Asian Journal of Chemistry; Vol. 37, No. 3 (2025), 653-660

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2025.33272

Evaluating Water Quality of Village Ponds using Water Quality Index and Multivariate Statistical Techniques: A Case Study of Rohtak Block, Haryana, India

AMITA KHATRI[1], VISHAL PANGHAL[1], ASHA SINGH[1], SHRUTI SHARMA[1], RACHNA BHATERIA[1], ROHIT KUMAR[2], SUNDER SINGH ARYA[3] and SUNIL KUMAR[1,*]

[1]Department of Environment Science, Maharshi Dayanand University, Rohtak-124001, India
[2]Department of Geography, Maharshi Dayanand University, Rohtak-124001, India
[3]Department of Botany, Maharshi Dayanand University, Rohtak-124001, India

*Corresponding author: E-mail: sunilevs@yahoo.com

Received: 26 December 2024; *Accepted*: 7 February 2025; *Published online*: 28 February 2025; AJC-21922

Pond water pollution has become a menace caused by various anthropogenic factors such as agricultural runoff, industrial waste and domestic wastewater. This study aims to assess the water quality and pollution levels in rural village ponds of Rohtak block, Haryana state, India. To assess the water quality, a total of 34 samples from 22 villages and one from the Tilyar city lake were collected. Various physico-chemical parameters were determined using standard methods. Total dissolved solids (TDS) were varied from 105 to 4254 mg/L, maximum was recored at S5 site (Shimli village). The 30% water samples for TDS, 62% for total hardness (TH) and 56% for Mg^{2+} surpass the prescribed limits of the Bureau of Indian Standards (BIS). The dissolved oxygen (DO) and biological oxygen demand (BOD) were ranged from 1.0 to 4.5 mg/L and 1.6 to 34.4 mg/L respectively, maximum recorded at S1 site (Sunderpur village). The 90% of the samples have very low DO (> 4 mg/L) and have higher BOD (< 2 mg/L) indicating a high organic load in the ponds. The water quality index (WQI) shows that 82% of samples were not fit for human consumption. Multivariate statistical technique, principal component analysis (PCA) reported that the first four principal components (PCs) accounted for 77.46% of the variance in water samples. Hierarchical cluster analysis (HCA) formed up four different clusters. It can be concluded that the pond water quality of the block has deteriorated and domestic wastewater treatment needs to be done by district administration.

Keywords: Rural ponds, Statistical techniques, Water quality, Organic pollution, Rohtak block.

INTRODUCTION

A pond is defined as an artificial or natural body of water that retains water for at least four months of the year and is typically utilized as a source of groundwater recharge [1,2]. Ponds are a common sight in many subtropical villages and have been used extensively as vital water sources for farming, raising fish, replenishing groundwater and strengthening the resiliency of the village against floods and droughts.Ponds offer humans a range of free ecological services, including those related to social, cultural, economic, scientific, medicinal and aesthetic aspects [3]. Ponds have been utlilized as a traditional source of water supply in India [4]. In previous decades, owing to the ecological importance attributed to ponds, each village typically maintained a minimum of four to five ponds for various water needs [5].

The rural community has long relied on the village ponds for various purposes; but, as a result of human activities, the water quality is gradually declining. Presently, many village ponds within these regions are contaminated with solid waste, agriculture runoff and domestic wastewater. Deterioration of water quality in these ponds *via* faecalmatter and animal waste poses significant public health risks due to the propagation of various diseases and the emission of foul odours [6]. Villages in subtropical nations deal with clogged ponds and stagnant drains, which urgently need to be fixed so that the ponds can be successfully used as a supply of water for agriculture, aquaculture and perhaps even bathing and drinking [7]. One activity which highly impacts the lake and pond water quality is a religious practice, that includes mass bathing and the immersion of ash, wheat, oil, soap and detergents as well as floral offerings [8]. The unregulated discharge of domestic wastewater into ponds leads to eutrophication of the ponds [9,10].

A common, standardized and repeatable unit of measurement for water quality information is the widely used water quality index (WQI), which is utilized by both policymakers and concerned citizens.The most popular multivariate statistical method for analyzing relationships between observed variables is principal component analysis (PCA), which reduces enormous amounts of data by extracting a small number of linear elements [11]. There were a lot of studies that used WQI [12-14] and multivariate statistics like PCA and hierarchical cluster analysis (HCA) to find out the water quality of groundwater and ponds [11,15,16].

The preservation of pond ecosystems has been hampered in some way by a lack of knowledge and comprehension [17]. In this study, an effort has been made to determine the level of pollution in village ponds of Rohtak block, Haryana by analyzing the physico-chemical properties of water. So far water quality of ponds has been checked in urban areas. Few studies have examined the water quality of rural ponds in India, and there has been no comprehensive research conducted on the ponds in the Rohtak block. Therefore, the objectives of the study were (i) to evaluate the physico-chemical properties and organic loadings of village pond water in Rohtak block; (ii) to determine WQI in pond water to know the water suitability; (iii) to categorize the pond water samples by using multivariate statistical techniques PCA and HCA. The impact assessment of surface runoff, small industries and residential wastewater on pond water is essential for environmental security. The accumulation of nutrients and organic waste in the water is a typical threat to pond water in rural areas.

EXPERIMENTAL

Study area description and water sampling: The study was conducted in Rohtak block which is part of Rohtakdistrict, one of 22 districts of Haryana, India. In terms of location, Rohtak lies at 28°15′ to 30° N and 76°12′45″ to 77°13′45″ E. The study area land was dominated by agricultural land, agricultural plantations, wasteland, grassland, built-up and water bodies (Fig. 1).

