



Multivariate analysis of soil and ground water quality in Sidhi district of Vindhya Plateau

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ABSTRACT

Ground water and soil samples collected from 20 different locations and analyzed for the physical properties, chemical properties and heavy metals contents in it. Pollution of water bodies is one of the areas of major concern to environmentalists. Water quality is an index of health and well being of a society. Industrialization, urbanization and modern agriculture practices have direct impact on the water resources. These factors influence the water and soil resources quantitatively and qualitatively the parameters like temperature, pH, turbidity, dissolved oxygen (DO) biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate, nitrite, chloride, sulphate, phosphate and heavy metals for water analysis and temperature, pH, OC (organic carbon) total nitrogen, phosphorus, exchangeable cation (Na^+ , K^+ , Ca^{++} , Mg^{++}) and heavy metals for soil analysis have been studied. The mean values of each parameter together with its standard deviation (SD) and coefficient of variation (CV) were calculated. The present study deals with the various relationship derived statistically by calculation 'r' and 't' among the physico-chemical parameters. The ground water samples from few locations in the sidhi district are found to be polluted and not fit for the drinking purpose.

Keywords: Ground water, Soil, Heavy Metals, Correlation coefficient, Sidhi District, Water and Soil quality, Vindhyan Plateau.

INTRODUCTION

Concern over pollution sources in integrated water and soil quality management has growing recently [1-2]. The quality of ground water is highly related with the local environmental and geological conditions. The quality of soil and rock and the water table determines the quality of ground water. The ground water source levels change by the regular withdrawal and hence the quality of ground water reported seasonal as well as annual change in the ground water quality [3-9]. Ground water is a part of hydrological cycle and 50% of the world's population depends on ground water for their drinking purposes. Due to anthropogenic activities such as urban development industrialization, agricultural runoffs, domestic activities leads to

wastes disposal and discharges, chemical spills and even individual house hold sewage systems have caused significant ground water contamination in areas that previously had clean potable ground water. The sources and causes of ground water pollution are closely associated with human use of water. A complex and interlinked series of modification to the natural water quality is created by the diversity of the human activities impairing hydrological cycle. For many years ground water was thought to be protected from contamination by the layers of rock and soil that acts as filters, but contaminants do make their way in to ground water and affect its quality. Pollution of ground water poses a serious problem. It has been reported that in developing countries, pollution of ground water cause 80% of human diseases. An important aspect of urbanization is the increase in demand and creation of potential with the possibility of pollution of ground water [10-11]. Ground water which now accounts for 80% of rural and 60% of urban water supply in India is depleting at an alarming rate in several states. The ground water table has declined by more than 4 meters compared to the level in 1980. Infact today at least 19 major cities of India already face chronic water shortage [12].

The Vindhya Pradesh plateau is environmentally very important to understand the rich Indian biodiversity and diffuse chemical pollution. Sidhi district is located on the northeastern boundary of the state between 22° 47' 5" and 24° 42' 10" North latitude and 81° 18' 40" and 82° 48' 30" East longitude. Sidhi district is one of the four district of Rewa division in Madhya Pradesh. Sidhi possesses abundant natural resources with the river son draining the district, and with coal deposits which feed major industries across the country.

Sidhi district comprises of variety of minerals including bauxite shale, laterite, flagstone, sandstone and granite etc. Soils derived from sandstone are generally non – permeable and have no water contents. The water table in sandstone is deeper in general shalis show little percolation of ground water hence has limited retaining and explanation of it. Limestone allows movement of ground water due to the presence of such geology the ground water of study area is highly affected in its quality, the aim of present work is to assess the quality of drinking water of the Sidhi district by analyzing various inorganic non-metallic constituent and heavy metals present in water.

MATERIALS AND METHODS

The samples were collected from 8 Tehsil, 2 industrial area, 4 crop field and 6 villages of Sidhi district. Twenty sampling locations consisting of bore wells and hand pumps were selected in the study area. Sampling was done during summer, rainy and winter seasons (of year 2009 to 2010). The month of April-May, July-August and December-January, were selected as representative month of summer, rainy and winter seasons respectively. Sampling was done in accordance with grab sampling methods in polyethylene bottles of one liter capacity. To avoid leaching of metals and interaction with the surface wall of the container, bottles were first cleaned with detergent and then with 1:1 HNO₃ for 24 hours. Finally bottles were cleaned and rinsed with the distilled water. During sampling bottles were rinsed two to three times with the sample to be examined before finally filling with it. Samples were collected by immersing the rinsed bottles in river water[13-14]. During sampling from hand pumps and bore wells, the water pumped to waste for about five minutes and sample was collected directly. All the samples were refrigerated at 4°C in the laboratory[14,15-17], and procedures were followed as per the standard methods[18-20], and different physicochemical parameters like, temperature, pH, turbidity, dissolved oxygen, BOD, COD, nitrate, nitrite, chloride, sulphate, phosphate and heavy metal were analyzed. Twenty soil samples were collected from different location in plastic bags, dried at 60°C for 48h and fine powder was made with the help of pistil mortar and sieved it with 2mm sieve. The pH of the soil samples was determined with Orion Research Analog pH meter/model 301 according to standard analytical method. Organic matter was determined using the chromic acid oxidation method (Walkey and Black, 1934). Soil samples were analyzed for Ca, mg, K and Na and these minerals were extracted by using ammonium chloride extracting solution methods. The samples were capped and weighed to determine possible acid

loss during digestion. The samples were then digested in CEM 2000 microwave digester at 100 ponds per square inch (PSI) for 5.5 min and filtered through What man 42 filters and transferred to 100ml volumetric flasks. Samples with weighed loss of greater than 10% were re-digested. The digested samples were analyzed for heavy metals using Atomic Absorption Spectrophotometer. The locations of sampling stations are shown in figure 1.

- The coefficient of variation (CV) was determined using the formula.

$$CV = \frac{SD}{Average} \times 100$$

Where CV = coefficient of variation, SD = Standard Deviation

- The correlation coefficient 'r' was calculated using the equation

$$r = \frac{\Sigma xy - \Sigma x \cdot \Sigma y}{\sqrt{(\Sigma x^2 - (\Sigma x)^2/n) (\Sigma y^2 - (\Sigma y)^2/n)}} \times 100$$

where x and y represents two different parameters.

- The t- test (t) was calculated by using the following formula

$$t = \frac{r}{\sqrt{1 - r^2}} \sqrt{n - 2}$$

at degree of freedom = n - 2

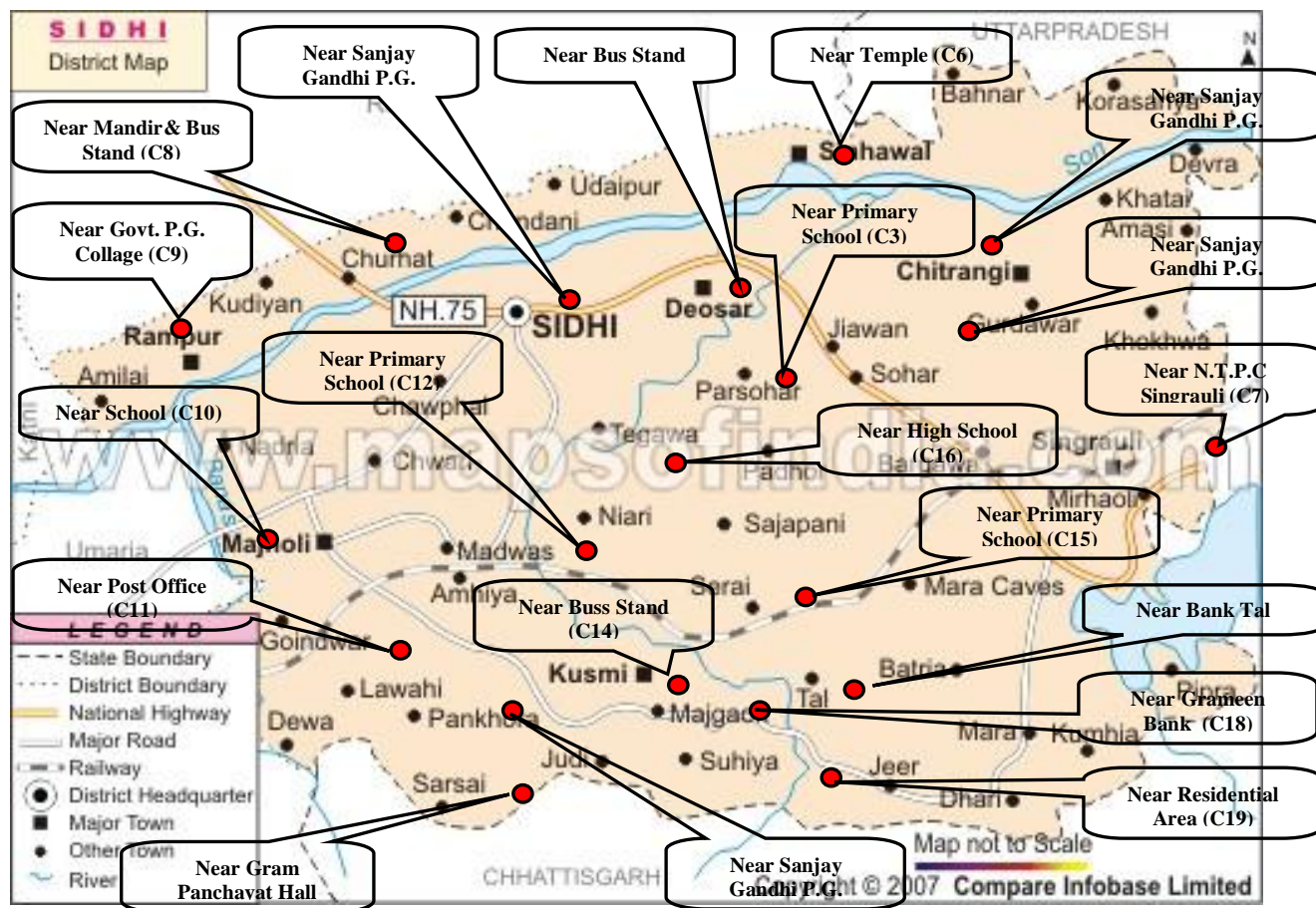


Figure 1: Sampling locations of Sidhi District

RESULTS AND DISCUSSION

Characteristics of ground water samples of Sidhi District: Ground water samples were collected from twenty different locations in Sidhi District, the details of the locations are depicted in the **figure 1**. The ground water samples were collected during the three seasons (Monsoon, winter and summer) to know the seasonal variation in characteristics. The physico-chemical characteristics of the ground water sample of Sidhi during the three seasons are presented in **tables 1 to 3**.

The mean values of eleven parameters of ground water analysed in 20 stations together with their SD and CV are presents in **table 1**. The water temperature averaged 35.5⁰C which was lower than the average value of ground water of NTPC Singrauli (35.6) at location C₇ and higher than those of near S.G. P.G college Sidhi (28.1) at location C₄ during monsoon season.

pH was ranging from 6.0-7.7 with an mean value of 6.62, WHO (1984) prescribed the desirable limit of pH range between 7 and 8.5mg L⁻¹. The turbidity of water was found to be 1.0-1.85 NTU and the mean value was 1.479 NTU. Dissolved oxygen was ranged between 2.2-8.2mg L⁻¹ the maximum value was recorded during the monsoon period in the sample C₁₈ collected from Majgaon. The mean values of DO, BOD and COD in the ground water during monsoon season were 3.9mg L⁻¹, 4.49mg L⁻¹ and 7.03mg L⁻¹ respectively. The biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were also found within the limits prescribed by the BIS and WHO. The CV values of temperature (7.7), pH (8.2), turbidity (18.8), dissolved oxygen (40.8), BOD (34.7) and COD (13.9) showed that wide fluctuation of therefor relations of these parameters did not occur between stations. In the case of nitrates, nitrites, sulphates, chlorides and phosphates, the mean value were recorded as 3.952, 1.235, 83.385, 46.471 and 0.425 mg L⁻¹ and all the results are within the permissible limit. It was found that amount of sulphate ranged from 2.0-278mg L⁻¹ (**Table 1**), and highest values of sulphate 278mg L⁻¹ at Deosar (C₂) which is higher in the WHO permissible limit. The phosphates content of water was found to be 0.15-1.8mg L⁻¹. the highest value of 1.8 mg L⁻¹ was recorded at location C₁₃ while the minimum value 0.15mg/l was recorded at location C₄, as show in the **table 1**. Values of phosphates at Sidhi (0.3), Persohar (0.31), Chitrangi (0.3), Madwas (0.52), Sarsal (1.8), Kusmi (0.41), Tagawa (1.5), Majgaon (0.55)mg L⁻¹ are higher than the permissible limit prescribed by WHO and BIS. The CV values of nitrates (68.2), nitrites (120.1), sulphates (112.8), chlorides (93.9), phosphates (103.1) indicated their significant variation from one station to another.

