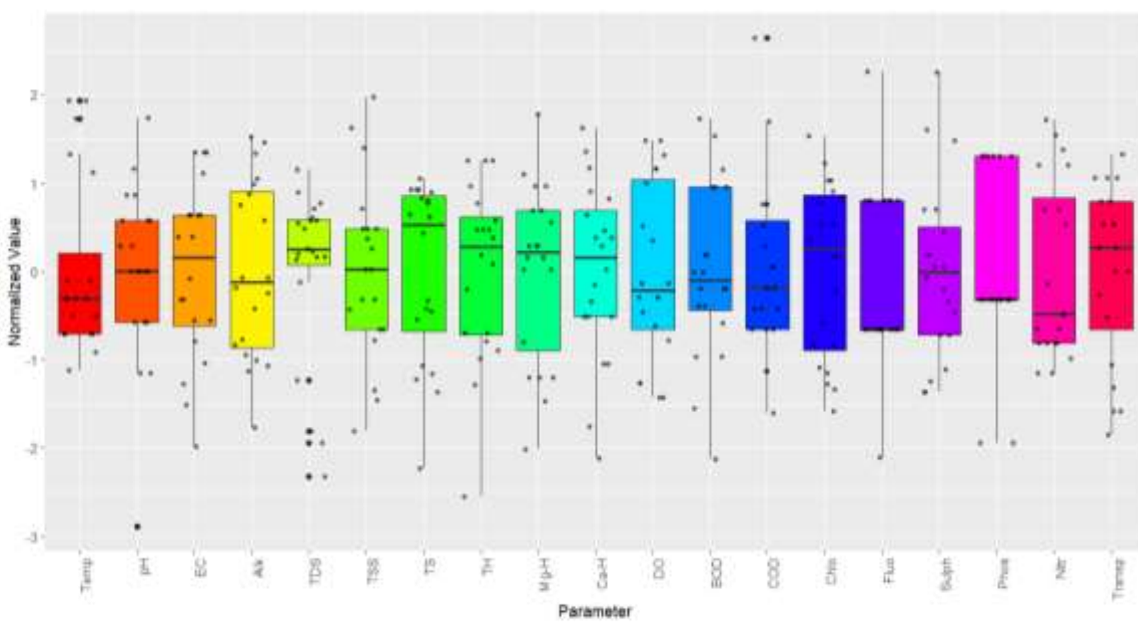

Fig 1. Spatio-temporal variations in water quality parameters for Sontariya pond (2023)

Table 4: Physicochemical Characteristics of Sontariya (S-1) Pond for Year 2022

	N-Jan	N-Apr	N-Jul	N-Oct	S-Jan	S-Apr	S-Jul	S-Oct	E-Jan	E-Apr	E-Jul	E-Oct	W-Jan	W-Apr	W-Jul	W-Oct	I-Jan	I-Apr	I-Jul	I-Oct
Temp	24.0	37.0	25.0	24.0	23.0	36.0	27.0	25.0	25.0	35.0	27.0	23.0	25.0	38.0	26.0	23.0	24.0	38.0	24.0	23.0
pH	8.4	8.7	8.2	8.9	8.3	8.7	8.2	8.5	8.2	8.5	8.4	8.1	8.8	8.1	7.4	8.5	8.6	8.3	7.9	8.2
EC	194.0	196.0	198.0	191.0	194.0	199.0	194.0	188.0	189.0	193.0	194.0	196.0	190.0	194.0	193.0	197.0	193.0	195.0	187.0	196.0
Alk	199.0	120.0	187.0	122.0	174.0	199.0	189.0	183.0	212.0	221.0	203.0	227.0	213.0	225.0	221.0	226.0	188.0	190.0	181.0	186.0
TDS	157.0	164.0	164.0	184.0	152.0	261.0	248.0	211.0	257.0	268.0	261.0	188.0	241.0	278.0	259.0	240.0	253.0	245.0	255.0	233.0
TSS	59.0	67.0	51.0	66.0	63.0	69.0	60.0	51.0	76.0	79.0	61.0	50.0	66.0	81.0	69.0	66.0	54.0	53.0	41.0	40.0
TS	554.0	557.0	542.0	557.0	551.0	553.0	540.0	547.0	542.0	562.0	565.0	551.0	459.0	494.0	489.0	499.0	511.0	512.0	517.0	522.0
TH	243.0	224.0	231.0	236.0	239.0	237.0	231.0	233.0	231.0	247.0	240.0	236.0	242.0	247.0	248.0	228.0	211.0	222.0	231.0	234.0
Mg-H	87.0	88.0	76.0	80.0	79.0	83.0	88.0	87.0	71.0	78.0	73.0	80.0	66.0	71.0	60.0	66.0	69.0	71.0	62.0	66.0
Ca-H	121.0	143.0	129.0	125.0	121.0	132.0	127.0	122.0	131.0	122.0	129.0	135.0	111.0	131.0	138.0	129.0	100.0	111.0	118.0	121.0
DO	5.9	4.1	5.9	5.3	5.1	5.4	8.2	4.9	5.1	5.6	4.1	4.8	5.1	5.8	6.1	5.3	5.1	5.7	4.2	5.1
BOD	7.13	6.14	15.09	5.00	8.04	15.58	12.71	7.94	12.83	15.63	7.87	11.41	13.81	3.22	3.10	16.39	12.90	3.65	4.73	15.65
COD	40.0	34.0	38.0	34.0	47.0	41.0	38.0	34.0	31.0	35.0	31.0	41.0	31.0	31.0	39.0	38.0	32.0	31.0	39.0	27.0
Cl^-	194.0	200.0	196.0	187.0	180.0	195.0	191.0	183.0	158.0	161.0	159.0	155.0	166.0	162.0	153.0	150.0	188.0	213.0	193.0	183.0
F^-	0.1	0.1	0.7	0.1	0.2	0.2	0.3	0.2	0.1	0.2	0.1	0.2	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.2
SO_4^{2-}	43.0	44.0	49.0	45.0	41.0	44.0	48.0	31.0	42.0	47.0	39.0	41.0	41.0	40.0	47.0	52.0	75.0	66.0	61.0	57.0
PO_4^{2-}	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.2
NO_3^-	27.0	40.0	35.0	27.0	22.0	30.0	21.0	25.0	26.0	33.0	30.0	22.0	21.0	22.0	24.0	26.0	38.0	39.0	41.0	44.0
Transp	30.0	31.0	23.0	25.0	28.0	25.0	24.0	25.0	25.0	23.0	17.0	14.0	24.0	16.0	13.0	26.0	26.0	24.0	15.0	19.0