The ponds water in the study area is mainly used for cattle drinking and bathing, groundwater recharge, irrigation of nearby land and aquaculture. A total of 33 ponds water samples were collected from 22 villages, while one sample was collected from Rohtak city lake (Tilyar). All the sampling locations were tabulated in Table-1 and also depicted in Fig. 2. Samples were collected in the month of January 2023. In some villages, more than 1 sample was taken depending on the village population density. Dissolved oxygen was fixed at the point of sampling with the alkaline potassium-iodide solution. These samples were

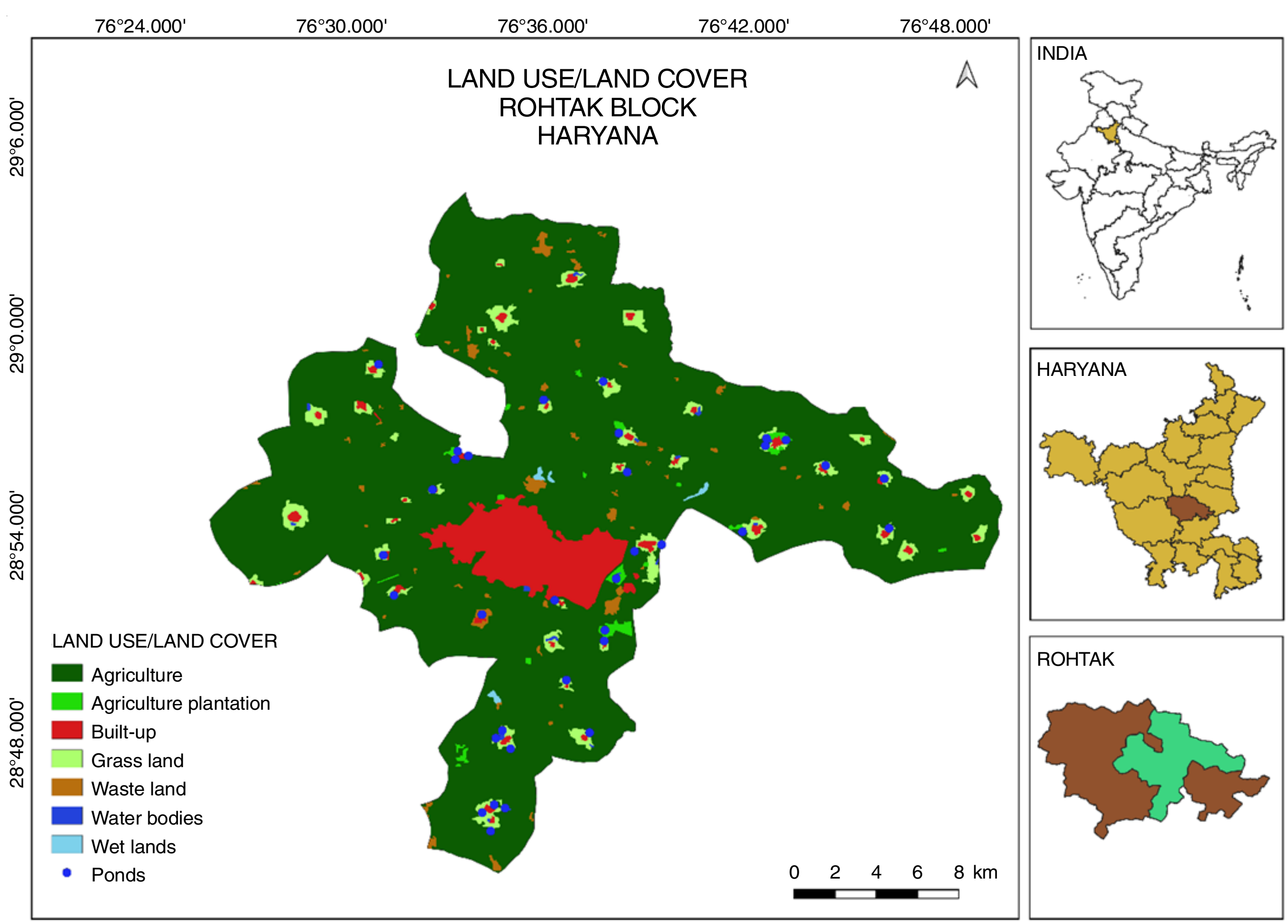

Fig. 1. Land use and occupation map of the study area

TABLE-1
SAMPLING LOCATION OF THE VILLAGE POND WATER SAMPLES WITH THEIR SAMPLE ID

Sample location	Sample Id	Sample location	Sample Id	Sample location	Sample Id	Sample location	Sample Id
Sunderpur (P1)	S1	Bohar (P1)	S10	Garnawathi (P3)	S19	Bhalot	S28
Sunderpur (P2)	S2	Bohar (P2)	S11	Kakrana	S20	Chamariya	S29
Sunderpur (P3)	S3	Singhpura	S12	Retoli	S21	Tilyar	S30
Khedisadh	S4	Kanheli	S13	Karontha	S22	Baliyana (P1)	S31
Shimli	S5	Sundana (P1)	S14	Gaddikheri	S23	Baliyana (P2)	S32
Pehrawar	S6	Sundana (P2)	S15	Kiloi (P1)	S24	Baliyana (P3)	S33
Makdauli	S7	Sundana (P3)	S16	Kiloi (P2)	S25	Majra	S34
Sunariya	S8	Garnawathi (P1)	S17	Kiloi (P3)	S26		
Makdauli Kalan	S9	Garnawathi (P2)	S18	Sasroli	S27		

