IMPACT OF BALCO INDUSTRIAL WASTES ON SURFACE AND GROUND WATER QUALITY OF KORBA, INDIA

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ABSTRACT

Water is precious natural component. Owing to its abundance occurrence in Earth it is known as Watery Planet. 79% earth's surface is covered by the water sources. Natural and anthropogenic factors make water unfit for human development, resulting the existence of biosystem has been dangerous. We have taken deeply study of different water sources in Balco industrial areas. Ten sites are selected and 60 water samples were collected in two litre capacity containers (Jan 2009 to Jun 2009) for physical and chemical analysis along with selected heavy metals by standard methods. The results were evaluated by statistical quality. The mean value for turbidity (SW 104.8 NTU, GW 26.4 NTU), TH (SW 700.9 mg/L), Fe (SW 1.6, GW4.4 mg/L), Al(SW 1.3 mg/L, GW 0.1 mg/L) were found above the threshold value. Strong +ive relation was calculated for SW and GW between TS vs TDS (SW r = +0.940, GW = +0.988). The high % CV was calculated for Fe 152.006 (SW) and 179.172 (GW). WQI index calculated displays the order BS1 < BS4< BS2< BS7< BS9< BS10< BS8< BS3< BS6< BS5. These data show water sources are not suitable for human consumption, prior treatment is necessary.

Key Words : Water Pollution, Heavy Metals, Statistical analysis, Correlation Matrix, WQI, Balco

INTRODUCTION

Environment is defined as one's surrounding consists of atmosphere (air), hydrosphere (water) and lithosphere (soil)[1]. The importance of water is described as one of the five elements in SHASTRA[2] for sustaining all kinds of life like human beings, flora, fauna and microbes on the watery planet.[3] Water and air make unique planet the earth considered as fundamental elements, without which life is not possible.[4] The source of water in nature is rain, surface and ground water. Ground water is a crucial source of fresh water, occupies the pores or crevices in sand, sand stone, lime stone and other rock formations.[5] In India, 30% urban and 90% rural population while on World wide 1.5 billion[6] people depend on ground water sources for drinking purposes. Water sources should be available for human development must possess high degree of purity, free from chemical contamination and bioorganisms.[7] During last three decades, consequences of increase in population, over industrialization and urbanization, the pollutants are tremendously mixed in water sources resulting our safe water become scarce commodity.[8]

Balco industrial area is located 8 Km away from Korba district head quarter in north - east direction. Topographically, the study area is plane and geologically belongs to lower gondwana group.

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Geographically the study area is spread in about 180 Km^2, average rainfall 823.6 mm and temperature. 35.58°C have been recorded during the study period. The field under investigation is located 304.8 m above mean sea level. The assessment area has been taken on the basis of environmental significance of aluminum refining plant. The input of industrial plant is bauxite procured from Mainpat and Kwardha district in Chhattisgarh state. Although the annual production of refined aluminum is 3.12 KT per annum.[9] The unplanned dumping and loading of raw materials and wastes around, surface water sources become contaminated through industrial effluents and ground water polluted by seepage and wastes leach ate. Hence a continuous monitoring of water sources becomes mandatory. In continuation of our previous work[10] we have taken monthly assessment of water quality status to check the pollutants. In the present paper we have presented the half yearly experimental results, however correlation matrix, % CV and WQI were used for ranking water sources.

MATERIAL AND METHODS

Water samples were collected from the selected ten site named BS1 to BS10 shown in **Fig. 1** in the period of Jan 2009 to Jun 2009 on the monthly basis in precleaned 2 L capcacity of

