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Research Article

Correlation Between Iron Pollution and Physicochemical Characteristics of Effluent of Steel Industries from Urla, Raipur (Chhattisgarh), India

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Abstract

Objective: In the present study the status of iron concentrations and various physicochemical parameters of the effluents of steel and iron casting industries were assessed. **Methodology:** The monthly observations showed that the iron concentrations ranged between 0.72-6.89 mg L^{-1} and physicochemical parameters were observed in the following ranges; pH 1.92-8.13, EC 0.9-8.33 mS cm^{-1}, TDS 488.43-5444 ppm, TSS 30-436.67 mg L^{-1}, turbidity 0.16-81.51 NTU, COD 22.4-147.2 mg L^{-1}, DO 0.2-10.6 mg L^{-1} and BOD 0.2-7.9 mg L^{-1}. The observations revealed that some of the parameters were out of permissible limits of water quality standards formulated by the CBCB and BIS. **Results:** Further, results showed the significant positive correlation of iron concentration with EC ($r = 0.594$), TDS ($r = 0.516$), DO ($r = 0.611$) and significant negative correlation with pH ($r = -0.818$) at $p<0.01$. **Conclusion:** In conclusion the industrial effluents may affect the quality of water resources, later may be then hazardous to human health.

Key words: Steel and iron casting industries, effluents, physicochemical parameters, water quality standards

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Raipur, the capital city (latitude 21°12'36"N and longitude 82°18'0" E) of Chhattisgarh state of India is a hub of industries, factories, coal mines, cement and other energy production plants; majority among these routinely discard their waste materials, effluents and coal washeries into the ground and nearby streams and rivers. These industrial effluents are rich in chemicals and metals like lead, nickel, copper and iron etc. Their deposition in nearby areas tends to increase the pollution of the aquatic as well as terrestrial environment and the environmental contamination of heavy metals on air, water and food has become threat to life forms (Sharma *et al*., 2013; Shukla, 2014). Even though, some trace elements from the environment are essential to human kind but their elevated levels can cause morphological abnormalities, reduce growth, increase mortality and mutagenic effects (Behera *et al*., 2012).

Among the aquatic reservoirs, surface water resources are most susceptible to contamination with heavy metals and other chemicals due to their easy availability to contact with disposal of industrial effluents (Sundaray, 2010; Sharma *et al*., 2013). Previous investigations have highlighted the negative impacts of industrial effluents on quality of water (Mishra *et al*., 2013; Nirgude *et al*., 2013). Their negative impacts on nearby aquatic reservoirs such as rivers and streams (Chatterjee *et al*., 2010; Chinhanga, 2010; Rai, 2010; Banerjee and Gupta, 2013; Iram *et al*., 2013; Olaniran *et al*., 2014; Ogwueleka, 2015) and on ground water quality (Thomas *et al*., 2011; Kumari *et al*., 2014) have been reported. Water as an abiotic renewable resource on earth for human consumption must be free from toxic chemicals, harmful microorganisms, organic matters and excessive concentration of minerals (Thomas *et al*., 2011). Consumption of trace elements at elevated level can cause tumor, renal disorder, gastric problems, colic problems, anemia, hepatic narcosis and cirrhosis, dermatitis and bronchitis etc. (Shukla, 2014).

In Chhattisgarh including Raipur, iron pollution not only seems a problem in particulate matter, but is also a major problem for the water resources (Das, 2014). The main factor responsible for such type of pollution is the rapid utilization of iron ore in steel plants or in casting industries. Raipur has a large number of ferroalloy and sponge iron units. These industries release their effluents, containing chemicals and metals into the nearby areas and contaminate the soil, groundwater and surface water, results in the loss of biodiversity and affect the health of the local population (Das, 2014).

Being a serious environmental problem, which is directly or indirectly affecting the human health. Therefore, in the present study it is aimed to investigate the status of iron concentrations and various physicochemical parameters of the effluents of steel and iron casting industries from the Urla region of Raipur, Chhattisgarh, India.

MATERIALS AND METHODS

Location of sampling sites: Industrial sector of Urla region Raipur has an area of about 815 ha (CSE., 2011) having several large and small steel industries. For the present study, four sampling sites (S1, S2, S3 and S4) from the aforesaid region were selected. The S1 is a steel and bar structure mill, the S2 is a ferroalloy manufacturing unit, S3 is an iron smelting and ferroalloy based big industry and S4 is a big runnel pass between of the Urla region, where domestic sewage water and industrial effluents get mixed together. Three of the sites; S1, S2 and S3 are completely industrial type of wastewater, whereas, S4 is a mixed type runnel containing both domestic and industrial wastewater.

Sample collection: Industrial effluent samples were collected in clean and plastic containers of 2 L capacity from all the sites. Samples were labeled and brought carefully into the laboratory for the analysis. The effluents were collected in triplicates in a month from each site.