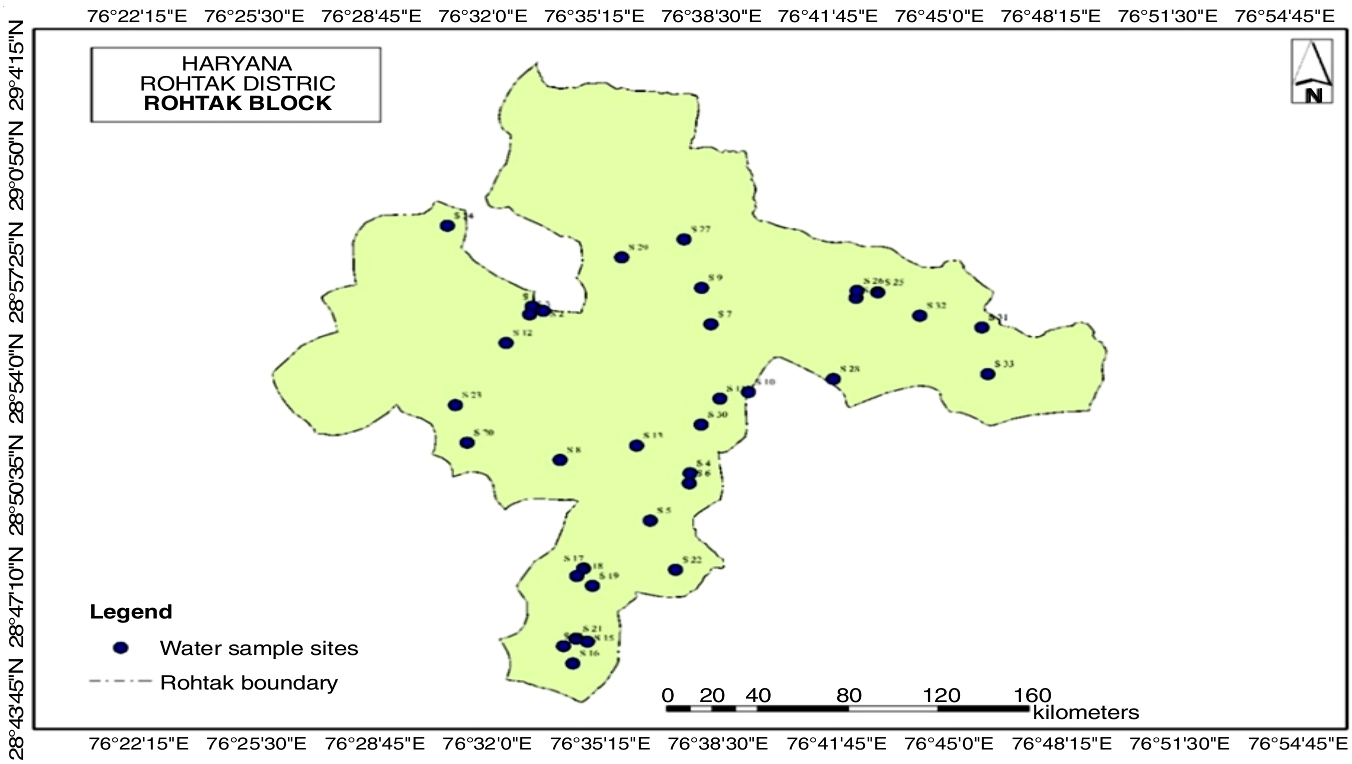

Fig. 2. Location of village ponds

collected in pre-washed bottles and preserved airtight to avoid evaporation, transferred and stored at 4 ºC and examined within 2 days.

Analysis of various parameters: Analysis of pond water samples was conducted in accordance with the American Public Health Association (APHA, 2005) [18]. Parameters like pH, electrical conductivity (EC) and total dissolved solids (TDS) were evaluated on the sites using Systonic water and soil testing kit model No. 371. Dissolved oxygen (DO) was obtained using Winkler's method. The biological oxygen demand (BOD)was determined by taking the difference in initial and final DO. The desirable dilution has been made before incubation of the samples for 3 days at 27 ºC. The determination of the chemical oxygen demand (COD) from those compounds that were capable of undergoing chemical oxidation was done by refluxing it with $K_2Cr_2O_7$ and H_2SO_4 in the presence of mercuric sulphate. Total alkalinity (TA) was estimated by a simple acid titration method. The HCO_3^- content of the sample was estimated indirectly by making use of the total alkalinity reading. Chloride (Cl^-) was measured by the argentimetric titration method using silver nitrate. Total Hardness (TH) was measured using the EDTA titration method. Sulphate (SO_4^{2-}) in water samples was estimated using barium chloride.Flame photometer model No. ESI 381 was used to analyze sodium (Na^+) and potassium (K^+).

Multivariate statistical analysis: Statistical parameters mean and standard deviation were computed using MS Excel. Pearson coefficient of correlation, PCA and HCA were applied among pond water parameters using SPSS 25.0.

Water quality index (WQI): The WQI is a simple method that uses a set of criteria to reduce large amounts of data to a particular sum that is usually dimensionless and easily replicable. The sub-indices (SI_i) corresponding to each parameter were derived from both the relative weight of the parameters (RW) and their quality ratings (Qi). These sub-indices (SI_i) are subsequently employed in the computation of the water quality index (WQI) using the following equations [19]:

$$SI_i = RW \times Qi$$

$$WQI = \Sigma SI_i$$

RESULTS AND DISCUSSION

The findings of the physico-chemical parameters of the examined samples are shown in Table-2. The Pearson correlation among parameters was calculated and presented in Table-3.