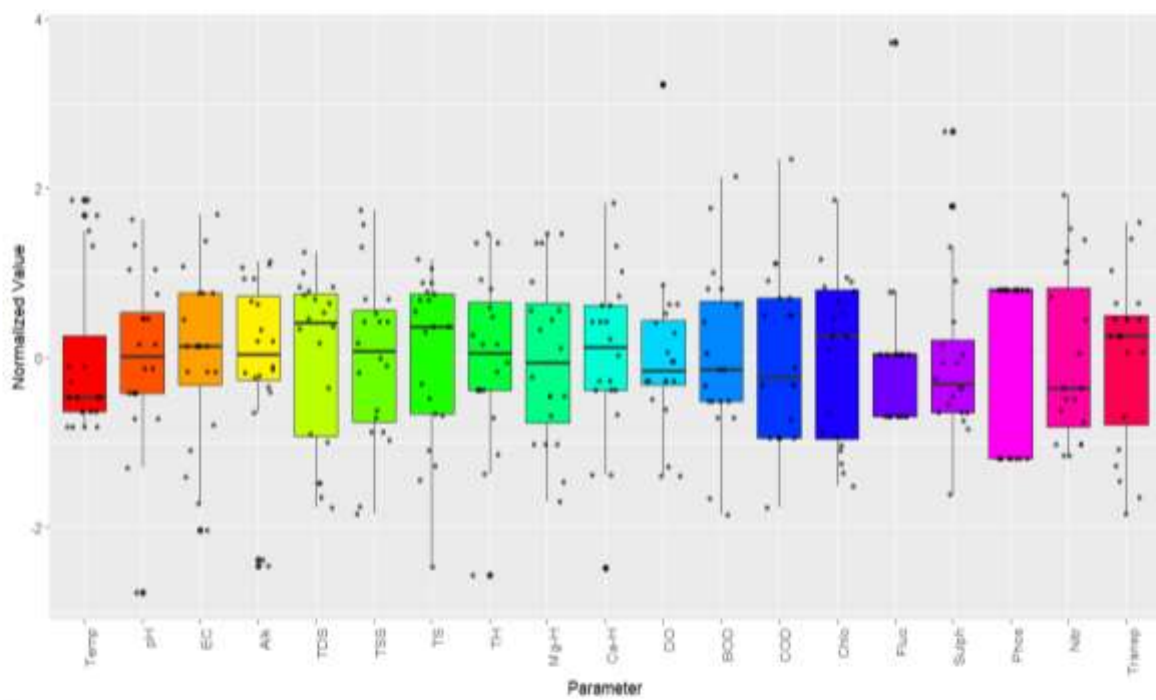

Fig 2. Spatio-temporal variations in water quality parameters for Sontariya pond (2022)

Table 5: Physicochemical Characteristics of Sontariya (S-1) Pond for Year 2021

	N-Jan	N-Apr	N-Jul	N-Oct	S-Jan	S-Apr	S-Jul	S-Oct	E-Jan	E-Apr	E-Jul	E-Oct	W-Jan	W-Apr	W-Jul	W-Oct	I-Jan	I-Apr	I-Jul	I-Oct
Temp	25.0	33.0	26.0	24.0	23.0	36.0	27.0	25.0	24.0	37.0	26.0	23.0	26.0	35.0	27.0	23.0	25.0	36.0	27.0	22.0
pH	8.3	8.8	8.9	8.1	8.1	8.9	8.3	8.2	8.9	8.1	8.3	8.6	8.4	8.9	8.1	8.3	8.1	8.8	8.3	8.4
EC	190.0	195.0	194.0	196.0	196.0	195.0	193.0	194.0	190.0	195.0	199.0	194.0	194.0	199.0	188.0	185.0	190.0	194.0	193.0	199.0
Alk	200.0	211.0	188.0	123.0	176.0	188.0	190.0	189.0	214.0	222.0	213.0	233.0	231.0	234.0	222.0	238.0	183.0	198.0	188.0	180.0
TDS	157.0	161.0	168.0	188.0	166.0	163.0	153.0	143.0	266.0	261.0	265.0	252.0	247.0	278.0	265.0	244.0	256.0	254.0	268.0	245.0
TSS	64.0	69.0	55.0	72.0	64.0	73.0	66.0	55.0	83.0	76.0	59.0	55.0	77.0	82.0	78.0	61.0	55.0	57.0	48.0	49.0
TS	559.0	551.0	531.0	562.0	559.0	557.0	540.0	531.0	567.0	561.0	557.0	548.0	560.0	496.0	567.0	489.0	513.0	522.0	526.0	528.0
TH	253.0	231.0	253.0	238.0	238.0	230.0	242.0	247.0	230.0	241.0	234.0	237.0	245.0	248.0	241.0	223.0	217.0	224.0	239.0	237.0
Mg-H	89.0	82.0	79.0	88.0	83.0	86.0	90.0	95.0	78.0	71.0	69.0	75.0	63.0	75.0	67.0	76.0	66.0	74.0	77.0	68.0
Ca-H	222.0	147.0	131.0	129.0	222.0	137.0	145.0	125.0	135.0	126.0	131.0	139.0	118.0	134.0	141.0	134.0	111.0	123.0	126.0	128.0
DO	6.1	6.3	5.7	5.2	5.7	5.2	8.5	5.6	5.7	5.7	4.9	4.8	5.9	5.3	6.7	5.2	4.5	5.7	5.2	6.4
BOD	11.51	17.19	2.15	8.87	9.57	17.59	12.71	12.89	6.19	6.94	5.13	16.71	12.95	5.32	6.32	7.45	14.80	3.93	8.77	9.93
COD	42.0	37.0	31.0	30.0	48.0	44.0	49.0	30.0	36.0	33.0	37.0	44.0	33.0	32.0	40.0	44.0	33.0	37.0	42.0	28.0
Cl^-	190.0	199.0	197.0	183.0	188.0	193.0	194.0	188.0	156.0	166.0	169.0	150.0	167.0	170.0	159.0	155.0	189.0	214.0	195.0	188.0
F^-	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.3
SO_4^{2-}	44.0	31.0	51.0	48.0	44.0	37.0	38.0	39.0	45.0	41.0	37.0	40.0	42.0	43.0	44.0	55.0	77.0	60.0	58.0	55.0
PO_4^{2-}	0.2	0.3	0.3	0.2	0.3	0.4	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4
NO_3^-	25.0	45.0	33.0	31.0	23.0	31.0	22.0	27.0	25.0	31.0	30.0	28.0	24.0	26.0	23.0	21.0	31.0	33.0	49.0	52.0
Transp	33.0	30.0	22.0	26.0	27.0	26.0	23.0	25.0	26.0	22.0	16.0	20.0	26.0	17.0	16.0	24.0	27.0	23.0	16.0	20.0

