Harichandan et al. J Pollut Eff Cont 2017, 5:3
DOI: 10.4176/2375-4397.1000199

Journal of Pollution Effects & Control
ISSN: 2375-4397

Research Article Open Access

Evaluation of Water Quality of Local Streams at Gandhamardan Iron Mines, Suakati, Keonjhar District of Odisha, India

Amarendra Harichandan[1], Himansu Sekhar Patra[2*] and Kabir Mohan Sethy[3]

[1]*Researcher in Environmental science, Department of Geography, Utkal University, Vanibihar, Bhubaneswar, Odisha, India*
[2]*Researcher in Environmental science, Odisha, India*
[3] *Department of Geography, Professor in Geography, Utkal University,Vanibihar,Bhubaneswar, Odisha, India*

Abstract

The present study focused on assessing the water quality by using water quality index (WQI) of six streams located surrounding iron ore mine of Suakati area of Keonjhar District of Odisha, which includes the physicochemical analysis of fourteen parameters: pH, colour, total dissolved solids (TDS), dissolve oxygen (DO), biochemical oxygen demand (BOD), total hardness (TH), chloride (Cl^-), nitrate (NO_3^-), oil & grease (O&G), sulphate (SO_4^{2-}), iron (Fe), manganese (Mn), fluoride (F^-) and arsenic(As). The WQI of these streams ranges from 4.47 to 244 indicating bad water quality of few streams. The high value of WQI has been found to be mainly from the higher values of TDS, TH, NO_3^-, O&G, Mn, SO_4^{2-}, As, Fe and F^- in different stream water. Correlation analysis shows a strongest value of positive Correlation coefficient (r) exist between O&G and WQI (r=0.979) at SW1, between as and WQI (r=0.985) at SW2, between O&G and WQI (r=0.99) at SW3, between O&G and WQI (r = 0.995) at SW4, between as and WQI (r=0.948) at SW5 and between TDS and WQI (r=0.753) at SW6. The analysis reveals average WQI score for water sample from locations SW1 (126.4), SW2 (222.6), SW3 (105.2) and SW6 (156.6) are in higher sides and quality is very poor. The study shows the quality of water is fit to use in irrigation but not fit for domestic purpose. It also proofs that anthropogenic activity like mining activity is putting deleterious impact on the surrounding water bodies.

Keywords: Water quality standards; Water quality index; Correlation; Multiple Linear Regression

Introduction

Water one of the most priceless gifts of nature is regarded as the life line on Earth. The importance of water and its role as essential for human health, animals and plants [1,2] essential for crop and animal production, for aquatic and terrestrial ecosystems [3] and for our daily life supporting activities [4] is well observed . Water of adequate quantity and quality is essential for sustainable development [5].

In fresh water, river water contribute a major percentage for multiple uses in every sector like drinking, domestic purpose, agriculture, industry, transportation, aquaculture, public water supply etc. [6]. The quality of surface water within a region is governed by both natural processes such as precipitation rate, weathering processes and manmade activities such as urban, industrial and agricultural activities and the human exploitation of water resources. Many Studies have indicated that many rivers/streams particularly in developing countries are heavily polluted due to industrial, municipal waste water discharges, as well as agricultural runoff [7-10] and impair their use for drinking, industrial, agricultural and recreational purposes [11]. Mining activity is not excluded from these. Mining is one of the major manmade activities causing deleterious impact on surrounding environment [12-14]. The environmental problems arise due to mining activities are land degradation, air pollution, surface and ground water pollution, deterioration of natural drainage system [12,13,15]. Surface and groundwater pollution is one of the significant impacts of mining activity [16-18]. Water pollution is a major concern in mining operation area [12,13,16,17,19-22]. Water pollution in mining areas are getting affected mainly due to overburden dumps(OBD), surface impoundments, industrial effluents, acid mine drainage, tailing ponds [23], discharge of pumped out mine water which contain heavy metal [24-27], discharge of leachate from mine waste, surface runoff from OBD [16,28], disposal of solid waste generated by mining operations, waste rock, sub-grade ore and mineralized reject which in result cause disturbance of water level of surface and ground water quality and environmental pollution [29,30]. Mining activity have added metal contaminant to surface or ground water [17,18,31]. These metals have accumulated in living organisms [32], either directly through consumption of contaminated water or indirectly by consumption of contaminated plants or meat [33]. Study shows that there is health risk associated with those metal contaminanted water [34]. Those metal contaminated water pose direct threat to human health when that water is used as drinking purpose [31,35] or pose indirect threat to human health when that water is used in irrigation purpose [23,35-37]. River and streams located near to mining activities get contaminated continuously from point as well as non-point source. It is a matter of fact that in India the river systems are getting polluted day by day and river water pollution has now reached to a point of crisis. Access to drinking water in India has increased over the past few decades with the tremendous adverse impact of unsafe water for health [23].Scarcity of clean and potable drinking water has emerged in recent years as one of the most serious developmental issues in many parts of India like West Bengal, Jharkhand, Orissa, Western Uttar Pradesh, Andhra Pradesh, Rajasthan and Punjab [38]. The 30% of urban and 90% of the rural Indian population still depends completely on untreated surface or groundwater resources [39]. In Orissa a large scale of mining activities and industrialization based on these metallic minerals are being carried out in the district of Keonjhar which has greatly affected both water quality and quantity. The inhabitants of this area are mostly Scheduled Tribe (ST) with very little or no awareness regarding the water

***Corresponding author:** Himansu Sekhar Patra, Researcher in Environmental science, Odisha, Tel: 06742567940; E-mail: heironymo@gmail.com/ Indiaharichandan.amarendra@gmail.com

Received July 18, 2017; **Accepted** September 20, 2017; **Published** September 26, 2017

Citation: Harichandan A, Patra HS, Sethy KM (2017) Evaluation of Water Quality of Local Streams at Gandhamardan Iron Mines, Suakati, Keonjhar District of Odisha, India. J Pollut Eff Cont 5: 199. doi: 10.4176/2375-4397.1000199

quality and its impact on health. Thus, there is an urgent need to create awareness among the local people about the contamination of water bodies, its impact and protection of these precious resources [40]. Hence access to safe drinking water remains an urgent necessity. Therefore to safeguard freshwater resources, management and protection strategies have to be developed for each water basin individually [41] including a comprehensive river water quality monitoring program to device ways and mean to protect it. The monitored data will help the planners both at the national and international levels to develop various environmental programs. However, when a large number of samples and parameters are monitored, it becomes difficult to evaluate and present the water quality as a single unit [42,43]. In this regard Index method is quite useful to express the quality of water. The Water quality index (WQI) is one of the most effective tool [44-46] used to transform large number of variables data into a single number to represents the water quality level [23,44-50] and to communicate information on the quality of water [51,52] to the concerned citizens and policy makers and ensure sustainable safe use of water for drinking [38]. Bordalo et al. [48] initially proposed the application of WQI and since then many different methods for the calculation of WQI have been developed. Therefore, the present study is made with an objective to evaluate water quality through water quality index of local streams water Bamni nala, Chamnda Nala, stream at Putulupani and surface water near Pond at Upar Jagar, Pond at Urumunda, Chamnda nala near Kumundi village and to assess the suitability of water for domestic and drinking purpose. This baseline information will also be very useful for managing future water resources in this region.

Study Area

The study area is located between 21˚37'09"-21˚40'02"N and 85˚29'20"-85˚31'30"E, near to Suakati town in Keonjhar district of Odisha . A major iron deposit of state namely Gandhmardan hill is located at the centre of study area, having an estimated reserves of 350 million tonne of iron ore. The existing iron ore mine at this hill is one of the oldest mines of Odisha. The iron ore mining started in Gandhamardan hill range by Odisha Mining Corporation (OMC), a State Goverment owned agency in 1965 and presently it has two open cast iron mines namely Gandhamardan A and B covering around 2200 hectare. Similarly two private owned mines are also operating at Putulpani (Talajagar) and at Urumunda village respectively covering a total area of 182.1932 hectares. The study area has dendritic pattern of drainage because of its hilly topography. The drainage channels emerging from the eastern half of the Gandhamardan area flow down to join the Kadal Nadi which flows northward to join the Ardei Nadi which is a tributary of Baitarani river.