Estimation of iron and other physicochemical parameters: All the samples were processed for measurement of soluble iron (Fe^{2+}) and other physicochemical parameters such as; Electrical Conductivity (EC), Total Dissolved Solids (TDS), pH, turbidity, Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD).

Methods of analysis: Iron concentration was determined using an iron test kit (Iron test 0.005-5.00 mg L^{-1}, Merck, Germany) and its absorbance level was measured by Spectroquant NOVA 60 (Merck, Germany). In which a red-violet complex was formed by iron, which reacts with a triazine derivative in a thioglycolate-buffered medium that is determined photo metrically (Popa *et al*., 2012). Where pH was adjusted using 1 N NaOH solution or 1 N HCL solution.

For EC, TDS and turbidity water quality analyzer PE 138 was used (Elico, India). The pH was measured in pH meter LI 127 (Elico, India). Effluents were filtered through the pre weighted Whattman filter paper No. 1 and the suspended solids were trapped. After drying from the weight of dried filter paper, the weight of the TSS was calculated. The COD was determined by Dichromate reflux method (APHA., 1998; Mishra *et al*., 2013) using COD vials. The digestion process of samples were carried out for 2 h at 150°C. The DO and BOD were measured by DO analyzer PE 135 (Elico, India). The BOD_3 in mg L^{-1} was measured by applying the equation:

$$BOD_3 = D_1 - D_2$$

where, D_1 is initial DO of sample (mg L^{-1}) and D_2 is DO after 3 days (Incubated at 27°C in BOD bottles). All analyzed results were compared with the permissible limits of wastewater standards given by Center Pollution Control Board (CPCB), New Delhi and Bureau of Indian Standard (BIS).

Statistical analysis: Correlation analysis between iron and different physicochemical parameters were performed using Pearson correlation using SPSS (16.0 version for windows). The linear regression analysis and other graphs were performed using MS-Excel for windows.

RESULTS

The assessment of water quality of industrial effluents was carried out following the standards of CPCB (1993) and BIS (Kumari *et al*., 2014). The study was done during the period of April-May (summer), July-August (rainy) and November-December (winter) in the year of 2014. The summary of soluble iron and physicochemical parameters of water samples are shown in Table 1.

Iron concentration: Variation of Fe^{2+} concentrations were within 0.72-6.89 mg L^{-1} in all the four sites (Fig. 1). In effluents, mean value of Fe^{2+} concentration was highest (4.93±0.7 mg L^{-1}) during the month of December (winter) and the minimum was (2.44±1.43 mg L^{-1}) during the month of May (summer) in all the samples (Table 1).

Electrical conductivity: The value of EC was found in between the range from 0.9-8.33 mS cm^{-1} for all the four sites (Fig. 2). The highest value of EC was recorded between

Table 1: Summary of analysis of the industrial effluents

	Mean±SE value in the months						
Parameters	April	May	July	August	November	December	Permissible limit of CPCB/BIS
Iron (mg L^{-1})	2.98±0.68	2.44±1.43	3.39±1.28	3.45±0.7	4.59±0.89	4.93±0.7	3
EC (mS cm^{-1})	4.98±1.15	4.64±1.34	1.69±0.44	1.47±0.22	4.63±1.55	6.53±1.56	2.5 (EPA)
TDS (ppm)	2796.87±642.38	3071.83±884.38	981.61±228.91	815.61±125.64	2148.65±767.59	3290.65±786.14	2100
pH (pH)	7.19±0.5	6.53±0.56	5.45±0.52	5.92±0.56	4.26±1.23	4.46±1.12	5.5-9.0
Turbidity (NTU)	22.80±6.55	8.50±5.5	2.14±1.2	2.83±1.95	41.62±16.53	4.76±3.39	5
TSS (mg L^{-1})	286.67±76.41	145.00±42.21	70.84±19.41	82.50±27.5	133.33±15.34	158.33±28.46	100
COD (mg L^{-1})	76.00±26.21	72.80±13.54	43.20±11.2	58.40±16.39	85.33±11.52	101.34±18.73	250
DO (mg L^{-1})	4.50±1.5	5.13±1.76	5.35±1.72	4.40±0.49	6.70±1.83	7.48±1.00	4
BOD (mg L^{-1})	3.50±1.17	2.23±0.8	3.83±1.14	3.20±0.16	1.53±0.54	5.48±1.02	30

