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PRE-MONSOON STATISTICAL ANALYSIS OF PHYSICO-CHEMICAL PARAMETERS AND HEAVY METALS IN DIFFERENT WATER BODIES OF BALCO AREA, KORBA (C.G.)

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ABSTRACT

In the present study our aim is to assess the presence and extent of heavy metal concentration with physicochemical quality of different water bodies i.e. surface and subsurface, due to pollution caused by BALCO and its captive power plant, around its adjoining areas. The water samples were collected from the ten sampling points during the study period viz. March 2009 to May 2009 (Pre – monsoon). The water quality such as Temp., pH, EC, Turbidity, TS, TDS, TSS, TH, Total alkalinity and Total acidity were examined by standard method while selected heavy metals like Fe. Al, Zn, Mn and As have been detected by ICP AES methods separately for surface and ground water. The results were compared with standard values of drinking water prescribed by BIS and WHO. Fe and Al were reported in enormous ranging from 0.1 – 24.0 mg/L and 0.03 – 0.28 mg/L for ground water, 0.19 – 10.620 mg/L and 0.14 – 6.93 mg/L for surface water. The statistical parameters like mean, SD, SE, CV and correlation coefficient were systematically calculated for physicochemical parameters.

Keywords: Physicochemical parameters, Heavy meals, Surface and Ground water, Statistical Parameters.

INTRODUCTION

All states of water viz. solid (ice), liquid and gas (vapour) are essential for the survival of flora, fauna and microbes. The water percentage in human system is 70% of the total weight of the body. The statistical distribution of water in earth planet is 80% occupied by surface water, in which 97% as sea and oceans, 2.14 % water trapped in the giant glaciers and polar ice-caps, only 1% fresh water is available for the bioconsumption. From many years ground water was thought purest form of water due to the protected layer of rocks and soil that act as filter.[1] Now this water source became contaminated through seepage of water via dumping wastes. Water has multiapplication, so the demand of water is now gradually increased in several folds. Owing to indiscriminated industrialization and anthropogenic sources, different water bodies are facing acute pollution; as a result, the water quality is deteriorated. Heavy metals are non-biodegradable and toxic to the living organisms. It enters into environment through combustion of fossil fuel, metallurgical process, agricultural runoff etc.[2, 3] Toxic metals reduce soil fertility and crop yield.[4] Some heavy metals such as Cu, Fe, Mn, Ni and Zn are compulsory as micro nutrients for Bio - Systems. Besides the metals like Cd, Cr and Pb are harmful beyond a certain limit.[5]

Chhattisgarh is the richest Indian state in natural resources. The Coal, Bauxite and Iron ore abundantly occur in northern and southern part of the state. Due to these rich raw materials, Korba has been developed as industrial hub and coal based thermal power plants such as NTPC, CSEB and BALCO are established. Balco is situated about 8 km in north – east direction from Korba, district head quarter. It

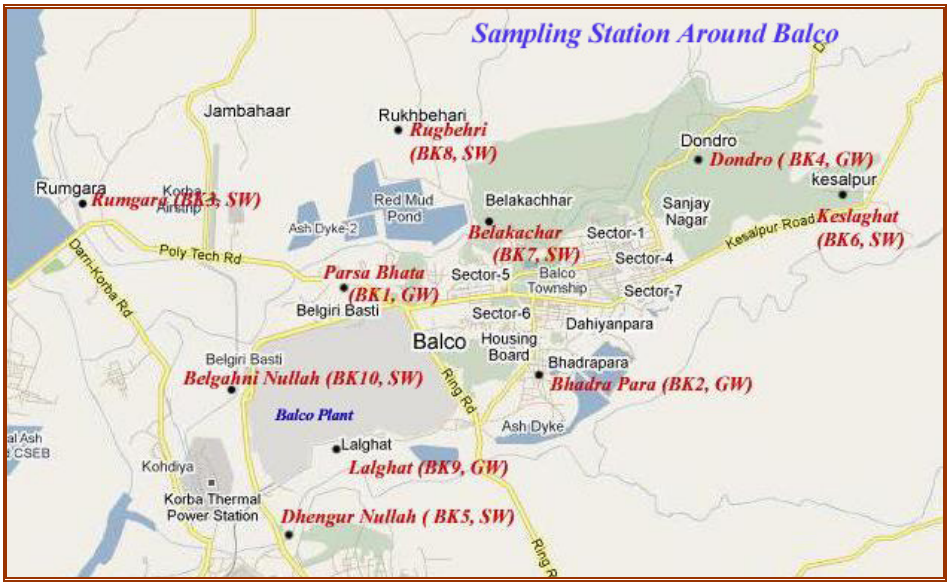
receives bauxite from Mainpat and Phutka hill area. The annual production of refined aluminum is 3 lacs tonnes. The increased contamination of different water bodies mainly can be attributed to blind dumping of mineral ores, solid waste, untreated and semitreated effluents in the present study area. In continuation of our previous work[6, 7, 8] we have undertaken to explore various pollutant in aquatic system of Balco area. In this paper we have only presented the premonsoon monitoring results of physicochemical parameters, selected heavy metals and their correlation values of both surface and ground water from selected sampling spots.

