

Analyzing Water Quality Index of Selected Pit-Lakes of Raniganj Coal Field Area, India

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Abstract The present research is performed to enumerate the water quality index of five selected pit-lakes of Raniganj block under Raniganj Coal Field, India during 2015-2017 in order to determine the water quality for public utilization, recreation and other needs. This paper focuses with the study of various water quality influencing parameter. In this research water quality index was established by different physico-chemical parameters such as pH, total hardness, total conductivity, alkalinity, dissolved oxygen, biological oxygen demand and chloride. The minimum and maximum value, mean, standard deviation, correlation between parameter and water quality index of selected pit-lakes are calculated. The mean values of studied parameters are compared with ICMR and BIS standards for drinking water quality. The WQI scores shows poor to very poor quality of water samples in all five pit-lakes. Out of the five pit-lake, Searsole

khad-1 (PL-1) and Ghanshyam khad (PL-3) are observed to be the most polluted pit-lake.

Keywords Water quality index, Pit-lake, Raniganj Coal Field.

Introduction

Extensive open-cut excavation has left a legacy of thousands of mine pit lakes throughout the globe where mining voids spread out below the water table (Castro and Moore 1997, Klapper and Geller 2002). Pit-lakes may come up with opportunities where wetland ecosystems are evolved as favorable end uses to attain mining industry dedication or commitments towards sustainability. Coal is one of the major resource and most important energy source in India. Coal mining put its drastic effect on surrounding environment in different ways. Several literature are available based on the impact of coal mining activity on public and environmental health (Pal et al. 2013, Peplow and Edmonds 2002, Ripley et al. 1996, Younger 2004). Physical and chemical property of pit-lakes is very different and unique in comparison to the other water bodies. Although water and total ecosystem of pit-lakes have vast resource and potential for beneficial uses but it tends to contaminate neighboring ground water and surface water resources (Kumar et al. 2009). Hence analyzing water quality index of five selected pit lakes in Raniganj block under RCF has been performed during 2015-2017 to evaluate the present hydrological status and efficacy to draw blueprints for effective management, conservation and ecological sustainability.

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Table 1. Details of study sites in Raniganj Coal Field (RCF), West Bengal, India.

Sl. No.	Name of the pit lake	Mine area	Block	Division	Nearest town/village	Latitude	Longitude
1	Searsol khad 1 (PL-1)	Raniganj	Raniganj	Asansol	Searsol	23°37'37.70"N	87°6'1.14"E
2	Searsol khad 2 (PL-2)	Raniganj	Raniganj	Asansol	Searsol	23°37'37.58"N	87°6'4.96"E
3	Ghanashyam khad (PL-3)	Raniganj	Raniganj	Asansol	Baktarnagar	23°36'31.07"N	87°8'36.00"E
4	Nimcha Harabanga Pit Lake (PL-4)	Satgram	Raniganj	Asansol	Harabhanga	23°36'32.9"N	87°4'2.4"E
5	Nimcha Damali Pit Lake (PL-5)	Satgram	Raniganj	Asansol	Damalia	23°36'31.9"N	87°4'6.1"E

Water quality index (WQI)

Water quality comprises overall characteristics (physico-chemical and biological) of water (Diersing and Nancy 2009). Certain water quality indicators (parameters) must be under surveillance at regular basis to maintain the water bodies' health at optimum level. A water quality index (WQI) abstracts huge amounts data related to water quality into elementary terms (excellent, good, poor, very poor and unsuitable) for reporting administrator and the communal at a regular basis (Huyla 2009). WQI could be effective machinery or tool for the comparison of different source of aquatic bodies' water quality and it provides a general conception of the possible water related hazards in a specific area. The index is very much effective and important to relate the tendency of water quality data with management of water quality (Jagadeeswari and Ramesh 2012).