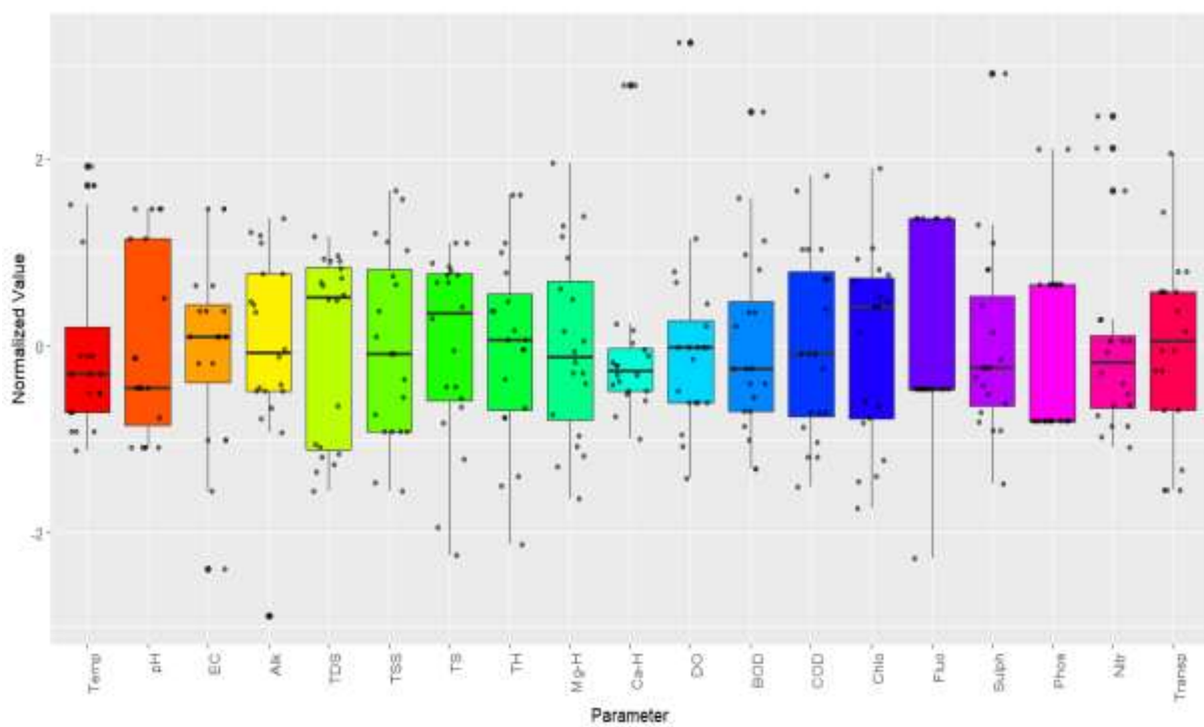

Fig 3. Spatio-temporal variations in water quality parameters for Sontariya pond (2021)

In most stations, pH values frequently exceeded 9; at S-1 being exception. These observations highlight the importance of regular pH monitoring in water bodies to evaluate their ecological and human health impacts. Electrical conductivity is a vital measure of water quality, indicating the level of dissolved minerals. It's essential for assessing water's suitability for drinking, agriculture, and industrial uses. The WHO recommends a maximum limit of 500 μmho/cm for drinking water's electrical conductivity. Exceedance of the WHO's recommended limit were identified at S-1 and S-2, highlighting the importance of continuous monitoring of electrical conductivity to ensure water quality and safety. Total solids, including dissolved and suspended solids, are key to assessing water quality. WHO's International Standards set the permissible limit for dissolved solids at 500 mg/l. However, both dissolved and suspended solids need to be measured for a comprehensive water quality assessment. High levels of these solids indicate possible contamination from agricultural runoff, industrial discharges, or urban pollution, impacting drinking water taste, aquatic habitats, and potentially carrying pollutants. During the assessment period 2021- 2023 maximum TDS found in 367 in the month of July 2021 in South Direction. Maximum Total Solids recorded 289 in April 2201 in North Direction at S-2. Other station S-1showed Maximum TDS and TS levels between 278 mg/l in west April 2022 and 565 mg/l in East July 2022.These findings emphasize the importance of monitoring and managing TDS and TS levels in water bodies for environmental protection and public health.

Total hardness, expressed in mg/l of calcium carbonate (CaCO3), is a key parameter in water quality assessment, encompassing the combined concentrations of calcium and magnesium ions. The WHO recommends a maximum acceptable level of 500 mg/l for total hardness. Exceeding this threshold may not pose direct health risks but can affect water utility for certain applications. Indian Standards set specific limits for calcium and magnesium hardness at 75 mg/l and 30 mg/l, respectively. Our study in 2021 found total hardness levels of 253 mg/l at S-9 in the North during January, under WHO guidelines. Other station S-10 showed maximum hardness observed 243 mg/l in the month of July in North Direction. Dissolved Oxygen (DO) is a crucial indicator of water quality, essential for aquatic life and various biological and chemical processes. Monitoring DO levels helps assess the health and ecological balance of water bodies. Factors such as pollution can deplete oxygen levels, posing risks to aquatic ecosystems. In this study, the highest DO level of 8.3 mg/l was recorded at S-10 in the north direction in January. The highest DO value of 8.5 mg/l was observed at S-9 in July 2021 at south direction. These variations underscore the dynamic nature of DO levels and their importance in water quality and ecosystem health evaluation.