Table 1: Physico-chemical characteristics of ground water in Sidhi District during monsoon

Parameters	Sampling Locations										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Temperature (°C)	28.6	28.7	28.7	28.1	28.8	29.5	35.6	33	33.2	33.8	34
pH	6.9	7.7	6	6.2	7.2	7.3	6	7	6.2	6	6.8
Turbidity (NTU)	1.4	1.16	1.8	1.85	1.62	1.25	1.23	1.05	1.36	1.12	1.9
Dissolved Oxygen	4.2	3.9	3.5	3.6	2.2	2.3	3.1	3.3	2.2	2.5	2.8
BOD	3.6	3.4	2.7	3.1	2.7	3.8	3.7	5.3	4.1	5	4.2
COD	6.9	7.2	6.2	8.5	6.7	7.3	8.5	7.2	5	6.3	5.8
Nitrates	7.23	3.87	0.3	3.87	2.03	3.87	ND	0.81	ND	0.569	2.83
Nitrites	ND	0.53	ND	0.12	ND	1	0.36	0.11	3.5	0.15	0.43
Sulphates	268	278	32	109	44	46	228	16.5	14	40.3	16.1
Chlorides	82	23	6	15	27	30	21	209	59.9	9.99	104
Phosphates	0.31	0.25	0.31	0.15	0.3	0.17	0.24	0.17	0.2	0.16	0.21

Table- 1 Continuous.....

Parameters	C12	C13	C14	C15	C16	C17	C18	C19	C20	Mean	S.D	C.V.
Temperature (°C)	32.24	32.53	32.7	28.6	31.8	31.6	31.8	29.3	35.5	31.403	2.435	7.7
pH	6.1	6.8	6.6	6.9	6.2	6	6.8	7.5	6.2	6.62	0.545	8.2
Turbidity (NTU)	1.7	1.5	1.8	1.6	1.16	1.61	1.85	1.4	1.23	1.479	0.279	18.8
Dissolved Oxygen	2.4	3.3	3.7	4.2	4.7	5.6	8.2	6.7	5.6	3.9	1.595	40.8
BOD	8.4	7.4	6.5	3.2	3.15	5.7	5.3	4.8	3.9	4.497	1.562	34.7
COD	8	7.2	7.5	8	6.5	6.1	5.7	8	8	7.03	0.983	13.9
Nitrates	7.38	7.17	7.7	4.1	5.8	2.4	3	8	0.22	3.952	2.696	68.2
Nitrites	2.6	0.5	0.3	0.5	2.5	5.3	0.4	2.3	0.4	1.235	1.484	120.1
Sulphates	15.8	5	25	2	100	5	180	38	205	83.385	94.070	112.8
Chlorides	25	84	25	31	42	61	75	25	34	49.444	46.471	93.9
Phosphates	0.52	1.8	0.41	0.32	1.5	0.27	0.55	0.51	0.16	0.425	0.439	103.1

C1: Near Sanjay Gandhi P.G. College Sidhi, C2: Near Deosar Bus stand, C3: Near primary school, Parsohar, C4: Near Sanjay Gandhi P.G. College, Jiawan, C5: Near Sanjay Gandhi P.G. College, Chitrangi, C6: Near temple Sinhawal, C7: Near N.T.P.C, Singrauli, C8: Near Bus stand & temple Churhat, C9: Near Rampur Govt. P.G. College, C10: Near Majholi school, C11: Near post office, Gainuwar, C12: Near Madwas primary school, C13: Near Sarsal gram panchayat hall, C14: Near Kusmi Bus stand, C15: Near primary school, Surai, C16: Near high school, Tagawa, C17: Near Bank Tal, C18: Near grameen Bank, Majgaon, C19: Suhiya residential area, C20: Near primary school, Pankuora.

All the parameters are expressed in mg/l except pH, Temperature and Turbidity, ND = Not detected

The correlation coefficient (r) among various water quality parameter are given in table 1.a. Temperature of ground water during monsoon showed positive relationship with BOD, nitrites, temperatures, chlorides and phosphates and negative relationship with pH, turbidity, DO, COD and nitrates. The pH of the ground water showed significant positive relationship between DO, COD, nitrates, sulphates and chlorides and negative relationship with temperature, turbidity, BOD, nitrites and phosphates. Turbidity showed significant positive relationship with DO, BOD and nitrates and negative relationship with temperature, pH, COD, nitrites, sulphates, chlorides and phosphates.

Table – 1a Correlation coefficients (r) among various water quality parameter (Physico chemical characteristics of ground water in Sidhi district during Monsoon)

Parameters	Temp	pH	Turbi dity	DO	BOD	COD	Nitrates	Nitrite s	Sulph ates	Chlorid es	Phosph ates
Temperature (°C)	1										
pH	-0.477 - 2.304*	1									
Turbidity (NTU)	-0.246 -1.076	- 0.133 - 0.658	1								
Dissolved Oxygen	-0.061 -0.275	0.117 0.499	0.131 0.560	1							
BOD	0.391 1.802	- 0.128 - 0.546	0.150 0.643	0.029 0.123	1						
COD	-0.101 0.479	0.105 0.447	-0.116 0.561	-0.006 -0.024	0.059 0.250	1					
Nitrates	-0.353 -1.601	0.365 1.662	0.225 1.028	0.182 4.241* *	0.435 2.050*	0.311 1.388	1				

Nitrites	0.096 0.409	- 0.269 - 1.184	-0.037 -0.150	0.164 0.704	0.287 1.271	-0.283 -1.251	0.092 0.391	1			
Sulphates	-0.02 -0.085	0.134 0.573	-0.289 0.975	0.31 1.384	-0.357 1.620	0.212 0.941	-0.060 -0.240	-0.323 -1.448	1		
Chlorides	0.253 1.109	0.215 0.934	-0.165 -0.708	0.039 0.165	0.229 1.002	-0.256 -1.123	-0.083 -0.326	-0.038 -0.155	-0.134 -0.573	1	
Phosphates	0.055 0.233	- 0.004 - 0.016	-0.031 -0.123	0.145 0.621	0.335 1.508	-0.037 -0.150	0.510 0.302	0.123 0.525	-0.139 -0.594	0.069 0.292	1

1% Level of significance = *, 5% Level of significance = *

Dissolved oxygen (DO) showed positive relationship with pH, turbidity, BOD, nitrates, nitrites, sulphates, chlorides and phosphates and negative relationship with temperature and COD. Biochemical Oxygen Demand (BOD) showed positive relationship with temperature, turbidity, DO, COD, nitrates, nitrites, chlorides and phosphates and negative relationship with pH and sulphates. Chemical Oxygen Demand (COD) showed positive relationship with pH, BOD, nitrates and sulphates and negative relationship with temperature, turbidity, DO, nitrites, chlorides and phosphates.

Nitrates showed significant positive relationship with pH, turbidity, DO, BOD, COD, nitrites and phosphates and negative relationship with temperature, sulphates and chlorides. Nitrites showed positive relationship with temperature, DO, BOD, nitrates and phosphates and negative relationship with pH, turbidity, COD, sulphates and chlorides. Sulphates of the ground water showed significant positive relationship with pH, DO and COD and negative relationship with temperature, turbidity, BOD, nitrates, nitrites, chlorides, phosphates. Chlorides showed significant positive relationship with temperature, pH, DO, BOD, and phosphates and negative relationship with turbidity, COD, nitrates, nitrites and sulphate. Phosphates showed significant positive relationship between ground water temperature, DO, BOD, nitrates, nitrites and chlorides and negative relationship with pH, turbidity, COD and sulphates.

The present study deals with the various relationship derived statistically by calculation 'r' and 't' among the physicochemical characteristics, the r value was negative 26 times and positive 29 times, this showed that positive relationship in the present study. The value of t is slightly exceeded from the calculated value of 5% significant level in the case of pH and temperature i.e -2.304, while nitrate and BOD shows positive relationship i.e 2.150 which is closer to the 1% significant value. For nitrate and DO also shows positive relationship up to 5% significant level i.e 4.241 which is two times more than from calculated value of 5% significant level. Showed that pH, temperature, nitrates, BOD, DO, play major role in the physicochemical characteristics of ground water of Sidhi District during monsoon season.

The mean values of eleven parameters of ground water analyzed in 20 station together with their SD and CV are presented in **table 2**. The water temperature averaged 23.43⁰C which was lower than the average value of ground water of Suhiya (24.8) at location C₁₉ and higher than those of Gainuwar (19.1⁰c) at location C₁₁ in Sidhi District during winter season.

pH was ranging from 6.0-7.6 with an mean value of 6.74, WHO (1984) prescribed the desirable limit of pH range between 7 and 8.5 mg/l. The turbidity of water was found to be 1.0-1.93 NTU and the mean value was 1.450NTU. The mean values of DO, BOD and COD in the ground water of Sidhi District during winter season were 3.37mg/l, 1.568mg/l and 7.37mg/l respectively. The DO, BOD and COD values observed in the present study were well with in the limit prescribed by WHO for drinking water. The CV values of temperature (7.7), pH (7.9), turbidity (19.1), dissolved oxygen (42.2), BOD (36.4) and COD (11.7) showed that wide fluctuation of there for relation of these parameters did not occur between stations. In the case of nitrate, nitrites, sulphates, chloride and phosphates, the mean value were recorded

as 3.702, 1.485, 70.97, 44.65 and 0.308mg/l and all the results are within the permissible limit. The phosphates content of water was found to be 0.1 to 1.2mg L⁻¹. the highest value of 1.2mg L⁻¹ was recorded at location Tagawa (C₁₆) while the minimum value 0.1mg L⁻¹ was recorded at location Jiawan (C₄) as show in the **table 2**. Values of phosphates at Madwas (0.46), Sarsal (0.87), Tagawa (1.2), Tal (0.45), Majgaon (0.46) mg L⁻¹ are higher than the permissible limit prescribed by WHO and BIS. The CV value of nitrates (60.2), nitrites (112.9), sulphates (106.3), chlorides (73.3), phosphates (92.6), indicated their significant variation from one station to another.

The correlation coefficient (r) among various water quality parameters are given in **table 2a**. The temperature of ground water during winter showed positive relationship with DO, COD, nitrates, nitrites and sulphates and negative relationship with pH, turbidity, BOD, chlorides and phosphates. The pH of the ground water showed significant positive relationship between DO, nitrates, sulphates and chlorides and negative relationship with temperature, turbidity, BOD, COD, nitrites and phosphates. Turbidity showed significant positive relationship with BOD, COD, nitrates and negative relationship with pH, DO, nitrites, sulphates, chlorides and phosphates.

Table 2: Physico-chemical characteristics of ground water in Sidhi District during winter

Parameters	Sampling Locations										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Temperature (°C)	24.3	24.3	24.1	24.4	23.4	24.7	24.8	19.2	23.1	24.6	19.1
pH	6.8	7.6	6.2	6.1	7.5	7.5	6.4	7	6.8	6.2	7.5
Turbidity (NTU)	1.5	1.2	1.7	1.7	1.6	1.2	1.2	1	1.4	1.2	1.93
Dissolved Oxygen	3.6	3.8	3.6	3.7	2.1	2	3.1	3.2	2	2.3	2.5
BOD	3.3	3.1	2.6	2.8	2.6	3.7	3.5	5.2	4	5	4
COD	7	7.5	6.7	8.2	7.3	7.4	9	7.5	5.4	7	6.1
Nitrates	6.76	3.22	ND	3.22	1.65	4.03	ND	0.75	2.34	0.547	1.34
Nitrites	ND	0.51	ND	0.15	ND	1.02	0.25	0.1	3.15	0.1	0.4
Sulphates	200	200	35	100	30	50	205	10	10	30	11.5
Chlorides	25	27	10	19	30	36	26	150	60	10	75
Phosphates	0.26	0.23	0.11	0.1	0.14	ND	0.2	0.15	0.18	0.15	0.12

Table- 2 Continuous.....