EXPERIMENTAL

Study Area and Sampling

As per environmental significance, we have chosen ten study sites (Showed in Fig 1 and Table 1), Six for surface and four for ground water in and around Balco area. Water samples were collected in the pre-cleaned polypropylene bottles during each month of the pre-monsoon season (March 2009 to May 2009). The chemicals used in the investigation were of analytical grade procured from E Merk's Germany and Qualigens Mumbai, India of high purity. All the glasswares are of graduated, calibrated and of carrying grade, manufactured by Borosil, India.

Chattisgarh → Korba District



Sampling Site and Study area

Analysis of water samples

Methods[9-12] was used for the measurement of selected physical, chemical and heavy metals illustrated in Table 2.

Statistical Analysis

The standard formulae[13] were used in the calculation for statistical parameters are as follows:

$$Mean\ (\mu) = \frac{\sum x}{N}$$

x = Value of Observation,
N = Number of Observation

$$\text{Standard Deviation } (\sigma) = \sqrt{\frac{n\sum x^2 - \left(\sum x\right)^2}{n(n-1)}}$$

x = Values of Parameter.
n = No. of Observations.

$$\text{Standard Error} = \frac{\sigma}{\sqrt{N}}$$

σ = Standard Deviation
N = No. of Observation

$$\text{Karl Pearson's Coefficient of Correlation } r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - \left(\sum x\right)^2}\sqrt{n\sum y^2 - \left(\sum y\right)^2}}$$

x,y = values of array 1 and array 2 respectively.
n = Number of Observations.

$$\%\ \text{vairation of CV} = \frac{\sigma}{\mu} \times 100$$

σ = Standard Deviation
μ = Mean

RESULT AND DISCUSSION

The statistical result range, mean, SD, SE, % CV, r values for surface and ground water are given in table No. 3, 4 and 5 respectively. Graphical variation for average distribution, standard deviation, %CV of heavy metals for SW and GW are represented in Graph No. 1, 2 and 3.

Physico – Chemical parameters for Surface Water

pH

The presence of hydrogen ion concentration is measured in terms of pH range. In our study the pH of surface water ranges from 7.69 to 9.91. The min. value responded at sampling location BK3 (Mar), while the max pH was noted on sampling point BK5 (May), which was above the max. permissible range as prescribed by BIS[14] and WHO[15] drinking water standards.

Electrical Conductivity

The electrical conductivity of water is due to the presence of dissolved inorganic salts. The average and ranging values were noted as 2114.3 $\mu mhos/cm$ and 1591 $\mu mhos/cm$ to 2421 $\mu mhos/cm$. The minima and maxima value were reported at the sampling location BK7(Mar) and BK3(May) respectively. The max. value is above the upper limit prescribed by BIS[14] standard.

Turbidity

Turbidity of water is due to the presence of suspened particles of the chemical substance. The mean value for the turbidity was 111.67 NTU and its ranging from 34.0 – 175 NTU. The min. value of turbidity was

recorded at the sampling spot BK7 (Mar). BK10 (May) had showed max. value. The range values were beyond from the standard value as set by BIS[14] and WHO[15] standard.

Total Hardness

This water quality is due to the presence of calcium and magnesium salt. The average value 832.37 mg/L and range covered from 649.5 mg/L to 979.5 mg/L as low and high value from the BK7 (Mar) and BK5 (May) sampling spots. The max. value was far from the limit level as per BIS[14] and WHO[15] standard.