BOD measures the amount of oxygen consumed by microorganisms in the oxidation of organic matter, indicating the level of organic pollution. WHO recommends a BOD threshold of 6 mg/l. Maximum BOD of 57 mg/l at S-2 in October 2021 suggests localized pollution sources. Continuous BOD monitoring is crucial for identifying pollution hotspots and safeguarding water quality and ecosystem health. COD provides a rapid estimate of organic matter content in water, crucial for managing and designing treatment plants. WHO's drinking water standard for COD is 10.0 mg/l. Current study revealed COD values above this limit at both stations, with a high of 47 mg/l at S-1 in South direction in the month of July 2023. This indicates significant organic pollution, necessitating management strategies to mitigate its impact on water quality and ecosystem health. Seasonal trends, with higher COD in summer, emphasize the need for continuous monitoring and adaptive management to maintain water quality and ecosystem balance.

The current study showed Chloride and fluoride concentration is a key indicator of pollution, particularly from sewage sources in water bodies. High chloride levels can impart a salty taste to water and pose risks to infrastructure and plant life. WHO and Indian Standards set the maximum allowable chloride level in drinking water at 250 mg/l and 300 mg/l, respectively. Current study found chloride and fluoride concentrations did not exceeding these limits, These findings indicate the presence of chloride pollution, necessitating effective management to mitigate its impacts on water quality and ecosystem health.

Sulphate ions, often from industrial and natural sources, are key water quality indicators. Indian standards set a maximum sulphate limit in drinking water at 150 mg/l. In this study the sulphate levels were found to be below this limit, These results suggest that water quality meets standards for sulphate concentration, but continuous monitoring is crucial for maintaining environmental sustainability and public health. Phosphates, mainly from agricultural runoff, contribute to phosphorus contamination in water, leading to environmental issues like eutrophication. The USPHS recommends a maximum phosphate concentration in drinking water of 0.1 mg/l. In this study phosphate levels were found to be consistently uder the permissible limit,

Nitrate pollution in water, from sources like fertilizers and waste, poses significant health risks. Elevated nitrate levels can lead to various disorders. This study found nitrate concentrations exceeding permissible limits at several stations, with the highest at 77 mg/l at S-2 in April 2021. This emphasizes the urgent need for strategies to mitigate nitrate pollution and safeguard human health and environmental well-being. Continuous monitoring and management are essential for the sustainability of water resources and community health.

Table 6: Physicochemical Characteristics of Tikari (S-2) Pond for Year 2023

	N-Jan	N-Apr	N-Jul	N-Oct	S-Jan	S-Apr	S-Jul	S-Oct	E-Jan	E-Apr	E-Jul	E-Oct	W-Jan	W-Apr	W-Jul	W-Oct	I-Jan	I-Apr	I-Jul	I-Oct
Temp	21.0	35.0	33.0	25.0	21.0	33.0	26.0	24.0	22.0	32.0	24.0	25.0	23.0	33.0	24.0	24.0	22.0	35.0	26.0	24.0
pH	8.4	8.8	8.2	8.4	8.7	8.9	8.2	8.5	8.4	8.8	8.2	8.5	8.4	8.8	8.2	8.5	8.2	8.7	8.2	8.4
EC	321.0	736.0	365.0	358.0	321.0	324.0	319.0	315.0	321.0	342.0	322.0	329.0	321.0	324.0	326.0	333.0	321.0	326.0	322.0	324.0
Alk	183.0	261.0	188.0	197.0	171.0	164.0	171.0	162.0	167.0	169.0	171.0	151.0	178.0	165.0	167.0	162.0	157.0	157.0	165.0	163.0
TDS	152.0	337.0	213.0	211.0	215.0	227.0	218.0	220.0	219.0	224.0	217.0	211.0	219.0	230.0	217.0	219.0	232.0	256.0	218.0	215.0
TSS	25.0	43.0	32.0	26.0	28.0	33.0	42.0	29.0	28.0	35.0	44.0	48.0	30.0	33.0	45.0	32.0	27.0	34.0	43.0	37.0
TS	276.0	284.0	237.0	240.0	228.0	233.0	220.0	222.0	229.0	236.0	213.0	212.0	235.0	247.0	213.0	212.0	239.0	243.0	222.0	230.0
TH	187.0	210.0	193.0	179.0	189.0	184.0	173.0	159.0	178.0	197.0	191.0	173.0	174.0	183.0	191.0	168.0	190.0	193.0	178.0	174.0
Mg-H	84.0	88.0	81.0	88.0	94.0	98.0	91.0	86.0	83.0	89.0	84.0	71.0	75.0	88.0	89.0	72.0	85.0	99.0	87.0	75.0
Ca-H	91.0	118.0	117.0	100.0	120.0	122.0	100.0	84.0	121.0	117.0	100.0	94.0	123.0	120.0	110.0	113.0	117.0	120.0	100.0	89.0
DO	7.3	7.8	7.2	7.5	6.1	7.4	6.6	6.9	7.0	6.4	6.4	6.8	6.3	7.5	6.8	6.1	6.1	7.5	6.9	6.2
BOD	2.38	3.09	10.62	6.56	7.74	5.24	5.21	17.46	11.59	12.18	12.79	3.70	2.32	6.82	15.05	3.13	17.06	8.39	4.30	6.19
COD	40.0	56.0	35.0	38.0	27.0	31.0	33.0	24.0	30.0	37.0	29.0	26.0	26.0	38.0	28.0	33.0	25.0	36.0	38.0	29.0
Cl^-	119.0	159.0	122.0	124.0	227.0	238.0	225.0	221.0	229.0	240.0	219.0	220.0	227.0	239.0	218.0	216.0	242.0	254.0	222.0	219.0
F^-	0.3	0.3	0.8	0.4	0.5	0.3	0.4	0.4	0.4	0.4	0.2	0.3	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4
SO_4^{2-}	36.0	56.0	39.0	44.0	37.0	48.0	49.0	44.0	39.0	52.0	39.0	37.0	37.0	42.0	40.0	39.0	41.0	36.0	44.0	41.0
PO_4^{2-}	0.2	0.3	0.3	0.4	0.2	0.2	0.2	0.1	0.3	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1
NO_3^-	33.0	43.0	32.0	43.0	32.0	34.0	31.0	32.0	33.0	41.0	35.0	37.0	32.0	38.0	29.0	27.0	33.0	34.0	36.0	20.0
Transp	20.0	15.0	22.0	16.0	22.0	16.0	15.0	18.0	22.0	15.0	16.0	15.0	22.0	16.0	20.0	18.0	20.0	18.0	22.0	15.0