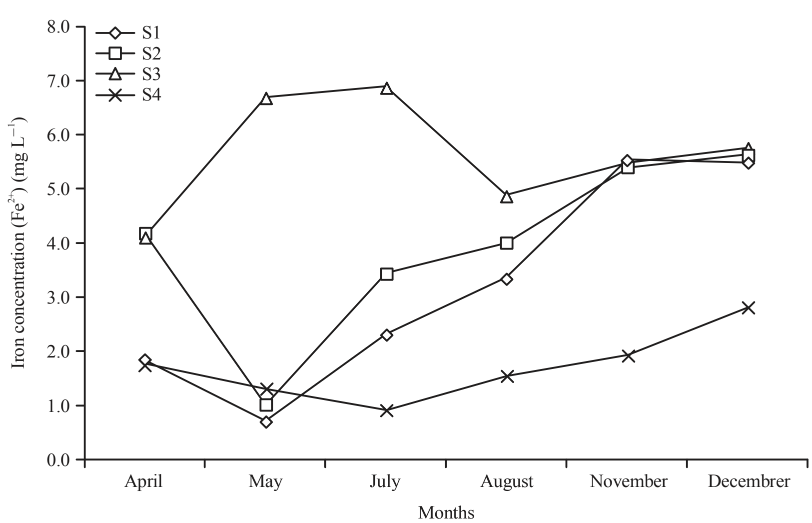

Fig. 1: Monthly variation of iron concentration at all sites

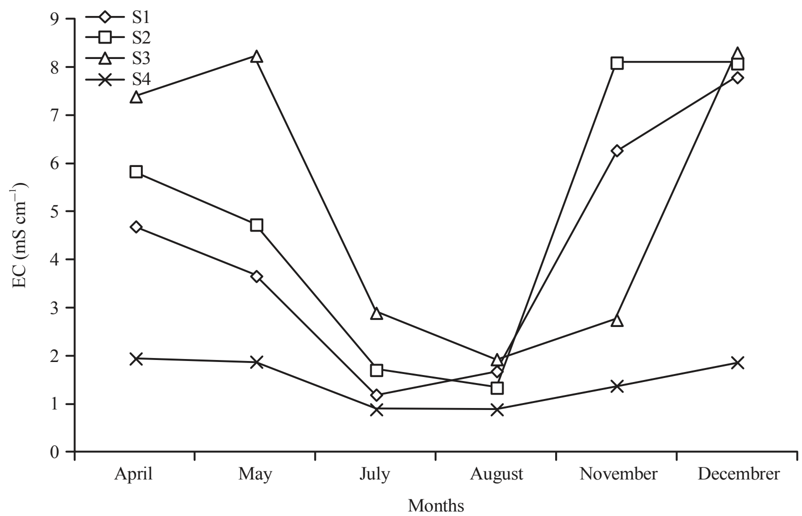

Fig. 2: Monthly variation of EC at all sites

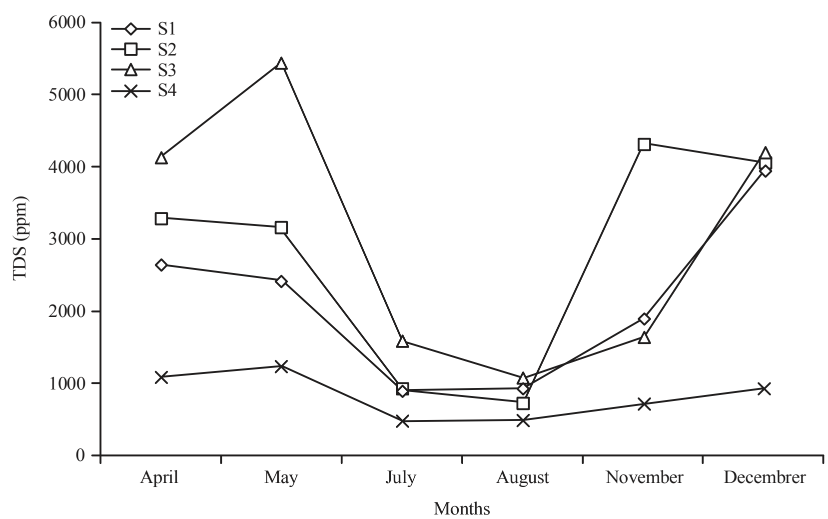

Fig. 3: Monthly variation of TDS at all sites

6.53±1.56 mS cm^{-1} during the month of December and lowest 1.47±0.22 mS cm^{-1} during the month of August (Table 1) for all the samples.

Total dissolved solids: The variations in TDS values were observed between 488.43-5444 ppm for all the four sites (Fig. 3). Among all months, highest TDS was recorded in December (3290.65±786.14 ppm) and lowest in August (815.61±125.64 ppm) in all samples (Table 1).

Acidity (pH): The pH values were observed between 1.92 and 8.13 in all the four sites (Fig. 4). Lower value of pH was observed in November (4.26±1.23), while a higher pH value was found during the month of April (7.19±0.5) in all the samples, which is not too high, since usually pH values for industrial wastewater is less than 9.0 (Table 1).