Physico-chemical analysis of pond water samples: The pH of analyzed samples varies from 7.42 to 9.31. The pH of samples from 61% of the ponds was higher than 8. When compared to the BIS standards of water quality, the pH values of all samples fall within permissible limits except one sample from site S31 (Baliyana P1). TDS fluctuated from 105 to 4254 mg/L in the present study. Sample of Tilyar Lake (S30) and Shimli (S5) pond water represented the lowest and highest concentrations of TDS, respectively. After comparison with the prescri-

TABLE-2
PHYSICO-CHEMICAL ANALYSIS AND WATER QUALITY INDEX (WQI) OF VILLAGE POND WATER SAMPLES

ID	pH	TDS	EC	DO	BOD	COD	TA	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO^{3-}	SO_4^{2-}	WQI
S1	7.92	2445	3650	1.0	34.4	107	150	1600	46	34	180	70	200	183	61	323
S2	8.25	3242	4840	3.0	32.2	84	150	1000	80	195	450	103	690	183	355	275
S3	7.86	1090	1627	3.5	16.4	91	50	440	44	80	100	60	175	51	67	158
S4	7.84	1054	1574	2.5	13.2	36	60	500	54	88	72	104	215	63	20	114
S5	7.95	4254	6350	1.0	25.0	85	50	6400	256	1404	173	250	2508	61	12	539
S6	7.90	670	1000	3.0	12.0	33	60	400	54	64	45	80	85	63	39	97
S7	8.01	1614	2410	3.5	16.2	34	100	1240	51	273	79	56	690	122	7.7	176
S8	8.33	1480	2210	3.0	13.2	42	140	800	64	156	112	130	260	170	13	150
S9	7.76	1013	1512	4.0	13.8	28	60	600	54	113	79	56	200	63	38	120
S10	8.35	1614	2420	3.0	12.0	42	150	300	38	49	146	61	260	183	24	127
S11	8.29	2733	4080	2.5	13.2	40	100	900	73	200	189	135	625	122	19	186
S12	8.30	1721	2570	3.0	16.2	38	150	600	48	117	152	70	275	183	31	148
S13	8.16	2278	3400	2.5	13.2	45	150	1440	48	322	140	190	400	183	20	206
S14	7.42	3376	5040	2.5	1.8	32	100	1700	137	330	175	111	155	122	22	211
S15	8.26	1514	2260	3.8	4.8	28	130	1000	64	204	114	110	225	158	24	144
S16	7.96	320	2200	4.0	1.6	48	100	500	80	73	88	74	150	122	13	116
S17	7.88	670	1000	3.0	12.8	45	70	300	35	51	85	6	50	85	27	102
S18	8.22	1447	2160	3.0	3.2	34	100	500	64	83	95	190	225	122	10	114
S19	8.08	3008	4490	3.0	19.2	51	200	1220	64	258	173	425	550	244	23	231
S20	8.27	1788	2670	3.0	7.2	28	150	1100	99	207	118	105	625	183	17	156
S21	7.99	738	1102	3.2	3.2	91	50	348	64	45	60	80	100	51	36	123
S22	8.26	1323	1975	3.0	12.0	28	60	680	38	142	100	89	285	63	49	129
S23	8.33	1059	1581	3.0	4.8	28	60	480	70	74	83	91	175	63	25	99
S24	7.70	1618	1200	1.5	11.2	57	150	1700	96	356	550	105	1401	183	149	201
S25	8.19	3149	4700	3.0	27.2	85	200	1200	64	253	195	165	400	244	45	261
S26	8.33	2244	3350	1.5	10.8	57	150	900	64	180	171	75	370	183	34	174
S27	7.81	324	485	3.0	18.0	42	40	320	44	50	16	14	50	48	23	96
S28	8.20	931	1390	3.0	9.0	57	50	388	35	73	80	73	147	51	20	116
S29	8.27	274	410	3.0	8.0	57	50	700	256	14	10	4	25	61	8.0	93
S30	8.29	105	157	4.5	7.8	57	30	200	25	33	8	3	10	36	25	88.5
S31	9.31	2613	3900	2.0	3.6	76	180	1200	48	263	155	170	460	219	17	338
S32	8.08	1835	2740	1.50	19.2	40	150	1100	64	229	120	215	400	183	12	372
S33	8.27	271	405	3.0	3.2	42	40	264	32	44	185	39	10	48.8	25	82
S34	8.19	615	1000	4.0	12.0	32	100	1840	128	370	112	36	500	122	56	183
Mean	8.12	1601.19	2407.58	2.85	12.6	50.5	103.82	995.88	73.18	189.35	135.61	104.26	379.57	124.29	40.66	
SD	0.307	1037.34	1524.28	0.82	7.202	22.0	50.57	1063.08	52.50	238.72	106.6	82.2	465.43	64.05	61.20	
BIS 2012	6.5-8.5	2000	–				600	600	200	100	–	–	1000	–	400	

Values of parameters are in mg/L, excluding pH (unitless) and EC (mmho/cm).

TABLE-3
PEARSON CORRELATIONS BETWEEN PHYSICO-CHEMICAL PARAMETERS OF PONDS WATER SAMPLES

	pH	TDS	EC	DO	BOD	COD	TA	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO^{3-}	SO_4^{2-}
pH	1														
TDS	0.062	1													
EC	0.079	.972**	1												
DO	0.005	-.583**	-.503**	1											
BOD	-0.064	.401*	.396*	-0.067	1										
COD	0.308	0.256	0.253	-.516**	0.151	1									
TA	0.324	.594**	.579**	-0.325	0.306	0.332	1								
TH	-0.118	.652**	.631**	-.522**	0.121	0.145	0.101	1							
Ca^{2+}	-0.136	0.281	0.281	-0.256	-0.150	-0.048	-0.118	.672**	1						
Mg^{2+}	-0.080	.640**	.617**	-.440**	0.135	0.080	0.087	.972**	.617**	1					
Na^{+}	-0.053	.513**	.411*	-.430*	0.192	0.103	.502**	0.276	0.070	0.275	1				
K^{+}	0.106	.664**	.660**	-.366*	0.231	0.257	.536**	.435*	0.129	.473**	0.242	1			
Cl^{-}	-0.061	.620**	.561**	-.508**	0.165	0.080	0.179	.892**	.544**	.914**	.509**	.449**	1		
HCO^{3-}	0.324	.594**	.580**	-0.326	0.299	0.330	.998**	0.116	-0.099	0.100	.504**	.528**	0.189	1	
SO_4^{2-}	-0.059	0.240	0.187	-0.051	.444**	0.030	0.194	0.012	-0.019	0.000	.728**	-0.062	0.193	0.189	1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