Total Alkalinity

The cause of alkalinity in water is due to the presence of various ions such as $^{-}OH, HCO_3^-, PO_4^{3-}, BO_3^{3-}$.

The mean and range values were reported as 645.72 mg/L and 435 - 792 mg/L respectively. The sampling spot BK3 (Mar) as low while BK5 (May) as high value noted. These values fluctuate from acceptable limit to beyond from upper limit prescribed by BIS[14] and WHO[15] standard.

Total Acidity

Acidity of water is its capacity to neutralize a strong base and is mostly due to the presence of strong mineral acids, weak acids and the salt of strong acid and weak base. The average value and ranges were detected as 135.33 mg/L and 79 – 234 mg/L respectively from BK5 (Mar) sampling spot shown as low value and BK7 (Apr) had expressed high value of total acidity.

Total Dissolved Solids (TDS)

The total dissolved solids are expressed by the weight of residue left when a water sample has been evaporated to dryness. The mean value was 1165.71 mg/L and the range varied from 383.77 to 1724.93 mg/L. The max. value was recorded at BK8(may) sampling spot which was exceeded the max. permissible limit prescribed by WHO[15] standard..

Heavy metals

Heavy metals are elements whose density is five times higher than that of water. The main sources of heavy metals in water are mixing of dangerous chemicals and industrial effluents. We have selected only five heavy metals to assess in different water source of Balco area.

Manganese

Mn imparts objectionable and tenacious stain to laundry and plumping fixtures. In our investigation the mean and ranges value were observed 0.17 mg/L and 0.58 – 0.03 mg/L as the low and high value at BK3 (Mar) and BK6 (May) respectively. The maximum data crossed the standard value prescribed by the BIS[14] and WHO[15] standard.

Arsenic

Arsenosis is main malady due to the excess ingestion of As through potable water. The mean and range value of As were reported as 0.003 mg/L and 0.001 – 0.015 mg/L. The maximum amount of As was detected on BK5 (May), where untreated or partially treated polluted water from Balco is discharged.

Aluminum

Al is the third most abundant element in the earth crust occuring in mineral rocks and clays. In our study the mean value was 1.31 mg/L while it ranges from 0.14 to 6.93 mg/L. The maximum value of this heavy metal was observed on BK5 (May) which is several folds greater than max. permissible limit prescribed by BIS[14] and WHO[15].

Zinc

Zn is essential for growth, reproduction, tissue repair and many metabolic activity[19]. It is chief element of animal enzyme. Low intake of Zn results anemia[16], immaturation and growth retardation. In our analysis, the statistics 0 .10 mg/L and 0.11 – 0.10 mg/L as mean and range value were found. BK5 (May) water contain high level of Zn, was reported. The low concentration of Zn in water sample could be due to the alkaline nature[17].

Iron

Iron is the main ingredient of hemoglobin, cytochrome and myoglobin. Long term consumption of drinking water with high concentration of iron may lead to liver diseases[18]. It serves as catalyst for fat oxidation[19]. It was reported 1.68 mg/L and 0.19 – 10.62 mg/L as the average and range value. The

highest value of iron was reported at the BK6 (May). This value was many times greater than maximum permissible level as per BIS[14] and WHO[15] standards.

Physico – Chemical patameters for Ground Water

pH

pH value was obtained 7.561 and 6.79 – 7.99 as mean and range values respectively. The min. value was reported at BK2 (May) and max values at BK9 (May). The pH ranges indicated the nature of ground water from acidic to slightly basic medium and under the acceptable range as per BIS[14] and WHO[15] standatard for drinking water.

Electrical Conductivity

The high salt concentration in the ground water may be due to the presence of higher soluble salt[20]. Electrical conductivity of ground water was reported 1332.58 $\mu mhos / cm$ and 583 – 1978 $\mu mhos / cm$ as mean and range value The high value was noted at the sampling spot BK4 (May) which was within the permissible limit prescribed by BIS[14] standard.

Turbidity

The mean value was 27.667 NTU, while ranges from 13 NTU to 48 NTU. BK2 (May) sample show max. value of turbidity; The high value of Turbidity was found from upper range given by BIS[14] and WHO[15].