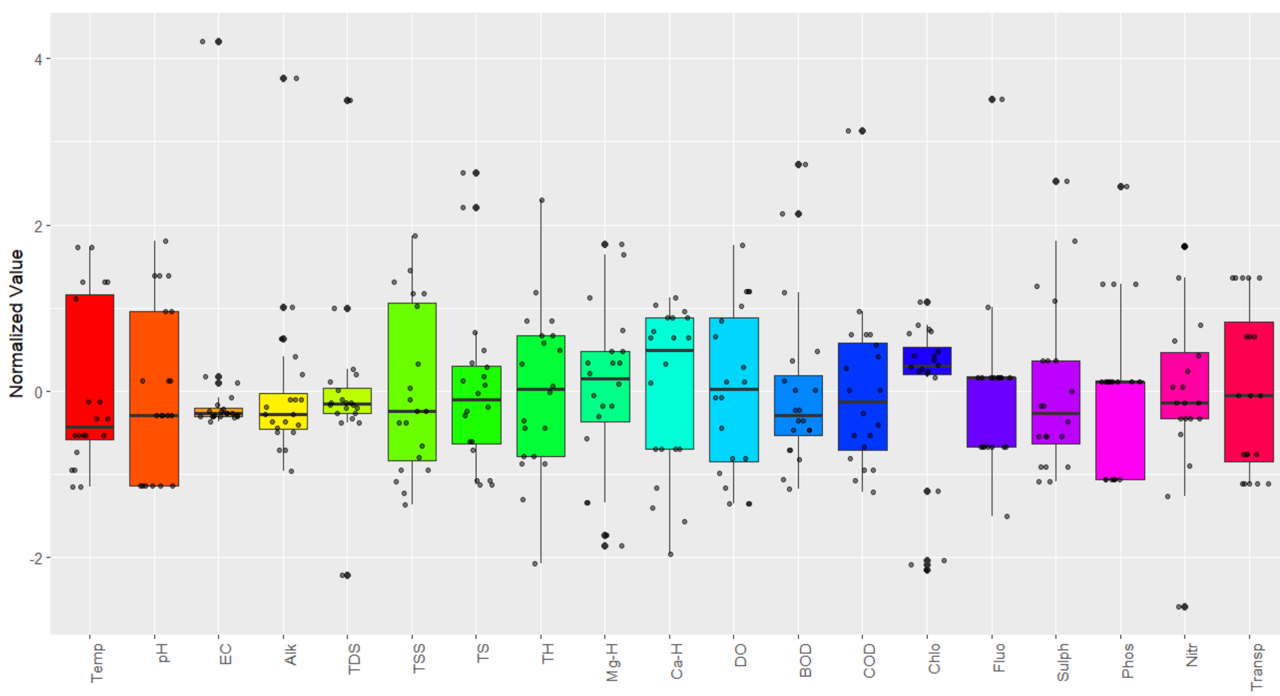

Fig 4. Spatio-temporal variations in water quality parameters for Tikari pond (2023)

Table 7: Physicochemical Characteristics of Tikari (S-2) Pond for Year 2022

	N-Jan	N-Apr	N-Jul	N-Oct	S-Jan	S-Apr	S-Jul	S-Oct	E-Jan	E-Apr	E-Jul	E-Oct	W-Jan	W-Apr	W-Jul	W-Oct	I-Jan	I-Apr	I-Jul	I-Oct
Temp	24.0	36.0	26.0	23.0	23.0	35.0	25.0	24.0	24.0	33.0	25.0	22.0	24.0	35.0	26.0	24.0	24.0	36.0	25.0	22.0
pH	8.5	8.1	8.3	8.9	8.3	8.4	8.7	8.1	8.5	7.6	8.3	8.5	8.1	8.9	8.5	8.3	8.4	8.3	8.5	8.9
EC	743.0	736.0	743.0	765.0	765.0	754.0	732.0	722.0	787.0	745.0	768.0	736.0	764.0	749.0	785.0	743.0	766.0	768.0	745.0	723.0
Alk	243.0	265.0	256.0	265.0	243.0	254.0	236.0	254.0	245.0	234.0	265.0	254.0	245.0	235.0	254.0	213.0	254.0	264.0	246.0	276.0
TDS	344.0	336.0	325.0	367.0	343.0	322.0	242.0	324.0	254.0	231.0	254.0	276.0	221.0	234.0	226.0	223.0	254.0	233.0	235.0	231.0
TSS	26.0	44.0	36.0	27.0	26.0	36.0	44.0	32.0	30.0	32.0	54.0	43.0	35.0	45.0	32.0	36.0	28.0	36.0	43.0	44.0
TS	275.0	287.0	288.0	254.0	256.0	287.0	237.0	246.0	267.0	246.0	246.0	267.0	265.0	287.0	244.0	214.0	265.0	245.0	243.0	265.0
TH	212.0	211.0	234.0	232.0	190.0	184.0	198.0	167.0	187.0	200.0	212.0	201.0	176.0	198.0	200.0	187.0	201.0	211.0	198.0	194.0
Mg-H	89.0	89.0	88.0	98.0	100.0	157.0	110.0	100.0	89.0	94.0	91.0	89.0	78.0	95.0	93.0	79.0	89.0	100.0	98.0	110.0
Ca-H	98.0	121.0	132.0	123.0	123.0	126.0	111.0	88.0	135.0	154.0	123.0	128.0	143.0	154.0	124.0	128.0	117.0	120.0	100.0	89.0
DO	7.9	7.4	7.3	7.1	7.3	7.5	6.8	7.2	7.5	6.2	6.8	7.3	6.3	7.9	6.2	6.7	6.5	7.2	7.1	7.3
BOD	6.10	6.10	7.08	7.28	8.21	3.38	3.86	3.15	10.34	3.85	4.72	3.81	6.23	7.99	6.28	4.53	7.38	2.53	11.23	7.22
COD	65.0	67.0	45.0	43.0	35.0	32.0	43.0	35.0	43.0	54.0	27.0	35.0	24.0	45.0	36.0	38.0	27.0	44.0	37.0	54.0
Cl^-	165.0	165.0	175.0	168.0	254.0	276.0	245.0	234.0	234.0	254.0	262.0	247.0	264.0	276.0	258.0	298.0	256.0	276.0	287.0	321.0
F^-	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.3	0.4	0.4	0.3	0.2	0.4	0.2	0.2	0.3	0.3	0.3	0.4
SO_4^{2-}	59.0	55.0	58.0	69.0	41.0	65.0	47.0	42.0	33.0	51.0	42.0	44.0	54.0	44.0	34.0	45.0	44.0	43.0	54.0	65.0
PO_4^{2-}	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3
NO_3^-	44.0	47.0	41.0	54.0	56.0	43.0	45.0	41.0	35.0	44.0	45.0	54.0	54.0	67.0	30.0	31.0	43.0	54.0	43.0	35.0
Transp	24.0	22.0	14.0	21.0	24.0	21.0	13.0	20.0	23.0	16.0	14.0	19.0	25.0	24.0	17.0	20.0	25.0	21.0	15.0	18.0