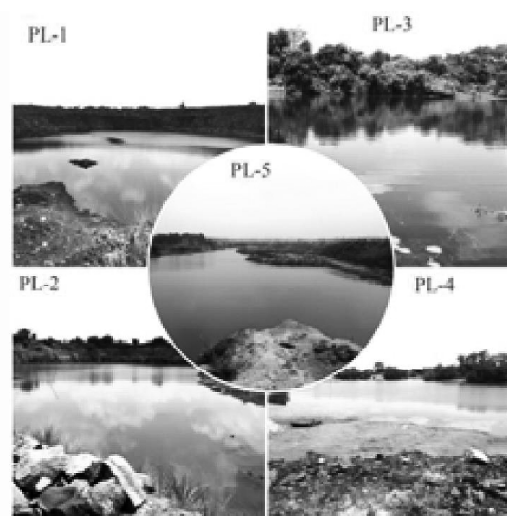
Materials and Methods

Study area

In India, Raniganj Coal Field (RCF) is the origin of coal mining. Raniganj Coal Field is dispersed over a number of different districts such as Burdwan, Birbhum, Bankura and Purulia in West Bengal and also in Dhanbad district under Jharkhand state and covers an area about 1530 km². Burdwan district (now known as Paschim and Purba Bardhaman) is the Heart of Raniganj Coal Field (RCF). For the present study five pit-lake of Raniganj block under RCF has been selected. The location map of the study area and sam-

pling sites and the details of the selected pit-lakes are shown in Table 1 and Figs 1 and 2.

Water samples were collected from five pit-lakes of Raniganj block under Raniganj Coal Field viz- Searsol khad-1 (Pit-Lake-1), Searsol khad-2 (Pit-Lake-2), Ghanashyam khad (Pit-Lake 3), Nimcha Harabanga Pit-Lake (PL-4) and Nimcha Damali Pit-Lake (PL-5) over a period of three years (2015-2017). Different physico-chemical water quality parameters of the samples were examined by the standard protocol of (APHA 2005). A set of eight water quality parameters namely pH, total conductivity (TC), total hardness (TH), total dissolved solid (TDS), chloride (C), alkalinity (A), dissolved oxygen (DO), biochemical oxygen demand (BOD) were taken for generating the

**Fig. 1.** Photographs of different pit lakes.

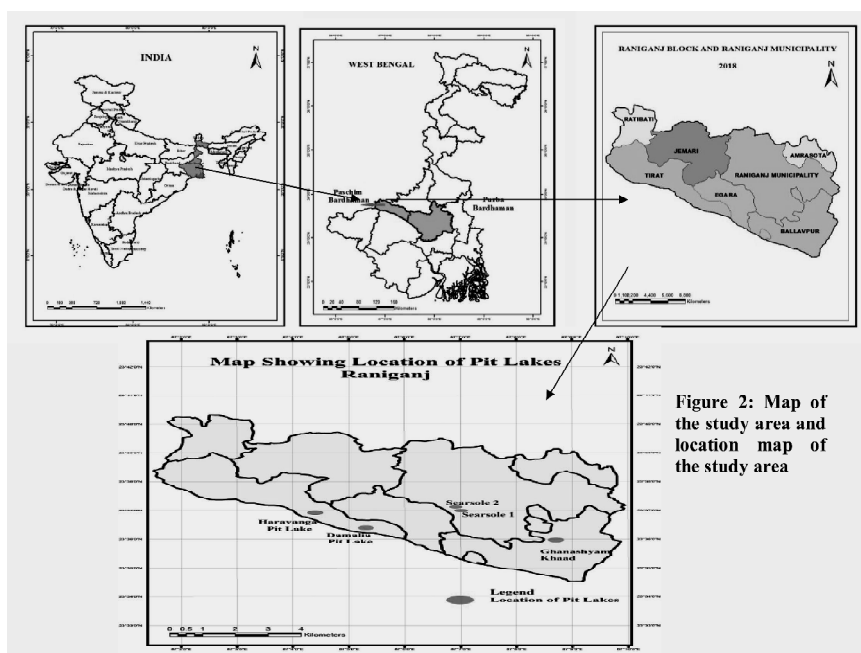


Figure 2: Map of the study area and location map of the study area

Fig. 2. Map of the study area and location map of the study area.

water quality index (WQI). WQI is calculated with the help of index method (Brown et al. 1972).