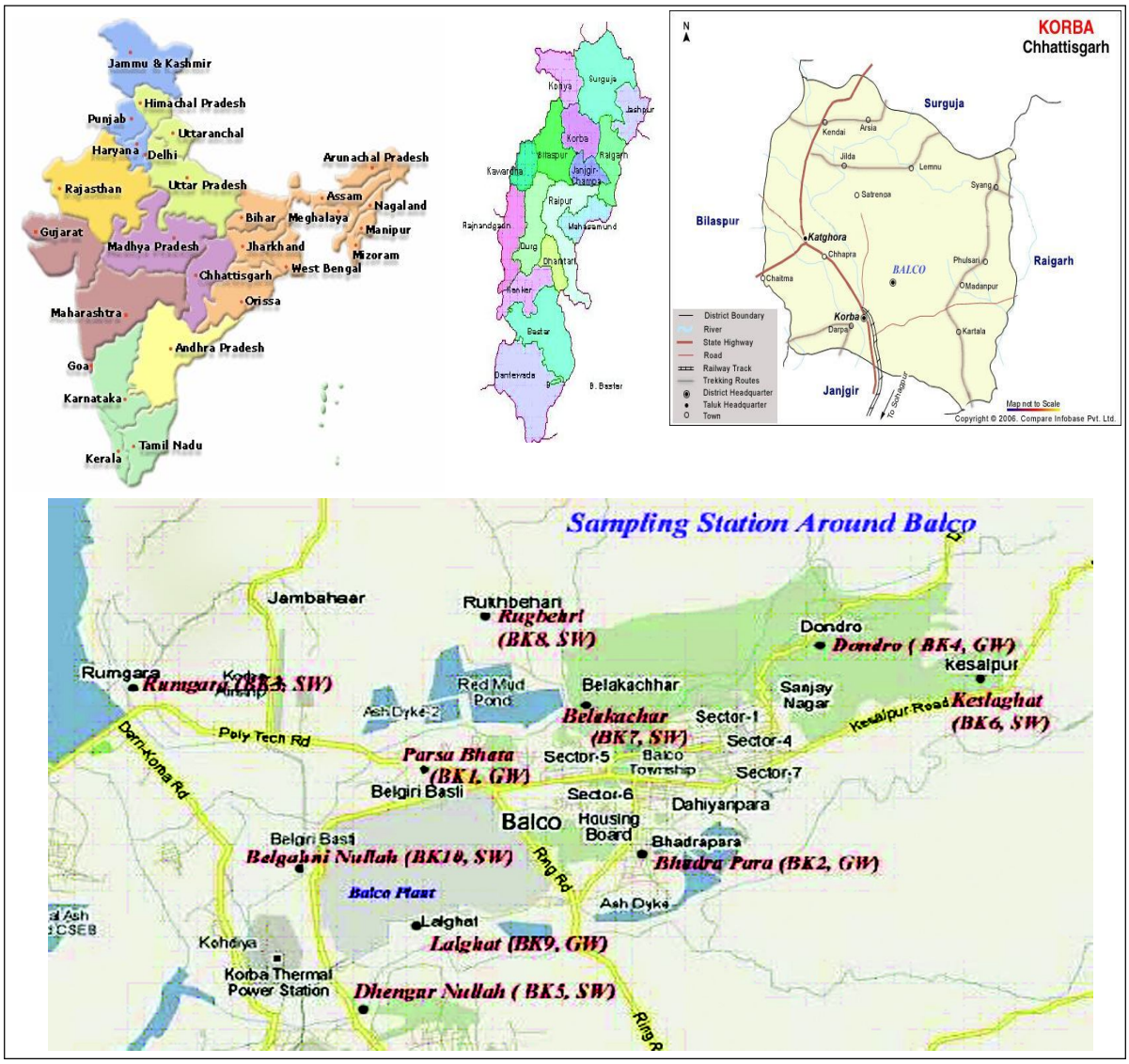

Fig. 1 : Location Map

each polyethylene bottles and glass bottles for selected physico - chemical and heavy metal monitoring. The parameters temperacure., pH, EC, TDS and Turbidity were estimated during the sampling by analyzer kit (Electronic India Model 172) at the locations immediately after the sample collection. Then samples were preserved by keeping in refrigerator at 4^0C and adding Conc. HNO_3. Other considered parameters such as Total Hardness, Total Alkalinity and Acidity were measured within one week of sample collection after preservation by standard method.[11,12] Metallic elements were determined after digestion, a known volume of water sample with acidic mixture by ICP - AES[13].

RESULTS AND DISCUSSION

The results of experimental values for various physicochemical parameters were depicted in **Table 1(a)** and **Table 1(b)** for surface and ground water respectively.