Material and Methods

The present study was carried out for a period of two year (2013-2014) covering pre monsoon period (March-June), monsoon period (July-October) & post monsoon period (November-February). Water samples were collected from six different locations located surrounding iron ore mine of Suakati area of Keonjhar District of Odisha (Table 1) as per the norms of the American Public Health Association (APHA 2000). Water samples were collected in acid-washed plastic bottles of one litre capacity having double stopper facilities to its full capacity without entrapping air bubbles inside. The analytical method of samples for fourteen physico-chemical parameters pH, colour, TDS, DO, BOD, TH, Cl^-, NO_3^-, O&G , SO_4^{2-}, iron, Mn, F and As follows APHA 2000. The parameters pH, and DO were monitored at the sampling site. These obtained data of fourteen parameters were compared with the standard

Location code	Location	Remarks
SW1	Bamni nala near Upar Jagar (mines area)	Stream water
SW2	Pond at Upar Jagar (2)	Surface water
SW3	Stream at Putulupani	Stream water
SW4	Pond at Urumunda	Surface water
SW5	Chamnda nala near Kumundi village	Surface water
SW6	Chamnda Nala near Suakat Town	Stream water

Table 1: Six sampling location with location code.

guideline values, recommended by IS:2296. The obtained analytical data of fourteen physico-chemical parameters from six sampling stations are used for calculation of WQI in eq-1 [53] for different studied period to assess the suitability of water for drinking purposes, for irrigation purpose, for industrial purpose, for biotic communities etc.

$$WQI = \sum_{i=1}^{n} q_n w_n / \sum w_n \quad (1)$$

Where, q_n=Quality rating of n^{th} water quality parameter.

W_n=Unit weight of n^{th} water quality parameter.

The quality rating (q_n) is calculated using the expression given in equation 2.

$$q_n=[(V_n-V_{id})/(S_n-V_{id})]\times 100 \quad (2)$$

Where,

V_n=Estimated value of n^{th} water quality parameter at a given sample location.

V_{id}=Ideal value for n^{th} parameter in pure water.

(V_{id} for pH=7, for DO=14.6mg/L and for all other parameters is zero)

S_n=Standard permissible value of n^{th} water quality parameter.

The unit weight (W_n) is calculated using the given equation 3.

$$W_n=k/S_n \quad (3)$$

Where,

S_n=Standard permissible value of n^{th} water quality parameter.

k=Constant of proportionality and it is calculated by using the bellow equation 4.

$$k=[1/(\Sigma 1/S_n=1,2,..n)] \quad (4)$$

WQI is calculated from the above equation-1 as per the details of water quality standard values and weightage factors, which Involves the Following Steps: First, the calculation of weightage of each parameter. Second, the calculation of the quality rating for each parameter. Third, the calculation of sub-indices and then, summation of these sub-indices of all parameters to get the overall index.

Subsequently Karl Pearson Correlation matrix-eq-2 [54] has used to find out the closeness of the relationship between fourteen tested parameters and that of with calculated WQI. Regression and multiple linear regression(MLR) analysis was tested to best represent the relation between a single dependent, single independent variable and between a single dependent, a set of independent variables. The obtained regression and MLR analysis is being used as a useful information to project the index value of the studied area, if the strongly WQI dependent variables are measured.

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(yi - \bar{y})^2}}$$

Where,

n=number of data points,

x=values of x- variable,

y=values of y-variable,

$\bar{x}$ =mean of all variables of x

ȳ=mean of all variables of y,y

r=Pearson Correlation.

Result and Discussion

The obtained data (Table 2) from laboratory analysis of water samples of six location showed that the observed physico-chemical parameters for different water samples are almost within the recommended standards except few parameter like colour, TDS, TH, O&G. These parameter are deteriorating the quality of water. Among all the analysed physico-chemical parameters. pH is an important parameter which determines the suitability of water for various purposes [55,56]. High pH levels are undesirable since they may impart a bitter taste to the water [57] and also depress the effectiveness of disinfection by chlorination, thereby requiring the use of additional chlorine or longer contact times [58]. In the present study, pH ranges from 6.1 to 7.8 (Table 2) for all six sampling location during entire studied period. This shows that the pH range obtained from six station water samples are almost within the recommended range of 6.50 to 8.50(IS 1982) except water samples from SW1,SW2,SW3 where the average recorded values were 6.2,6.3,6.4 respectively during study period and were just below the recommended range(IS 1982).

The water color results from the existence of dissolved substances like presence of some metallic ions (iron and manganese), bacterial activity and colored effluents discharges from some industries [59]. As the studied sampling station of six stream water receives a great quantity of effluents from heavy vehicle repairing garage, surface runoff water from mining area, thus quality of these effluents has a great influence on the water color which is cleared from correlation study between color and WQI. The average value for color at six sampling sites were ranging from 79hazen to 292 hazen where lowest value is registered at SW6 (79hazen) and highest value is registered at SW1. At other stations SW2, SW3, SW4, SW5 the values were 237, 228, 178, 89 respectively (Table 2). Though the values were within the limit (IS 1982) but it was observed that during monsoon period (356 hazen) & postmonsoon period (312 hazen) at SW1, monsoon period (345hazen) at SW2,monsoon period (324 hazen) at SW3 higher values of colour parameter was registered which greatly influenced the WQI at those stations during observed period.

TDS in ground water may affect persons suffering from kidney and heart diseases [60]. The dissolved solid is due to surface runoff from mining area and industrial discharge .The TDS value of all water samples collected from six studied location ranges from 1200 mg/L to 1650 mg/L, 1560 mg/L to 1820 mg/L, 1450 mg/L to 1620 mg/L, 1200 mg/L to 1400 mg/L, 1200 mg/L to 1468 mg/L, 1650 mg/L to 1880 mg/L at station SW1, SW2, SW3, SW4, SW5, SW6 respectively (Table 2). At sampling stations SW2, SW3 and SW6, the average TDS values was found at 1710 mg/L, 1537 mg/L, 1777 mg/L which were well above the recommended limit (IS 1982). Whereas at sampling station SW1 (1400 mg/L), SW4 (1275 mg/L), SW5 (1339 mg/L) the average values of TDS were recorded below the recommended limit. At sampling stations SW1, SW2, SW3, SW4, SW5, SW6 the highest values for TDS 1650 mg/L, 1820 mg/L, 1620 mg/L, 1400 mg/L, 1468 mg/L, 1880 mg/L are observed during pre-monsoon, postmonsoon, monsoon, (Table 2) respectively whereas at same stations the lowest values of 1200 mg/L, 1560 mg/L, 1450 mg/L, 1200 mg/L, 1200 mg/L, 1650 mg/L for TDS are recorded during monsoon, premonsoon period respectively. Among the data obtained from all the station shows station, SW6 registered highest value of 1880 mg/L for TDS and was excepted probable due to the surface runoff generated from the overburden, mining site during rainy season.

DO is an important parameter for all aquatic organisms that possess aerobic respiration [61] and its presence in water may be due to direct diffusion from air and photosynthetic activity of autotrophs [62]. It gives direct and indirect information regarding bacterial activity, photosynthesis, availability of nutrients, stratification etc. of water [63].

Parameter	Standard (IS 2296)	SW1			SW2			SW3			SW4			SW5			SW6		
		Pr.M	M	P.M	Pr.M	M	P.M	Pr.M	M	P.M	Pr.M	M	P.M	Pr.M	M	P.M	Pr.M	M	P.M
pH	8.5	6.1	6.4	6.3	6.5	6.2	6.4	6.2	6.8	6.4	7.1	7.3	7.3	7.4	7.8	7.1	6.9	6.2	7.2
Colour	300	210	356	312	156	345	204	174	324	186	123	289	122	89	124	56	58	123	56
TDS	1500	1650	456	1450	1820	1560	1750	1540	1450	1620	1200	1405	1225	1200	1468	1350	1650	1850	1800
DO	4 Min	5	5.6	4.8	4.2	3.5	3.8	3.4	5.2	3.9	4.5	4.1	5.6	4.5	3.7	5.2	3.9	3.2	4.3
BOD	3	1.8	2.8	2.1	1.8	2.2	3.7	2.2	2.1	3.1	1.2	1.8	1.6	2.2	2.6	1.1	3.2	4.2	1.6
TH	300	475	395	435	515	412	505	455	255	465	514	125	495	605	222	575	395	214	405
Cl^-	600	35.4	42.2	112	52	35.5	24.6	560	57.5	620	435	121	455	550	235	415	550	212	580
NO_3^-	50	45	32	25	35	22.1	44	35	24.5	30	25	25	32	40	32	35	53	14	44
O & G	0.1	0.3	0.01	0.21	0.21	0.05	0.04	0.24	0.03	0.21	0.02	0	0	0.03	0.01	0.02	0.2	0.06	0.3
SO_4^{2-}	400	135.6	121	56.7	52.5	23..5	95	15.3	21.2	12.5	56	15	7.5	17.4	12.3	11.2	23.4	26.8	45.4
Iron	50	4.5	15.2	2.4	9.4	35.4	12.2	11.4	12.3	6.5	11.2	7.4	2.3	1.8	0.45	2.3	21	12.8	21.3
Mn	0.5	0.7	0.01	0.3	0.2	0.12	0.21	0.12	0.21	0.04	0.12	0.02	0.134	0.023	0	0	0.01	0.04	0.02
F^-	1.5	0.01	0.4	0.3	0.2	0.2	0.02	0.2	0.23	0.15	0.02	0.01	0.012	0.001	0	0.03	0.012	0.01	0.02
As	0.2	0.001	0.01	0.01	0.01	0.01	0.04	0.02	0.12	0.14	0.001	0.01	0.002	0.051	0.12	0.11	0.04	1.1	0.01
WQI	--	244	10.9	125	122	34.1	512	138.6	40	137	15.8	4.47	5.57	11.98	25.1	27.9	117	186	167
Note: All parameter are in mg/L except pH, colour (Hazen) and WQI. Pr.M (pre monsoon), M (monsoon), PM (post monsoon)																			

Table 2: Physicochemical parameters of water samples of six local streams at Gandhamardan iron mines, Suakati, Keonjhar district in the pre-monsoon, monsoon and post monsoon season.