Calculation of WQI

Calculation of WQI was performed by following the ‘weighted arithmetic index method’ (Brown et al. 1972), using the equation :

$$WQI = \frac{\sum Q_n W_n}{\sum W_n}$$

Where Q_n is the quality rating of n^{th} water quality parameter, W_n is the unit weight of n^{th} water quality parameter.

The quality rating Q_n is calculated using the equation :

$$Q_n = 100[(V_n - V_i) / (V_s - V_i)]$$

Where V_n is the actual value of the parameter observed, V_i represents the ideal value of that parameter.

[$V_i = 0$, except for pH ($V_i = 7$) and DO ($V_i = 14.6 \text{ mg/l}$)], V_s is the standard permissible value for the n^{th} water quality parameter.

Unit weight (W_n) is calculated using the formula:

$$W_n = k/V_s$$

Where K is the constant of proportionality and it is calculated using the equation :

$$k = [1/\sum 1/V_s = 1, 2, \dots, n].$$

The water quality status (WQS) according to WQI is shown in Table 2.

Table 2. WQI range and status of the water sample (Brown et al. 1972).

WQI	Water quality status
0-25	Excellent
26-50	Good
76-100	Very poor
Above 100	Unsuitable

Table 3. Important water parameters measured in pit-lakes of Raniganj block under RCF.

Parameters	Mean	SD	Max	Min
pH	7.49	0.38	8.2	6.9
Total hardness (mg/l)	567.53	288.67	894	124
Total conductivity (μ S/cm)	374.44	75.16	421	136
Alkalinity (mg/l)	12.20	9.69	36	3.25
TDS (mg/l)	802.51	457.49	1422	196
DO (mg/l)	4.1	1.08	5.8	2.1
BOD (mg/l)	2.67	0.77	4.22	1.8
Chloride (mg/l)	68.36	59.74	178	15

Statistical analysis

XLSTAT-2017 statistical package was used for data analyzing. Graphs are made by Microsoft Excel-2007. Correlation analysis and Agglomerative Hierarchical Cluster (AHC) analysis has been applied to predict the water quality in these five pit lakes.

Results and Discussion

The statistical summary of the selected water quality

parameters at various pit-lakes of RCF is presented in Table 3 and Table 4. The variation water quality parameters at different pit-lakes are shown in Fig. 3. pH is the concentrations of hydrogen ions (H⁺) concentration in water and it determines acidity or alkalinity. The pH is an important parameter of most of the aquatic animals and plants as it has an influencing role in metabolic activities of aquatic organisms. In present study the average pH value of five pit-lakes is 7.49 ± 0.38 which is within the standard limits (6.5-8.5). The highest average pH value is observed in PL-3 (8.05 ± 0.17). Hardness depends on the amount of calcium and magnesium present in the water. The average observed values of total hardness for the water samples of the five pit-lakes is $567.53 \text{ mg/l} \pm 288.67$ which is much greater than the standard value (300). The highest average total hardness value is observed in PL-1 ($854.66 \text{ mg/l} \pm 44.39$). Electrical conductivity describes the electric current carrying capacity of a water sample and is due to the presence of dissolved ions in the water. Digital conductivity meter is used to measure the EC and the outcomes were expressed in microsiemen/centimeter (μ S/cm). Observed mean EC value for the water sample of five pit-lakes is $374.44 (\mu\text{S/cm}) \pm 75.16$ which is greater than the standard

Table 4. Descriptive statistics for the water quality parameters of different pit lake.

Name of the pit-lake	Parameter															
	pH				Total hardness				Total conductivity				Alkalinity			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
PL-1	7.42	7.95	7.73	0.23	780	894	854.66	44.39	412	419	415.66	2.44	6.24	6.78	6.39	0.18
PL-2	7.12	7.52	7.41	0.12	752	754	753	0.87	416	420	418.55	1.42	6.52	6.66	6.55	0.04
PL-3	7.8	8.2	8.05	0.17	752	755	753.62	1.06	418	421	419.12	1.23	3.25	3.28	3.27	0.01
PL-4	6.9	7.1	7.02	0.09	124	200	174.5	31.71	320	345	334.38	11.99	12	28	21	7.01
PL-5	7.12	7.58	7.28	0.16	180	404	264.56	104.17	136	387	285	113.23	12	36	23.78	8.27

Table 4. Continued.