bed water quality standards of BIS (2012) [20], it is revealed that 29.41% of samples were above standard limits. The main cause of pond water quality degradation is the disposal of domestic wastewater, high soil salinity and agricultural activity in the surrounding area. The wastewater from the village contains detergents, cow dung, rotten vegetable waste and a variety of other organic compounds, making the water rich in inorganic and organic material [17]. Total dissolved solids (TDS) exhibited a strong positive correlation with electrical conductivity (EC) and a moderate positive correlation with HCO_3^-, TA, TH, Cl^-, Mg^{2+} and K^+ besides it shows a weak positive correlation with Na^+ ions respectively. EC ranged from 157 to 6350 μmhos/cm. The maximum and minimum values were shown by the samples of Shimli (S5) and Tilyar Lake (S30), respectively. According to standards laid down by CPCB (2019), a total of 47% of samples fail the criteria of a standard value of 2250 μmhos/cm for irrigation [21]. According to Ekhalak *et al.* [22], the outflow of salts from homes and agricultural fields, as well as water evaporation, are likely to be the causes of the elevated EC values in ponds. EC depicted a moderate positive correlation with TH, Mg^{2+}, K^+ and a weak positive correlation with Cl^-, TA and HCO_3^-. The range of total alkalinity varied from 30 mg/L to 200 mg/L. The highest and lowest concentrations of total alkalinity were found at the sites S19, S25 and S30, respectively. All samples were found within the prescribed limits. TA shows a distinct positive correlation with HCO_3^- and a weak positive correlation with Na^+ and K^+. TH varied from 200 to 6400 mg/L with being minimum at Tilyar (S30) and highest at Shimli pond (S5). A total of 61.76% of samples have elevated values than as prescribed by BIS. The potential cause of this elevated hardness could be attributed to untreated residential wastewater that is dumped straight into the water. TH shows a moderate positive correlation with Ca^{2+} and a weak positive correlation with Mg^{2+} and Cl^-. In present study, it was investigated that Ca^{2+} differs from a minimum value of 25.6 mg/L at Tilyar lake (S30) to a maximum of 256 mg/L at S29 (Chamariya) and S5 (Shimli). Only 2 samples of Ca^{2+} show higher values than prescribed by BIS. Ca^{2+} shows a moderate positive correlation with Mg^{2+} and a weak positive correlation with Cl^-. Mg^{2+} concentration in pond water samples varied from 14 mg/L to 1404 mg/L. The minimum value was detected at Chamariya pond (S29) while the maximum was found in Shimli pond (S5). 55.88 % of the samples show values higher than the advised standards. The high quantity of Mg^{2+} may be attributed to runoff into the ponds from a large agricultural area [18]. It shows a strong positive correlation with Cl^-. The minimum observed value of sodium is 8 mg/L at Tilyar Lake (S30) and the maximum value is 550 mg/Lat the S24 (Kiloi P1) site. The elevated presence of sodium in ponds may be attributed to human waste disposal, particularly in the form of soap solutions and detergents [17]. Na^+ shows an average positive correlation with SO_4^{2-} and a weak positive correlation with Cl^- and HCO_3^-. The value of K^+ ranged between 3 mg/L (Tilyar Lake) to 425 mg/L (Garnavati P3). The main source of K^+ waste might be agricultural field run-off. K^+ shows a weak positive correlation with HCO_3^-. The concentration of Cl^- varied between 10 mg/L to 2508 mg/L. The water sample of S30 (Tilyar lake) and S33 (Baliyana P3) village constituted the lowest and Shimli pond water (S5) showed the highest values of Cl^-. A total of two samples exceeds the standard limits laid down by BIS. The SO_4^{2-} content varied from 7.7 mg/L to 355 mg/L. The minimum and maximum concentrations of SO_4^{2-} were shown by the S7 (Makdauli) pond water and S2 (Sunderpur P2), respectively. A comparison with BIS standards of water quality revealed that all the samples are within the permissible limits. The HCO_3^- concentration fluctuated from 36 mg/L to 244 mg/L. The maximum and minimum values are found at S19, S25 (Garnawati P3 and Kiloi P2) and S30 (Tilyar Lake), respectively.

Organic matter estimation: One of the key factors in assessing water quality is dissolved oxygen (DO) levels. These levels are influenced by factors like water temperature, salinity, altitude, water inflow and the photosynthetic activity of algae and plants [23,24]. DO of all samples was found to be below 5 mg/L ranging from 1.0 mg/L to 4.5 mg/L. The lowest value of DO1mg/L was found at S1 and S5 (Shimli and Sunderpur P1) ponds. The ponds of the study area were also used for fish culture. The aquaculture potential of these ponds was greatly damaged by the organic waste from the surrounding area. The survival and distribution of flora and animals are impacted by dissolved oxygen, making it one of the most important factors in evaluating the quality of water [13]. The CPCB states that for fisheries and aquatic life to proliferate, the DO in the water must be greater than 4 mg/L. These low DO contents obviously indicate the impact of the organic loadings on the water quality of ponds [25]. All the ponds except Tilyar (S30) were unsuitable for fish breeding (DO values were less than 4) when compared to standards laid down by CPCB, 2019 [21]. Because there are no significant industries nearby, the main source of organic pollution is domestic and, to a lesser amount, adjacent runoff. Goyal *et al.* [7] and Singh *et al.* [26] also reported DO as an indicator of pond water quality in their study of pond water quality in different areas. Shukla *et al.* [6] in their study of rural ponds found DO in the range of 3.8-6.4 mg/L. Goyal *et al.* [7] also determined the DO level of Muzaffar Nagar ponds in their study and they also reported very low DO which was in good agreement with our study indicating that neighbouring state ponds were also impacted by anthropogenic activities.