The mean values of DO and BOD have never reached critical values in the most times at the studied areas. The obtained values are almost within the recommended limits except of few samples, indicating less biodegraded load in water and microbial activity. The average lowest DO value of 3.6 mg/L was recorded at SW2 indicating possible organic pollution. Whereas the highest value of 4.9 mg/L was recorded at SW1 indicating very less organic pollution. The DO value for different period below the limit are 3.5 mg/L (during monsoon period) & 3.8 mg/L (during post monsoon period) at SW2, 3.4 mg/L (during pre-monsoon period) & 3.9 mg/L (during post monsoon period) at SW3, 3.7 mg/L (during monsoon period) at SW5 and 3.2 mg/L (during monsoon period) at SW6 respectively were recorded indicating high BOD load. At stations SW3, SW4, SW5, SW6 average DO values were, 4.2, 4.7, 4.3, 3.7 mg/L respectively indicating DO level was with in the limit as per (IS 1982) and also indicates less BOD load which was cleared from obtained data. At station SW6 highest average BOD value of 3 mg/L was found whereas at SW1, SW2, SW3, SW4, SW5 low BOD values of 2.2, 2.5, 2.4, 1.5, 1.9 mg/L respectively were obtained. Higher BOD value of 3.7 mg/L at SW2, 3.1 mg/L at SW3, 3.9 mg/L and 4.2 mg/L at SW6 were obtained during post monsoon, pre-monsoon, monsoon period respectively. The high levels of BOD value from analysis indicated the nature of pollution.

Total hardness of water determines suitability of water for domestic, industrial and drinking purposes and attributed to presence of bicarbonates, sulphates, chlorides and nitrates of calcium and magnesium. The observation from water samples reveals that the total hardness value ranges between 124.5 to 605 mg/l with minimum at SW4 during monsoon and maximum at SW5 during pre-monsoon. The results shows that the average total hardness values at all station (at SW1- 435 mg/L, at SW2-477 mg/L, at SW3-391 mg/L, at SW4-377 mg/L, at SW5- 467 mg/L, at SW6-337 mg/L) found above the permissible limit from the value recommended by the WHO for different water use. These deviations are due to different sources of pollutions at different sampling station. The registered low and high values at six station were 395 mg/L (monsoon) to 475 mg/L (pre-monsoon) at SW1, 412 mg/L(monsoon) to 515 mg/L (pre-monsoon) at SW2, 255 mg/L (monsoon) to 465 mg/L (pre-monsoon) at SW3, 124.5 mg/L (monsoon) to 514 mg/L (pre-monsoon) at SW4, 221.6 mg/L (monsoon) to 605 mg/L (pre-monsoon) at SW5, 213.5 mg/L (monsoon) to 405 mg/L (post-monsoon) at SW6 indicating water at all station are hard water.

The salts of sodium, potassium and calcium contribute chlorides in water. Large contents of chloride in freshwater is an indicator of pollution [58]. Average chloride value obtained in the studied area ranges from 37 mg/L at SW2 to 447 mg/L at SW6. Though all the average values are well below the recommended standard, but the values of chloride at SW3 (412 mg/L), SW4 (337 mg/L), SW5 (400 mg/L) and at SW6 (447 mg/L) reflects that the water from these sampling station are heading towards chloride pollution. In fact it is observed that at SW3 during post monsoon period, the obtained chloride value was 620 mg/L (Table 2), which indicates water pollution due to chloride whereas during pre-monsoon period (560mg/L) quality of water is near the line of chloride pollution. At SW6 during pre-monsoon and post monsoon period the obtained chloride value was 550 mg/L and 580 mg/L respectively which indicates water pollution due to chloride which may be possibly due to pollution sources such as domestic effluents, fertilizers, surface runoff, sewage water and industrial effluent.

Nitrate concentration in water depends upon the activity of nitrifying bacteria. Nitrate contributes to freshwater through discharge of sewage and industrial wastes and run off from agricultural fields [64]. The highest amount of nitrate concentration was known to support the formation of blooms [65]. The average value of nitrate recorded in the water samples during the year 2012-2013 at six different stations, at SW1 34 mg/L, at SW2 33 mg/L, at SW3 29 mg/L, at SW4 27 mg/L and at SW5 35 mg/L (Table 2) shows the value are well below the desired limit (as per IS 2296-1982, 50 mg/L) even during all three studied period except at SW6. At SW6 highest nitrate value of 53 mg/L is observed during pre-monsoon period but the average value at SW6 is 37 mg/L. These values of nitrate at all sampling points reflects that no algal bloom or very less algal bloom presence in those water sample from six stations.

Oil and Grease present in the water samples represent the contamination caused by the petrol, diesel and other hydrocarbon fractions spilled from the machinery and washed down by rain. The average value for oil and grease content in the water samples of six location ranges between 0.006 mg/L at SW4 to 0.18 mg/L at SW6. Presence of Oil & Grease indicates an extreme water pollution as it can pollute the whole water table and can significantly make the water unfit for drinking purposes. The study shows that the average value of Oil & Grease at sampling location SW1 was 0.17, at SW2 0.1, at SW3 0.16 and at SW6 0.18 which are in higher sides with comparison to IS 2296 standard (0.1 mg/L), which Indicates poor water quality at those locations. This was expected because of heavy mining activity and large number of vehicular activity, machinery activity .Higher values of Oil & Grease were registered during pre-monsoon (0.3 mg/L) and post-monsoon (0.21 mg/L) at SW1, during pre-monsoon (0.21 mg/L) at SW2, during pre-monsoon (0.24 mg/L) and post-monsoon (0.21 mg/L) at SW3, during pre-monsoon (0.2 mg/L) and post-monsoon (0.3 mg/L) at SW6 (Table 2).

Sulphate ions does not affect the taste of water if present in low concentration, but imparts a slightly milder taste to drinking water than chloride. No significant taste effects were detected below 300 mg/L [66]. The average sulphate concentration at six different station fluctuates between 13.6 mg/L at SW5 to 104 mg/L at SW1, indicating SO_4^{2-} concentration is well within the prescribed limit. The highest value of 135.6 and 121.4 mg/L was observed at SW1 during pre-monsoon and post-monsoon period where as at other places and even in any studied period the observed value SO_4^{2-} was below the 100 mark. The lowest SO_4^{2-} value of 7.5 mg/L was noticed at station SW4 during post monsoon period.

It is found from different study that increase in metal concentration in water have adverse health effect either by directly [31,35] or indirectly [35-37]. Excess iron is an endemic water quality problem in many parts of India [23]. Iron is an abundant element in the earth's crust, but exists generally in minor concentrations in natural water systems. The observed value for iron present in table 2 reveals that the values are <25 mark which is well below the desired limit as per (IS 1982) even during any studied period except at SW2 during monsoon period (35.4 mg/L). This higher value of iron results were due to surface runoff of water from mining area. The average observed value for all sampling station ranges from 1 mg/L at SW5 to 19 mg/L at SW2.

Manganese is commonly found in water and is an essential element required in small amounts by all living organisms. All stream water during study period shows Mn concentration in far below the recognized standard as per (IS 1982). Mental diseases like alzheimer's and manganism are the caused due to intake of drinking water containing high concentrations of Mn [67]. High Mn contamination in drinking water also affects the intellectual functions of 10-year-old children [68]. In the present study the values are ranging from 0.008 mg/L at SW5 to 0.3 mg/L at SW1. At other station the recorded average

value for Mn were 0.17 mg/L (at SW2), 0.12 mg/L (at SW3), 0.09 mg/L (at SW4) and 0.01 mg/L (at SW4). The results show that manganese concentration in water at SW1 station during pre-monsoon (07 mg/L) was above the maximum permissible limit. Manganese in water supposed due to weathering of manganese bearing minerals and rocks. Except this point and period the Mn value was well below the desired limit.

Fluoride (F^-) occurs in almost all waters from trace to high concentrations. Small amount of it is beneficial for human health for preventing dental cavities but consuming fluoride contaminated water (>1 ppm) cause fluorosis. Human health risk is associated with higher concentration of fluoride content in water [69]. There are evidences of tooth mottling, bone deformities and skin diseases [70] due fluoride pollution. The fluoride content in drinking water should be in the range of 0.5 to 1.5 ppm [71]. The continuous intake of fluorides causes permanent inhabitation of growth [72-74] "Implications of fluoride-an endless Uncertainty", Journal of Environmental Biology, 23:81-87.). The concentration of fluoride in groundwater is principally governed by climate, the composition of the host rock and hydrogeology [75-83]. Fluoride is released to the soil and groundwater by the process of weathering of primary rock or leaching of landfill contaminants [75]. The observed data in Table 2 reveals highest average F^- value of 0.23 mg/L at SW1 and lowest of 0.011 mg/L at SW5 indicating water from all sampling station are well below the recommended limit of 1.5 mg/L (IS 1982). These average low values of 0.14, 0.19, 0.01, 0.12 mg/L at sampling points SW2, SW3, SW4 and SW6 respectively reflects the water is free from fluoride pollution. During three studied period, the lowest value for F^- (0.001 mg/L) is observed at SW5 in pre-monsoon period where as highest value of 0.4 mg/L is obtained at SW1 during monsoon period.