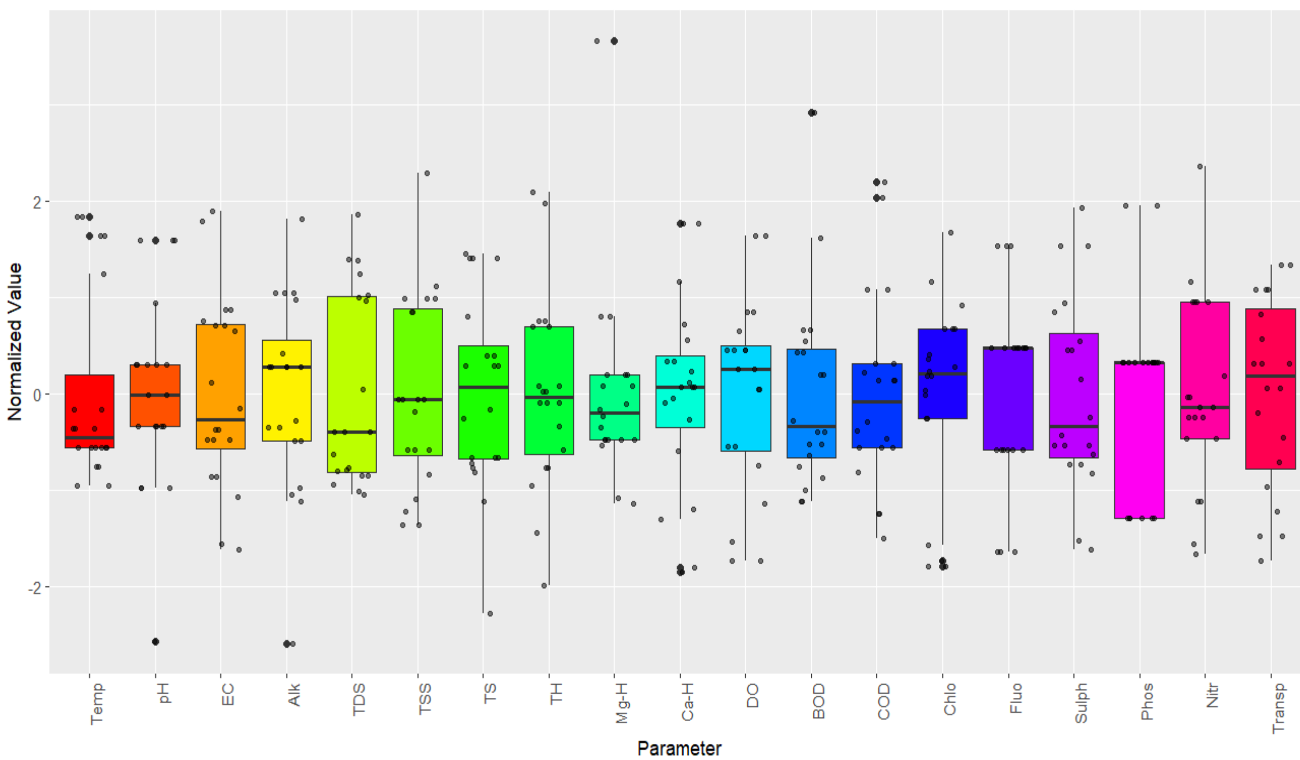

Fig 5. Spatio-temporal variations in water quality parameters for Tikari pond (2022)

Transparency is the measure of suspended minerals, bacteria, plankton and dissolved organic and inorganic substances. It is often associated with surface water sources. In most waters, turbidity is due to Colloidal and extremely fine dispersions. Secchi Disk Secchi disks are used to measure Secchi depth. Secchi depth provides an estimate of water clarity and is a measure of how far down light penetrates into the water column. The average transparency for both ponds ranged between 13 to 31 cm . The current study provides a detailed analysis of the physico-chemical characteristics of water in two selected ponds over a three-year period, highlighting the significant seasonal and spatial variations in water quality. These findings are consistent with other studies that have investigated the impact of environmental factors and anthropogenic activities on water bodies.

3.1 Nutrients and Eutrophication: Our study identified high concentrations of nutrients such as nitrates and phosphates in the ponds, which contribute to eutrophication—a phenomenon where excessive nutrients stimulate the growth of aquatic plants and algae. This process, in turn, leads to oxygen depletion and reduced light penetration, which can severely harm aquatic life. Similar findings have been reported by Zhang et al. (2022) in the Yangtze River, where nutrient enrichment from agricultural runoff and sewage discharge was identified as a major contributor to declining water quality. The excessive growth of algae and subsequent oxygen depletion observed in our study align with the results of Jhingran et al. (1989), who also noted significant impacts of nutrient pollution on aquatic ecosystems.

3.2 Temperature Fluctuations: Temperature variations were observed across the sampling stations, with notable differences between seasons and directions. The temperatures recorded ranged from 21°C to 38°C, influenced by factors such as seasonal changes and subsurface heat dynamics. These fluctuations are critical as temperature influences the metabolic rates of aquatic organisms and the solubility of gases like oxygen. The findings align with those of Taniwaki et al. (2019), who reported similar seasonal temperature variations in tropical headwater streams and emphasized the influence of agricultural practices on water temperature.

3.3 pH Levels: The study found that pH levels in most stations frequently exceeded 9, indicating alkaline conditions. This high pH can affect nutrient solubility and the health of aquatic organisms, as observed in Xia and Chen (2015), who studied the Huai River Basin and found that alkaline conditions were detrimental to aquatic biodiversity. The regular exceedance of pH levels beyond the neutral range suggests the influence of local geology and possible pollution sources, similar to the findings of Alvarez et al. (2018), who reported that industrial discharges and agricultural runoff could lead to elevated pH levels in water bodies.