Turbidity: In this study, turbidity of industrial effluents ranged from 0.16-81.51 NTU in all the four sites (Fig. 5). The highest turbidity was found in the month of November (41.62±16.53 NTU), while the lowest in the month of July (2.14±1.2 NTU) in all the samples (Table 1).

Total suspended solids: The observation of TSS varies with in the range from 30-436.67 mg L^{-1} in all the four sites (Fig. 6). Among all months TSS was found maximum in the month of April (286.67±76.41 mg L^{-1}) and minimum in the month of July (70.84±19.41 mg L^{-1}) in all the samples (Table 1).

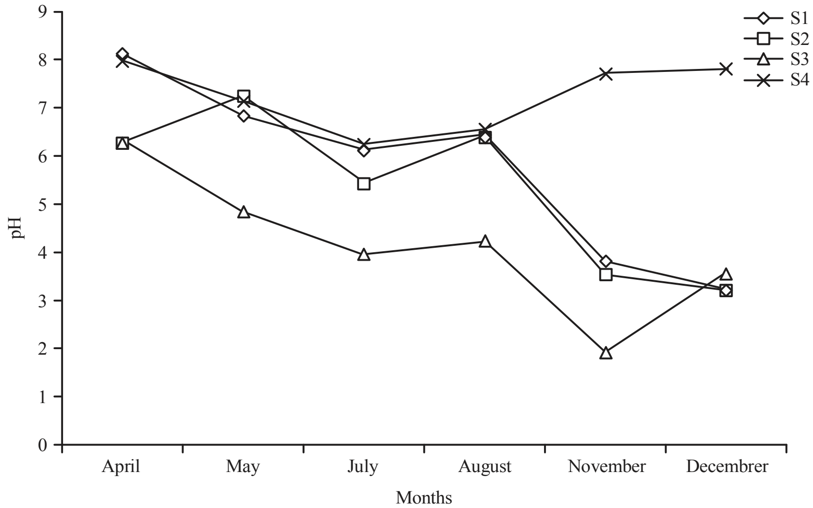

Fig. 4: Monthly variation of pH at all sites

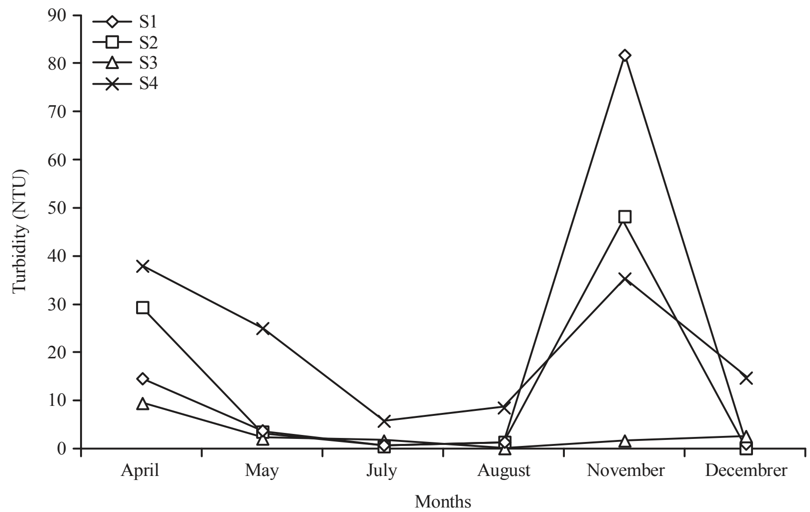

Fig. 5: Monthly variation of turbidity at all sites

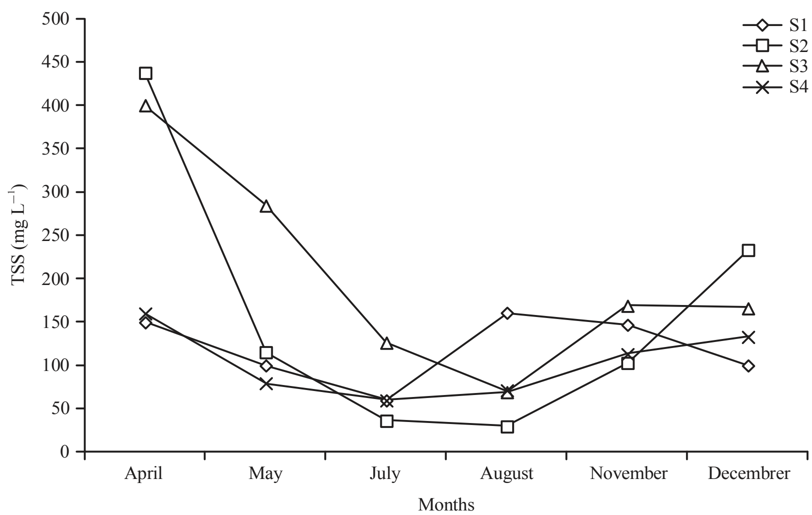

Fig. 6: Monthly variation of TSS at all sites

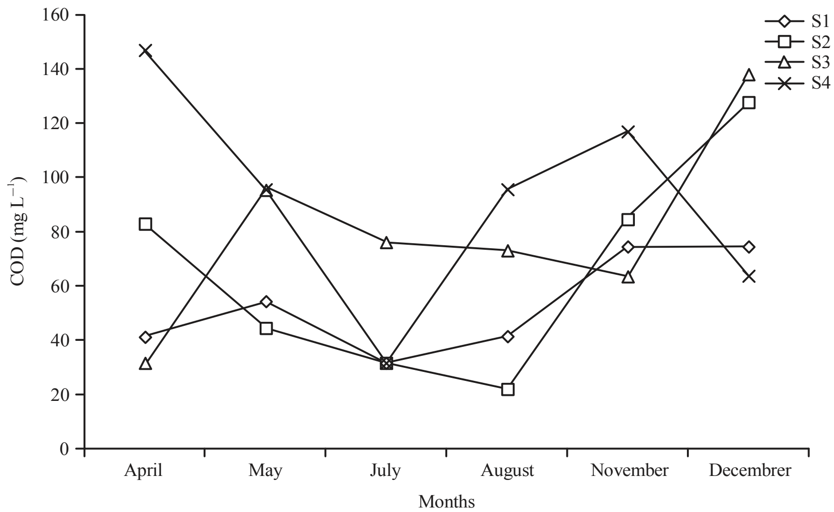

Fig. 7: Monthly variation of COD at all sites

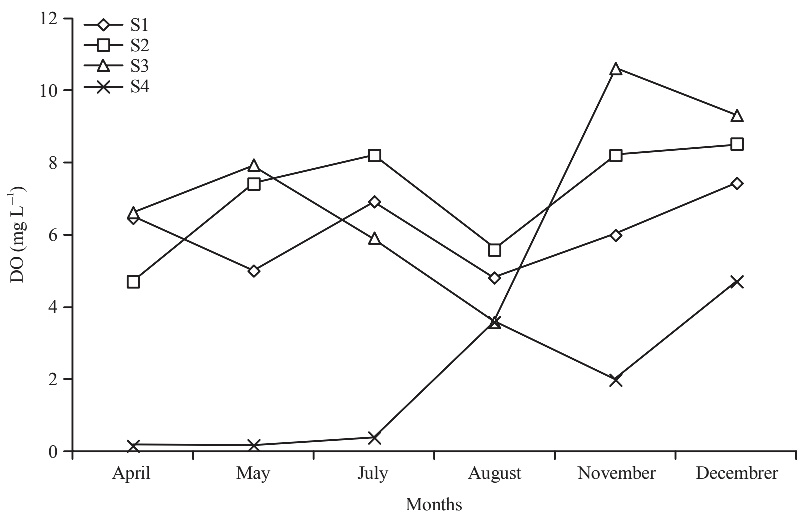

Fig. 8: Monthly variation of DO at all sites

Chemical oxygen demand: In the present study, COD ranged from 22.4-147.2 mg L^{-1} in all the four sites (Fig. 7). Among all months, maximum COD value was recorded 101.34$\pm$18.73 mg L^{-1} during the month of December and minimum value was 43.20$\pm$11.2 mg L^{-1} during the month of July in all samples (Table 1).

Dissolved oxygen: Among all the months, higher value of DO 7.48$\pm$1.00 mg L^{-1} was found during the month of December and lower value 4.40$\pm$0.49 mg L^{-1} during the months of August in all samples (Table 1). The value of DO ranges from 0.2-10.6 mg L^{-1} in all the four sites (Fig. 8).

Biochemical oxygen demand: In the present study, BOD values ranged from 0.2-7.9 mg L^{-1} in all the four sites (Fig. 9). The maximum value of the BOD was recorded 5.48$\pm$1.02 mg L^{-1} during the month of December and minimum value of 1.53$\pm$0.54 mg L^{-1} during the month of November in all samples (Table 1).

Correlation between iron and different physicochemical parameters: The experimental results showed that some parameters were significantly associated and some were not (Table 2). An important relationship was observed for Fe^{2+} concentration with EC, TDS, pH and DO. The Fe^{2+} concentration showed significant positive correlation ($r = 0.594$, 0.516 and 0.611 at $p<0.01$) with EC, TDS and DO respectively, whereas, significant negative correlation ($r = -0.818$ at $p<0.01$) with pH.