Total Dissolved solid (TDS)

861.46 mg/L and 178.25 – 851.49 mg/L as mean and range data observed respectively. The max value was at BK1 (May) which was greater than upper value as per WHO[15] standard.

Total Hardness

The average value of total hardness was 471.94 mg/L and the range from 231 – 766 mg/L was observed in study period. The minimum value was recorded at the sampling spot BK4 (Mar) and the max. value was noted at BK9 (May indicated water is very hard as per BIS[14].

Total Alkalinity

The mean value of total alkalinity was 514.667 mg/L while the range noted from 236mg/L as minima and 713 as maxima on the sampling spot BK2(Mar) and BK9(May) respectively. The high value was above the maximum permissible level as set by BIS[14] and WHO[15] standard.

Total Acidity

The total acidity was noted 132.83 as mean and 68 – 234 as range. The high and low value has been reported from sampling spots BK2 (Apr) and BK9 (May) respectively.

Heavy metals

In ground water heavy metals entered by rock weathering and seepage of contaminated surface water. In ground water the mean value of Mn was calculated 0.125 mg/L and range varied from 0.05 – 0.3 mg/L, which exceeds the upper limit of standard value as set by BIS[14] and WHO[15] standard. Zn was estimated within the desirable limit at all the sampling spot. The average and ranging value 0.60 mg/L and 0.01 – 2.77 mg/L were observed. Aluminum was measured as highest amount 0.28 mg/L at the sampling location spot BK2 (Mar) due to leaching of crude aluminum ore of the Balco factory. The mean and range values were found 0.11 mg/L and 0.03 – 0.28 mg/L respectively. Iron was also detected above the maximum permissible limit on the sampling spot BK9 (May) i.e 24.0 mg/L, which is many folds greater than upper limit prescribed by BIS[14] and WHO[15] standard. The mean and ranging statistics were 5.02 mg/L and 0.1 – 24.0 mg/L respectively.

r-Value for the surface water

91 correlation coefficient (r) among various water quality parameters were observed. 13 were found to have significant at 5% level ($r > 0.649$). 71 cases were calculated out positive correlation while 20 cases were calculated out negative. Only a few parameters show high degree of positive correlation such as Turb. with EC ($r = 0.805$), TS with EC ($r = 0.801$), TDS with EC ($r = 0.773$) and TS ($r = 0.940$). Between TSS and pH ($r = 0.713$). TH correlate with EC ($r = 0.901$), TS ($r = 0.829$) and TDS ($r = 0.709$), T.Alk. with pH ($r = 0.777$). Al showed positive r value with pH ($r = 0.792$), TSS ($r = 0.833$) and As (r

= 0.734). Fe established positive correlation matrix with Mn(r =0.896). High degree negative correlation was shown by T.Aci. with EC (r = -0.931), TS (r = -0.828), TDS (r = -0.787) and TH (r = -0.945). Zn does not correlate with other parameters. All these relations have been tested by t – value.

r-Value for ground water

22 correlation were found to have significant at 5 % level (r = > 0.649). 53 positive and 38 inverse correlations were calculated. The major r values were found between EC and pH (r = 0.688), TS and pH (r = 0.661), TDS and TS (r = 0.995). TSS with pH (r = 0.771), TS (r = 0.807), and TDS (r = 0.744), TH with TSS (r = 0.654), T.Alk. with pH (r = 0.966), EC (r = 0.720), TSS (r = 0.730). Between T.Aci. and Turb. (r = 0.853), Mn with TS (r = 0.697), TDS (r = 0.650), TSS (r = 0.820) and TH (r = 0.911). Zn with TH (r = 0.813), Mn (r = 0.833). Fe showed positive correlation with TSS (r = 0.806), TH (r = 0.857), Mn (r = 0.934) and Zn (r = 0.970). High inverse correlations were reported between Turb. with pH and EC (r = -0.833, - 0.866) respectively, T.Alk. with Turb. (r = -0.885), T.Aci. with pH (r = - 863), TS (r = - 0.855) and T.Alk. (r = - 0.819). Arsenic did not showed r value with other parameters. t – test were used for testing the significance of these correlations.