3.4 Electrical Conductivity and Total Solids: Electrical conductivity (EC) and Total Dissolved Solids (TDS) levels exceeded WHO recommendations in certain areas, particularly at stations S-1 and S-2. These elevated levels indicate the presence of dissolved minerals, likely from agricultural runoff and potential sewage contamination. This observation is consistent with the findings of Uhl et al. (2012), who noted that increased EC and TDS were often linked to anthropogenic activities, including agricultural and urban runoff. The high TDS levels observed in our study during the monsoon season, particularly in July, suggest that surface runoff during this period contributes to the increased mineral content in the ponds.

3.5 Total Hardness: The study's assessment of total hardness revealed levels that exceeded WHO guidelines in several instances, particularly in the north direction during January and July. High hardness levels, mainly due to elevated concentrations of calcium and magnesium ions, can affect the usability of water for domestic purposes. Sinha (1995) similarly reported high hardness in rural pond water, which posed challenges for its use without appropriate treatment. The observed hardness in our study emphasizes the need for pre-treatment to ensure the water's suitability for consumption.

3.6 Dissolved Oxygen (DO), BOD, and COD: Dissolved Oxygen (DO) levels were found to fluctuate significantly, with the highest values recorded during cooler months. The variation in DO levels is crucial for assessing the health of aquatic ecosystems, as low oxygen levels can lead to fish kills and reduced biodiversity. The study's findings are in line with those of Jadhav (1992), who reported that pollution and organic matter decomposition significantly reduced DO levels in water bodies. The elevated Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) observed in our study, particularly during the monsoon season, suggest the presence of organic pollution, which is further supported by the findings of Manivasakam (2018), who highlighted the impact of organic waste on water quality.

3.7 Chlorides and Fluorides: While chloride and fluoride levels in the ponds were within permissible limits, their presence indicates possible contamination from sewage and other sources. The findings are consistent with Khurana and Sen (2021), who reported that chloride contamination is often associated with urban runoff and sewage discharge, which can degrade water quality over time.

Table 8: Physicochemical Characteristics of Tikari (S-2) Pond for Year 2021

	N-Jan	N-Apr	N-Jul	N-Oct	S-Jan	S-Apr	S-Jul	S-Oct	E-Jan	E-Apr	E-Jul	E-Oct	W-Jan	W-Apr	W-Jul	W-Oct	I-Jan	I-Apr	I-Jul	I-Oct
Temp	23.0	35.0	24.0	22.0	24.0	34.0	26.0	22.0	25.0	34.0	26.0	24.0	24.0	34.0	25.0	23.0	25.0	35.0	26.0	23.0
pH	8.6	8.2	8.4	8.7	8.8	8.4	8.3	9.2	9.4	8.4	8.1	8.6	8.5	8.3	8.1	8.9	8.9	8.4	8.7	8.2
EC	765.0	734.0	768.0	759.0	765.0	786.0	732.0	738.0	754.0	757.0	724.0	748.0	734.0	738.0	768.0	749.0	754.0	786.0	724.0	758.0
Alk	254.0	276.0	246.0	276.0	243.0	276.0	254.0	287.0	253.0	276.0	265.0	287.0	247.0	265.0	287.0	244.0	254.0	276.0	287.0	269.0
TDS	356.0	354.0	346.0	321.0	325.0	354.0	367.0	321.0	264.0	237.0	256.0	253.0	232.0	254.0	265.0	237.0	265.0	244.0	265.0	255.0
TSS	25.0	46.0	36.0	21.0	26.0	23.0	45.0	44.0	44.0	31.0	65.0	32.0	37.0	48.0	31.0	29.0	31.0	35.0	43.0	54.0
TS	265.0	289.0	267.0	267.0	276.0	298.0	254.0	287.0	276.0	265.0	287.0	234.0	256.0	298.0	265.0	255.0	265.0	254.0	213.0	245.0
TH	234.0	231.0	243.0	214.0	200.0	190.0	212.0	211.0	195.0	212.0	221.0	233.0	187.0	200.0	213.0	211.0	211.0	123.0	210.0	201.0
Mg-H	89.0	91.0	67.0	100.0	111.0	189.0	123.0	126.0	98.0	100.0	113.0	101.0	99.0	98.0	100.0	110.0	110.0	112.0	101.0	126.0
Ca-H	119.0	122.0	143.0	135.0	132.0	156.0	126.0	100.0	143.0	156.0	132.0	153.0	154.0	136.0	138.0	143.0	113.0	143.0	112.0	111.0
DO	8.3	7.4	7.8	7.3	7.5	7.1	6.8	7.9	7.3	6.2	6.1	7.8	5.7	7.9	6.3	6.8	7.4	7.3	7.1	7.8
BOD	6.88	5.14	6.08	6.66	5.71	1.62	6.64	4.98	6.84	3.74	7.36	3.55	4.24	6.79	3.75	10.35	3.88	6.71	5.95	3.94
COD	46.0	79.0	54.0	44.0	35.0	33.0	54.0	35.0	45.0	66.0	53.0	25.0	26.0	43.0	31.0	42.0	54.0	42.0	31.0	54.0
Cl^-	165.0	176.0	157.0	187.0	265.0	278.0	256.0	234.0	254.0	265.0	276.0	243.0	256.0	276.0	287.0	247.0	245.0	275.0	256.0	245.0
F^-	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4
SO_4^{2-}	67.0	54.0	67.0	98.0	43.0	67.0	56.0	59.0	43.0	45.0	31.0	55.0	59.0	32.0	54.0	67.0	55.0	45.0	56.0	61.0
PO_4^{2-}	0.3	0.3	0.3	0.2	0.4	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2
NO_3^-	32.0	48.0	43.0	58.0	65.0	44.0	54.0	45.0	37.0	48.0	54.0	65.0	65.0	77.0	45.0	56.0	44.0	65.0	68.0	43.0
Transp	26.0	24.0	16.0	20.0	25.0	22.0	15.0	18.0	27.0	23.0	19.0	22.0	27.0	23.0	18.0	22.0	27.0	25.0	17.0	20.0