Determination of BOD is used to measure the amount of organic materials in an aquatic system that supports the development of microorganisms as well as to evaluate organic pollution [27]. The BOD of pond water from 34 villages varied from a minimum of 1.2 mg/L in Kiloi (P1) village to a maximum of 34.4 mg/L in Sunderpur 1 (S1) village. BOD is a good indicator of contamination and so helps in determining the appropriateness of water for consumption [28]. Comparison with standards of drinking water that were laid down by CPCB (2019) demonstrated that only 3 samples are within the permissible limit (< 3 mg/L) namely, S14 (Sundana P1), S16 (Sundana P3) and S24 (Kiloi P1), while others had a high concentration of BOD representing heavy organic pollution load in the pond water of villages. According to Khanom *et al.* [29], BOD should not exceed 6 mg/L for aquaculture. In present study, 76% of the ponds were unfit for aquaculture. Both parameters (DO and

BOD) indicate that human activities affect the aquaculture potential and great threat to the livelihood of rural communities. Activities of people and animals near the pond, such as washing and defecation, among other things, result in a high organic load concentration and a high BOD. The primary sources of the organic contaminants are animal faeces from pastures and the discharge of domestic wastewater from villages into ponds. Sarkar *et al.* [4], Goyal *et al.* [7] and Toor *et al.* [30] also analyzed BOD in their study of pond water samples and reported low values indicating degraded pond water quality due to high organic loadings in the ponds.

The value of COD varied from 28 to 107 mg/L. The maximum COD was present at site S1 (Sunderpur P1) while the minimum value of COD was found at pond water of villages S15 (Sundana P2), S20 (Kakrana), S22 (Karauntha) and S23 (GaddiKhedi). The higher the amount of pollutants, the higher the COD of the water samples indicating that organic waste is entering the ponds through sewage discharges, agricultural runoff and animal waste from pastures in the villages being the most likely sources [7]. The high organic loadings indicate that water is of very low quality for fish breeding or domestic purposes. Degradation of organic waste leads to low DO and foul odour. Degraded pond water quality serves as a breeding ground for mosquitoes, perhaps resulting in mosquito-borne diseases. Bhatnagar & Thakral [13] in their study of pond water quality of Kurukshetra reported the similar results with COD ranging from 20 to 269 in the pre-monsoon season while 13 to 226 mg/L in the post-monsoon season. Goyal *et al.* [7] also reported very high COD (56-380 mg/L) in the ponds of the Meerut and Muzaffarnagar cities of India.

Principal component analysis (PCA): The original data set was consolidated using PCA into a few variables that can explain the extremes of the variation in the dataset. Table-4 illustrates the PC-inserted data with the percentage of variance and cumulative percentage of variance described by each other. In this investigation, PCs with eigenvalues above one were chosen and shown in Table-4. It shows that four major PCs accounted for 77.460% of the variance. PC1, PC2, PC3 and PC4 all displayed variances of 40.329%, 18.559%, 11.305% and 7.267%, respectively. The key contributing parameters to PC1's 40.329% variance were TDS, EC, TH, Mg^{2+}, Na^{+}, K^{+} and Cl.The main contributors indicate ions in water which are increased by sources of pollution such as runoff from pasture facilities, agricultural runoff and as well as the use of detergents and soaps which increase electrical conductivity [31]. The key contributors to PC2's 18.559% variance are pH, BOD, COD, TA and HCO^{3-}. The main contributors indicate the presence of oxygen-consuming waste indicating waste from pasture facilities, defecation and bathing of animals near ponds, various anthropogenic activities like runoff from street channels containing domestic wastewater and as well as agricultural runoff. PC3 accounts for 11.305% variance with BOD, Na^{+} and SO_4^{2-} being the main contributors. PC4 shows a 7.267% variance with DO being the main contributor. Furthermore, it is evident that BOD consistently plays a significant role across all 4 PCs, showing a similar value that suggests organic pollution remains a persistent issue in the village ponds.

TABLE-4
PCA LOADING OF THE DATA ALONG WITH VARIMAX ROTATED COMPONENTS

	Components			
	PC1	PC2	PC3	PC4
pH	0.076	0.416	-0.478	-0.201
TDS	0.927	0.078	-0.002	0.166
EC	0.888	0.078	-0.060	0.242
DO	-0.669	0.050	0.167	0.482
BOD	0.369	0.318	0.392	0.376
COD	0.350	0.318	-0.388	-0.523
TA	0.621	0.680	-0.126	0.087
TH	0.778	-0.582	-0.058	-0.006
Ca^{2+}	0.399	-0.673	-0.040	-0.105
Mg^{2+}	0.763	-0.578	-0.050	0.072
Na^{+}	0.611	0.245	0.559	-0.335
K^{+}	0.699	0.126	-0.303	0.333
Cl^{-}	0.794	-0.454	0.121	-0.079
HCO_3^{-}	0.626	0.666	-0.128	0.082
SO_4^{-}	0.275	0.282	0.820	-0.237
Total	6.049	2.784	1.696	1.090
% of Variance	40.32	18.559	11.305	7.267
Cumulative %	40.32	58.887	70.193	77.460

Cluster analysis: Ward's method of hierarchical agglomerative cluster analysis was done while considering Euclidean distance as an estimate of similarity. The results of cluster analysis are represented using a dendrogram (Fig. 3). Cluster 1 is made up of sampling locations, *viz.* S1, S2, S11, S13, S14, S19, S25, S26 and S31. Ponds in cluster 1 have poor water quality which could be attributed byslightly higher TDS and low DO (< 3 mg/L). Cluster 2 consists of S3, S4, S6, S9, S16, S17, S21, S23, S27, S28, S29, S30 and S33. Ponds in cluster 2 have slightly