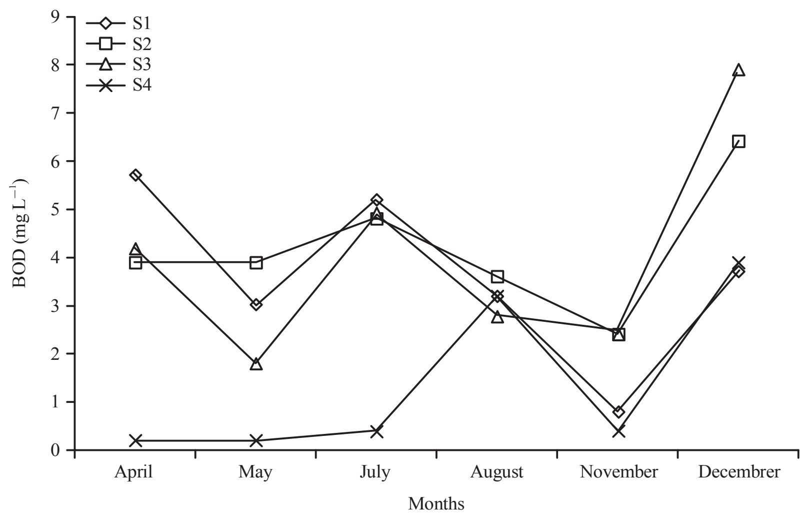

Fig. 9: Monthly variation of BOD at all sites

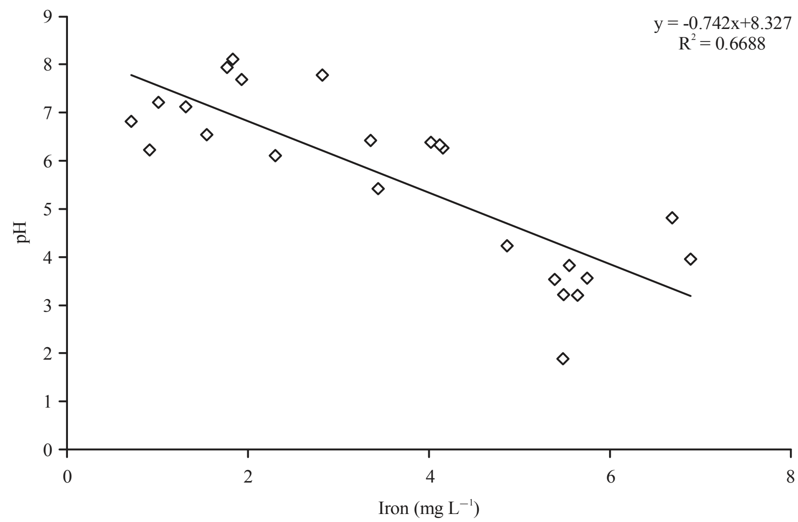

Fig. 10: Linear regression analysis between iron concentration and pH

Table 2: Correlation coefficient R^2 for the different parameter of industrial effluents

Variables	Iron	EC	TDS	pH	Turbidity	TSS	COD	DO	BOD
Iron	1.000								
EC	0.594**	1.000							
TDS	0.516**	0.960**	1.000						
pH	-0.818**	-0.493*	-0.396^{NS}	1.000					
Turbidity	0.008 ^{NS}	0.156^{NS}	-0.012^{NS}	0.063^{NS}	1.000				
TSS	0.332^{NS}	0.567**	0.597**	-0.054^{NS}	0.108^{NS}	1.000			
COD	0.23^{NS}	0.302^{NS}	0.256^{NS}	-0.178^{NS}	0.3^{NS}	0.19^{NS}	1.000		
DO	0.611**	0.585**	0.578**	-0.639**	-0.259^{NS}	0.193^{NS}	-0.136^{NS}	1.000	
BOD	0.302^{NS}	0.343^{NS}	0.344^{NS}	-0.235^{NS}	-0.510*	0.15^{NS}	-0.091^{NS}	0.656**	1.000

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed) and NS: Not significant

Regression analysis: The linear regression analysis is used to evaluate the relationship between iron (Fe^{2+}) concentration (taken as independent variable) with pH, EC, TDS and DO (the dependent variables) of the industrial effluents. The R^2 values for different physicochemical parameter are shown in Fig. 10-13. The value of R^2 is representing the variation in the dependent variables described by a linear equation. The value of R^2 was well defined in the relationship between