CONCLUSION

In this investigation, it is concluded that the surface and ground water sources near the Balco factory are much polluted. Aluminum and iron were reported in several times higher than standard upper limit as given by BIS[14] and WHO[15] during the study period. The sampling spot BK5(May) and BK2(Mar) have 6.93 mg/L and 0.28 mg/L, while BK6(May) and BK9(May) showed 10.62 mg/L and 24.0 mg/L aluminium and iron in surface and ground water respectively. Thus high level of these metal ion concentration in aquatic system is due to discharge of partial treated effluent and seepage of water through indiscriminated dumping of industrial solid wastes. In case of surface water the highest and lowest positive correlation were recorded between TS and TDS (r = 0.940) and TSS with Fe (r = 0.006) respectively. The maxima and minima inverse r value was observed between TH and T.Aci. (r = -0.945) and T.Alk. and Temp. (r = -0.039). TS and TDS (r = 0.995) and Temp. with T.Aci. (r = 0.035) showed the high and low r value and Temp. with TH (r = -0.001) and Turb. with EC(r = -0.866) were noted low and high negative relations for ground water.

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[RJC-674/2010]

Table-1: Sampling Spots of Surface and Underground water

S. No.	Spot Name	Water Source	Habitat
1	BK1	Under Ground water	Domestic
2	BK2	Under Ground water	Domestic
3	BK3	Surface Water	Commercial
4	BK4	Under Ground water	Domestic
5	BK5	Surface Water	Commercial
6	BK6	Surface Water	Domestic
7	BK7	Surface Water	Domestic
8	BK8	Surface Water	Commercial
9	BK9	Under Ground water	Domestic
10	BK10	Surface Water	Commercial

* BK1(Mar – May),BK2(Mar – May), BK3(Apr, May), BK4(Mar - May), BK8(Mar), BK9(Mar – May), BK10(Mar – May)

** , *** All Samples having same amount of Zn, **** No Change of the amount of As

Table-2: Parameters and Standard Methods

S. No.	Parameter	Method
1.	Temperature	9-parameter analyzer kit
2.	pH	9-parameter analyzer kit
3.	Turbidity	9-parameter analyzer kit
4.	Electrical Conductivity	9-parameter analyzer kit
5.	Total Hardness	Titrimetric
6.	Total Alkalinity	Titrimetric
7.	Total Acidity	Titrimetric
8.	Total Dissolved Solid	Gravimetrically
9.	TotalSuspended Solid	Mathematically
10.	Total Solid	Gravimetrically
11.	Manganese	ICP - AES
12.	Iron	ICP – AES
13.	Zinc	ICP – AES
14.	Arsenic	ICP - AES
15.	Aluminium	ICP - AES

Table-3: Statistical Parameters of different Physical and Chemical Parameter of Surface and Ground water