Arsenic, a well-known carcinogen, is considered as one of the world's most hazardous chemicals [84,85]. It is carcinogenic to human health even at extremely low levels of exposure (Centers for Disease Control and Prevention: Atlanta, GA, USA, 1999). Acute exposure to arsenic compounds may cause nausea, vomiting, abdominal pain, muscle cramps and diarrhoea (National Research Council: Washington, DC, [86] while chronic exposure is associated with peripheral nerve damage. Concentration of as toxic to human and aquatic life has resulted from mining activities. Arsenic (As) is introduced into soil and water during weathering of rocks and minerals followed by subsequent leaching and runoff. Excessive and long term (such as 5-10 years) human intake of toxic inorganic As from drinking water and food may result in arsenicosis, a common name generally used for As related health problems including skin disorders, skin cancers, internal cancers (bladder, kidney, and lung), diseases of the blood vessels of the legs and feet, possibly diabetes, increased blood pressure, and reproductive disorders [87].

Result from WQI

Water quality index indicates the quality of water in terms of index number which represents overall quality of water for any intended use [66]. In this study, the WQI is established from important physico-chemical parameters such as pH, total alkalinity, chlorides, sulphate, nitrate, total hardness, calcium, magnesium, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total dissolved solids and total suspended solids. The average values of obtained WQI from the different sampling stations were found to be varied from 8.6 to 222.7 (Table 2) .The result shows that the WQI at sampling stations SW1 (126.6), SW2 (222.7), SW3 (105.2), SW6 (156.6) were in higher side and quality of water is very poor which is not suitable for drinking or other use (Table 3). The obtained WQI score for sampling stations SW1, SW2, SW3, SW6 indicates restricting possible use of water for Irrigation (Table 3). The observed range of WQI at sampling stationSW1 during studied period ranges from 10.9 to 244 which reveal that in monsoon the water quality was excellent(WQI=10.9) whereas during pre and post-monsoon water quality are very poor (WQI=244.6,125). Also in sampling station SW2, SW3, SW6 during pre-monsoon higher values of index value were observed (WQI=122, 138.6, 117) which reflects water was unsuitable for drinking as the quality of water was very poor (Table 2). Similarly in sampling station SW2, SW3, SW6 during post-monsoon higher values of index value were observed (WQI=512, 137, 167) which reflects water quality was very poor (Table 2). But in sampling station SW4 and SW5 the average calculated index score (WQI=8.6, 21.66) shows the WQI value fall in the categories of 'excellent' to 'good' (Table 2). In station SW4 the index score ranges between 4.47 to15.8 indicating quality of water was excellent in all three study period but in station SW5 the index score ranges between 11.98 to 27.9 indicating quality was excellent in pre-monsoon (WQI=11.98) whereas during monsoon and post-monsoon (WQI=25.1, 27.9) quality is good [89-91].

SL.No.	WQI	Status	Possible usages
1	0-25	Excellent	Drinking, Irrigation and Industrial
2	25-50	Good	Domestic, Irrigation and Industrial
3	51-75	Fair	Irrigation and Industrial
4	76-100	Poor	Irrigation
5	101-150	Very Poor	Restricted use for Irrigation
6	Above 150	Unfit for Drinking	Proper treatment require before use

Table 3: Water Quality Index and corresponding water quality status [88].

Result from co-relation study

From the present correlation analysis (Table 4a-4f) it was clear that the higher values of WQI score result mainly from higher values of the water quality parameters TDS, TH, BOD, NO_3^-, SO_4^{2-}, Cl^-, Iron, F, Oil & Grease, Mn, As. Correlation study reveals there exist strongly correlation between these water quality parameter and WQI at different sampling station. At sampling station SW1 higher values of WQI was resulted from water quality parameter like TDS, TH, O&G, Mn as there exist strong positive correlation between WQI and mentioned water quality parameter with correlations co-efficients r=0.721, 0.87, 0.979, 0.948 (Table 5a). The strong positive correlation found between WQI and water quality parameter (BOD, TH, NO_3^-, SO_4^{2-}, Mn, As) at sampling station SW2 with correlations co-efficients r=0.883, 0.61, 0.883, 0.971, 0.672, 0.985 (Table 5b) respectively. Higher value of WQI at sampling station SW3 was due to higher value of water quality parameter TDS, TH, Cl^-, NO_3^-, O&G which was cleared from correlations study as strong correlations exist with correlations co-efficients of r=0.85,0.921,0.81,0.869,0.99 respectively (Table 5c). Though in sampling station SW4 and SW5 the quality of water was excellent and good. There also exist strong correlation between WQI and different water quality parameter. At SW4 strong positive correlation found between WQI and water quality parameter (TH, Cl^-, O&G, SO_4^{2-}, Iron, F^-) with correlation co-efficients r=0.631,0.588, 0.995,0.97,0.79,0.987 respectively (Table 5d). Whereas correlation co-efficients of r=0.547, 0.701, 0.948 (Table 5e) found between WQI and water quality parameter like TDS,F^-,As respectively at sampling station SW5. At sampling station SW6 strong correlation found between WQI and water quality parameter TDS with co-relation co-efficients r=0.753 (Table 5f) .The result from Co-relation study shows strongest positive co-relation between WQI and O&G (r=0.979) at SWI, between

SW1	Water quality parameter(x)													
	pH	Colour	TDS	DO	BOD	TH	Cl^-	NO^{3-}	O & G	SO_4^{2-}	Iron	Mn	F^-	As
WQI (y)	y = -600.6x + 3900.42	y= 1.622732437 + 590.4731466	y = 0.145850698x - 78.5006124	y = 0.91 x + 97.166	y = 234.8793103 x + 641.8474138	y = 2.864174212 x - 1145.722869	y= - 0.1044352772x + 108.0399369	y= 8.495880536x - 172.3671473	y= 747.5956284x - 1.169398907	y= 0.3063405142 x + 68.90783308	y= - 10.854842 x + 175.4379256	y = 355.2028736x -.375898007	y= - 515.9043033 x + 218.993229	Y= - 17223.26733x + 265.2460396
R2	0.9102	0.91905	0.52	2E-05	0.923	0.75773	0.0014	0.50529	0.959	0.00974	0.3333	0.89896	0.6376	0.864
Regression coefficient (R)	-600.6	-1.6227	0.146	0.91	-234.9	2.86417	0.1044	8.49588	747.6	0.30634	-10.855	355.203	-515.9	-17223
MLR	y=505.8630313 O&G - 78.59381709 F - 5068.012022 As+ 98.09504079													

Table 4a: Regression study of WQI with fourteen tested water quality parameter and multiple linear regression of WQI at location SW1.

SW2	Water quality parameter(x)													
	pH	Colour	TDS	DO	BOD	TH	Cl^-	$NO3^-$	O&G	SO_4^{2-}	Iron	Mn	F^-	As
WQI (y)	y = -31.92307692x + 396.803846	y = -1.172162874x + 469.2886825	y = 0.8864754468x - 306.135411	y = 140.1278539x - 324.069863	y = 234.6450809 x - 413.3110834	y = 2.719764796 x - 1086.709513	y = -11.54883933x + 612.7213566	y = 21.26241526 x - 516.6068679	y = -521.6847151x + 33.1564619	y = 6.987470276x - 182.9296598	y = -6.950998088x + 307.502992	y = 3623.179487 x - 452.214359	y = -1417.647059x + 332.6647059	y = 14271.11111x - 58.84444444
R2	0.00094	0.1881	0.231	0.07595	0.7809	0. 3732927087	0.36666	0.781	0.0433	0.942932	0.1593	0.45214	0.33793608	0.9712716
Regression coefficient (R)	- 31.923	- 1.1722	0.886	140.128	234.65	2.71976	- 11.549	21.262	- 521.68	6.98747	- 6.951	3623.18	- 1417.6471	14271.111
MLR	y = 1080.793651 Mn + 28.73015873 F + 12812.1164 As - 228.0259259													

Table 4b: Regression study of WQI with fourteen tested water quality parameter and multiple linear regression of wqi at location SW1.