Parameters	C12	C13	C14	C15	C16	C17	C18	C19	C20	Mean	S.D	C.V.
Temperature (°C)	21	21.1	24.7	24.3	24.1	24.1	24.3	24.8	24.2	23.43	1.811	7.7
pH	6	6.7	6.2	6.7	6.5	6.2	7	7.4	6.5	6.74	0.533	7.9
Turbidity (NTU)	1.75	1.8	1.5	1.68	1	1.4	1.1	1.5	1.65	1.450	0.278	19.1
Dissolved Oxygen	2.3	3.2	3.6	4	4.3	5.4	8	6.5	5.4	3.73	1.575	42.2
BOD	8.3	7	6.3	3	2.9	5.6	5.2	4.2	3.7	4.3	1.568	36.4
COD	8.3	7.5	7.6	8.2	6.7	7.6	6.2	8	8.2	7.37	0.863	11.7
Nitrates	6.86	6.92	6.23	3.02	4.27	2.13	2.98	6.68	ND	3.702	2.230	60.2
Nitrites	2.8	0.7	0.5	ND	3.3	5.8	ND	2.7	0.8	1.485	1.678	112.9
Sulphates	5	5	15	ND	75	7	150	35	175	70.973	75.451	106.3
Chlorides	29	87	27	36	45	65	69	28	39	44.65	32.759	73.3
Phosphates	0.46	0.87	0.23	0.21	1.2	0.23	0.45	0.46	0.11	0.308	0.285	92.6

C1: Near Sanjay Gandhi P.G. College Sidhi, **C2:** Near Deosar Bus stand, **C3:** Near primary school, Parsohar, **C4:** Near Sanjay Gandhi P.G. College, Jiawan, **C5:** Near Sanjay Gandhi P.G. College, Chitrangi, **C6:** Near temple Sinhawal, **C7:** Near N.T.P.C,

Singrauli, C8: Near Bus stand & temple Churhat, C9: Near Rampur Govt. P.G. College, C10: Near Majholi school, C11: Near post office, Gainuwar, C12: Near Madwas primary school, C13: Near Sarsal gram panchayat hall, C14: Near Kusmi Bus stand, C15: Near primary school, Surai, C16: Near high school, Tagawa, C17: Near Bank Tal, C18: Near grameen Bank, Majgaon, C19: Suhiya residential area, C20: Near primary school, Pankuora.

All the parameters are expressed in mg/l except pH, Temperature and Turbidity, ND = Not detected

Table – 2a Correlation coefficients (r) among various water quality parameter (Physico chemical characteristics of ground water in Sidhi district during winter)

Parameters	Temp	pH	Turbidity	DO	BOD	COD	Nitrates	Nitrites	Sulphates	Chlorides	Phosphates
Temperature (°C)	1										
pH	-0.172 -0.740	1									
Turbidity (NTU)	-0.269 -1.184	0.128 0.546	1								
Dissolved Oxygen	0.338 1.522	0.002 0.008	-0.185 -0.798	1							
BOD	-0.415 -1.936	0.328 1.081	0.109 0.464	0.004 0.016	1						
COD	0.209 0.906	0.275 1.213	0.111 0.473	0.059 0.250	0.109 0.464	1					
Nitrates	0.018 0.076	0.026 0.110	0.180 0.776	0.088 0.375	0.447 2.120*	0.093 0.394	1				
Nitrites	0.032 0.135	0.199 0.862	-0.098 0.379	0.167 0.718	0.290 1.285	-0.07 1.125	0.213 0.924	1			
Sulphates	0.431 2.026*	0.097 0.413	-0.299 -1.329	0.315 1.407	-0.392 -1.808	0.205 0.885	-0.124 -0.530	-0.307 -1.369	1		
Chlorides	-0.729 4.520**	0.249 1.090	-0.209 0.906	0.071 0.301	0.328 1.473	-0.232 1.023	-0.091 -0.355	0.089 0.378	-0.284 -0.961	1	
Phosphates	-0.079 -0.311	0.116 0.495	-0.159 -0.682	0.258 1.132	0.253 1.109	-0.088 2.906**	0.497 2.431*	0.340 1.534	-0.059 -0.236	0.152 0.651	1

1% Level of significance = **, 5% Level of significance = *

Dissolved oxygen (DO) showed positive relationship with temperature, pH, BOD, COD, nitrates, nitrites, Sulphates, chlorides and phosphates and negative relationship with turbidity. Biochemical oxygen demand (BOD) showed positive relationship with turbidity, DO, COD, nitrates, nitrites, chlorides and phosphates and negative relationship with temperature, pH, sulphates. Chemical oxygen demand (COD) showed positive relationship with temperature, turbidity, DO, BOD, nitrates and sulphates and negative relationship with pH, nitrites, chlorides and phosphates.

Nitrates Showed significant positive relationship with temperature, pH, turbidity, DO, BOD, COD, nitrites and phosphates and negative relationship with sulphates and chlorides. Nitrites showed positive relationship with temperature, DO, BOD, nitrates, chlorides and phosphates and negative relationship with pH, turbidity, COD and sulphates. Sulphates showed significant positive relationship with temperature, pH, DO, and COD, and negative relationship with turbidity, BOD, nitrates, nitrites, chlorides and

phosphates. Chlorides showed significant positive relationship with pH, DO, BOD, nitrites and phosphates and negative relationship with temperature, turbidity, COD, nitrates and sulphates.

Phosphates showed significant positive relationship between ground water DO, BOD, nitrates, nitrites and phosphates and negative relationship with temperature, pH, turbidity, COD, and sulphates.

The various relationship derived statistically by calculation 'r' and 't', among the physicochemical characteristics the r value was negative 24 times and positive 31 times this showed that positive relationship in the present study. During winter season, correlated different parameter each other statically which shows great variation negative to positive values for 1% significant value (2.878), and 5% significant value (2.101). For the nitrate and BOD we have found 2.120 correlations which is slightly greater than 5% significant value. Further phosphate and nitrate shows the 2.431 which greater than 5% significant value. While chloride and temperature, phosphate and COD shows negative relationship i.e - 4.520 and -2.906 respectively with each other at 1% significant level. It showed that nitrates, BOD, phosphates chlorides play major role in the physicochemical characteristics of ground water of Sidhi District during winter season.

The mean values of eleven parameters of ground water analysed in 20 stations together with their SD and CV are present in **table 3**. The water temperature averaged 36.86⁰C which was lower than the average value of ground water of Pankuora (39.2⁰C) at location C₂₀ and higher than those of surai (35.0⁰c) at location C₁₅ in Sidhi District during summer season.

pH was ranging from 5.9-7.7 (mean value of 6.75), and turbidity of water was found to be 1.0-7.82 NTU (mean value 2.005 NTU). The highest value of 7.82 NTU was found at location C₁₃, while the minimum value 1.0 NTU was found at location C₅ as show in the **table 3**. The mean value of DO in the ground water of Sidhi District during summer season was 3.605mg/l which ranged between 1.8-7.1mg/l, the maximum value was recorded during the summer period in samples C₁₈ collected from Majgaon. The mean values of BOD and COD in the ground water of Sidhi District during monsoon season were 4.135mg/l and 7.805mg/l respectively. The biochemical oxygen demand of water was found to be 2.1- 8.0mg/l and highest value of BOD 8.0mg/l recorded at location C₁₂, while the minimum value 2.1 mg/l was recorded at location C₂ as show in the **table 3**. Values of BOD at Madwas (8.0), Sarsal (6.5) mg/l exceeded within permissible limit prescribed by WHO and COD values observed within the permissible limit (10mg/l for COD) prescribed by WHO for drinking water. The CV values of temperature (2.7), pH (6.7), dissolved oxygen (39.9), BOD (41) and COD (12.6) are lower than 50%, therefore variation of these parameters are not significant between sampling stations, while turbidity (98.4) shows CV value which means value of turbidity do not varies from one sampling stations to another station. In the case of nitrates, nitrites, sulphate, chloride and phosphates the mean values were recorded as 3.600, 1.48, 62.51, 48.6, 0.301mg/l and all the results are within the permissible limit. The phosphates content of water was found to be 0.09-1.0mg/l. the highest value of 1.0mg/l was recorded at location Tagawa (C₁₆), while the minimum value 0.09 mg/l was recorded at location Parsohar (C₃) as show in **table 3**. Values of phosphates at Madwas (0.37), Sarsal (0.75), Majgaon (0.37) Suhiya (0.45) mg/l are higher than the permissible limit prescribed by WHO and BIS. The high CV values of nitrates (61), nitrites (108.2), sulphate (114.8), chloride (66.2) and phosphates (80.9) indicated their significant variation from one station to another.

The correlation coefficient (r) among various water quality parameters are given in **table 3a**. The temperature of ground water in Sidhi District during summer showed positive relationship with pH, nitrites, sulphates and phosphates and negative relationship with turbidity, DO, BOD, COD, nitrates and chlorides. The pH of the ground water showed significant positive relationship between temperature, DO, sulphates and Chlorides and negative relationship with turbidity, BOD, COD, nitrates, nitrites and

phosphates. Turbidity showed significant positive relationship with BOD, COD, nitrates, chlorides and phosphates and Negative relationship with temperature, pH, DO, nitrites and sulphates.

Dissolved oxygen (DO) showed positive relationship with pH, COD, nitrates, nitrites, sulphates, chlorides and phosphates and negative relationship with temperature, turbidity and BOD. Biochemical oxygen demand (BOD) showed positive relationship with turbidity, COD, nitrates, nitrites, chlorides and phosphates and negative relationship with pH, DO and sulphates. Chemical oxygen Demand (COD) showed positive relationship with turbidity, DO, BOD, nitrates and sulphates and negative relationship with temperature, pH, nitrites, chlorides and phosphates.

Nitrates showed significant positive relationship with turbidity, DO, BOD, COD, nitrites, sulphates, chlorides and phosphates and negative relationship with temperature, pH. Nitrites showed positive relationship with temperature, DO, BOD, nitrates and phosphates and negative relationship with pH, turbidity, COD, sulphates and chlorides. Sulphates of the ground water showed significant positive relationship with temperature, pH, DO, COD, nitrates and phosphates and negative relationship with turbidity, BOD, nitrites and chlorides. Chloride showed significant positive relationship with pH, turbidity, DO, BOD, nitrates and phosphates and negative relationship with temperature, COD, nitrites and sulphates.

Phosphates showed significant positive relationship between ground water temperature, turbidity, DO, BOD, nitrates, nitrites, sulphates and chlorides and negative relationship with pH and COD.

The present study deals with the various relationship derived statistically by calculation 'r' and t among the physicochemical characteristics the r value was negative 23 times and positive 32 times this showed that positive relationship in the present study. During summer season we have investigated the different physico-chemical characteristics of ground water of Sidhi district and stabilised the correlation by using ANOVA statistical software. The table values of 5% significant level were 2.101 and at 1% significant level were 2.878. In case of nitrate and turbidity, phosphate and nitrate we established a correlation ship which were positive and values were 2.291 and 2.680 respectively, which was greater than 5% significant level. For sulphate and BOD we have found negative value of corelationship at 5% significant level i.e - 2.536. It showed that nitrates, turbidity, sulphates, BOD, phosphates play major role in the present study.

Table 3: Physico-chemical characteristics of ground water in Sidhi District during summer

Parameters	Sampling Locations										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Temperature (°C)	36.5	37.5	36.1	36.2	36.8	37.3	36.3	35.2	38.5	38.1	36.5
pH	6.6	7.4	6.4	5.9	7.4	7.7	6.6	6.8	6.5	6.5	7.1
Turbidity (NTU)	1.2	1.8	1.5	1.8	1	1	1.4	1.1	1.2	1.1	1.5
Dissolved Oxygen	3.9	3.8	3.4	3.6	2.3	1.8	3	3.1	2	2	2.3
BOD	2.2	2.1	2.5	2.5	2.4	3.9	3.5	5.4	3.9	5.2	3.9
COD	7.1	8.2	7.5	8.6	7.9	7.5	9.3	8.2	5.7	7.2	6.2
Nitrates	6.55	3.19	ND	3.16	1.35	3.85	ND	0.71	ND	0.535	1.15
Nitrites	ND	0.34	ND	0.03	ND	0.02	0.21	ND	3	0.35	0.23
Sulphates	210	198	20	95	35	30	185	12	10	5	2.9
Chlorides	91	28	15	14	33	47	30	130	50	7	80
Phosphates	0.25	0.21	0.09	0.35	ND	ND	0.15	0.13	0.15	0.12	0.17

Table- 3 Continuous.....