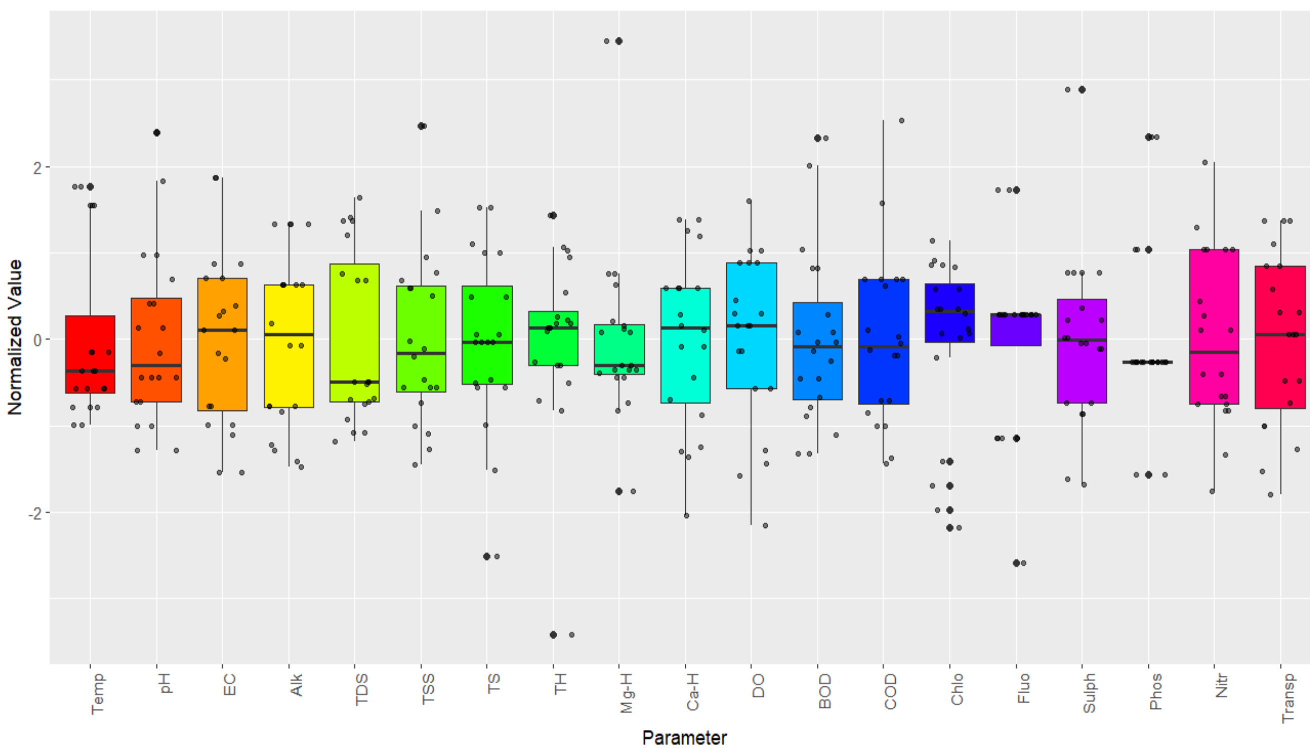

Fig 6. Spatio-temporal variations in water quality parameters for Tikari pond (2021)

3.8 Sulphates and Phosphates: The study found that sulphate levels remained below the Indian standards, indicating limited industrial impact in the region. However, the continuous monitoring of sulphate is recommended to prevent future contamination, as noted by Venkataeswarlu (1999). Phosphate levels, primarily from agricultural runoff, were found to be within permissible limits, suggesting that current agricultural practices have not yet led to excessive phosphorus contamination. This finding aligns with the results of Bakker (2012), who emphasized the importance of managing agricultural runoff to prevent eutrophication and other environmental issues.

3.9 Nitrates: Nitrate concentrations in several stations exceeded permissible limits, posing significant health risks, especially for infants and pregnant women. Elevated nitrate levels can lead to disorders such as methemoglobinemia, also known as *"blue baby syndrome."* The study's findings are consistent with those of Vogel (2008), who highlighted the dangers of nitrate pollution in drinking water, particularly in agricultural areas where fertilizers are heavily used.

3.10 Transparency: The transparency of the water, as measured by Secchi depth, ranged between 13 to 31 cm, indicating varying levels of suspended solids and other particulates. Lower transparency often correlates with higher levels of turbidity, which can impact aquatic life by reducing light penetration and hindering photosynthesis. This observation is in line with the findings of Manivaskam (2000), who reported that turbidity is a key indicator of water quality, particularly in surface water sources.

4. Conclusion

The present study offers a thorough analysis of the physico-chemical characteristics of pond water in Birkona village, revealing significant seasonal and spatial variations that have important implications for water quality and public health. While some parameters, such as sulphates and phosphates, were found to be within acceptable limits, others, including nitrates, hardness, and BOD/COD, consistently exceeded recommended thresholds, highlighting potential risks to both human health and aquatic ecosystems.

These findings underscore the critical importance of regular monitoring and proactive management to address these water quality issues. The challenges observed in Birkona village are not isolated but rather reflect broader environmental trends influenced by agricultural practices, urbanization, and seasonal dynamics, as documented in other studies. Addressing these challenges will require a coordinated effort that includes local authorities, community education, and the implementation of effective water treatment and management strategies to ensure the long-term sustainability and safety of these vital water resources.

Human activities such as farming, deforestation, and industrial processes significantly impact the temperature, transparency, total dissolved solids (TDS), and total suspended solids (TSS) of surface water, as seen in similar studies across various regions of India (Khurana and Sen, 2021). The uncontrolled discharge of untreated agricultural, domestic, and industrial wastes has led to a marked decline in water quality, with increased levels of nitrogen compounds, toxic metals, and other pollutants that pose significant risks to the environment and human health.

The study's key findings include the observation of high pH levels indicating alkaline conditions, elevated TDS levels, and total hardness that consistently exceeded WHO guidelines, suggesting that the pond water in Birkona requires pretreatment before being deemed suitable for domestic use. Furthermore, Dissolved Oxygen (DO) levels exceeded permissible limits, indicating potential risks to aquatic life due to factors such as oxygen diffusion, water temperature, and salinity.

In conclusion, this study highlights the urgent need for careful management and ongoing monitoring of the pond waters in Birkona village to ensure their continued suitability for domestic purposes. The implementation of appropriate water treatment measures and environmental protection strategies will be essential in safeguarding these water resources and the health of the local population.

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