Active hydrogen ions [H^+] concentration is measured in terms of pH, which evaluate the nature of acid - base in water system.[14] In our study pH ranges were varied from 7.31 to 9.91 with 8.3 mean value for surface system of water. However for subsurface water the mean was 7.5 and ranging fluctuates from 6.31 to 8.06. The maximum. value was detected at the sampling point BS5 (SW) in the month of May due to elevated temperature, which is marginally higher than the acceptable range; 6.5 to 8.5 as per BIS[15] and WHO[16] standard for drinking water.

The suitability of water for irrigation and industrial purpose is determined in terms of electrical conductivity whose high value cause of high concentration of dissolved ionic solids.[17,18] The analysis period ranged was changing from 1457 µm hos/cm to 2437 µm hos/cm with 2033.1 µmhos/cm mean value for surface water while for subsurface water the mean and ranging data were lesser observed 1241.9 µm hos/cm and 511.00 - 1978.00 µm hos/cm respectively, within permissible level set by BIS[15] 750 - 2250 µmhos/cm. The high value of EC was noted at the point BS3 in the month of June 2009. At this period due to high atmospheric and surface water temperature the concentration of dissolved solids increased.

The dispersion and suspended form of clay, organic and inorganic even microorganism measured by turbidity, in which light rays scattered[19] 29 to 179 NTU ranged analyzed in case of surface aquatic systems with mean value 104.8 NTU which is too much far beyond the maximum allowable value as set by BIS[15] and WHO[16]. 13

Table 1 (A) : Statistical Value of Physico Chemical and Heavy Metal analysis Surface water

Parameter	Range	Mean	SD	% CV	Std. Err	Min		Max	
						Spot	Month	Spot	Month
Temperature	16.4-33.3	27.483	5.386	19.596	2.199	BS3	JAN	BS3	MAY
pH	7.31-9.91	8.280	0.649	7.832	0.265	BS3	JAN	BS5	MAY
EC	1457-2437	2033.056	278.268	13.687	113.602	BS7	JAN	BS3	JUN
Turbidity	29-179	104.778	46.016	43.917	18.786	BS7	JAN	BS10	JUN
TDS	466.4578-1949.359	1337.607	442.459	33.078	180.633	BS7	MAR	BS5	JUN
TSS	383.77-1734.73	1129.416	379.121	33.568	154.776	BS7	APR	BS8	JUN
TS	42.217-68.457	208.191	155.888	74.877	63.641	BS5	MAY	BS7	FEB
T.Aci	79-234	129.583	42.503	32.800	17.352	BS5	MAR	BS7	APR
T.Alk	218-792	548.361	156.053	28.458	63.708	BS7	JAN	BS5	MAY
TH	291.5-979.5	700.922	218.846	31.223	89.344	BS6	JAN	BS5	MAY
Mn	0.03-0.59	0.201	0.150	74.692	0.061	BS3	JUN	BS6	JUN
As	0.001-0.015	0.004	0.005	138.041	0.002	*		BS5	MAY, JUN
Zn	0.1-0.1	0.100	0.000	0.000	0.000	**			
Al	0.114-7.31	1.324	1.862	140.615	0.760	BS7	JAN	BS	JUN
Fe	0.19-10.782	1.597	2.428	152.006	0.991	BS3	APR	BS	JUN

* 2* 23 observations recorded ** same observation in all spots.

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Table 1 (B) : Statistical Value of Physico Chemical and Heavy Metal analysis Ground water