Parameters	C12	C13	C14	C15	C16	C17	C18	C19	C20	Mean	S.D	C.V.
Temperature (°C)	36.6	36.4	37.5	35	37.4	36.3	36.8	37.1	39.2	36.865	1.012	2.7
pH	6	6.8	6.4	6.5	6.8	6.5	7	7.2	6.9	6.75	0.458	6.7
Turbidity (NTU)	1.6	7.82	7.6	1.5	1	2.1	1.4	1.12	1.36	2.005	1.973	98.4
Dissolved Oxygen	2.3	3.1	3.5	4	4.2	5.3	7.1	6.2	5.2	3.605	1.440	39.9
BOD	8	6.8	6.1	2.8	2.6	5.7	5.4	4.6	3.2	4.135	1.697	41
COD	8.7	7.7	8.2	9.7	6.9	7.9	6.8	8.2	8.6	7.805	0.984	12.6
Nitrates	6.17	6.57	6.12	3	4.1	2	2.62	6.53	ND	3.600	2.197	61
Nitrites	3.2	1	0.8	1.2	2.6	5.7	0.6	3.1	1.3	1.48	1.602	108.2
Sulphates	10	3	20	ND	70	9	95	28	150	62.521	71.835	114.8
Chlorides	35	93	20	47	38	68	81	23	42	48.6	32.199	66.2
Phosphates	0.37	0.75	0.26	ND	1	0.21	0.37	0.45	0.1	0.301	0.244	80.9

C1: Near Sanjay Gandhi P.G. College Sidhi, C2: Near Deosar Bus stand, C3: Near primary school, Parsohar, C4: Near Sanjay Gandhi P.G. College, Jiawan, C5: Near Sanjay Gandhi P.G. College, Chitrangi, C6: Near temple Sinhawal, C7: Near N.T.P.C, Singrauli, C8: Near Bus stand & temple Churhat, C9: Near Rampur Govt. P.G. College, C10: Near Majholi school, C11: Near post office, Gainuwar, C12: Near Madwas primary school, C13: Near Sarsal gram panchayat hall, C14: Near Kusmi Bus stand, C15: Near primary school, Surai, C16: Near high school, Tagawa, C17: Near Bank Tal, C18: Near grameen Bank, Majgaon, C19: Suhiya residential area, C20: Near primary school, Pankuora.

All the parameters are expressed in mg/l except pH, Temperature and Turbidity, ND = Not detected

Table -3a Correlation coefficients (r) among various water quality parameters (Physico chemical characteristics of ground water in Sidhi district during summer)

Parameters	Temp	pH	Turbidity	DO	BOD	COD	Nitrates	Nitrites	Sulphates	Chlorides	Phosphates
Temperature (°C)	1										
pH	0.210 0.910	1									
Turbidity (NTU)	-0.011 0.046	-0.170 -0.731	1								
Dissolved Oxygen	-0.008 -0.032	0.062 0.263	-0.035 -0.143	1							
BOD	-0.041 -0.180	-0.254 -1.113	0.477 1.776	-0.009 -0.038	1						
COD	-0.370 -1.688	-0.213 -0.929	0.092 0.391	0.136 0.581	0.018 0.076	1					
Nitrates	-0.123 -0.525	-0.030 -0.123	0.475 2.291*	0.182 0.785	0.331 1.488	0.121 0.517	1				
Nitrites	0.140 0.598	-0.226 -0.795	-0.012 -0.049	0.315 1.407	0.393 1.813	-0.042 -0.170	0.169 0.726	1			
Sulphates	0.196 0.847	0.123 0.525	-0.211 -0.916	0.273 1.203	-0.513 - 2.536*	0.176 0.758	0.001 0.004	-0.305 -1.358	1		
Chlorides	-0.383 -1.759	0.181 0.776	0.077 0.199	0.105 0.445	0.245 1.072	-0.245 -1.072	0.058 0.246	-0.025 -0.103	-0.047 -0.209	1	
Phosphates	0.045 0.190	-0.127 -0.542	0.331 1.488	0.287 1.271	0.224 0.975	-0.186 -0.803	0.534 2.680*	0.306 1.363	0.006 0.025	0.088 0.376	1

1% Level of significance = **, 5% Level of significance = *

The average physicochemical characteristics of Sidhi District are presented in table 4. The variation of temperature in this District was observed to be 19.1°C minimum to 39.2°C maximum. pH was ranging from 5.9 to 7.7 with an average of 6.03-7.57. The range of turbidity was found to be 1.0 to 7.82 NTU and dissolved oxygen was ranged between 1.8 to 8.2 mg/l. BOD and COD were in the range of 2.1 - 8.4, 5.0 - 9.7mg/l respectively. In

the case of nitrates, nitrites, sulphates, chlorides and phosphates, values were ranged between 0.22, 0.02, 2.9, 6.0 and 0.09 to 7.7, 5.8, 278, 209 and 1.8 mg/l respectively. The maximum nitrate, sulphates, chlorides and phosphates concentrations were observed during the monsoon season. In the case of turbidity only one location that is C13 was found to be maximum and exceeding the prescribed limit. Even the sulphates concentration in the ground water of Sidhi District was also exceeding the prescribed limit.

Table 4: Average physico-chemical characteristics of ground water in Sidhi District

	Sampling Locations									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Temperature (oC)	29.8	30.2	29.6	29.6	29.7	30.5	32.2	29.1	31.6	32.2
SD (±)	6.2	6.7	6.1	6.0	6.7	6.4	6.4	8.7	7.8	6.9
pH	6.77	7.57	6.20	6.07	7.37	7.50	6.33	6.93	6.50	6.23
SD (±)	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.1	0.3	0.3
Turbidity (NTU)	1.4	1.4	1.7	1.8	1.4	1.2	1.3	1.1	1.3	1.1
SD (±)	0.2	0.4	0.2	0.1	0.4	0.1	0.1	0.1	0.1	0.1
Dissolved Oxygen	3.9	3.8	3.5	3.6	2.2	2.0	3.1	3.2	2.1	2.3
SD (±)	0.3	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.3
BOD	3.0	2.9	2.6	2.8	2.6	3.8	3.6	5.3	4.0	5.1
SD (±)	0.7	0.7	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.1
COD	7.0	7.6	6.8	8.4	7.3	7.4	8.9	7.6	5.4	6.8
SD (±)	0.1	0.5	0.7	0.2	0.6	0.1	0.4	0.5	0.4	0.5
Nitrates	6.85	3.43	0.30	3.42	1.68	3.92	ND	0.76	2.34	0.55
SD (±)	0.3	0.4	-	0.4	0.3	0.1	-	0.1	-	0.0
Nitrites	ND	0.46	ND	0.10	ND	0.68	0.27	0.11	3.22	0.20
SD (±)	-	0.1	-	0.1	-	0.6	0.1	0.0	0.3	0.1
Sulphates	226	225	29	101	36	42	206	13	11	25
SD (±)	37	46	8	7	7	11	22	3	2	18
Chlorides	66	26	10	16	30	38	26	163	57	9
SD (±)	36	3	5	3	3	9	5	41	6	2
Phosphates	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
SD (±)	0.03	0.02	0.12	0.13	0.11	-	0.05	0.02	0.03	0.02

Table- 4 Continuous.....

Parameters	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
Temperature (oC)	29.9	29.9	30.0	31.6	29.3	31.1	30.7	31.0	30.4	33.0
SD (±)	9.4	8.0	8.0	6.5	5.4	6.7	6.2	6.3	6.2	7.8
pH	7.13	6.03	6.77	6.40	6.70	6.50	6.23	6.93	7.37	6.53
SD (±)	0.4	0.1	0.1	0.2	0.2	0.3	0.3	0.1	0.2	0.4
Turbidity (NTU)	1.8	1.7	3.7	3.6	1.6	1.1	1.7	1.5	1.3	1.4
SD (±)	0.2	0.1	3.6	3.4	0.1	0.1	0.4	0.4	0.2	0.2
Dissolved Oxygen	2.5	2.3	3.2	3.6	4.1	4.4	5.4	7.8	6.5	5.4
SD (±)	0.3	0.1	0.1	0.1	0.1	0.3	0.2	0.6	0.3	0.2
BOD	4.0	8.2	7.1	6.3	3.0	2.9	5.7	5.3	4.5	3.6
SD (±)	0.2	0.2	0.3	0.2	0.2	0.3	0.1	0.1	0.3	0.4
COD	6.0	8.3	7.5	7.8	8.6	6.7	7.2	6.2	8.1	8.3
SD (±)	0.2	0.4	0.3	0.4	0.9	0.2	1.0	0.6	0.1	0.3
Nitrates	1.77	6.80	6.89	6.68	3.37	4.72	2.18	2.87	7.07	0.22
SD (±)	0.9	0.6	0.3	0.9	0.6	0.9	0.2	0.2	0.8	-
Nitrites	0.35	2.87	0.73	0.53	0.85	2.80	5.60	0.50	2.70	0.83
SD (±)	0.1	0.3	0.3	0.3	0.5	0.4	0.3	0.1	0.4	0.5
Sulphates	10	10	4	20	2	82	7	142	34	177
SD (±)	7	5	1	5	-	16	2	43	5	28
Chlorides	86	30	88	24	38	42	65	75	25	38
SD (±)	16	5	5	4	8	4	4	6	3	4
Phosphates	0.2	0.5	1.1	0.3	0.3	1.2	0.2	0.5	0.5	0.1
SD (±)	0.05	0.08	0.57	0.10	0.08	0.25	0.03	0.09	0.03	0.03

The heavy metals concentrations in the ground water samples of Sidhi District in different seasons and average values with their standard deviations are presented in **table 5** and **6**. The lead concentration was recorded maximum during the summer season (1.0 ppm) and minimum of 0.01 ppm in monsoon season. Cadmium concentration was found to be 0.076 ppm maximum in monsoon and minimum of 0.003 ppm during summer. Maximum concentrations of Nickel, Iron, Chromium and Copper are observed to be 0.659, 2.33, 0.062 and 0.91 ppm, while minimum values were recorded as 0.007, 0.01, 0.017, 0.005 ppm, respectively. The average individual metals concentrations from different locations in Sidhi District are presented in **figure 2a** and **2b**.

Table5: Seasonal variation of metals concentration in ground water samples at different sampling points in Sidhi District

Metals (ppm)		Sampling Locations									
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Lead	Monsoon	0.048	0.022	0.043	0.035	0.123	0.02	0.40	0.565	0.345	0.285
	Winter	0.057	0.037	0.057	0.071	0.095	0.05	0.20	0.567	0.348	0.289
	Summer	0.043	0.021	0.036	0.049	0.81	1.00	0.01	0.569	0.415	0.300
Cadmium	Monsoon	0.057	0.068	0.056	0.073	ND	0.076	0.068	0.047	0.037	0.052
	Winter	0.049	0.062	0.059	0.067	ND	0.072	0.059	0.039	0.041	0.047
	Summer	0.047	0.065	0.053	0.062	ND	0.066	0.00	0.028	0.032	0.041
Nikel	Monsoon	0.025	ND	ND	0.023	0.027	0.042	0.019	0.015	0.023	0.015
	Winter	0.027	ND	ND	0.033	0.038	0.023	0.021	0.017	0.013	0.007
	Summer	0.024	ND	ND	0.027	0.028	0.033	0.019	0.018	ND	0.011
Iron	Monsoon	0.155	0.05	0.10	1.22	0.14	0.21	0.55	0.27	1.19	0.35

	Winter	0.19	0.07	0.12	1.24	0.18	0.23	0.67	2.33	1.21	0.38
	Summer	0.15	0.03	0.06	1.00	0.12	0.20	0.47	2.21	1.00	0.34
Cromium	Monsoon	0.023	0.024	0.37	0.045	0.046	0.02	0.018	0.039	0.028	0.036
	Winter	0.030	0.026	0.042	0.044	0.045	0.02	0.019	0.040	0.019	0.038
	Summer	0.027	0.023	0.03	0.041	0.043	0.02	0.017	0.042	0.025	0.035
Copper	Monsoon	0.03	0.01	0.05	0.76	0.26	0.52	0.45	0.26	0.25	0.16
	Winter	0.18	0.25	0.14	0.91	0.35	0.76	0.88	0.45	0.48	0.24
	Summer	0.04	0.02	0.07	0.87	0.33	0.65	0.50	0.31	0.37	0.19

Table- 5 Continuous.....

