SUITABILITY OF WATER QUALITY FOR DOMESTIC AND INDUSTRIAL PURPOSES IN KARSTIC LIMESTONE OF CHHATTISGARH, INDIA

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ABSTRACT

The Urla Industrial Area (UIA) is situated in Raipur district, Chattisgarh India, started its growth from 1980's decade in the Peripheries of urban centre. It is located in towards right flank of Kharun river of Mahanadi drainage system and positioned nearly south western part in the Chattisgarh Sedimentary Basin (CSB) where entire area is underlain by limestone belonging to Chandi formation of Chhattisgarh Supergroup due to Karstic nature of limestone with dissolution of groundwater it generates the sinkholes, grykes, solution cavities, fissures and underground conduits etc. constituting the aquifer zones. Earlier no referable works has been made to evaluate the quality of the water in this limestone terrain. An attempt has been made to carry out the quality of surface and groundwater for domestic and industrial purposes. The water samples from Ponds/ Streams/ Dugwells and Tubewells were chemically analysed, adopting the standard method for examination of water standard procedures of APHW-AWW methodologies. The study reveals that all the water samples of this Urla Industrial Belt (UIB) have been found suitable for domestic purposes. The total hardness (TH) of waer samples varies from 28 to 212 ppm. Other chemical constituents elements Na^+, $K^+, F^-, Cl^-, NO^{3-}, SO^{4-}, HCO^{3-}$ *and* CO^3 ion concentrates falls within the standard norms and specifications for domestic and industrial purposes.

KEYWORDS : KARSTIC LIMESTONE, WATER QUALITY, CHATTISGARH, AQUIFERS, DOMESTIC WATER SPECIFICATION, CHEMICAL ANALYSIS.

INTRODUCTION

The Urla Industrial Area (UIA) lies in the North peripheries of capital town, Raipur of Chhattisgarh state India. It is included in Survey of India Toposheet no.64 G/11 and bounded by longitude 81°36' 36"-81° 37'6" E and Latitude 20° 18'19" - 20° 18'36"N . The Urla Industrial Area core sector A have been critically analysed and interpreted for suitability of water quality for domestic and industrial purposes. It is extended in 96.20 hectares in areal coverage. (Fig-)

B. CLIMATOLOGIC AND GEOMORPHIC CONDITIONS -

The subtropical humid climate is prevailing in the region. It falls under J3C3 Agro climatic zone of India with the rainfall of 1350 mm annually. The average temperature vary from 6°C to 13°C in winter and rises up to 43°C during summer seasons. Surface water bodies, Ponds, Tanks, Streams gets water during monsoon period and dry out in the summer season. The streams are ephemeral in nature. Effluent streams have been observed, and it is common in the limestone terrain with limited discharge of groundwater at sites of resurgence points in streams. Ground slopes vary between 3° - 15° in undulating Plains and mounds respectively. Low lying areas slope is found below 3° and mostly covered with in situ soil mental. Geomorphologically, the limestone terrain of central part of Chattisgarh Sedimentary Basin (CSB) shows undulating plains with ground elevation in ranges of 270 meters AMSL to 320 meters AMSL. At the highest elevations limestones are capped with ferrugenous platy sandstone and Lateritic covered mounds. It acts as recharge zone due to high porosity and permeability of Pisolitic Laterites. The water from rainfall gets transmitted quickly and percolate downwards recharging g.w. through fissures and joints of underneath limestone. The Subtropical and subhumid climate is favourable for the generation of fissures and dissolution of limestone by karstification processes. The stromatolitic limestone shows cavernous in nature leads secondary porosity for groundwater movements. The alluvium and soil covers are confined in the stream channels and river banks of Kharun in the North Western part.

C. GEOLOGIC SETTING

Previously some work has been carried out on various lithological aspects of Chhattisgarh sedimentary basin. The record reveals that Ball(1877) and King(1885) were first who distinguished the presence of sedimentary sequences of Chattisgarh basin on the basis of regional traverses. The name Chhattisgarh supergroup was proposed by Schinitzer (1971) who made a valuable contribution to the stratigraphy of Chhattisgarh basin. He proposed the cyclic nature of sedimentation and identified each cycle by a local Geographic name. The intercratonic Chattisgarh basin is crescent shape and occupy an area of about 33000 Km square Murty (1987). Das, et.al. (1992) have divided their Chattisgarh basin into two sub basins namely Hirri subbasin and Baradwar subbasin. The Hirri sub basin is the main basin which extends lengthwise 300 kilometre along ENE-WSW direction and width wise about 150 Km. In its south central part the Baradwar subbasin is a small embryonic shape basin located in the east of the main basin. Both the subbasin are separated by narrow strip of Sona Khan highlands.