SW3	Water quality parameter(x)													
	pH	Colour	TDS	DO	BOD	TH	Cl -	NO3 -	O&G	SO42 -	Iron	Mn	F -	As
WQI (y)	y = - 206.9 x + 1428.5	y = - 0.5298748507x + 00.8848107	y = 0.7155851852x - 1005.828444	y = - 63.26436782x + 349.3603448	y = 54.2962963x - 50.73333333	y = 0.5636577247x - 127.0170746	Y = 0.200946888x + 4.150387298	y = 11.68536355x - 253.7648725	y = 538x + 16.4	y = - 6.592896781x + 186.8288346	y = - 11.44205128x + 199.2147179	y = - 299.0361446x + 116.5439759	y = - 789.411764x + 233.6382353	y = 123.3259424x + 74.09223947
R2	0.71641	0.3393159	0.7230598	0.5827407	0.149863	0.8485639	0.6563596	0.756254863	0.9809058	0.1638533	0.213624	0.1242119	0.1772939	0.0143494
Regression coefficient (R)	- 206.9	- 0.529875	0.7155852	- 63.26437	54.2963	0.5636577	0.2009469	11.6853636	538	- 6.592897	- 11.4421	- 299.0361	- 789.4118	123.32594
MLR	y = 895.9207161 F - + 0.7750767263 TH + 295.3772379 As - 399.1515985													

Table 4c: Regression study of WQI with fourteen tested water quality parameter and multiple linear regression of WQI at location SW1.

SW4	Water quality parameter(x)													
	pH	Colour	TDS	DO	BOD	TH	Cl -	NO3 -	O&G	SO42 -	Iron	Mn	F -	As
WQI (y)	y = - 2.288059701x + 24.10492537	y = - 0.03542784456x + 14.01122976	y = - 0.03895572522x + 57.87034584	y = - 1.530991736x + 15.07471074	y = - 19.31866667x + 37.26346667	y = 0.01842725598x + 1.198632139	y = 0.01726196942x + 2.843999284	y = - 0.6257251908x + 4.85351145	y = 533.1666667 x + 5.136666667	y = 0.2382409396x + 2.114497568	y = 0.1090601504x + 0.931710526	y = 26.64825918 x + 5.044405175	y = 1110.441176 x - 6.633235294	y = - 585.6545155x + 9.896214893
R2	0.0 1020045129	0. 2711661933	0.457219557	0.032991	0.814001941	0.398907808	0.34621808	0.149158653	0.9920124087	0.941627823	0.625651677	0.078532795	0.975371134	0.224097988
Regression coefficient (R)	- 2.288059701	- 0.035427845	- 0.03895572	- 1.53099	- 19.31866667	0.018427256	0.017261969	- 0.62572519	533.166667	0.238240939	0.10906015	26.64825918	1110.441176	- 585.6545155
MLR	y = - 0.7578947368 pH + 0.002968960864 TH + 501.1005398 O&G + 9.632995951													

Table 4d: Regression study of WQI with fourteen tested water quality parameter and multiple linear regression of WQI at location SW1.

SW5	Water quality parameter(x)													
	pH	Colour	TDS	DO	BOD	TH	Cl^-	$NO3^-$	O&G	SO_4^{2-}	Iron	Mn	F^-	As
WQI (y)	y = 2.076923077x + 3.700769231	y = 0.04684875384x + 5.20497781	y = 0.04268166078x - 8.47554915	y = 3.637474542x + 3.15604888	y = -6.783098592x + 33.31450704	y = -0.01746948796x + 27.278912	y = -0.04474444011x + 37.538267	y = -1.854814815x + 87.69814815	y = -194.5454545x + 22.47454545	y = -2.481769468x + 52.76002052	y = 1.324837046 x + 17.24172488	y = -461.1695906x + 22.29818713	y = 396.2606232 x + 15.50365439	y = 171.9388388 x + 6.131602379
R2	0.004985	0.0285752	0.2999089	0.072193	0.2904146	0.123468	0.4618763	0.8257883	0.0462646	0.6003242	0.0160391	0.3233116	0.4927656	0.9002434
Regression coefficient(R)	2.076923	0.0468488	0.0426817	3.6374745	- 6.7830986	- 0.0174695	- 0.0447444	- 1.8548148	- 194.54545	- 2.4817695	1.324837	- 461.16959	396.26062	171.93884
MLR	y = - 23.50936615 Fe + 961.5606622 Mn + 1575.129601 As + 30.60583424													

Table 4e: Regression study of WQI with fourteen tested water quality parameter and multiple linear regression of WQI at location SW1.

SW6	Water quality parameter(x)													
	pH	Colour	TDS	DO	BOD	TH	Cl^-	$NO3^-$	O&G	SO_4^{2-}	Iron	Mn	F^-	As
WQI (y)	y = -46.71232877x + 487.090411	y = 0.4312541473x + 140.1746848	y = 0.3.192402817x - 401.7623172	y = -40.26153846x + 323.9307692	y = -5.619172685x + 188.8241628	y = -0.2823431978x + 66.0879624	y = -0.08149890147 x + 210.500618	y = -1.952380952x + 235.4261905	y = 116.2658228 x + 145.0462025	y = 1.358688315 x + 129.2681707	y = -3.790341379x + 225.1733235	y = 2377.334284 x + 124.8089808	y = 2051.428571x + 146.7942857	y = 14.39914627x + 168.767048
R2	0.2087693	0.0979556	0.567072	0.1841254	0.2100894	0.3343125	0.0994527	0.7553734	0.1492934	0.0908011	0.7511617	0.3464158	0.0064349	0.031677
Regression coefficient (R)	- 46.712329	0.4312541	0.3.1924028	- 40.261538	- 5.6191727	- 0.2823432	- 0.0814989	- 1.952381	116.26582	1.3586883	- 3.7903414	2377.3343	2051.4286	14.399146
MLR	y = - 303.1546811 pH + 1.101221167 TDS - 15859.56581 Mn + 550.3480326													

Table 4f: Regression study of WQI with fourteen tested water quality parameter and multiple linear regression of WQI at location SW1.

Parameter	pH	Colour	TDS	DO	BOD	TH	Cl^-	NO_3^-	O&G	SO_4^{2-}	Iron	Mn	F^-	As	WQI
pH	1	0.887	- 0.48	- 0.3	0.84	- 0.7	0.124	- 0.79	- 0.925	- 0.17	0.327	- 0.83	0.648	0.958	- 0.95
Colour		1	- 0.73	0.091	0.91	- 0.93	0.26	- 0.81	- 0.886	- 0.33	0.531	- 0.99	0.926	0.944	- 0.96
TDS			1	- 0.68	- 0.87	0.924	0.256	0.219	0.74	- 0.17	- 0.95	0.836	- 0.8	- 0.48	0.721
DO				1	0.24	- 0.45	- 0.29	0.353	- 0.02	0.223	0.735	- 0.24	0.385	- 0.24	0.004
BOD					1	- 0.92	- 0.17	- 0.51	- 0.974	0.093	0.78	- 0.94	0.797	0.796	- 0.96
TH						1	- 0.08	0.577	0.824	0.171	- 0.77	0.975	- 0.96	- 0.76	0.87
Cl^-							1	- 0.71	0.167	- 1	- 0.53	- 0.15	0.354	0.371	- 0.03
NO_3^-								1	0.563	0.74	0.06	0.708	- 0.71	- 0.92	0.71
O&G									1	- 0.1	- 0.65	0.894	- 0.7	- 0.85	0.979
SO_4^{2-}										1	0.44	0.23	- 0.44	- 0.42	0.098
Iron											1	- 0.66	0.587	0.264	- 0.58
Mn												1	- 0.94	- 0.88	0.948
F^-													1	0.781	- 0.8
As														1	- 0.93
WQI															1

Table 5a: Correlation coefficient matrix of water quality parameter and WQI of water sample location SW1.

Parameter	pH	Colour	TDS	DO	BOD	TH	Cl -	NO_3^-	O&G	SO_4^{2-}	Iron	Mn	F^-	As	WQI
pH	1	- 0.545	0.268	- 0.21	0.009	0.303	0.139	0.359	0.036	0.145	- 0.83	0.575	- 0.53	- 0.16	- 0.03
Colour		1	- 0.95	- 0.67	- 0.07	- 0.96	- 0.36	- 0.79	- 0.617	- 0.63	0.899	- 0.93	0.195	- 0.28	- 0.43
TDS			1	0.857	0.048	0.985	0.396	0.753	0.719	0.65	- 0.73	0.855	- 0.01	0.346	0.48
DO				1	- 0.2	0.784	0.548	0.415	0.856	0.385	- 0.28	0.479	0.449	0.195	0.275
BOD					1	0.214	- 0.9	0.671	- 0.638	0.789	- 0.22	0.411	- 0.83	0.916	0.883
TH						1	0.237	0.855	0.589	- 0.39	- 0.43	0.152	- 0.05	0.017	0.61
Cl^-							1	- 0.06	0.215	- 0.19	- 0.08	0.001	0.228	- 0.02	- 0.61
NO_3^-								1	0.02	0.427	- 0.43	0.156	- 0.19	0.027	0.883
O & G									1	- 0.02	- 0.16	0.05	0.198	- 0.01	- 0.21
SO_4^{2-}										1	- 0.33	0.137	- 0.19	0.032	0.971
Iron											1	- 0.15	0.158	- 0.01	- 0.4
Mn												1	- 0.16	0.018	0.672
F^-													1	- 0.02	- 0.63
As														1	0.985
WQI															1

Table 5b: Correlation coefficient matrix of water quality parameter and WQI of water sample location SW2.