Parameter	Range	Mean	SD	% CV	Std. Err	Min		Min	
						Spot	Month	Spot	Month
Temperature	18.6-24.5	21.413	1.714	8.007	0.700	BS4	JAN	BS1	MAY
pH	6.31-8.06	7.512	0.517	6.886	0.211	BS2	FEB	BS1	JUN
EC	511-1978	1241.917	522.763	42.093	213.417	BS2	JUN	BS4	MAY
Turbidity	13-54	26.417	11.286	42.725	4.608	BS4	MAR	BS2	JUN
TDS	217.891-1010.667	677.867	277.375	40.919	113.238	BS2	MAR	BS1	JUN
TSS	178.25-937.78	566.650	253.653	44.764	103.553	BS2	MAR	BS1	JUN
TS	29.814-190.812	111.217	46.810	42.089	19.110	BS4	FEB	BS9	APR
T.Aci	68-234	138.100	52.658	38.130	21.498	BS9	MAY	BS2	APR
T.Alk	161-713	437.917	187.145	42.735	76.402	BS2	JAN	BS4	MAY
TH	139-776	407.096	195.127	47.931	79.660	BS4	JAN	BS9	JUN
Mn	0.04-0.3	0.116	0.076	65.744	0.031	BS2	JAN	BS9	APR
As	0.001-0.011	0.001	0.002	144.088	0.001	*		BS2	JAN
Zn	0.01-2.77	0.534	0.798	149.333	0.326	**		BS9	MAY
Al	0.01-0.31	0.113	0.079	70.151	0.032	BS1	JAN	BS2	JUN
Fe	0.091-24	4.377	7.842	179.172	3.201	BS1	JAN	BS9	MAY

* 23 observations recorded ** 6 observation recorded

NTU to 54 NTU value was fluctuated for sub-surface water with 26.4 NTU mean data. The sampling location BS10 (Jun 2009) showed highest value owing to mixing of various type surface runoff through premonsoon rain water.

Dissolved and suspended solids in water medium expressed in terms of TS and TDS[20]. Its value is depended upon the dissolved and suspended form in inorganic salts and organic compounds. TDS mean and ranged showed for surface water 1129.4 mg/L and from 383.770 mg/L as the minima to 1734.73 mg/L as the maxima, which is slightly upper from standard value as per WHO[16], but too much less concentration was observed for GW as mean 566.7 mg/L as ranged covered as 178.250 mg/L to 937.78 mg/L indicating SW more polluted than GW in context of dissolved parameters.

The concentration of basic components like OH^-, HCO_3^-, CO_3^{--} and Bo_3^{3-} are characterized by the alkalinity[21], which measures the neutralization capacity of water with H^+ ions In study field the mean and range data for SW detected as 548.4 mg/L and 218.00 mg/L to 792.00 mg/L and GW samples were expressed 437.9 mg/L and 161.00 to 713.00 mg/L as average and ranging statistical value. The maximum values were found at the sampling points BS7 (Jun 2009) and BS4 (May 2009) crossed the excessive permissible range : 200 - 600 mg/L as by water testing agency.

Total hardness causing the dissolved cations like Ca^{++},Mg^{++},Sr^{++}, Mn^+, Fe^{++}, etc. and anions such as SO_4^{2-},CO_3^{2-} Cl^-, HCO_3^- etc.[22] The degree of hardness is depended upon the concentration of dissolved ions. For SW, TH was found from 291.5 mg/L to 979.5 mg/L as low and high value. The high value is more than threshold limit; 600 mg/L as the point BS5 in the month of May 2009.

In metallic elements we have analyzed Mn, As, Zn, Al and Fe for surface and subsurface water sources. Al was detected in surface water as low 0.114 to maximum. 7.310 mg/L. The high value was obtained at the sampling stations BS5 in the month of Jun 2009 due to elevated temperature and high Al containing effluents discharged into water sources while GW the mean was 0.1 mg/L and ranging covered 0.010 to 0.310mg/L which is less polluted in reference of aluminum concentration. In both source of water the maximum value was crossed the standard value as per ISI[23]. In similar trend Fe was monitored for sur-