ParaMeters	Surface Water								Drinking water Standard	Under ground water							
	N	Range	Min	Max	Mean	SD	% CV	Std. Err		N	Range	Min	Max	Mean	SD	% CV	Std. Err
Temp.	18	27.1 - 33.3	BK8 Mar	BK3 May	30.578	1.718	5.619	0.405	27 - 28 (WHO)	12	20.1 - 24.5	BK9 Mar	BK1 May	22.375	1.398	6.249	0.404
pH	18	7.69 - 9.91	BK3 Mar	BK5 May	8.417	0.657	7.806	0.155	6.5 - 8.5 (WHO, BIS)	12	6.79 - 7.99	BK2 Mar	BK9 May	7.564	0.491	6.492	0.142
EC	18	1591 - 2421	BK7 Mar	BK3 May	2114.278	277.651	13.132	65.443	750 - 2250 (BIS).	12	583 - 1978	BK2 Mar	BK4 May	1332.583	519.334	38.972	149.919
Tur.	18	34 - 175	BK7 Mar	BK10 May	111.667	46.049	41.238	10.854	5 - 25 NTU (WHO)	12	13 - 48	BK4 Apr	BK2 May	27.667	11.539	41.708	3.331
TS	18	466.4578 - 1931.337	BK7 Mar	BK5 May	1421.527	467.926	32.917	110.291	-	12	217.891 - 993.3347	BK2 Mar	BK9 May	679.959	312.245	45.921	90.137
TDS	18	383.77 - 1724.93	BK7 Apr	BK8 May	1165.711	396.527	34.016	93.462	500 - 1500 (WHO)	12	178.25 - 851.49	BK2 Mar	BK1 May	560.934	275.994	49.203	79.673
TSS	18	55.2287 - 618.457	BK7 Mar	BK5 May	255.816	165.034	64.513	38.899	-	12	39.641 - 190.812	BK2 Mar	BK9 Apr	119.024	46.654	39.197	13.468
T H	18	649.5 - 979.5	BK7 Mar	BK5 May	832.372	104.912	12.604	24.728	300 - 600 (WHO)	12	231 - 766	BK4 Mar	BK9 May	471.942	195.194	41.360	56.348
T Alk.	18	435 - 792	BK3 Mar	BK5 May	645.722	108.371	16.783	25.543	200 - 600 (WHO)	12	236 - 713	BK2 Mar	BK4 May	514.667	188.697	36.664	54.472
T Aci.	18	79 - 234	BK5 Mar	BK7 Apr	135.333	52.089	38.490	12.278	-	12	68 - 234	BK9 May	BK2 Apr	132.833	59.358	44.686	17.135
Mn	18	0.03 - 0.58	BK3 Mar	BK6 May	0.174	0.139	79.486	0.033	0.1-0.3 (WHO, BIS)	12	0.05 - 0.3	BK2 Apr-May	BK9 Apr	0.125	0.091	72.403	0.026
As	18	0.001 - 0.015	*	BK5 May	0.003	0.005	146.225	0.001	0.05 (WHO, BIS)	12	0.001 - 0.001	****	****	0.001	0.000	0.000	0.000
Zn	18	0.001 - 0.001	**	***	0.100	0.000	0.000	0.000	5.0- 15.0 (WHO, BIS)	12	0.01 - 2.77	BK1 BK2 May	BK9 May	0.602	0.913	151.794	0.264
Al	18	0.14 - 6.93	BK3 Mar	BK5 May	1.317	1.851	140.529	0.436	0.03 - 0.2 (WHO, BIS)	12	0.03 - 0.28	BK1 May	BK2 Mar	0.110	0.075	67.920	0.022
Fe	18	0.19 - 10.62	BK3 Apr	BK6 May	1.676	2.503	149.399	0.590	0.3- 1.0 (WHO, BIS)	12	0.1 - 24	BK2 Apr	BK9 May	5.022	8.855	176.342	2.556

Table : 4
Correlation Matrix for Pre- Monsoon Surface Water

	Temp.	pH	EC	Turb.	TS	TDS	TSS	TH	T. Alk	T.Aci	Mn	As	Zn	Al	Fe
Temp.															
pH	0.249														
EC	0.129	0.160													
Turb.	0.411	0.073	0.805												
TS	0.093	0.507	0.800	0.625											
TDS	-0.061	0.301	0.773	0.614	0.940										
TSS	0.411	0.713	0.410	0.298	0.576	0.263									
TH	0.103	0.488	0.901	0.621	0.829	0.709	0.647								
T. Alk	-0.039	0.777	0.124	0.152	0.573	0.514	0.389	0.340							
T.Aci	0.053	-0.304	-0.931	-0.587	-0.828	-0.787	-0.456	-0.945	-0.255						
Mn	0.297	0.260	-0.316	-0.033	0.059	0.083	-0.031	-0.316	0.363	0.366					
As	0.058	0.460	0.264	0.057	0.277	0.097	0.552	0.513	0.235	-0.410	-0.133				
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			
Al	0.278	0.792	0.155	0.166	0.447	0.181	0.833	0.458	0.598	-0.249	0.228	0.734	0.000		
Fe	0.281	0.095	-0.265	0.051	0.047	0.053	0.006	-0.302	0.209	0.337	0.896	-0.062	0.000	0.246	