Parameter	pH	Colour	TDS	DO	BOD	TH	Cl^-	NO3 -	O&G	SO_4^{2-}	Iron	Mn	F^-	As	WQI
pH	1	0.227	- 0.03	0.167	- 0.047	- 0.021	- 0.44	- 0.137	- 0.328	0.134	0.071	0.118	0.068	0.068	- 0.846
Colour		1	- 0.029	0.16	- 0.094	- 0.196	- 0.454	- 0.104	- 0.239	0.196	0.12	0.192	0.11	0.007	- 0.582
TDS			1	- 0.7	0.812	0.914	0.849	0.898	0.828	- 0.72	- 0.857	- 0.818	- 0.818	0.291	0.85
DO				1	- 0.33	- 0.918	- 0.932	- 0.922	- 0.84	0.742	0.386	0.641	0.559	0.464	- 0.763
BOD					1	0.559	0.642	0.092	0.347	- 0.765	- 0.966	- 0.846	- 0.946	0.456	0.387
TH						1	0.974	0.876	0.946	- 0.721	- 0.62	- 0.664	- 0.676	- 0.077	0.921
Cl^-							1	0.804	0.85	- 0.857	- 0.69	- 0.807	- 0.791	- 0.157	0.81
NO_3^-								1	0.926	- 0.44	- 0.167	- 0.324	- 0.274	- 0.383	0.869
O&G									1	- 0.459	- 0.423	- 0.389	- 0.426	- 0.016	0.99
SO_4^{2-}										1	0.772	0.987	0.932	0.219	- 0.404
Iron											1	0.845	0.947	0.449	- 0.462
Mn												1	0.971	0.087	- 0.352
F^-													1	- 0.145	- 0.421
As														1	0.119
WQI															1

Table 5c: Correlation coefficient matrix of water quality parameter and WQI of water sample location SW3.

Parameter	pH	Colour	TDS	DO	BOD	TH	Cl -	NO3 -	O&G	SO_4^{2-}	Iron	Mn	F^-	Arsenic	WQI
pH	1	0.261	0.063	0.055	0.437	- 0.014	0.384	0.245	- 0.07	- 0.193	0.007	- 0.54	0.029	0.587	- 0.1
Colour		1	0.96	- 0.71	0.753	- 0.958	- 0.797	- 0.499	- 0.442	- 0.341	0.107	- 0.924	- 0.559	0.934	- 0.52
TDS			1	- 0.601	0.796	- 0.997	- 0.913	- 0.402	- 0.611	- 0.492	- 0.089	- 0.784	- 0.733	0.828	- 0.676
DO				1	- 0.073	0.647	0.593	0.961	- 0.262	- 0.397	- 0.735	0.726	- 0.088	- 0.575	- 0.181
BOD					1	- 0.749	- 0.565	0.191	- 0.866	- 0.852	- 0.528	- 0.638	- 0.868	0.792	- 0.902
TH						1	0.931	0.461	0.565	0.436	0.035	0.778	0.698	- 0.809	0.631
Cl^-							1	0.484	0.539	0.377	0.079	0.518	0.695	- 0.539	0.588
NO_3^-								1	- 0.453	- 0.594	- 0.831	0.513	- 0.275	- 0.328	- 0.386
O&G									1	0.982	0.841	0.195	0.98	- 0.396	0.995
SO_4^{2-}										1	0.893	0.141	0.926	- 0.357	0.97
Iron											1	- 0.314	0.739	0.093	0.79
Mn												1	0.281	- 0.974	0.28
F^-													1	- 0.453	0.987
As														1	- 0.473
WQI															1

Table 5d: Correlation coefficient matrix of water quality parameter and WQI of water sample location SW4.

Parameter	pH	Colour	TDS	DO	BOD	TH	Cl^-	NO_3^-	O&G	SO_4^{2-}	Iron	Mn	F^-	As	WQI
pH	1	0.967	0.455	- 0.867	0.757	- 0.855	- 0.65	- 0.48	- 0.354	0.092	- 0.83	0.031	- 0.656	0.308	0.07
Colour		1	0.324	- 0.719	0.609	- 0.758	- 0.597	- 0.555	- 0.15	0.152	- 0.662	0.162	- 0.542	0.439	0.169
TDS			1	- 0.493	0.235	- 0.85	- 0.926	- 0.664	- 0.923	- 0.808	- 0.663	- 0.875	0.034	0.473	0.547
DO				1	- 0.954	0.804	0.509	0.122	0.585	- 0.11	0.976	0.087	0.845	0.115	0.268
BOD					1	- 0.591	- 0.228	0.159	- 0.404	0.367	- 0.882	0.14	- 0.963	- 0.374	- 0.538
TH						1	0.919	0.662	0.75	0.412	0.88	0.489	0.375	- 0.447	- 0.351
Cl^-							1	0.865	0.732	0.693	0.64	0.683	- 0.017	- 0.706	- 0.679
NO3 -								1	0.328	0.636	0.23	0.478	- 0.343	- 0.965	- 0.908
O&G									1	0.679	0.74	0.847	0.158	- 0.1	- 0.215
SO_4^{2-}										1	0.101	0.954	- 0.601	- 0.574	- 0.774
Iron											1	0.297	0.724	0.023	0.126
Mn												1	- 0.388	- 0.355	- 0.568
F^-													1	0.51	0.701
As														1	0.948
WQI															1

Table 5e: Correlation coefficient matrix of water quality parameter and WQI of water sample location SW5.

Parameter	pH	Colour	TDS	DO	BOD	TH	Cl^-	NO_3^-	O&G	SO_4^{2-}	Iron	Mn	F^-	As	WQI
pH	1	- 0.891	- 0.356	0.997	- 0.812	0.969	0.9123	0.83	0.516	0.601	0.552	- 0.874	0.833	- 0.819	- 0.456
Colour		1	0.538	- 0.863	0.813	- 0.932	- 0.998	- 0.718	- 0.752	- 0.398	- 0.213	0.949	- 0.714	0.986	0.312
TDS			1	- 0.292	- 0.053	- 0.572	- 0.506	- 0.716	- 0.045	0.522	- 0.348	0.739	0.17	0.494	0.753
DO				1	- 0.823	0.95	0.888	0.806	0.503	0.649	0.56	- 0.837	0.859	- 0.788	- 0.429
BOD					1	- 0.711	- 0.832	- 0.36	- 0.856	- 0.834	- 0.018	0.615	- 0.965	0.826	- 0.144
TH						1	0.942	0.905	0.488	0.395	0.551	- 0.963	0.693	- 0.861	- 0.578
Cl^-							1	0.728	0.744	0.44	0.243	- 0.944	0.746	- 0.98	- 0.315
NO_3^-								1	0.085	0.104	0.8	- 0.88	0.391	- 0.603	- 0.869
O&G									1	0.532	- 0.428	- 0.518	0.699	- 0.838	0.386
SO_4^{2-}										1	0.103	- 0.185	0.925	- 0.387	0.301
Iron											1	- 0.426	0.191	- 0.052	- 0.866
Mn												1	- 0.537	0.9	0.588
F^-													1	- 0.696	0.08
As														1	0.177
WQI															1

Table 5f : Correlation coefficient matrix of water quality parameter and WQI of water sample location SW6.

WQI and As (r=0.985) at SW2, between WQI and O&G (r=0.99) at SW3, between WQI and O&G (r=0.995) at SW4, between WQI and As (r=0.987) at SW5 and between WQI and TDS (r=0.753) at SW6 which indicates the higher values of WQI are due to these water quality parameter at these locations [92,93].

Regression study founds regression coefficients of R=355.2028736, 14271.1111, 538, 1110.44117, 396.2606232, 2377.334284 between Mn, As, F^-, O&G, F and Mn water quality parameter and WQI (Table 5a-5f) at six sampling station SW1, SW2, SW3, SW4, SW5, SW6 respectively and these parameter at respective location are good at predicting WQI. Whereas MLR study (Table 5a-5f) reveals that water quality parameter: O&G, F^-, As at SW1, water quality parameter: Mn, F^-, As at SW2, water quality parameter: F^-, Th, As at SW3, water quality parameter: pH, Th, O&G at SW4, water quality parameter: Fe, Mn, As at SW5, water quality parameter: pH, TDS, Mn at SW6 respectively are good at predicting WQI at respective different sampling points [94].