Table 2(A) : Correlation Matrix for Surface Water

	Temperature	pH	EC	Turbidity	TS	TDS	TSS	T.Aci	T.Alk	TH	Mn	As	Zn	Al	Fe
Temperature															
pH	0.459(1.033)														
EC	0.398(0.868)	0.329(0.697)													
Turbidity	0.452(1.013)	0.196(0.400)	0.765(2.376)												
TS	0.400(0.873)	0.545(1.300)	0.826(2.931)	0.654(1.729)											
TDS	0.278(0.579)	0.388(0.842)	0.754(2.296)	0.616(1.564)	0.940(5.510)										
TSS	0.457(1.028)	0.603(1.512)	0.511(1.189)	0.359(0.769)	0.553(1.327)	0.235(0.484)									
T.Aci	0.025(0.050)	-0.173(0.351)	-0.755(2.303)	-0.537(1.273)	-0.749(2.261)	-0.720(2.075)	-0.375(0.809)								
T.Alk	0.643(1.679)	0.631(1.627)	0.444(0.991)	0.314(0.661)	0.620(1.580)	0.560(1.352)	0.397(0.865)	-0.138(0.279)							
TH	0.862(3.401)	0.528(1.243)	0.619(1.576)	0.524(1.230)	0.639(1.661)	0.501(1.158)	0.595(1.481)	-0.317(0.668)	0.715(2.045)						
Mn	-0.037(0.074)	0.186(0.379)	-0.317(0.668)	-0.209(0.427)	-0.018(0.036)	0.064(0.128)	-0.206(0.421)	0.295(0.617)	0.098(0.197)	-0.238(0.490)					
As	0.080(0.161)	0.346(0.738)	0.335(0.711)	0.110(0.221)	0.368(0.792)	0.210(0.430)	0.535(1.266)	-0.427(0.944)	0.226(0.464)	0.304(0.638)	-0.168(0.341)				
Zn	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)			
Al	0.207(0.423)	0.622(1.589)	0.267(0.554)	0.187(0.381)	0.481(1.097)	0.287(0.599)	0.667(1.790)	-0.295(0.617)	0.471(1.068)	0.345(0.735)	0.136(0.275)	0.789(2.568)	0.000(0.000)		
Fe	0.289(0.604)	0.173(0.351)	-0.091(0.183)	0.120(0.242)	0.127(0.256)	0.145(0.293)	0.009(0.018)	0.228(0.468)	0.253(0.523)	0.083(0.167)	0.758(2.324)	-0.050(0.100)	0.000(0.000)	0.266(0.552)	

Table 2(B) : Correlation Matrix for Ground Water

	Temperature	pH	EC	Turbidity	TS	TDS	TSS	T.Aci	T.Alk	TH	Mn	As	Zn	Al	Fe
Temperature															
pH	0.092(0.185)														
EC	0.061(0.122)	0.695(1.933)													
Turbidity	0.351(0.750)	-0.681(1.860)	-0.717(2.057)												
TS	0.302(0.634)	0.726(2.111)	0.306(0.643)	-0.476(1.083)											
TDS	0.333(0.706)	0.711(2.022)	0.327(0.692)	-0.458(1.030)	0.988(12.793)										
TSS	-0.017(0.034)	0.452(1.013)	0.045(0.090)	-0.337(0.716)	0.569(1.384)	0.438(0.974)									
T.Aci	-0.073(0.146)	-0.813(2.793)	-0.712(2.028)	0.791(2.586)	-0.758(2.324)	-0.734(2.162)	-0.513(1.195)								
T.Alk	0.245(0.505)	0.832(2.999)	0.637(1.653)	-0.496(1.142)	0.556(1.338)	0.532(1.257)	0.410(0.899)	-0.726(2.111)							
TH	0.445(0.994)	0.300(0.629)	-0.281(0.586)	0.224(0.460)	0.590(1.461)	0.557(1.341)	0.479(1.091)	-0.232(0.477)	0.404(0.883)						
Mn	0.070(0.140)	0.464(1.048)	-0.154(0.312)	-0.154(0.312)	0.686(1.886)	0.651(1.715)	0.534(1.263)	-0.362(0.777)	0.441(0.983)	0.804(2.704)					
As	-0.325(0.687)	-0.330(0.699)	-0.290(0.606)	0.124(0.250)	-0.268(0.556)	-0.282(0.588)	-0.060(0.120)	0.214(0.438)	-0.315(0.664)	-0.167(0.339)	-0.212(0.434)				
Zn	-0.038(0.076)	0.503(1.164)	-0.115(0.232)	-0.207(0.423)	0.562(1.359)	0.512(1.192)	0.554(1.331)	-0.356(0.762)	0.469(1.062)	0.717(2.057)	0.868(3.496)	-0.140(0.283)			
Al	-0.009(0.018)	-0.198(0.404)	-0.511(1.189)	0.499(1.152)	-0.163(0.330)	-0.135(0.272)	-0.235(0.484)	0.503(1.164)	-0.194(0.396)	0.345(0.735)	0.346(0.738)	-0.036(0.072)	0.265(0.550)		
Fe	0.052(0.104)	0.477(1.085)	-0.148(0.299)	-0.119(0.240)	0.588(1.454)	0.528(1.243)	0.624(1.597)	-0.418(0.920)	0.515(1.202)	0.827(2.942)	0.853(3.269)	-0.116(0.234)	0.907(4.307)	0.169(0.343)	