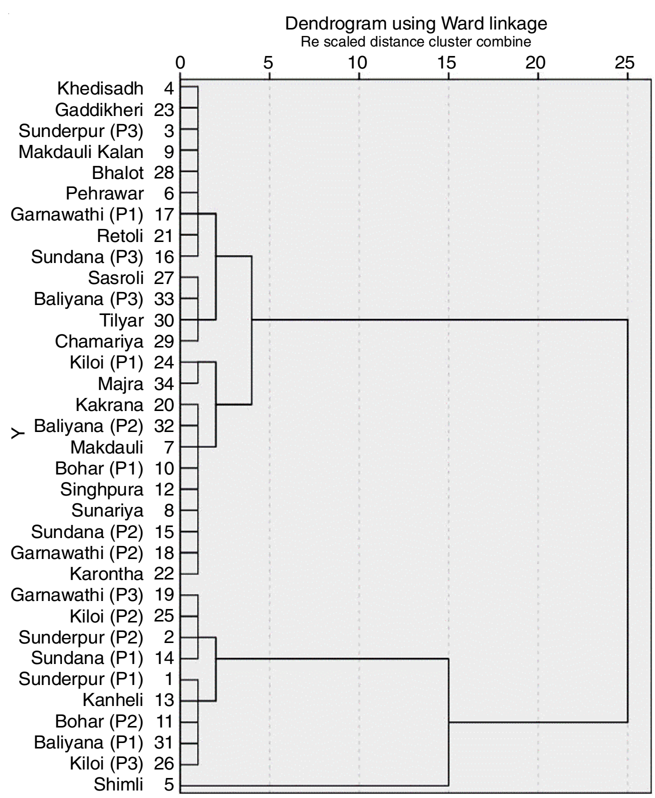

Fig. 3. WQI of pond water samples

betterwater quality in comparison to other clusters due to the lower EC and TDS. Cluster 3 has only one sample *i.e.* S5, which falls under the extremely poor water quality having the highest EC, TDS, TH and the lowest level of DO. Cluster 4 has 11 samples namely S7, S8, S10, S12, S15, S18, S20, S22, S24, S32 and S34 with moderate EC and TDS.

Water quality index (WQI): Out of the total samples, six samples fall in the category of good water quality, indicating a lesser inflow of wastewater from villages to these ponds. Eighteen samples fall in the category of poor water and six under the very poor water quality category, indicating the possibility of inflow of wastewater from villages carrying organic waste. The remaining 4 samples were found to be of unsuitable water quality, which indicates wastewater was heavily loaded with feces from pastures in villages as well as organic waste from catchment areas and there were also inflows from agricultural lands (Fig. 4).

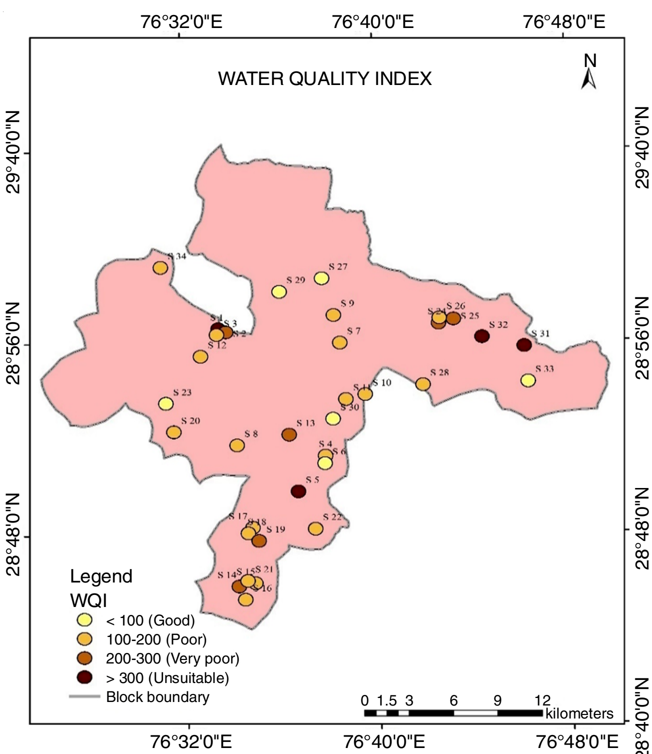

Fig. 4. WQI of pond water samples

Bhatnagar & Thakral [13] in their study of sacred ponds of Kurukshetra reported WQI from 35 to 264. Their findings were quite similar to our findings with ponds falling from good water quality to unsuitable water quality. They also mentioned that agricultural runoff and wastewater from villages containing animal faeces highly impact the water quality of ponds.

Conclusion

The villagers use pond water for cattle drinking, irrigation purposes and fish farming. The present study evaluated the physico-chemical parameters of village ponds of Rohtak block, Haryana state, India. Evaluation of these parameters revealed that most of the parameters did not match with standard values recommended by BIS for drinking and public health. The DO values obtained were below than 4 mg/L for most of the samples indicating that water is unfit for drinking purposes and the survival of aquatic life. Most of the samples showed a higher level of BOD indicating water is contaminated with organic matter. TDS, TH, Cl^-, Ca^{2+} and Mg^{2+} were above the prescribed limit in 30%, 55%, 5.9%, 5.9% and 47% of the samples, respectively. As per PCA, 41.116% variance is contributed by TDS, EC, TH, Mg^{2+}, and Cl^- in PC1. WQI described that 28 samples have degraded water quality unfit for drinking and domestic purposes. In conclusion, it is clear from the findings that the ponds have unusually high levels of organic and ion loading, which has led to low dissolved oxygen concentrations. Since ponds are essential to rural communities, it is necessary to properly restore the water quality using low-cost wastewater treatment methods, such as constructed wetlands.