Name of the pit-lake	Parameter															
	TDS				DO				BOD				Chloride			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
PL-1	1214	1422	1284.22	85.77	2.1	2.5	2.27	0.15	2.1	2.4	2.26	0.13	16	18	17.17	2.45
PL-2	1210	1212	1211.33	0.87	4.1	4.3	4.18	0.67	2.1	2.4	2.67	0.11	15	20	17.33	1.58
PL-3	946	949	947.38	1.30	4.1	4.22	4.18	0.05	2.32	2.42	2.40	0.03	176	178	176.81	0.92
PL-4	196	2962	271.8	31.22	4.3	5.8	5.16	0.57	2.1	2.6	2.3	0.21	37.94	67.93	42.08	10.45
PL-5	202	282	254.89	39.67	4.2	5.7	4.83	0.54	1.8	3	2.47	0.49	23.98	50.95	38.85	11.76

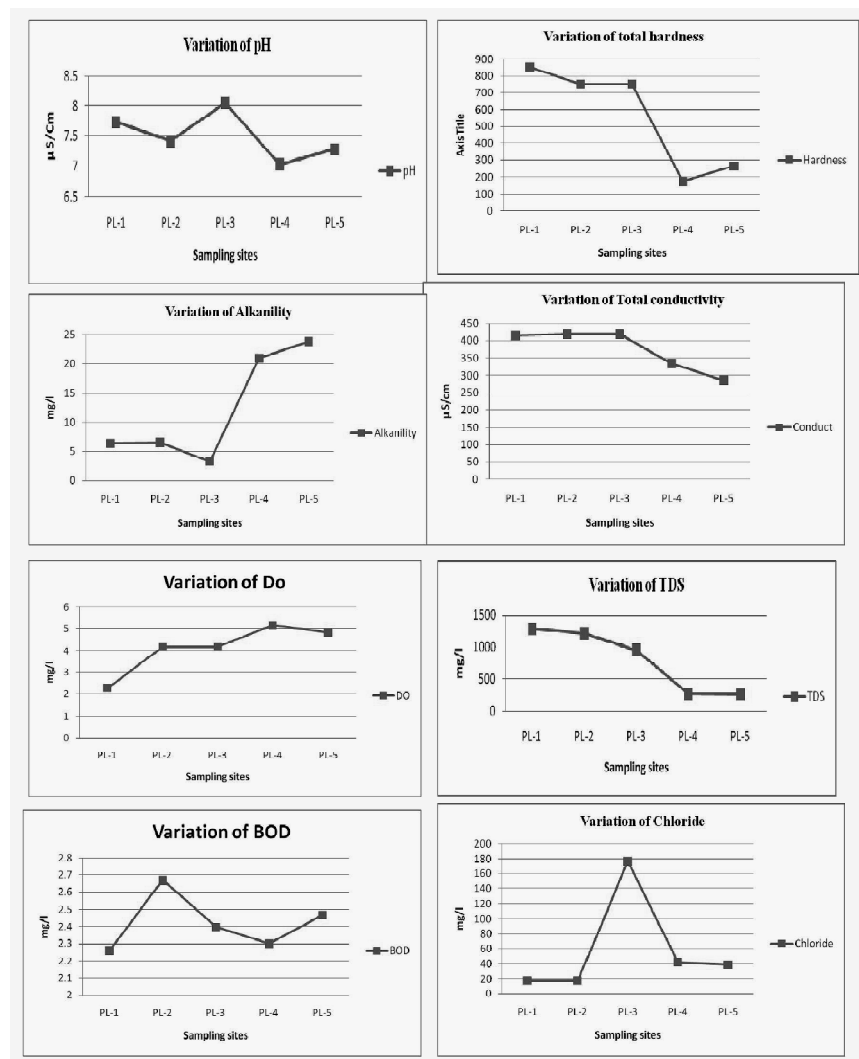


Fig. 3. Variation of different water quality parameter in different pit-lakes.