face water 1.6 mg/L as average and fluctuation value 0.190 to 10.782 mg/L were noted by statistical calculations. The maximum value was found at the sampling point BS6 in the month of Jun 2009. Conversely in GW the mean and ranging values were found as 4.4 mg/L and 0.091 to 24.0 mg/L respectively. The maximum value in both sources of water above the permissible level and indicated the GW is more contaminated by iron than surface water owing to lithologically and geologically formation. Mn was detected mean and ranged value 0.2 mg/L and 0.030 mg/L to 0.590 mg/L for SW. In ground water the same mathematical parameter calculated as 0.1 mg/L and 0.040 mg/L to 0.300 mg/L. The high value above the limited data, it means water sources BS6 (SW Jun 2009) and BS9 (GW Apr 2009) are polluted accordingly this quality. As and Zn were detected in water sources; SW and GW, results were neither significant nor goes beyond the permissible level.

Correlation Matrix

r value[24] was calculated differently for surface and subsurface water with t - value. **Table 2(a)** and **Table 2(b)** showed r values between depended and independent WQPs variables.

Surface Water

Total 90 correlations were observed, 71 pairs are positive and 19 relations are negative. High and low significant positive correlations were detected between TS and TDS [r = 0.940, t = 5.510] and Fe vs TSS [r = 0.009, t = 0.018]. Similarly high and mild degree correlations were seen between T. Alk. and Temperature [r = 0.643, t = 1.679], TH vs Temperature [r = 0.765, t = 2.376], TS vs EC [r = 0.826, t = 2.931], TDS vs EC [r = 0.754, t = 2.296], TS vs Turb. [r = 0.654, t = 1.729], Al vs TSS [r = 0.667, t = 1.790], TH vs T. Alk. [r = 0.715, t = 2.045], Fe vs Mn [r = 0.758, t = 2.324], Al vs As [r = 0.789, t = 2.568]. These relations clearly demonstrates that two parameters like TH and Temperature, Temperature vs EC, TS vs EC and TH vs T. Alk. are interrelated together and parallel increase and decrease in their concentration. Highest and lowest negative relations were calculated between T. Aci. and EC [r = -0.755, t = 2.303] and Mn vs TS [r = -0.018, t = 0.036]. Zn didn't form any relations with other selected parameters.

Ground Water

104 correlations were found between two WQPs, 59 +ive and 45 -ive. Highest +ive relations was calculated between TDS vs TS [r = 0.988, t = 12.793] and lowest r value was found between Fe with Temperature [r = 0.052, t = 0.104]. Between various parameters showed significant positive relations were EC vs pH [r = 0.695, t = 1.933], TS vs pH [r = 0.726, t = 2.110], TDS vs pH [r = 0.711, t = 2.022], T. Alk. vs pH [r = 0.832, t = 2.999], T. Aci. vs Turbidity [r = 0.791, t = 2.586], Mn vs TS [r = 0.686, t = 1.886], Mn vs TDS [r = 0.651, t = 1.715], Mn vs TH [r = 0.804, t = 2.704), Zn vs TH [r = 0.717, t = 2.057], Fe vs TH [r = 0.827, t = 2.942], Zn vs Mn [r = 0.862, t = 3.496], Fe vs Mn [r = 0.853, t = 3.211]. Like SW, GW showed high positive relation between Ts and TDS. High inverse correlations were found between T. Aci. and TS [r = - 0.758, t = 2.324], other negative relations were seen between Turbidity vs EC (r = -0.717, t = 2.057], T. Aci. vs EC [r = -0.712, t = 2.028], T. Aci. vs TDS [r = - 0.734, t = 2.162].