Conclusion

The study shows presence of high values of physicochemical parameters such as TDS, Fe, Mn, O&G, As in six streams (Table 2) located surrounding iron ore mine of Suakati area of Keonjhar District of Odisha which indicates poor quality of water except location at SW4 and SW5. The WQI reveals that degradation of water quality was due to high concentrations of these parameters at different locations. Overall assessment is that almost all of the samples vary from poor to very poor category. This may be due to low volume of water, low flow condition, dense population in the catchment area and flowing of streams in the close proximity of various iron mines having lot of anthropogenic activities. The sources of contamination are soil erosion, mines run off and anthropogenic activities with extensive recreational use of the streams and the river. Mostly the quality of water was very poor during pre-monsoon and post-monsoon period at almost all sampling location indicating unfit for domestic purpose and need special attention for treatment before its use. The quality of water at some location is found unfit for public consumption purpose. The streams of this area are part of upper catchment of Baitarani river, one of the largest river of the state. The area is inhabited by poor tribal having no idea of water pollution thus aggravating the problem. Thus there is a need of necessary efforts to overcome the problem of pollution for maintenance of healthy aquatic ecosystems and its balance in this area. There is an urgent need for proper management to check the human activities along the streams and river/river catchment along with public awareness to ensure its minimal negative impact on the water body. Further study is needed to find out whether the metal content are accumulating in agricultural product or not, as water is used in irrigation purpose. Deforestation should be strictly enforced to check the massive soil erosion at mining surrounding area. Similarly plantation along with coir-mattering should be practised on overburden dump site to check soil erosion. The present baseline information of the physico-chemical parameters of water samples would form a useful tool for further ecological and environmental assessment and monitoring of these water ecosystems, leading to the safe survival of the inhabitants in the study area.

References

1. Pejman HA, Bidhendi GRN, Karbassi AR, Mehrdadi N, Bidhendi ME (2009) Evaluation of spatial and seasonal variations in surface water quality using multivariate statistical techniques. Internat J Environ Sci Technol 6: 467-476.
2. Zhao Y, Xia XH, Yang ZF, Wang F (2012) Assessment of water quality in Baiyangdian lake using mul- tivariate statistical techniques. Proce Environ Sci 13: 1213-1226.
3. Cooper J, Rediske R, Northup M, Thogerson M, Denend J (1998) Agricultural water quality index. Scientific Technical Reports. paper 11.
4. Ayibatele NB (1992) First season environmental baseline survey, In Proc Internal Conf Water Environ 1: 4.
5. Khalil B, Ouarda TMBJ (2009) Statistical approaches used to assess and redesign surface water quality monitoring networks. J Environ Moni 11: 1915-1929.
6. Kumar N (2010) An approach to river water quality management through correlation study among various water quality parameters. Rep Opinion 2: 58-63.
7. Singh KP, Malik A, Sinha S (2005) Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques-a case study. Analytical Chimica Acta 538: 355-374.
8. Li S, Gu S, Liu W, Han H, Zhang Q (2009) Spatio- temporal dynamics of nutrients in the upper han river basin, China. J Hazard Mater 162: 1340-1346.
9. Pizarro J, Vergara PM, Rodriguez JA, Valenzuela AM (2010) Heavy Metals in Northern Chilean Rivers: Spatial Variation and Temporal Trends. J Hazard Mater 181: 747-754.
10. Li S and Zhang Q (2010) Spatial characterization of dissolved trace elements and heavy metals in the upper river (china) using multivariate statistical techniques. J Hazard Mater 176: 579-588.
11. Kumar A, Dua A (2009) Water quality index for assessment of water quality of river ravi at Madhopur (India). Glob J Environ Sci 8: 49-57.
12. Sumi L, Thomsen S (2001) Mining in remote areas, issues and impacts. Mining Wat Canada.
13. Dasgupta A (2012) Impact of mining on rural environmental and economy. A case study, Kota district, Rajasthan. Internat J Remote sensing Geosci 2 :21-26.
14. Ahmad M, Ratan S, Dhar BB (1994) Environmental impact of mill tailings. proc. of second nat. seminar on minerals and ecology.
15. Mondal S, Bandayopahyay J, Chakarvarty D (2014) Scientific investigation of the environmental impact of mines using geospatial tecniques over a small part of Keonjhar Dstrict of Orissa. Inter J Scient Res Public 4: 1-8.
16. Hudson T (2011) Living with Earth, An Introduction to Environmental Geology. PHI Learning Private Limited.
17. Mahato MK, Singh G, Singh PK, Singh AK, Tiwari AK (2017) Assessment of mine water quality using heavy metal pollution index in a coal mining area of Damodar River Basin, India. Bullet Environ Contamin Toxicol 99: 54-61.
18. Tiwari AK, Singh PK, Mahato MK (2017) Assessment of metal contamination in the mine water of the West Bokaro coalfield, India. Mine Water Environ pp: 1-10.
19. Allen SK, Allen JM, Lucas S (1996) Concentration of contaminants in surface water samples collected in west-central Indiana impacted by acid mine drainage. Environ Geol 27: 34-37.
20. Choubey VD (1991) Hydrological and environmental impact of coal mining, Jharia coalfield, India. Environ Geol 17: 185-194.
21. Galero DM, Pesci HE, Depetris PJ (1998) Effects of quarry mining and of other environmental impacts in the mountainous Chicam-Toctina drainage basin (Cordoba,Argentina). Environ Geol 34: 159-166.
22. Ratha DS, Venkataraman G (1997) Application of statistical methods to study seasonal variation in the mine contaminants in soil and groundwater of Goa, India. Environ. Geol. 29: 253-262.
23. Singh AK, Raj B, Tiwari AK, Mahato MK (2013) Evaluation of hydrogeochemical processes and groundwater quality in the Jhansi district of Bundelkhand region, India. Environ Earth Sci 70: 1225-1247.
24. Younger PL, Wolkersdorfer C (2004) Mining impacts on the fresh water environments: Technical and managerial guidelines for catchment scale management. Mine Water Environ 23: S2-S80.
25. Singh AK, Mahato MK, Neogi B, Singh KK (2010) Quality assessment of mine water in the Raniganj coalfield area, India. Mine Water Environ 29: 248-262.
26. Singh AK, Mahato MK, Neogi B, Tewary BK, Sinha A (2012) Environmental geochemistry and quality assessment of mine water of Jharia coalfield, India. Environ Earth Sci 65: 49-65.

27. Singh AK, Mahato MK, Neogi B, Mondal GC, Singh TB (2011) Hydrogeochemistry, elemental flux, and quality assessment of mine water in the Pootkee-Balihari mining area, Jharia coalfield, India. Mine Water Environ 30: 197.

28. Karmakar HN, Das KP (2012) Impact of mining on ground & surface water. Intern Mine Water Assoc.

29. Singh G (1988) Impact of coal mining on mine water quality. Internat J Mine Water 7: 49-59.

30. Dhar BB (1993) Environmental scenario of indian mining industry. In: Choudhary, kumar S (eds) Environment management, Geo water and engineering aspects.

31. Adamu CI, Nganje T, Edet A (2015) Heavy metal contamination and health risk assessment associated with abandoned barite mines in cross river state, Southeastern Nigeria. Environ Nanotech Monito Manage 3: 10-21.

32. Qiao-qiao C, Guang-wei Z, Langdon A (2007) Bioaccumulation of heavy metals in fishes from Taihu Lake, China, J Environ Sci 19: 1500-1504.

33. Dogan-Saglamtimur N, Kumbur H (2010) Metals (Hg, Pb, Cu, and Zn) bioaccumulation in sediment, fish, and human scalp hair: a case study from the city of mersin along the southern coast of Turkey. Biol Trace Elem Res 136: 55-70.

34. Koki IB, Bayero AS, Umar A, Yusuf S (2015) Health risk assessment of heavy metals in water, air, soil and fish. Afric J Pure App Chem 9: 204-210.

35. Bempah CK and Ewusi A (2016) Heavy metals contamination and human health risk assessment around Obuasi gold mine in Ghana, Environ Monit Assess 188: 261.

36. Singh A, Sharma RK, Agrawal M, Marshall FM (2010a) Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. Tropic Ecol 51: 375-387.

37. Modoi OC, Roba C, Torok Z, Ozunu A (2014) Environmental risks due to heavy metal pollution of water resulted from mining wastes in NW Romania, Environ Eng Manag J 13: 2325-2336.

38. Tiwari AK, Singh AK (2014) Hydrogeochemical investigation and groundwater quality assessment of Pratapgarh district, Uttar Pradesh. J Geolog Soci India 83: 329-343.

39. Kumar R, Singh RD, Sharma KD (2005) Water resources of India. Curr Sci 89: 794-781.

40. Dash A, Das HK, Mishra B (2015) Hydrochemical characteristics and water quality of surface water in and around Joda of Keonjhar, Odisha, India, Internat Energy Sustain Environ Eng 1: 128-136.

41. Yahya SM, Rahman A, Abbasi HN (2012) Assessment of seasonal and polluting effects on the quality of river water by using regression analysis: a case study of river Indus in province of Sindh, Pakistan. Internat J Environ Protect 2: 10-16.

42. Chapman D (1992) Water quality assessment. A guide to use of biota, sediments and water in environmental monitoring. (2ndedn), on behalf of UNESCO, WHO and UNEP, London.