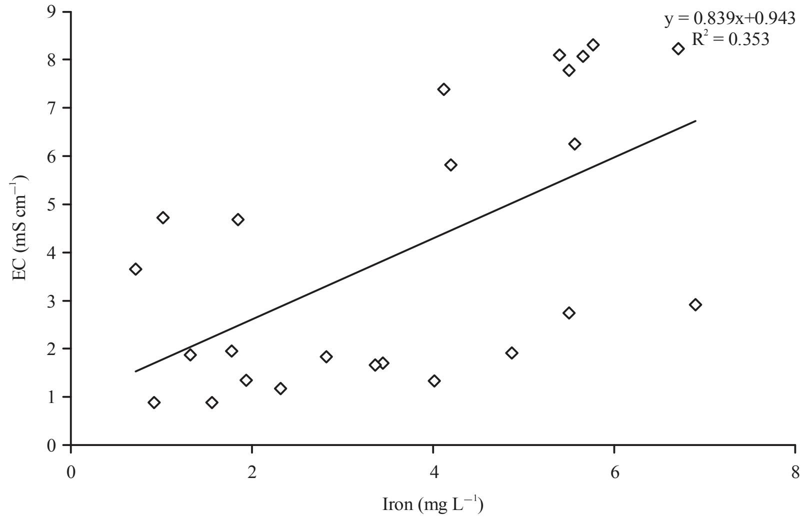

Fig. 11: Linear regression analysis between iron concentration and EC

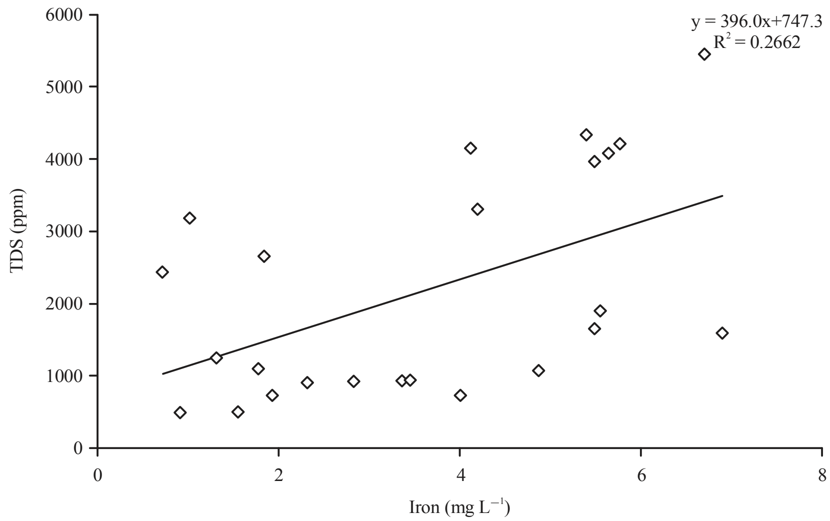

Fig. 12: Linear regression analysis between iron concentration and TDS

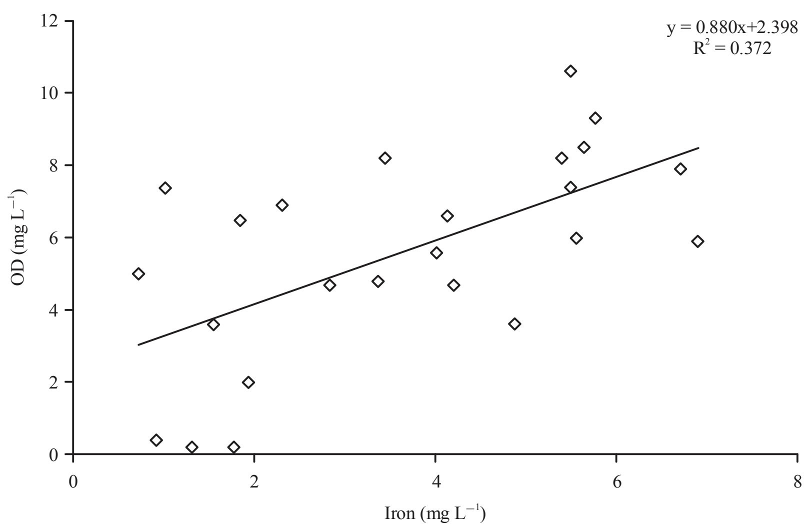

Fig. 13: Linear regression analysis between iron concentration and DO

Fe^{2+} and EC ($R^2 = 0.353$), Fe^{2+} and TDS ($R^2 = 0.2662$) and Fe^{2+} and DO ($R^2 = 0.3728$). Similarly, R^2 value was also obtained from the inverse relationship between Fe^{2+} and pH ($R^2 = 0.6688$).