value (300). The highest mean conductivity value is observed in PL-3 ($419.12 \mu\text{S}/\text{cm} \pm 1.23$). Alkalinity of water depends mainly on salts of weak acids such as bicarbonates, carbonates and the salts of humic and fulvic acids present in the water (Budhlani et al. 2014). Average value of total alkalinity of these five pit-lakes is $12.20 \text{ mg}/\text{l} \pm 9.69$. The highest value of alkalinity is observed in PL-5 ($23.78 \text{ mg}/\text{l} \pm 8.27$). TDS is the measurement of total suspended and dissolved particles

present in a water sample such as salts, some organic materials and varieties of other different things from nutrients to toxic material. If synthetic organic chemicals such as fuels, detergents, paints, solvents, are present, leads to unpleasant tastes, smells and colors to aquatic animals in low concentrations also (Nollet 2000). In the present study, mean TDS value is $802.51 \text{ mg}/\text{l} \pm 457.79$. The highest value of TDS is observed in PL-1 ($1284.22 \text{ mg}/\text{l} \pm 85.77$). In simple term

Table 5. Relative weights (W_n) of the parameters used for WQI determination. All the parameters are in mg/l except pH and total conductivity ($\mu\text{S}/\text{cm}$).

Parameters	ICMR/BIS standard (Vs)	Unit weight (W_n)
pH	6.5-8.5	0.218
BOD	5	0.0061
DO	5	0.0061
Total conductivity	300	0.0155
Total hardness	300	0.0037
Chloride	250	0.317
TDS	500	0.317
Alkalinity	120	0.0074

dissolved oxygen is the availability of free oxygen present in water. It is a vital water quality parameter as it influence the aquatic organisms. Measurement of dissolved oxygen is very important for maintaining aerobic treatment also (Parmar and Parmar 2010).

In present study, the mean DO value is $4.1 \text{ mg/l} \pm 1.08$ and the highest value is observed in PL-4 ($5.16 \text{ mg/l} \pm 0.57$). Biological oxygen demand is the amount of dissolved oxygen used by aerobic microorganisms for metabolizing organic matter in water. BOD indicate pollution due to organic matter; the higher the BOD value, the greater the amount of organic pollution. Present study revealed the mean BOD values is $2.67 \text{ mg/l} \pm 0.77$, the highest value is observed in PL-2 ($2.67 \text{ mg/l} \pm 0.11$). Chloride is another vital inorganic anion in water. The main source of chloride in water in the domestic sewage discharge. The concentration of chloride in freshwater is an indicator of sewage pollution (Trivedy and Goel 1984, Wetzel 1966). The average chloride concentration for the measured water samples of five pit-lakes is $68.36 \text{ mg/l} \pm 59.74$ and the highest value of chloride is observed in PL-3 ($176.81 \text{ mg/l} \pm 0.92$). Variation of different water quality parameter of five selected pit-lakes are represented in Fig. 3.

Table 6. Calculation of water quality index of Sampling Station PL-1. Water quality index (WQI) = $\frac{\sum W_n Q_n}{\sum W_n} = 77.21$.

Sl. No.	Parameters	Observed value (V_n)	Standard value (Vs)	Unit weight (W_n)	Quality rating (Q_n)	$W_n Q_n$
1	pH	7.73	6.5-8.5	0.218	48.67	10.610
2	TH	854.66	300	0.0061	284.89	1.738
3	TC	415.66	300	0.0061	138.55	0.845
4	Alkalinity	6.39	120	0.0155	5.33	0.083
5	TDS	1284.22	500	0.0037	256.84	0.950
6	DO	2.27	5	0.317	128.44	40.715
7	BOD	2.26	5	0.317	45.2	14.328
8	Chloride	17.17	250	0.0074	6.87	0.051
				$\sum W_n = 0.8908$		$\sum W_n Q_n = 68.78$

Table 7. Calculation of water quality index of Sampling Station PL-2. Water quality index (WQI) = $\frac{\sum W_n Q_n}{\sum W_n} = 68.15$.