% CV

Percentage of correlation variance was calculated for surface and ground water of different selected water quality. The high % CV was found for iron 152.006 (SW) and 179.172 (GW) respectively, indicating vast difference in the variation of the parameters observation in the variation of the parameters observed for different sampling points. Likewise, other quality also showed high variation in observation for various selected investigation points such as Al (SW = 140.615, GW = 0.151), As (SW = 138.041, GW = 144.088), Mn (SW = 74.642, GW = 65.774), T. Alk. (SW = 28.458, GW = 42.735), TH (SW = 31.223, GW = 44.764), Turb. (SW = 43.917, GW = 42.725), EC (SW = 13.687, GW = 42.093).

WQI

In our investigation WQI values were obtained in wide ranges from minimal 116.028 at the site no. BS1 to max. 8242.343 at site no. BS5 shown in **Fig. 2** and **(Table 3)**. The high value of WQI has been found to be closely related with high values of physical and chemical quality such as

Table 3 : Water Quality Index

Spots	ΣQiWi	ΣWi	WQI = ΣQiWi / ΣWi
BS1	38248.871	329.653	116.028
BS2	99122.716	329.653	300.688
BS3	247603.166	329.653	751.102
BS4	43129.041	329.653	130.832
BS5	2717115.314	329.653	8242.343
BS6	952784.788	329.653	2890.263
BS7	110922.126	329.653	336.481
BS8	236123.440	329.653	716.278
BS9	187837.366	329.653	569.803
BS10	190077.125	329.653	576.597

EC, TDS, Turbidity, TH, T. Alk., Fe and Aluminum. WQI found high for surface water sources than ground water indication of extra pollutants discharge in surface water by industrial and domestic effluent.

CONCLUSION

The physicochemical, metallic element and statistical study revealed that the water samples were collected from different locations of Balco industrial areas of Korba district are not suitable for drinking, irrigation and industrial purposes. Surface and subsurface water contain reported high value of iron (1.6 and 4.4 mg/L) and aluminum (1.3 and 0.1 mg/L). Spot No. BS6 and BS9 showed high concentration of Fe: 10.782 and 24.00 mg/L. Like aluminum was found at the site no BS5 and BS2: 7.310 and 0.310 mg/L. Correlations were carried out and results indicated TDS is directly proportional to TS in both water sources. Water Quality Index method is an effective tool to determine the status of potable water. From results it is concluded site no. BS5 has nigh value of WQI: 8242.343 giving indication of high loading of various types of pollutants. However due to the presence of more amount of chemical contamination in these water, if they are used continuously for various use, they pose pollution problems. The public to the instructed to purify before using by common methods like boiling, precipitation, filtration etc.

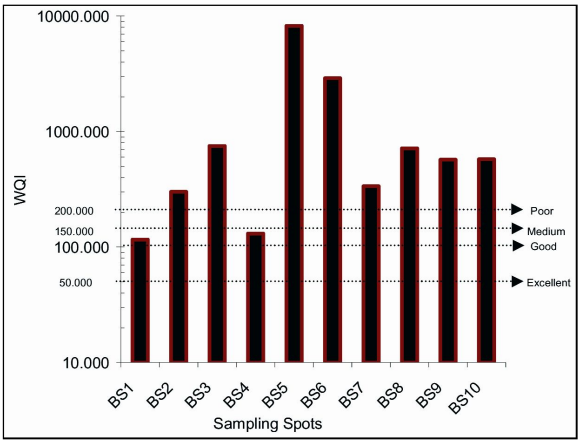

Fig. 2 : WQI values.

REFERENCES

1. Prasad N. R. and Patel J. M., A study of physico - chemical parameters of Krishna river water, particulary in western Maharashtra, *Rasayan J. Chem.*, **1**(4), 943 - 958, **(2008)**.
2. Sindhu S.K. and Mishra A., Study on some physico - chemical characteristics of ground water of district Rampur - A statistical approach, *E - J. Chem.*, **4**(02), 162 - 165, **(2007)**.
3. Begum A., Ramaiah M., Khan H. I. and Veena K., Heavy metal pollution and chemical profile of Cauvery river water, *E - J Chem.*, **6** (1), 47 - 52, **(2009)**.
4. Khadse G. K. and Nanoti M. V., Watershed approach in water resources planning and quality management, *J. Environ. Sci. Engg.*, **49**(3), 178 - 182, **(2007)**.
5. Masood A., Sumbul R. and Mohd. A., Hydrochemical survey of ground water of Delhi, India, *E-J.Chem.*, **6**(2), 429 - 436, **(2009)**.
6. Maheswaran G. and Elangovan K., Hydrogeochemical studies of groundwater in Salem district, Tamil Nadu (India), *J. Environ. Sci. Engg.*, **52**(1), 47 - 52, **(2010)**.
7. Raja G. and Venkateshan P.,Assessment of ground water pollution and its impact in and around Punnam area of Kurur district, TamilNadu, India, *E - J. Chem.*, **7**(2), 473 -