ACKNOWLEDGEMENTS

The authors are thankful to Department of Environmental Sciences, Maharshi Dayanand University, Rohtak, Haryana, India for the use of their research facilities for some analysis.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES

1. S. Mushtaq, D. Dawe, H. Lin and P. Moya, *Agric. Water Manage.*, **83**, 100 (2006); https://doi.org/10.1016/j.agwat.2005.10.004
2. P. Passy, J. Garnier, G. Billen, C. Fesneau and J. Tournebize, *Sci. Total Environ.*, **430**, 280 (2012); https://doi.org/10.1016/j.scitotenv.2012.04.035
3. F. Xinyi, Y. Yihong, M. Lin, L. Xiaoying, H. Zhehui, L. Jiajie, L. Liu and W. Fushun, *Acta Geochim.*, **40**, 640 (2021); https://doi.org/10.1007/s11631-021-00478-y
4. R. Abdeldayem, *Appl. Water Sci.*, **10**, 1 (2020); https://doi.org/10.1007/s13201-019-1058-x
5. C.R. Gupta and T. Kaushik, *J. Trop. Life Sci.*, **2**, 95452 (2012).
6. B.K. Shukla, A. Gupta, P.K. Sharma and A.R. Bhowmik, *Mater. Today Proc.*, **32**, 824 (2020); https://doi.org/10.1016/j.matpr.2020.03.823
7. V.C. Goyal, O. Singh, R. Singh, K. Chhoden, J. Kumar, S. Yadav, N. Singh, N.G. Shrivastava and L. Carvalho, *J. Environ. Manage.*, **277**, 111450 (2021); https://doi.org/10.1016/j.jenvman.2020.111450
8. P. Devi, A. Bhtnagar and M.P. George, *J. Appl. Nat. Sci.*, **11**, 361 (2019); https://doi.org/10.31018/jans.v11i2.2044
9. Y. Li, A. Wright, H. Liu, J. Wang, G. Wang, Y. Wu and L. Dai, *Agric. Ecosyst. Environ.*, **272**, 155 (2019); https://doi.org/10.1016/j.agee.2018.11.021
10. M. Ni, J.L. Yuan, M. Liu and Z.M. Gu, *Aquacult. Rep.*, **11**, 53 (2018); https://doi.org/10.1016/j.aqrep.2018.06.002
11. V. Panghal, P. Sharma, M. Sharma and R. Bhateria, *Environ. Geochem. Health*, **44**, 3581 (2021); https://doi.org/10.1007/s10653-021-01120-9
12. A. Tamrakar, K. Upadhyay and S. Bajpai, *IOP Conf. Ser. Earth Environ. Sci.*, **1032**, 012034 (2022); https://doi.org/10.1088/1755-1315/1032/1/012034
13. A. Bhatnagar and N. Thakral, *Sustain. Water Resour. Manag.*, **9**, 159 (2023); https://doi.org/10.1007/s40899-023-00939-7
14. V. Panghal and R. Bhateria, *Environ. Geochem. Health*, **43**, 2615 (2021); https://doi.org/10.1007/s10653-020-00654-8

15. A. Dixit, N.S. Siddaiah and P. Joshi, *Arab. J. Geosci.*, **14**, 199 (2021); https://doi.org/10.1007/s12517-020-06423-2
16. V. Panghal, R. Bhateria, R. Kumar, S.S. Arya and S. Kumar, *J. Geol. Soc. India*, **99**, 430 (2023); https://doi.org/10.1007/s12594-023-2327-8
17. A. Nandal, N. Kaushik, S.S. Yadav, A.S. Rao, N. Singh and S.S. Gulia, *Indian J. Ecol.*, **47**, 1 (2020).
18. APHA 2005, Standard Methods for the Examination of Water and Wastewater, American Public Health Association, Washington DC, USA, edn. 21 (2005).
19. R. Das Kangabam, S.D. Bhoominathan, S. Kanagaraj and M. Govindaraju, *Appl. Water Sci.*, **7**, 2907 (2017); https://doi.org/10.1007/s13201-017-0579-4
20. BIS (Bureau of Indian Standard), Indian Standard Specification for Drinking Water, IS:10500[S] (2012).
21. CPCB (Central Pollution Control Board), Water Quality Standards (2019); Available at: https://cpcb.nic.in/wqstandards
22. A. Ekhalak, G. Mohini and S. Ranjana, *Int. J. Innov. Res. Sci. Eng.*, **2**, 4458 (2013).
23. D.G. George, S.C. Maberly and D.P. Hewitt, *Freshw. Biol.*, **49**, 760 (2004); https://doi.org/10.1111/j.1365-2427.2004.01223.x
24. J.F.N. Abowei, *Adv. J. Food Sci. Technol.*, **2**, 36 (2010).
25. B. Bhattacharyya and N. Ghosh, *Int. J. Environ. Sci.*, **7**, 54 (2018).
26. U.B. Singh, A.S. Ahluwalia, R. Jindal and C. Sharma, *Water Qual. Expo. Health*, **5**, 149 (2013); https://doi.org/10.1007/s12403-013-0098-y
27. S.R. Barai, *J. Environ. Biol.*, **34**, 259 (2013).
28. M. Parween, S. Verma, S. Sahoo, A. Kumar, M. Priyanka and J. Mishra, *Scholars Acad. J. Biosci.*, **10**, 1 (2022); https://doi.org/10.36347/sajb.2022.v10i01.001
29. U.S. Khanom, S. Sharmeen, J. Ferdouse, W. Shumi, A. Abdu, H.A. Hamid and M.A. Hossain, *Agric. Environ.*, **12**, 389 (2014).
30. A.S. Toor, M.P.S. Khurana, B.S. Sidhu, J.S. Khera and K.K. Brar, *Environ. Monit. Assess.*, **172**, 571 (2011); https://doi.org/10.1007/s10661-010-1355-1
31. D.K. Sharma and R.P. Singh, *Int. J. Netw. Secur.*, **4**, 90 (2013).