Metals (ppm)		Sampling Locations									
		C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
Lead	Monsoon	ND	0.297	0.230	0.219	ND	0.012	0.025	0.047	0.015	0.026
	Winter	ND	0.312	0.230	0.221	ND	0.017	0.028	0.049	0.018	0.033
	Summer	ND	0.315	0.235	0.223	ND	0.018	0.029	0.039	0.022	0.035
Cadmium	Monsoon	0.072	ND	0.005	0.007	0.003	0.006	0.004	0.003	ND	0.0058
	Winter	0.065	ND	0.005	0.007	0.003	0.005	0.004	0.003	ND	0.0046
	Summer	0.058	ND	0.005	0.006	0.003	0.00	0.029	0.0028	ND	0.0056
Nikel	Monsoon	0.025	0.346	0.298	0.655	ND	0.041	0.015	0.011	0.012	0.015
	Winter	0.034	0.659	0.293	0.356	ND	0.022	0.18	0.016	0.01	0.018
	Summer	0.027	0.654	0.295	0.358	ND	0.032	0.017	0.013	0.01	0.020
Iron	Monsoon	0.47	0.30	0.05	0.16	0.19	0.20	0.05	1.05	1.27	0.65
	Winter	0.52	0.35	0.09	0.19	0.21	0.24	0.15	1.07	1.35	0.77
	Summer	0.36	0.27	0.02	0.10	0.17	0.18	0.03	0.01	0.75	0.54
Cromium	Monsoon	0.023	0.046	0.034	0.037	ND	0.033	0.039	0.047	0.05	0.061
	Winter	0.025	0.048	0.036	0.039	ND	0.037	0.028	0.052	0.05	0.062
	Summer	0.023	0.045	0.033	0.035	ND	0.031	0.035	0.045	0.052	0.060
Copper	Monsoon	0.47	0.07	0.05	0.047	0.12	0.007	ND	0.095	0.009	0.092
	Winter	0.44	0.020	0.048	0.043	0.12	0.005	ND	0.046	0.006	0.042
	Summer	0.51	0.112	0.083	0.075	0.032	0.012	0.012	0.105	0.012	0.103

Table 6: Average metals concentration of ground water in Sidhi District

Parameters	Sampling Locations									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Lead	0.049	0.027	0.045	0.052	0.343	0.357	0.203	0.567	0.369	0.291
SD (±)	0.007	0.009	0.011	0.018	0.405	0.557	0.195	0.002	0.040	0.008
Cadmium	0.051	0.065	0.056	0.067	ND	0.071	0.042	0.038	0.037	0.047
SD (±)	0.005	0.003	0.003	0.006	-	0.005	0.037	0.010	0.005	0.006
Nikel	0.025	ND	ND	0.028	0.031	0.033	0.020	0.017	0.018	0.011
SD (±)	0.002	-	-	0.005	0.006	0.010	0.001	0.002	0.007	0.004
Iron	0.165	0.050	0.093	1.153	0.147	0.213	0.563	1.603	1.133	0.357

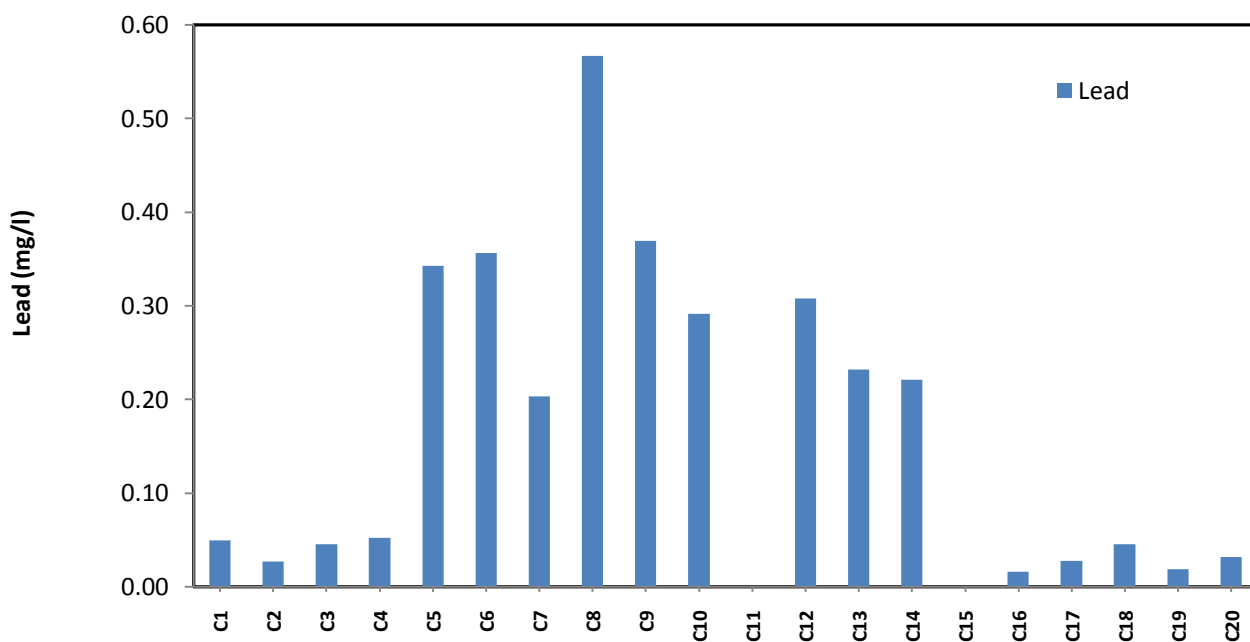
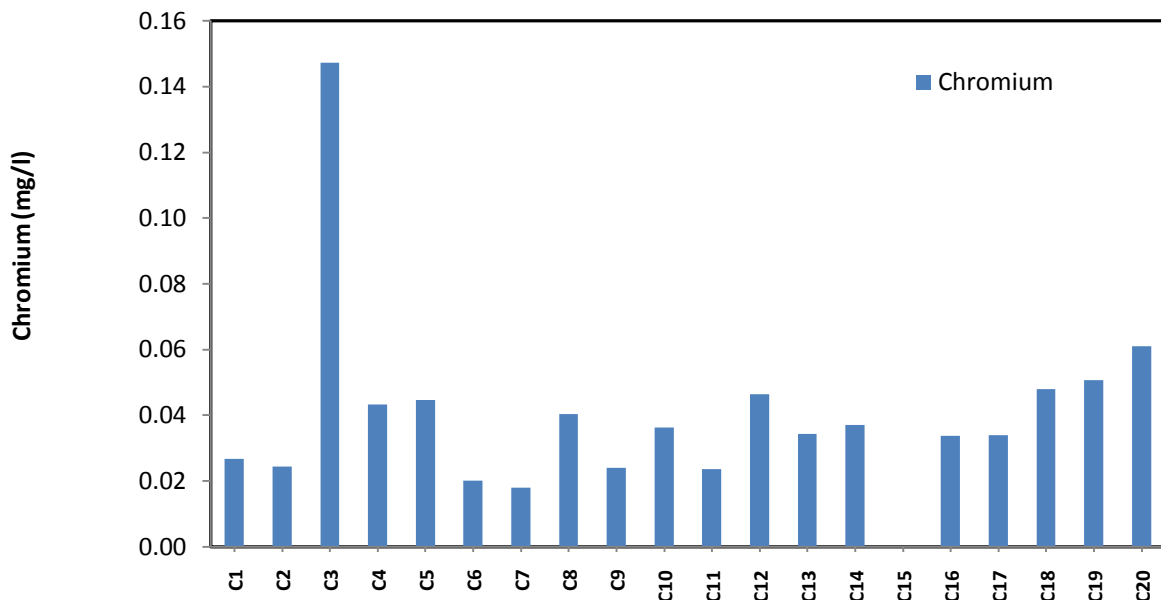
SD (\pm)	0.022	0.020	0.031	0.133	0.031	0.015	0.101	1.156	0.116	0.021
Cromium	0.027	0.024	0.147	0.043	0.045	0.020	0.018	0.040	0.024	0.036
SD (\pm)	0.004	0.002	0.193	0.002	0.002	0.000	0.001	0.002	0.005	0.002
Copper	0.083	0.093	0.087	0.847	0.313	0.643	0.610	0.340	0.367	0.197
SD (\pm)	0.084	0.136	0.047	0.078	0.047	0.120	0.235	0.098	0.115	0.040

Table- 6 Continuous.....

Parameters	Sampling Locations									
	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
Lead	ND	0.308	0.232	0.221	ND	0.016	0.027	0.045	0.018	0.031
SD (\pm)	-	0.010	0.003	0.002	-	0.003	0.002	0.005	0.004	0.005
Cadmium	0.065	ND	0.005	0.007	0.003	0.004	0.012	0.003	ND	0.005
SD (\pm)	0.007	-	0.000	0.001	0.000	0.003	0.014	0.000	-	0.001
Nikel	0.029	0.553	0.295	0.456	ND	0.032	0.071	0.013	0.011	0.018
SD (\pm)	0.005	0.179	0.003	0.172	-	0.010	0.095	0.003	0.001	0.003
Iron	0.450	0.307	0.053	0.150	0.190	0.207	0.077	0.710	1.123	0.653
SD (\pm)	0.082	0.040	0.035	0.046	0.020	0.031	0.064	0.606	0.326	0.115
Cromium	0.024	0.046	0.034	0.037	ND	0.034	0.034	0.048	0.051	0.061
SD (\pm)	0.001	0.002	0.002	0.002	-	0.003	0.006	0.004	0.001	0.001
Copper	0.473	0.067	0.060	0.055	0.091	0.008	0.012	0.082	0.009	0.079
SD (\pm)	0.035	0.046	0.020	0.017	0.051	0.004	-	0.032	0.003	0.033

C1: Near Sanjay Gandhi P.G. College Sidhi, **C2:** Near Deosar Bus stand, **C3:** Near primary school, Parsohar, **C4:** Near Sanjay Gandhi P.G. College, Jiawan, **C5:** Near Sanjay Gandhi P.G. College, Chitrangi, **C6:** Near temple Sinhawal, **C7:** Near N.T.P.C, Singrauli, **C8:** Near Bus stand & temple Churhat, **C9:** Near Rampur Govt. P.G. College, **C10:** Near Majholi school, **C11:** Near post office, Gainuwar, **C12:** Near Madwas primary school, **C13:** Near Sarsal gram panchayat hall, **C14:** Near Kusmi Bus stand, **C15:** Near primary school, Surai, **C16:** Near high school, Tagawa, **C17:** Near Bank Tal, **C18:** Near grameen Bank, Majgaon, **C19:** Suihya residential area, **C20:** Near primary school, Pankuora.