478, **(2010)**.
8. Chaturvedi M. K. and Basin J. K.,Assessing the water quality index of water treatment plant and borewells in Delhi, India, Environ. *Monit. Assess.*, **163**, 449 - 453, **(2010)**.
9. Vedanta resources plc annual report, Accessed on 18 - Oct - **2010** http://ar2010. vedantaresources.com/downloads/downloads.html
10. Dewangan S., Vaishnav M.M. and Chandrakar P.L., Pre - monsoon statistical analysis of physicochemical parameters and heavy metals in different water bodies of Balco area, Korba (C.G.), *Rasayan J. Chem.*, **3**(4), 710 - 720, **(2010)**.
11. APHA, Standard methods for examination of water and waste water (20**th** Edn.) American Public Health Association, Washington DC, **(1991)**.
12. R. K. Trivedi and P. K. Goel, Chemical and Biological methods for water pollution studies, *Environmental publications*, Karad (1984).
13. Thomas J. M. and William R. G., Industively copled plasma - atomic emission spectrometry - The chemical educator, Springer - verlag New Yorc, inc., **2**(1),1 - 13, **(1997**) accessed on 15-Jan-2009 http://journals. springer-ny.com/chedr.
14. Shyamala R., Shanti M. and Lalitha P., Physico chemical analysis of borewell water samples of Telungupalayam area in Coimbatore district, Tamil Nadu, India, *E- J. Chem.*, **5**(4), 924 - 929, **(2008)**.
15. BIS, Indian Standard : Drinking Water Specification, First revision, Bureau of Indian Standards, New Delhi IS : 10500 **(1991)**.
16. WHO, Guidelines for drinking water quality, Vol-I recommendations, World Health Organisation, Geneva, **(1984)**.
17. Sudhir D. and Kaur A., Assessment of physico - chemical characteristics of underground water in rural areas of Tosham subdivision, Bhiwani district, Haryana, *J. Environ. Polln.*, **6**(4), 281 - 288, **(1999)**.
18. Shah M. C., Shilpkar P. and Sharma S., Correlation, regression study on physicochemical parameters and water quality assessment of ground water of Mansa Taluka in Gujarat , *Asian J. Chem.*, **19**(5), 3449 - 3454, **(2007)**.
19. Ashraf M. A., Jamil Maah M. and Yusaff Ismail, Water quality characterization of Varsity lake, University of Malaya, Kuala Lumpur, Malaysia, *E - J. Chem.*, **7**(1), S245 - S254, **(2010)**.
20. Ahamed M. R., Azarudeen R., Karunakaran M. and Barkarudeen A., A study on the quality of ground water in and around Ramanathapuram city, *Curr. World. Environ.*, **3**(1), 143 - 146, **(2008)**.
21. Sharma M. R., Assessment of ground water quality of Hamirpur area of Himachal Pradesh, *Pollut. Res.*, **23** (01), 131 - 134, **(2004).**
22. Shrinivasa B. Rao and Venkateswarlu P., Evaluaion of ground water quality in Chirala Town, Prakasam District, *Indian J. environ. Prot.*, **20**(3), 161, **(2000)**.
23. Indian Standards Institution, Tolerance limits for inland surface waters subjected to pollution, IS : 2296, New Delhi **(1982)**.
24. Karunakaran K., Thamilarasu P. and Sharmila R., Statistical study on physico-chemical characteristics of ground water in and around Namakkal, TamilNadu, India, *E - J. Chem.*, **6**(3), 909 - 914, (**2009).**