43. Pesce SF, Wunderlin DA (2000) Use of water quality indices to verify the impact of Cordoba city (Argentina) on Suquy´a River. Water Res 34: 2915–2926.

44. Mishra PC, Patel RK (2001) Study of the pollution load in the drinking water of Rairangpur, a small tribal dominated town of North Orissa. Ind J Environ Ecoplann 5: 293-298.

45. Singh DF (1992) Studies on the water quality index of some major rivers of Pune, Maharashtra. Proceed Acad Environ Biol 1: 61-66.

46. Tiwari TN, Mishra MA (1985) A preliminary assignment of water quality index of major Indian rivers. Ind J Environ Protect 5: 276-279.

47. Sanchez E, Colmenarejo MF, Vicente J, Rubio A, García MG (2007) Use of the water quality index and dissolved oxygen deficit as simple indicators of watershed pollution. Ecological Indicators 7: 315-328.

48. Bordalo AA, Teixeira R, Wiebe WJ (2006) A Water Quality Index Applied to an International Shared River Basin: the Case of Douro River Environ Manage 38: 910-920.

49. Rao NS (1997) Studies on water quality index in hard rock terrain of Guntur District, Andhra Pradesh, India. National seminar on hydrogeology of precambrian terrains and hard rocks areas, Dharwad. pp: 129-134.

50. Giri S, Singh AK (2014) Assessment of surface water quality using heavy metal pollution index in Subarnarekha river, India. Water Qual Expo Health 5: 173-182.

51. Kannan K (1991) Fundamentals of environmental pollution. S Chand & Company Ltd, New Delhi.

52. Rizwan R, Gurdeep S (2010) Assessment of ground water quality status by using water quality index method in Orissa, India. World App Sci J 9: 1392-1397.

53. Bora M, Goswami DC (2016) Water quality assessment in terms of water quality index (WQI): case study of the Kolong River, Assam, India. Appl Water Sci 7: 3125-3135.

54. Kreyszig Erwin (2004) Advanced Engineering Mathematics. In: John wiley & Sons (eds) (8thedn), Asia, Pte. Ltd, Singapore.

55. Subba RC, Sreenivasa RB, Hariharann AVLNSH, Manjula NB (2010) Determination of water quality index of some areas in Guntur district Andhra Pradesh. Internat J Appl Biol Pharmaceu Technol 1: 79-86.

56. Ahipathy MV, Puttaiah ET (2006) Ecological Characteristics of Vrishabhavathy River in Bangalore (India). Environ geol 49: 1217-1222.

57. Etim EE, Odoh R, Itodo AU, Umoh SD, Lawal U (2013) Water quality index for the assessment of water quality from different sources in the Niger Delta region of Nigeria. Fronti Sci 3: 89-95.

58. Chandra S, Singh A, Tomar P K (2012) assessment of water quality values in porur lake Chennai, Hussain Sagar Hyderabad and Vihar lake Mumbai, India. Chem Sci TranS 1: 508-515.

59. Esteves FA (1988) Fundamentos de Limnologia. FINEP, Rio de Janeiro 602.

60. Gupta S, Kumar A, Ojha CK Singh GJ (2004) Environmental Science and Engineering. 46: 74.

61. Wetzel RG (2001) Limnology: Lake and River Ecosystems. Academic Press, New York. pp: 1006.

62. Shanthi K, Ramasamy P, Lashmanperumalsamy M (2002) Hydrological study of Singanallur lake at Coimbatore. Nature Environ Pollut Technol 1: 97-101.

63. Vikal P (2009) Multivariant analysis of drinking water quality parameters of lake Pichhola in Udaipur, India. Biological Forum, 1: 86-91.

64. Solanki H (2012) Status of soils, water reservoirs near industrial areas of Baroda: pollution and soil-water chemistry. Lambert Academic Publishing, Germany. Ecol.

65. Uduma AU (2014) Physico-chemical analysis of the quality of sachet water consumed in Kano metropolis. Ameri J Environ Energy Power Res 2: 1-10.

66. Etim EE, Akpan IU, Andrew C, Edet EJ (2012) Determination of water quality index of pipe borne water in Akwa Ibom State, Nigeria. Internat J Chem Sci 5: 179-182.

67. Dieter HH, Bayer TA, Multhaup G (2005) Environmental copper and manganese in the pathophysiology of neurologic diseases (Alzheimer's disease and Manganism) Clean Soil Air Wat. 33:72-78.

68. Wasserman GA, Liu X, Parvez F, Ahsan H, Levy D, et al. (2006) Water manganese exposure and children's intellectual functions in Araihazar, Bangladesh. Environ Health Perspect 114: 124-129.

69. Tiwari AK, Singh AK, Mahato MK (2016) GIS based evaluation of fluoride contamination and assessment of fluoride exposure dose in groundwater of a district in Uttar Pradesh, India. Human Ecologi Risk Assess. 23: 56-66.

70. Srivastava RK (2012) Fluoride concentraction. Indian J Dental Sci 4: 121-123.

71. Edmunds WM, Smedley PL (1996) Ground water geochemistry and health: An overview. Environ geochem healt, London: Geological Society, Special Publication 113: 91-105.

72. Ramesam V, Rajagopalan K (1985) Fluoride ingestion into the natural water of hard rock areas, peninsular India J Geol Soc Ind 26: 125-132.

73. Andezhath SA, Ghosh G (1998) Fluorosis management in India: The impact due to networking between health and rural drinking water supply agencies, AHS-AISH Publication. Interdiscipli Perspect Drink Water Risk Assess Manage 260: 159-165.

74. Pillai KS, Stanley VA (2002) Implications of fluoride-an endless Uncertainty. J Environ Biol 23: 81-87.

75. Sujatha D (2003) Fluoride levels in the groundwater of the southeastern part of Ranga Reddy district, Andhra Pradesh, India. Environ Geol 44: 587-591.

76. Hussain J, Sharma KC, Ojha KG, Hussain I (2000) Fluoride distribution in ground waters of Sirohi district in Rajasthan. Ind J Environ Eco-plann 3: 661-664.

77. Hussain J, Sharma KC, Hussain I (2003) Fluoride distribution in groundwater of Raipur Tehsil in Bhilwara District. Intern J Biosci Rep 1: 580-587.

78. Hussain J, Sharma KC, Hussain I (2004) Fluoride in drinking water and its ill effect on human health: A review. J Tissue Res 4: 263-273.

79. Hussain J, Sharma KC, Hussain I (2005) Fluoride distribution in groundwater of Banera Tehsil in Bhilwara District, Rajasthan. Asian J Chem 17: 457-461.

80. Hussain J, Sharma KC, Arif M, Hussain I (2007) Fluoride distribution and modeling using best subset procedure in Nagour District of Central Rajasthan, India. In The XXVIITH conference of the international society for fluoride research (ISFR XXVII), Beijing, China.

81. Hussain J, Hussain I, Sharma KC (2010) Fluoride and health hazards: community perception in a fluorotic area of central Rajasthan (India): an arid environment. Environ Monitor Assess 162: 1-14.

82. Hussain I, Arif M, Hussain J (2012) Fluoride contamination in drinking water in rural habitations of central Rajasthan, India. Environ Monitor Assess 184: 5151-5158.

83. Arif M, Hussain I, Hussain J, Sharma S, Kumar S (2012) Fluoride in the drinking water of Nagaur Tehsil of Nagaur District, Rajasthan, India. Bull Environ Contam Toxicol 88: 870-875.

84. USEPA (2001) National primary drinking water regulations: arsenic and clarifications to compliance and new source contaminants monitoring. Federal Register. pp: 6975-7066.

85. USEPA (2017) Drinking water requirements for states and public water systems.

86. National Research Council (1999) Arsenic in Drinking Water; National Research Council: Washington, DC, USA. pp: 251-257.

87. Santra SC, Samal AC, Bhattacharya P, Banerjee S, Biswas A, et al. (2013) Arsenic in food chain and community health risk: a study in gangetic west Bengal. Procedia Environ Sci 18: 2-13.

88. Brown RM, McClelland NI, Deininger RA, O'Connor MF (1972) A water quality index-crashing the physiological barrier. Indic Environ Qual 1: 173-182.

89. Agency for toxic substances and disease registry (1999) Lead: toxicological profiles; centers for disease control and prevention: Atlanta, GA, USA.

90. APHA (2000) Standard methods for the examination of water and waste water. (19th edn.), American Public Health Association, Washington DC, USA.

91. Bellingham, Stevens K (2012) Water monitoring systems: 205-209.

92. Singh PK, Tiwari AK, Mahato MK (2013) qualitative assessment of surface water of west Bokaro coalfield, Jharkhand by using water quality index method. Inter J Chem Tech Res 5: 2351-2356.

93. Tiwari AK, Singh PK, Mahato MK (2014) GIS-based evaluation of water quality index of groundwater resources in west Bokaro coalfield, India, Current World Environ 9: 843-850.

94. WHO (2008) Guidelines for Drinking-Water Quality. 4.