Concentration of metals are expressed in mg/l, ND = Not detected



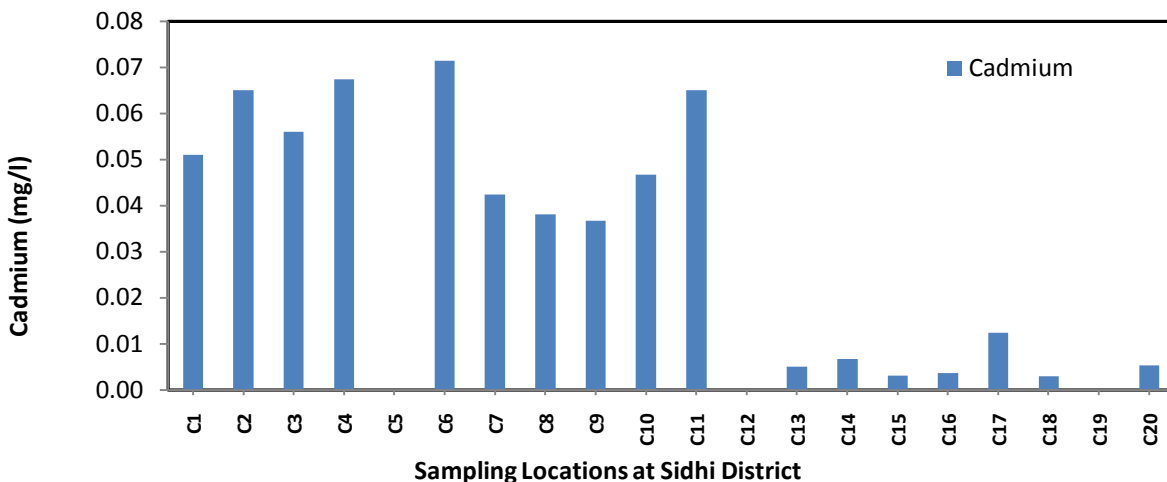
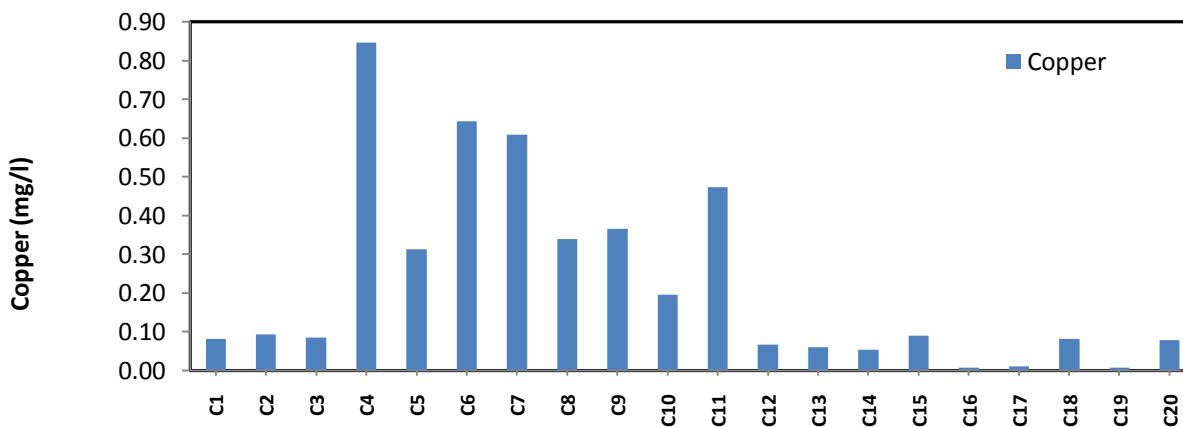
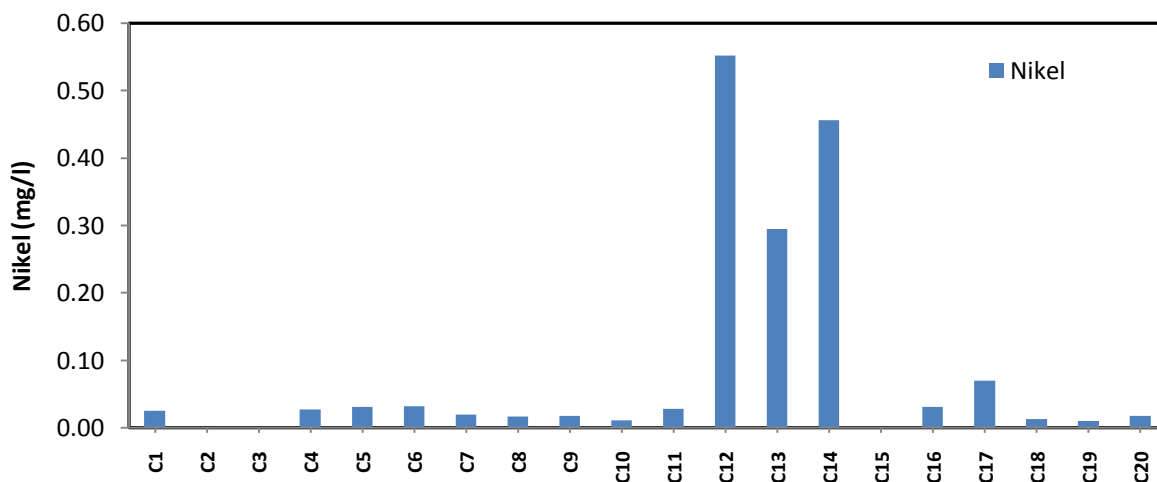


Figure 2a: Metals content in the ground water samples of Sidhi District



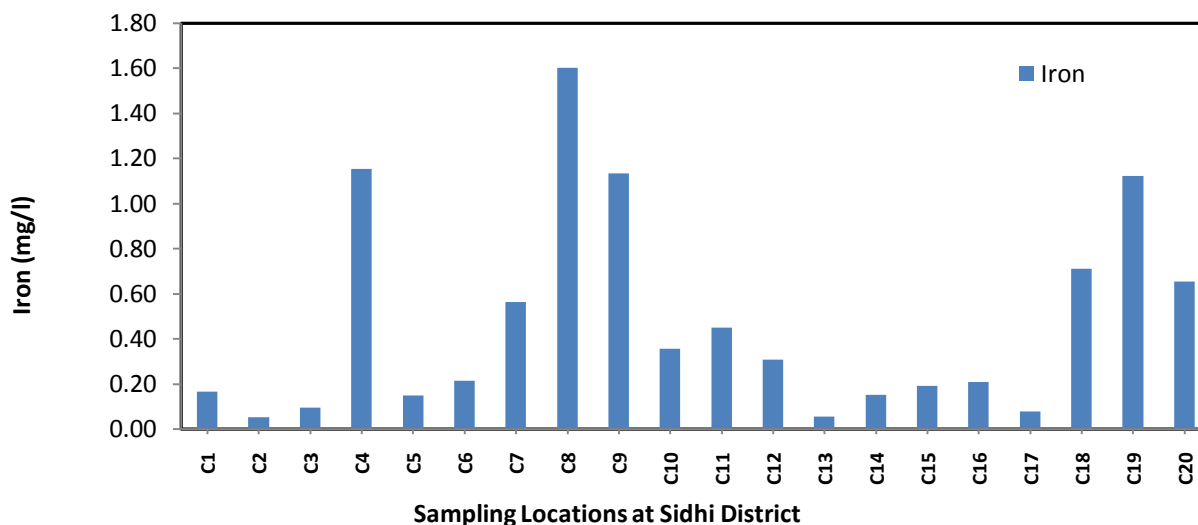


Figure 2b: Metals content in the ground water samples of Sidhi District

Characteristics of soil samples of Sidhi District: Soil samples collected from 20 different locations and analyzed for the physical properties, chemical properties and heavy metals contents in it. The physical properties of the soils collected from Sidhi District for the three seasons are presented in table 7, while chemical properties are presented in table 8. Heavy metals concentrations in the soils of Sidhi with seasons are presented in table 9 and the average metals concentrations are showed in table 10. The maximum concentration of chromium (58.0 mg/kg) and lead (77.0 mg kg⁻¹) was observed at sample C7 and C14 respectively (Figure 3a & 3b). The maximum concentration of cadmium 27.0 mg kg⁻¹ was observed at the location C9, while Nikel was found to be 52.0 mg kg⁻¹ maximum at C5 location. The maximum concentration of copper (56.0 mg kg⁻¹) was detected at sampling station of C7 and maximum Iron concentration found to be 97 mg kg⁻¹ in the same location. All the results were compared with the standards set by bureu of Indian standards (10500 : 1991), world health organization (1994) and SQGL value as given in table 11.

Table 7: Physical characteristics of Soli collected from Sidhi Distrect in Vindhya Pradesh

	SEASONS	Sampling Locations									
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Temp 0c	Summer	36.65	35.00	34.28	36.14	41.71	39.42	32.25	38.28	35.72	35.00
	Winter	21.00	16.85	17.57	24.00	27.85	25.57	18.65	24.42	24.12	18.56
	Monsoon	32.06	29.31	28.56	33.45	36.28	34.00	29.28	34.16	32.54	27.34
PH	Summer	5.8	5.0	6.8	7.8	6.2	8.0	7.5	7.6	8.5	7.2
	Winter	5.5	5.5	6.6	7.8	5.9	7.6	7.8	7.7	8.6	7.7
	Monsoon	5.2	6.0	5.9	7.0	5.7	7.0	7.4	8.7	8.4	7.9
Sand %	Summer	65.7	44.1	30.8	45.7	65.6	45.3	19.4	29.0	28.6	19.3
	Winter	64.0	42.6	39.1	44.1	68.0	44.2	20.5	32.3	32.0	30.1
	Monsoon	69.7	32.8	34.1	42.5	68.0	25.4	16.1	21.4	28.7	16.1

Silt %	Summer	7.8	13.9	24.2	21.8	7.8	28.5	29.5	35.0	22.5	34.5
	Winter	7.8	17.4	22.7	19.2	7.1	26.1	18.5	39.7	25.0	24.8
	Monsoon	11.0	26.7	27.2	9.8	7.1	35.3	33.7	41.3	22.4	33.6
Clay %	Summer	26.5	42.1	45.0	32.5	27.3	26.2	16.1	36.0	48.9	46.1
	Winter	28.2	40.0	30.2	36.7	24.9	29.7	33.7	28.0	43.1	45.1
	Monsoon	19.3	40.5	38.7	47.7	20.9	39.3	50.2	37.3	48.9	50.2

Table- 7 Continuous.....

	SEASONS	Sampling Locations									
		C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
Temp 0c	Summer	35.43	34.00	30.42	31.63	27.28	26.15	25.00	27.24	29.88	32.95
	Winter	22.59	24.85	19.38	22.56	16.28	16.57	19.81	21.40	23.42	20.10
	Monsoon	30.85	31.71	32.36	33.29	25.14	27.85	24.54	23.47	25.24	25.42
PH	Summer	8.1	7.5	8.1	8.1	7.9	7.8	8.4	5.6	7.8	7.8
	Winter	8.2	7.7	7.9	7.9	8.0	7.5	8.0	5.8	7.8	7.5
	Monsoon	8.1	7.1	7.2	7.2	7.6	8.0	7.7	6.0	7.5	7.2
Sand %	Summer	32.3	59.5	67.7	41.1	66.7	38.2	45.7	38.2	58.8	60.3
	Winter	27.0	60.8	60.5	44.0	66.7	34.4	42.0	34.4	47.6	51.3
	Monsoon	34.3	56.7	55.2	40.4	67.7	36.0	33.3	36.0	20.6	74.3
Silt %	Summer	19.8	14.0	10.3	31.2	13.6	14.0	18.9	14.0	9.7	20.3
	Winter	25.4	10.8	10.9	13.9	17.6	10.8	22.0	10.8	20.8	30.3
	Monsoon	27.0	12.3	10.1	14.3	11.6	12.3	22.3	12.3	25.4	14.3
Clay %	Summer	47.9	47.8	22.1	27.7	19.7	47.8	35.4	47.8	31.5	19.4
	Winter	47.6	54.8	28.6	42.2	15.7	54.8	36.0	54.8	31.6	18.4
	Monsoon	38.7	51.7	30.9	45.3	20.7	51.7	44.4	51.7	54.0	11.4

Table 8: Chemical composition of soils collected from different locations in Sidhi District

	SEASONS	Sampling Locations									
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
O.C.	Summer	0.37	0.78	0.83	0.96	3.19	0.19	1.43	0.75	0.23	0.38
	Winter	0.34	0.75	0.85	0.95	3.15	0.15	1.54	0.76	0.21	0.35
	Monsoon	0.30	0.72	0.87	0.98	3.00	0.12	2.43	0.78	0.19	0.33
N	Summer	19.21	26.08	28.1	36.12	33.00	32.12	36.53	37.45	30.10	30.4
	Winter	21.63	21.63	29.3	34.24	32.33	34.24	35.37	33.51	32.27	29.7
	Monsoon	26.08	19.21	29.2	32.12	31.09	36.12	32.22	30.90	36.00	29.3
P	Summer	0.39	1.12	3.89	0.19	0.24	0.29	0.51	0.29	0.47	3.88
	Winter	0.47	2.72	3.86	0.18	0.21	0.24	0.48	0.30	0.55	3.91

Na+	Monsoon	0.55	2.52	3.91	0.13	0.18	0.19	0.45	0.35	0.65	3.85
	Summer	29.12	24.28	36.57	40.08	34.26	45.90	37.0	23.11	28.08	40.0
	Winter	28.80	25.97	32.14	38.81	35.21	47.98	39.0	23.58	35.94	38.0
	Monsoon	35.09	29.09	45.99	36.87	33.77	49.96	41.0	24.80	36.23	49.0
K+	Summer	22.2	8.0	20.4	10.2	8.2	9.2	12.8	9.4	12.2	13.5
	Winter	20.4	10.7	24.97	13.1	8.4	6.9	12.3	10.0	11.6	13.8
	Monsoon	19.1	13.59	30.93	18.3	9.0	7.8	12.4	15.0	11.3	15.0
Ca++	Summer	52.0	45.2	57.5	91.0	30.0	165	112	62.0	43.0	ND
	Winter	39.2	42.0	52.0	82.0	21.0	157	80.3	45.0	38.0	ND
	Monsoon	35.6	42.1	57.3	77.0	26.0	152	92.5	57.0	36.5	ND
Mg++	Summer	20.0	16.0	15.0	53.0	48.0	40.0	17.5	26.0	60.0	44.0
	Winter	21.0	18.0	13.0	48.0	45.2	32.0	17.2	26.0	56.0	39.0
	Monsoon	23.5	20.1	11.0	42.3	43.0	27.0	18.0	27.3	52.0	34.0

Table- 8 Continuous.....