Significant at 5% level at r > 0.649

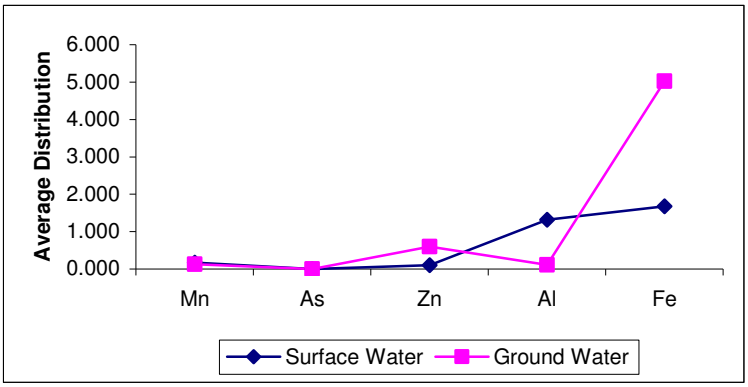

Fig.-1: Average Distribution of Heavy Metals

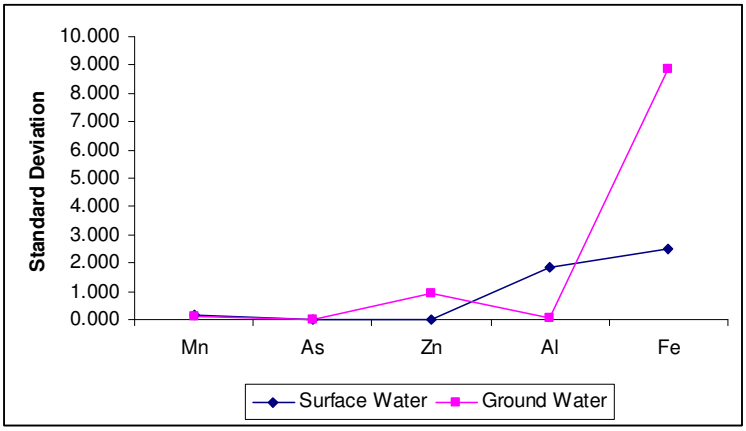

Fig.-2: Standard Deviation of Heavy Metals

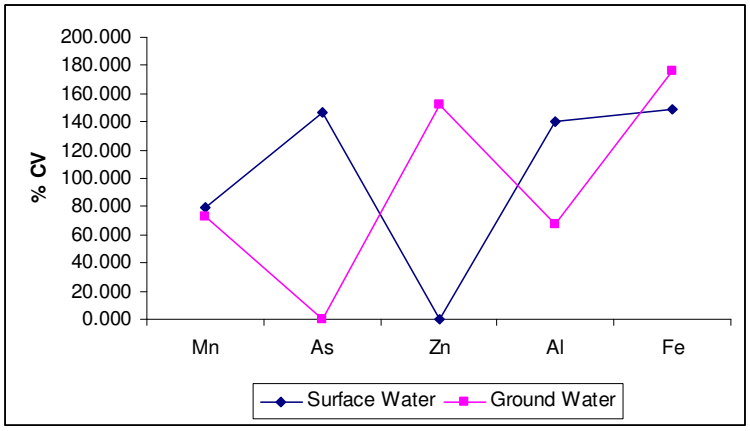

Fig.-3: % CV of Heavy Metals

Table 5
Correlation Matrix for Pre- Monsoon Ground Water

	Temp.	pH	EC	Turb.	TS	TDS	TSS	TH	T. Alk	T.Aci	Mn	As	Zn	Al	Fe
Temp.															
pH	-0.364														
EC	-0.071	0.688													
Turb.	0.353	-0.833	-0.866												
TS	0.170	0.661	0.328	-0.525											
TDS	0.235	0.618	0.330	-0.506	0.995										
TSS	-0.255	0.771	0.242	-0.523	0.807	0.744									
TH	-0.001	0.197	-0.473	0.122	0.638	0.611	0.654								
T. Alk	-0.493	0.966	0.720	-0.885	0.545	0.493	0.730	0.085							
T.Aci	0.035	-0.863	-0.690	0.853	-0.855	-0.843	-0.736	-0.286	-0.819						
Mn	-0.264	0.473	-0.210	-0.200	0.697	0.650	0.820	0.911	0.420	-0.497					
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
Zn	-0.344	0.503	-0.191	-0.205	0.551	0.491	0.780	0.813	0.483	-0.457	0.883	0.000			
Al	-0.338	-0.383	-0.680	0.406	-0.297	-0.296	-0.233	0.329	-0.358	0.453	0.269	0.000	0.227		
Fe	-0.284	0.486	-0.227	-0.145	0.579	0.519	0.806	0.857	0.451	-0.446	0.934	0.000	0.970	0.187	

Significant at 5% level at r > 0.649