Sl. No.	Parameters	Observed value (V_n)	Standard value (Vs)	Unit weight (W_n)	Quality rating (Q_n)	$W_n Q_n$
1	pH	7.41	6.5-8.5	0.218	27.33	5.957
2	TH	753	300	0.0061	251	1.531
3	TC	418.55	300	0.0061	139.52	0.851
4	Alkalinity	6.55	120	0.0155	5.49	0.085
5	TDS	1211.33	500	0.0037	242.28	0.896
6	DO	4.18	5	0.317	108.54	34.407
7	BOD	2.67	5	0.317	53.4	16.927
8	Chloride	17.33	250	0.0074	6.93	0.051
				$\sum W_n = 0.8908$		$\sum W_n Q_n = 60.705$

Table 8. Calculation of water quality index of PL-3. Water quality index (WQI) = $\sum W_n Q_n / \sum W_n = 76.93$.

Sl. No.	Parameters	Observed value (Vn)	Standard value (Vs)	Unit weight (Wn)	Quality rating (Qn)	WnQn
1	pH	8.05	6.5-8.5	0.218	70	15.26
2	TH	753.62	300	0.0061	251.20	1.532
3	TC	419.12	300	0.0061	139.71	0.852
4	Alkalinity	3.27	120	0.0155	2.73	0.042
5	TDS	947.38	500	0.0037	189.48	0.701
6	DO	4.18	5	0.317	108.54	34.407
7	BOD	2.4	5	0.317	48	15.216
8	Chloride	176.81	250	0.0074	70.72	0.523
				$\sum W_n = 0.8908$		$\sum W_n Q_n = 68.533$

Table 9. Calculation of water quality index of Sampling Station PL-4. Water quality index (WQI) = $\sum W_n Q_n / \sum W_n = 53.54$.

Sl. No.	Parameters	Observed value (Vn)	Standard value (Vs)	Unit weight (Wn)	Quality rating (Qn)	WnQn
1	pH	7.02	6.5-8.5	0.218	1.33	0.289
2	TH	174.5	300	0.0061	58.17	0.354
3	TC	343.78	300	0.0061	114.59	0.698
4	Alkalinity	21	120	0.0155	17.50	0.271
5	TDS	271.8	500	0.0037	54.36	0.201
6	DO	5.16	5	0.317	98.33	31.171
7	BOD	2.3	5	0.317	46	14.582
8	Chloride	42.08	250	0.0074	16.83	0.125
				$\sum W_n = 0.8908$		$\sum W_n Q_n = 47.69$

WQI analysis

First of all unit weight for each parameter is estimated to a common scale. Standard value of drinking water quality and the unit weights assigned to each parameter used for calculating the WQI is shown on Table 5. Maximum weight is provided to DO and BOD both (0.317), suggesting the significance and impact of

these two parameter in water quality index. WQI values of the water samples from all the five pit-lakes are presented in Tables 6–10 and the summary of WQI values of all the pit-lakes are presented in Table 11 and Fig. 4 given below. The results showed that majority of the water sample fall under poor water category. Highest WQI value is recorded in PL-1 (77.21).

Table 10. Calculation of water quality index of PL-5. Water quality index (WQI) = $\sum W_n Q_n / \sum W_n = 60.30$.

Sl. No.	Parameters	Observed value (Vn)	Standard value (Vs)	Unit weight (Wn)	Quality rating (Qn)	WnQn
1	pH	7.28	6.5-8.5	0.218	18.67	4.070
2	TH	264.56	300	0.0061	88.19	0.5379
3	TC	285	300	0.0061	95	0.5795
4	Alkalinity	23.78	120	0.0155	19.82	0.3072
5	TDS	254.89	500	0.0037	50.98	0.1886
6	DO	4.83	5	0.317	101.77	32.261
7	BOD	2.47	5	0.317	49.4	15.659
8	Chloride	38.85	250	0.0074	15.54	0.1149
				$\sum W_n = 0.8908$		$\sum W_n Q_n = 53.7181$

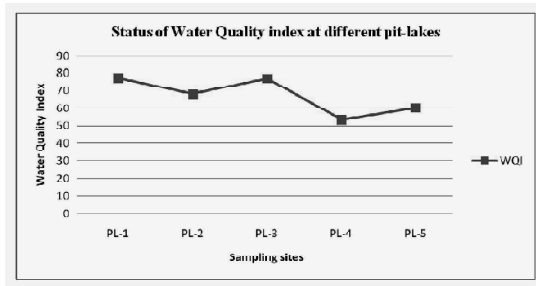


Fig. 4. WQI rating of various pit-lakes in Raniganj under RCF.