	SEASONS	Sampling Locations									
		C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
O.C.	Summer	0.35	0.19	0.31	0.12	0.40	0.33	0.23	0.57	0.47	0.25
	Winter	0.38	0.14	0.28	0.08	0.36	0.28	0.27	0.54	0.45	0.27
	Monsoon	0.40	0.09	0.26	0.06	0.32	0.23	0.30	0.51	0.42	0.29
N	Summer	29.39	26.6	3.99	30.94	32.57	29.98	19.41	8.86	19.66	33.76
	Winter	28.48	28.48	4.60	29.27	31.00	31.11	19.31	9.40	19.66	29.98
	Monsoon	25.40	30.82	5.29	26.29	26.82	33.76	19.03	9.87	19.16	31.11
P	Summer	0.57	2.65	0.36	0.31	3.95	0.23	0.23	0.55	4.02	0.48
	Winter	0.66	2.87	0.32	0.37	3.97	0.23	0.20	0.52	3.75	0.53
	Monsoon	0.72	3.00	0.51	0.46	3.97	0.34	0.17	0.49	3.96	0.63
Na+	Summer	26.0	32.0	12.0	31.71	39.12	46.2	28.0	25.97	34.8	47.08
	Winter	23.0	36.0	13.5	35.14	40.50	49.5	23.0	27.93	33.4	42.18
	Monsoon	32.0	42.0	16.0	38.29	43.59	50.1	35.0	27.29	27.2	43.59
K+	Summer	15.0	28.0	35.3	9.5	18.1	25.0	30.4	34.2	18.0	26.9
	Winter	12.6	30.0	34.1	9.3	18.2	29.0	29.5	32.5	19.0	27.0
	Monsoon	13.7	32.0	36.5	9.7	19.0	30.2	29.0	31.4	21.0	28.5
Ca++	Summer	35.5	10.0	16.2	12.0	14.0	12.0	14.0	12.0	15.2	25.0
	Winter	27.2	8.5	15.3	12.0	6.0	12.0	6.0	12.0	13.0	23.1
	Monsoon	23.0	10.2	17.5	14.0	21.0	13.0	21.0	13.0	19.0	25.2
Mg++	Summer	40.0	48.0	ND	56.0	29.0	29.0	35.0	39.0	ND	45.0
	Winter	35.0	45.0	ND	53.0	26.3	29.0	33.0	37.0	ND	43.0
	Monsoon	30.0	42.0	ND	50.0	22.0	27.0	31.0	35.0	ND	46.0

Table 9: Seasonal variation of metals concentration in soils collected from Sidhi District in Vindhya Pradesh

HM	SEASONS	Sampling Locations									
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Chromium	Summer	45.0	19.8	20.0	17.8	32.0	19.0	62.2	26.6	21.8	46.6
	Winter	41.5	19.2	18.6	17.6	28.3	18.3	59.0	26.0	21.3	47.0
	Monsoon	37.2	18.7	17.5	16.8	26.4	15.6	53.0	25.7	20.6	52.8

Lead	Summer	69.0	42.6	13.4	12.5	54.0	33.0	48.5	54.0	12.8	69.4
	Winter	62.3	39.5	15.6	14.2	55.1	30.2	44.6	51.4	10.6	66.7
	Monsoon	57.0	35.2	16.2	17.5	56.4	26.5	40.0	47.3	9.2	62.5
Cadmium	Summer	21.4	6.5	3.7	4.8	16.2	10.0	19.6	3.7	29.6	14.5
	Winter	19.7	4.9	3.2	3.0	15.6	9.7	18.5	2.1	27.0	10.6
	Monsoon	16.0	4.5	2.8	2.5	15.4	8.4	15.6	1.9	24.4	8.5
Nickel	Summer	43.4	10.4	12.4	3.8	58.2	3.2	14.0	50.4	16.2	21.8
	Winter	39.5	7.1	13.6	3.7	51.0	2.8	11.0	47.1	18.0	16.8
	Monsoon	34.6	4.8	13.0	2.5	45.8	2.2	9.5	42.2	17.5	11.6
Copper	Summer	12.4	13.0	ND	0.00	19.5	6.3	59.4	15.2	6.3	31.2
	Winter	12.0	10.5	ND	0.00	19.0	4.7	56.3	16.0	4.7	25.0
	Monsoon	11.6	7.4	ND	0.00	18.5	3.2	53.4	15.0	3.2	33.5
Iron	Summer	40.8	73.2	18.2	20.4	94.7	80.7	99.5	18.4	31.0	9.8
	Winter	37.2	73.0	12.3	19.2	90.2	77.4	95.6	3.0	28.0	8.6
	Monsoon	34.5	72.0	12.0	18.0	87.4	73.2	94.8	12.4	24.7	8.0

Table- 9 Continuous.....

HM	SEASONS	Sampling Locations									
		C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
Chromium	Summer	25.2	19.0	17.2	42.8	18.2	22.2	20.6	23.6	51.2	42.6
	Winter	28.3	21.5	27.1	37.4	22.5	26.1	17.2	19.2	44.6	51.2
	Monsoon	32.5	26.4	35.8	32.0	25.0	29.5	14.5	14.7	37.2	55.6
Lead	Summer	18.2	7.2	44.5	87.0	33.6	17.6	41.5	41.8	44.8	38.8
	Winter	19.5	9.5	43.4	75.0	30.0	21.5	43.6	38.5	45.0	36.0
	Monsoon	21.0	11.5	42.6	67.5	25.6	23.4	45.0	36.0	45.5	33.2
Cadmium	Summer	1.2	5.0	1.2	7.8	1.8	3.2	1.8	2.0	2.6	0.4
	Winter	1.0	3.5	1.0	7.5	2.5	3.0	1.8	2.0	3.2	0.2
	Monsoon	1.7	2.4	0.7	7.1	2.0	2.5	1.6	1.9	2.8	0.2
Nickel	Summer	7.2	1.6	24.0	ND	6.6	9.0	7.5	8.4	ND	0.8
	Winter	5.0	1.0	19.7	ND	4.5	13.2	8.5	9.5	ND	0.5
	Monsoon	3.2	0.7	14.5	ND	4.0	15.7	11.4	13.2	ND	0.2
Copper	Summer	3.1	35.2	33.2	27.2	5.2	ND	26.4	25.0	32.8	3.4
	Winter	3.0	34.3	27.2	25.6	2.5	ND	23.2	21.0	27.5	2.4
	Monsoon	2.8	35.0	23.0	21.2	1.8	ND	19.8	17.5	23.1	1.2
Iron	Summer	88.5	ND	26.4	81.7	73.0	22.8	18.5	92.5	32.4	96.0
	Winter	85.1	ND	22.0	75.0	69.0	18.4	11.4	87.4	31.6	91.0
	Monsoon	83.2	ND	18.2	78.3	64.2	14.3	9.2	82.5	30.0	86.0

Table 10: Average metals concentration in soils collected from Sidhi District in Vindhya Pradesh

Metals	Sampling Locations									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Chromium	41.23	19.23	18.70	17.40	28.90	17.63	58.07	26.10	21.23	48.80
SD (±)	3.91	0.55	1.25	0.53	2.85	1.80	4.67	0.46	0.60	3.47

Lead	62.77	39.10	15.07	14.73	55.17	29.90	44.37	50.90	10.87	66.20
SD (±)	6.01	3.72	1.47	2.54	1.20	3.26	4.25	3.38	1.81	3.48
Cadmium	19.03	5.30	3.23	3.43	15.73	9.37	17.90	2.57	27.00	11.20
SD (±)	2.76	1.06	0.45	1.21	0.42	0.85	2.07	0.99	2.60	3.04
Nikel	39.17	7.43	13.00	3.33	51.67	2.73	11.50	46.57	17.23	16.73
SD (±)	4.41	2.81	0.60	0.72	6.23	0.50	2.29	4.13	0.93	5.10
Copper	12.00	10.30	ND	0.00	19.00	4.73	56.37	15.40	4.73	29.90
SD (±)	0.40	2.81	-	0.00	0.50	1.55	3.00	0.53	1.55	4.40
Iron	37.50	72.73	14.17	19.20	90.77	77.10	96.63	11.27	27.90	8.80
SD (±)	3.16	0.64	3.50	1.20	3.68	3.76	2.51	7.76	3.15	0.92

Table- 10 Continuous.....

Metals	Sampling Locations									
	C11	C12	C13	C14	C15	C16	C17	7.00	C19	C20
Chromium	28.67	22.30	26.70	37.40	21.90	25.93	17.43	19.17	44.33	49.80
SD (±)	3.66	3.76	9.31	5.40	3.44	3.65	3.06	4.45		6.61
Lead	19.57	9.40	43.50	76.50	29.73	20.83	43.37	38.77	45.10	36.00
SD (±)	1.40	2.15	0.95	9.84	4.01	2.96	1.76	2.91	0.36	2.80
Cadmium	1.30	3.63	0.97	7.47	2.10	2.90	1.73	1.97	2.87	0.27
SD (±)	0.36	1.31	0.25	0.35	0.36	0.36	0.12	0.06	0.31	0.12
Nikel	5.13	1.10	19.40	ND	5.03	12.63	9.13	10.37	ND	0.50
SD (±)	2.00	0.46	4.76	-	1.38	3.39	2.03	2.51	-	0.30
Copper	2.97	34.83	27.80	24.67	3.17	ND	23.13	21.17	27.80	2.33
SD (±)	0.15	0.47	5.13	3.11	1.80	-	3.30	3.75	4.86	1.10
Iron	85.60	ND	22.20	78.33	68.73	18.50	13.03	87.47	31.33	91.00
SD (±)	2.69	-	4.10	3.35	4.41	4.25	4.86	5.00	1.22	5.00