DISCUSSION

In the present investigation, the levels of some physicochemical parameter were significantly higher while some were under the Indian standard. According to CPCB (1993), in industrial effluents iron concentration should not be more than 3 mg L^{-1}. Thomas *et al.* (2011) and Majagi *et al.* (2008) have also observed lower value of iron in summer due to the precipitation of iron sulfate and higher value in rainy season in comparison with summer, this could be due to leaching of iron from neighboring soil. The high concentration of iron in ground water and surface water resources is hazardous (Rao, 2008; Shivkumar *et al.*, 1997). The EC gives information about the capacity of a solution to conduct an electric current, which is depend upon the dissolved ionic substances, their concentration and temperature (Rai, 2010). The CPCB and BIS has not mentioned any maximum permissible limit for EC. According to EPA guideline maximum permissible limit of EC is 2.5 mS cm^{-1} (Patil *et al.*, 2012). Except for rainy season, EC was more than the permissible limit in both winter and summer season. The values of TDS were higher in winter and summer season, which are more than water quality standards (2100 ppm) except during rainy season.

The mean of pH value of summer and rainy season both were between the permissible limits (5.5-9.0) except for winter season, which has an acidic pH. At low pH, solubility of metals increase; therefore, it could be harmful for the environment (Nirgude *et al.*, 2013). According to USEPA (1997), turbidity measures the clarity of water, where suspended particles decrease the passage of light through water. It has an important role in decreased dissolved oxygen of water, because high turbid water absorbs more heat due to the presence of suspended particles and warm water holds lack of dissolved oxygen than cold. Overall, the mean value of turbidity of summer and winter season both shows high turbidity, which is more than the water quality standard (5 NTU) except for the rainy season.

The TSS is solid particles, including organic and inorganic, which are passed into the water streams (Rai, 2010). Summer and winter both have much higher TSS value than the water quality standard of 100 mg L^{-1} except in rainy season. The COD value denotes the toxicity and biological resistance substances of water (Nirgude *et al.*, 2013). The means of COD value for all months are under the permissible limit (250 mg L^{-1}) of water quality standards.

The DO of water indicates presence of free oxygen, which represents the concentration of chemical and biological substances that can be oxidized and it influences a sum of the processes that is photosynthesis, the metabolic activities of microorganisms and degradation of organic matters etc. (Popa *et al.*, 2012). Low DO values are indications of higher contamination of water. More than 4 mg L^{-1} is desirable; therefore, all months show mean values of DO, which are within limits of water quality standards. The low value of the DO may be due to higher temperature during summer and increased microbial activity in the water (Nirgude *et al.*, 2013). The BOD o f water indicates the amount of oxygen required for microorganism for degradation of organic matters (Patil *et al.*, 2012). Overall means of BOD for all months have values, which are below the permissible limits of water quality standards (30 mg L^{-1}).

Correlation analysis suggested that individual parameters are significantly correlated to another. A similar analysis was applied by Igbinosa and Okoh (2009), Sundaray (2010), Popa *et al.* (2012) and Mishra *et al.* (2013). A significant positive correlation was obtained in Fe^{2+} concentration with EC, TDS and DO. Similarly, significant negative correlation was obtained between Fe^{2+} concentration and pH. These correlation studies will help to understand that the nature of individual physicochemical parameter, which affects directly or indirectly to another variable.

The linear regression analysis reveals that the Fe^{2+} concentration as an independent variable was significantly related to depending variables such as pH, EC, TDS and DO. A similar approach was applied by Sundaray (2010), Waziri and Ogugbuaja (2010) and Saleem *et al.* (2012) who observed relationships among various physicochemical parameters. The value of R^2 (coefficient of determination) for the relationship between Fe^{2+} and pH ($R^2 = 0.6688$) indicates that 66.88% of the variation in pH is explained by Fe^{2+}. Similarly, the R^2 obtained from the relationship of Fe^{2+} and EC ($R^2 = 0.353$), Fe^{2+} and TDS ($R^2 = 0.2662$) and Fe^{2+} and DO ($R^2 = 0.3728$) signified 35.3, 26.62 and 37.28% variation in EC, TDS and DO, respectively is explained by Fe^{2+}. The results of regression analysis suggested that the effluents are highly affected by the presence of iron and the higher exposure of iron may be risk for the aquatic flora and fauna of nearby water resources (Banerjee and Gupta, 2013).

CONCLUSION

In the present study, monthly variation was observed in Fe^{2+} concentration, EC, TDS, pH, turbidity, TSS, COD, DO and BOD during the summer, rainy and winter season. Most of the physicochemical parameters were found higher than permissible limits of water quality standards described by CPCB, BIS and Environment Protection Agency (EPA). In conclusion, Raipur is a developing area for new industrial growth, there are a number of large as well as small established iron and steel casting industries. Major problem seems that these industries may does not have the proper effluent treatment units, therefore, the physicochemical parameters measured of the effluent samples were high, except for some which were under the permissible limits.

The results of the present study suggest that there are needs for proper treatment of the effluents before discharging into the environment and to seek a solution for iron pollution, which should be not only eco-friendly as well as cost effective too.

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