Table 11. Summary of WQI of different pit lakes in Raniganj under RCF.

Sampling Site	WQI	WQS
Pit-lake-1	77.21	Very Poor
Pit-lake-2	68.15	Poor
Pit-lake-3	76.93	Very Poor
Pit-lake-4	53.54	Poor
Pit-lake-5	60.30	Poor

Correlation coefficient analysis among the chemical parameters of five pit-lakes reveals significant relationships (Table 12). There is significant positive relationship for total hardness with total chloride and total dissolved solid and significant negative relationship with alkalinity. Total hardness is positively correlated with total conductivity and TDS. There is a positive correlation between DO and BOD. Total dissolved solid is positively correlated with total hardness and total conductivity. Quite similar findings were also observed by other researcher also (Pathak and

Table 12. Correlation matrix of water quality parameters in the selected pit-lakes Correlation matrix (Pearson). Values in bold are different from 0 with a significance level alpha = 0.05.

Variables	pH	TH	TC	Alkalinity	TDS	DO	BOD	Chloride
pH	1	0.805	0.697	-0.826	0.659	-0.587	-0.091	0.664
TH	0.805	1	0.914	-0.952	0.975	-0.802	0.140	0.176
TC	0.697	0.914	1	-0.976	0.928	-0.637	0.097	0.252
Alkalinity	-0.826	-0.952	-0.976	1	-0.921	0.644	-0.127	-0.376
TDS	0.659	0.975	0.928	-0.921	1	-0.803	0.180	-0.001
DO	-0.587	-0.802	-0.637	0.644	-0.803	1	0.303	0.166
BOD	-0.091	0.140	0.097	-0.127	0.180	0.303	1	-0.116
Chloride	0.664	0.176	0.252	-0.376	-0.001	0.166	-0.116	1

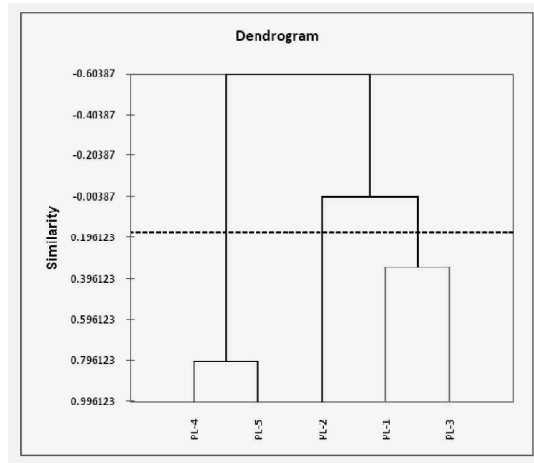


Fig. 5. Dendrogram derived from Agglomerative Hierarchical Cluster (AHC) analysis represent association among the selected pit-lakes based on water quality parameters during the study period.

Banerjee 2006, Singh 2006) in different coal mine in India.

Dendrogram derived from AHC analysis shows three cluster having similarities among the pit-lakes. Pit Lake 4 and 5 shows significant similarities (Fig. 5).

Conclusion

The WQI of the five pit-lakes ranges from 53.54 to 77.21. The WQI indicates the poor quality of the pit-lake’s water. The high value of WQI of these pit-lakes is mainly due to the high value of total hardness, total dissolved solids. The result of WQI showed that the water is not suitable for drinking

purposes but can be used for agricultural activities. Determination of water quality index is very useful to assess the quality of the water as well as in water quality management. Our findings can also support decision makers to develop strategies for sustainability.

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