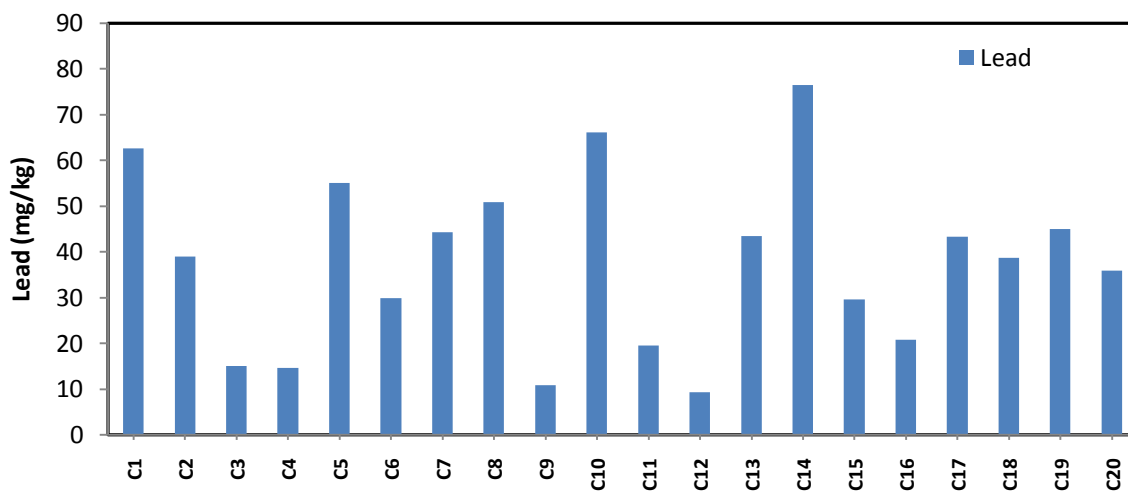
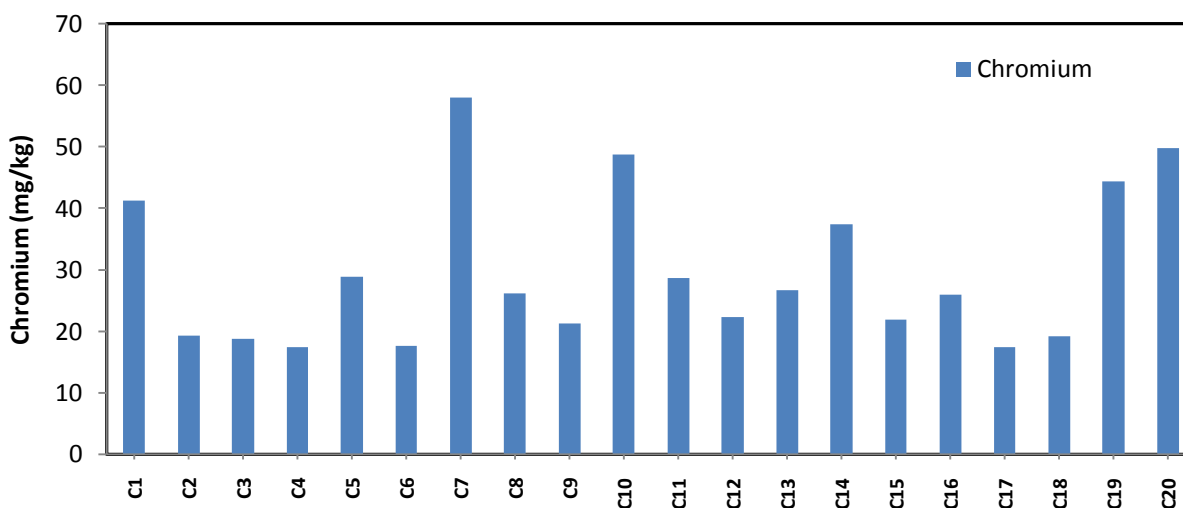
C1: Near Sanjay Gandhi P.G. College Sidhi, C2: Near Deosar Bus stand, C3: Near primary school, Parsohar, C4: Near Sanjay Gandhi P.G. College, Jiawan, C5: Near Sanjay Gandhi P.G. College, Chitrangi, C6: Near temple Sinhawal, C7: Near N.T.P.C, Singrauli, C8: Near Bus stand & temple Churhat, C9: Near Rampur Govt. P.G. College, C10: Near Majholi school, C11: Near post office, Gainuwar, C12: Near Madwas primary school, C13: Near Sarsal gram panchayat hall, C14: Near Kusmi Bus stand, C15: Near primary school, Surai, C16: Near high school, Tagawa, C17: Near Bank Tal, C18: Near grameen Bank, Majgaon, C19: Suhiya residential area, C20: Near primary school, Pankuora.

Concentration of metals are expressed in mg/kg, ND = Not detected

Table 11: Standards for Drinking Water and Soil

Water					Soil	
Parameter	BIS (10500 : 1991) mg/l		WHO (1994) mg/l		Parameter	Soil Quality Guide line level mg/kg
	Desirable	Permissible	Excessive	Permissible		
pH	-	6.5	8.5	6.5		
Turbidity	-	--	5.0	10	Temp.	-
DO	3.0	--	6.0	4.0	pH	-
BOD	-	2.0	--	6.0	O.C.	-
COD	-	--	--	10.0	N	-
Nitrate	100	45	10	10	P	-
Nitrite	-	--	10	40	Na+	62
Sulphate	1000	--	400	250	K+	60

Chloride	1000	250	600	250	Ca ⁺⁺	250
Phosphate	--	--	0.3	0.1	Mg ⁺⁺	30
Lead	0.05	No relaxation	0.01	0.05	Lead	140
Cadmium	0.01	No relaxation	0.003	--	Cadmium	10
Nikel	--	--	--	0.02 mg/l.	Nikel	50
Iron	0.3	1.0	0.3	--	Iron	-
Chromium	No relaxation	0.05	--	0.05	Chromium	64
Copper	1.5	0.05	1.00	--	Copper	63



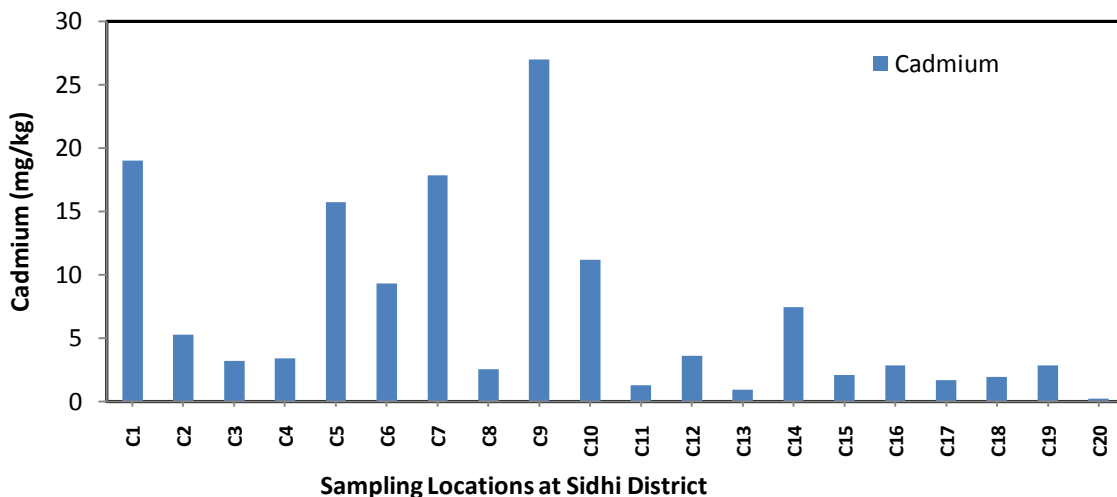
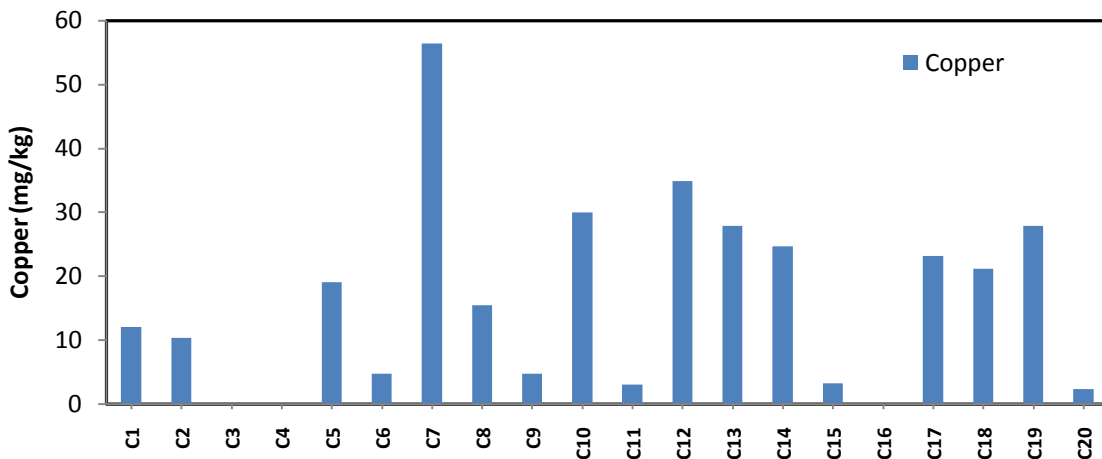
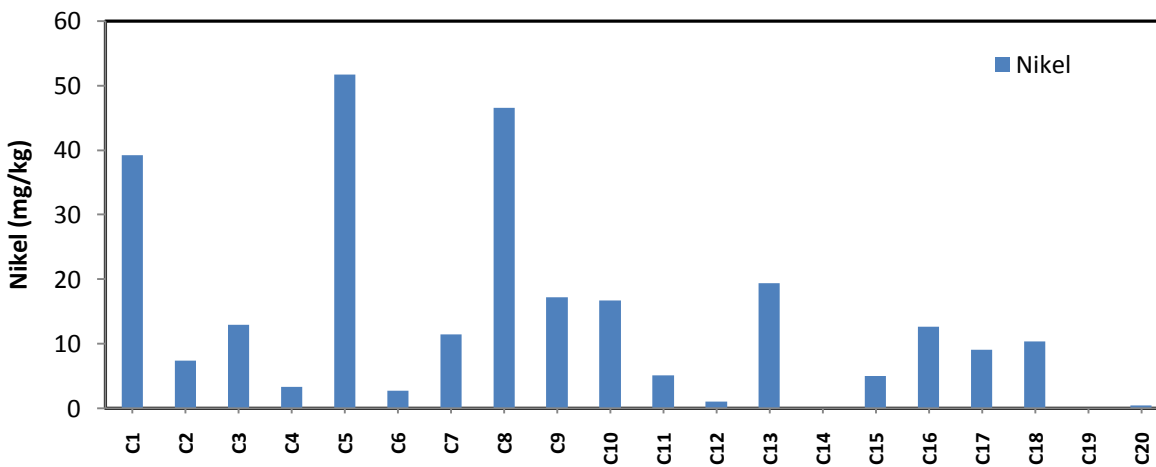


Figure 3a: Metals content in the soils of Sidhi District



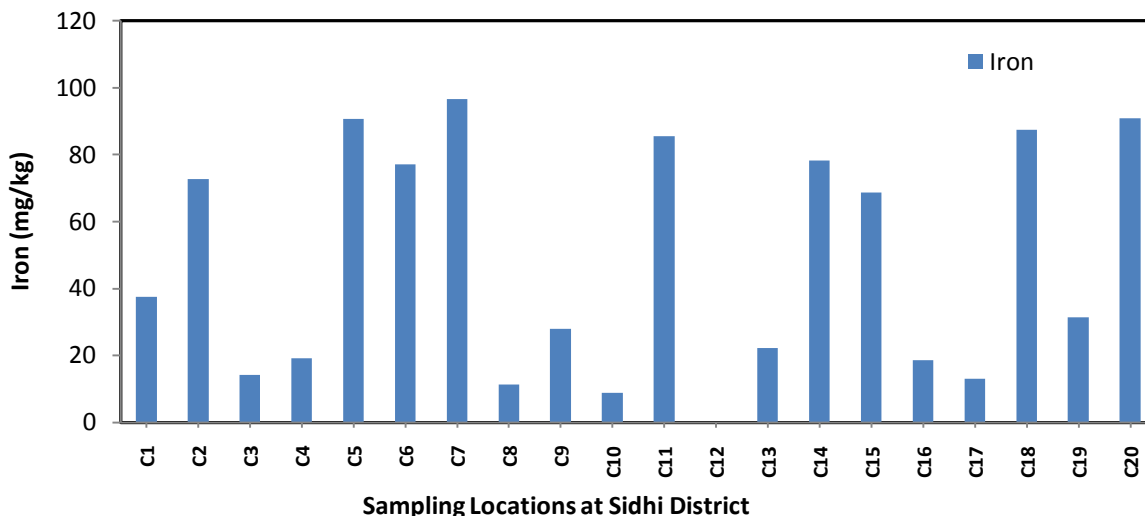


Figure 3b: Metals content in the soils of Sidhi District

APPLICATIONS

The present study is useful to Municipal Corporation in the planning of town solid waste and wastewater management.

CONCLUSIONS

After analysis of physico-chemical parameters of ground water samples from different location it has been observed that some parameter are within the permissible limit while few were very higher than the permissible limits prescribed by WHO. Therefore, it is concluded that the sampling station Chitrangi (C5), Singrauli (C7), Churahat (C8), Madwas (C12), Sarsal (C13), Majgaon (C18) and Suihya (C19) more polluted and their water is not fit for the drinking purpose. In the Sidhi district soil samples were contain 40 - 45% clay, 30 - 40% sand, 5 - 25% slit shows clay and sand are dominated in the soils. The organic content in these soils are very poor and ranging from 0.06 to 3.19 mg/kg. Nitrogen concentration ranging from 3.9 to 37.45 mg/kg, phosphorus content was ranged from 0.13 to 4.02 mg/kg and potassium levels in the soils ranged from 6.9 mg/kg to 36.5 mg/kg. Finally the soil of Sidhi district has more concentration of metal and other constituents which may be originated from industrial and agricultural activities which is predominant in this district.

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