A. Lithology and Rock characteristics of Urla Industrial Area (UIA)

The study area lies in the central part of Chhattisgarh sedimentary basin belonging to Proterozoic age. The most of the area occupies Raipur limestone and Deodongar sandstone. Deodongar sandstone is exposed near in the outer fringes of Urla village (Fig.1). The limestone of the study area belongs to Raipur group of Chandi formation. It is stromatolitic limestone purple and grey colour rock. This flagy limestone at some places

intercalated with shale. This shale found here are Khaki coloured and also becomes dark Grey. The geological succession of the study area and their characters is given in table.

a) **Laterites -**

The Rocks containing ferrous iron minerals has sufficiently, the Rock products are called laterite. The grain size are Pisolites containing relics of sandstone and shales. Laterite found here is a residual clay enriched in ferric Hydroxide as a result of chemical weathering in the humid tropics. The area under study at few places laterite are exposed. These are exposed in forms of patches. These occur as capping of soil layer over the Chandi lime stone formation. It acts as recharge zones.

b) **Chandi limestone -**

The thick bedded Chandi formation of the Raipur group occupies a large part of the study area. It varies from purple to grey in general, rock is purple but at places it shows Grey to grayish green. It is observed that pockets of non stromatolitic massive limetone intercalated in the stromatolitic limestone. The limestone in the study area exhibits stromatolitic structure. In general the regional trend of joints orientation N-S direction but at few places vertical joints were observed in limestone. Due to solution effect caverns becomes widened along most of conspicuous joints, giving rise karstic feature like solution cavities.

D. CHEMICAL CONSTITUENTS OF WATER

a) **Physical parameters and properties –**

The physical characteristics like temperature, colour, taste and odour, do not directly measure the safety of water supply, but they do give an indication of its acceptability (Bouwer1978). All the groundwater samples are clear, odourless and with inoffensive taste except the surface waters which are mostly turbid in nature.

The temperature reading show the general variation from 31.9 to 38.2°C with no abnormal air temperature variation.

b) **Chemical Constituents**

i) Ca^{++} and Mg^{++}

The concentration of calcium varies from 12 to 168 ppm as presented in table no. 3 Concentration of Magnesium greater than 125 mg/l can also exert a catheritic and diuretic action, chemical softening or ion exchange reduces the magnesium concentration varies from 12 o 52 ppm.

ii) Na^{+} and K^{+}

Sodium and Potassium are found vary with in the range of 18 to 212 ppm and 19 to 27 ppm as respectively. The concentration of sodium and potassium values are presented in Table no. 3

iii)Sulphate (SO_4)

The sources responsible for concentration of sulphate in water are gypsum, airborne sulphate compounds originating from sea and from dust, gaseous Sulphur Dioxide, decaying organic matter, volcanic exhalations, and the weathering products of some magmatic rocks. The maximum permissible limit for Sulphur

concentration in drinking water is 250 ppm. Water with high sulphur concentration causes diarrhoea. The concentration of sulphate where is from 10 to 37 ppm.

iv) **Nitrate (NO_3)**

The major source of nitrate in groundwater is due to oxidation of organic matter by aerobic bacteria. Concentration over 20 ppm in groundwater indicates pollution due to organic matter. Human contribution towards nitrate pollution is due to the use of fertilizers, industrial effluents, solid waste disposal, and concentration of live stock. The concentration of nitrate in drinking water should not exceed 45 ppm. Nitrates cause infantile methemoblobinemia ("Blue Baby" condition) and irritation of mucous membranes of the stomach in adults and increases diuresis. Nitrate concentration is found to vary from 0.0684 to 0.0756 ppm.

v**) Fluoride (F^-)**

Fluoride concentration of approximately 1.0 mg/litre effectively prevents dental caries without harmful effects. On health fluoride may occur naturally in water or may be added in controlled amounts. The concentration of Fluoride ranges from 0.129 to 0.6 96 ppm. The maximum permissible limit of fluoride prescribed by ISI is 1.5 mg/litre. The range indicates there is no abnormal varieties in concentration.

vi) **Chloride** (Cl^-)

The concentration of chloride in natural water varies widely when present in large amount, it is an indicator of pollution due to chemical origin. Higher levels of chloride causes test variation. An upper limit of 250 ppm has been set for chloride. The concentration of chloride vary from 9 to 174 ppm in the area.

E**. HYDROGEOLOGIC PROPERTIES OF ROCKS-**

(Aquifer Characteristics)

In the study area the limestone formation constitutes the main aquifers. Shale of the area represents aquiclude, which contains water but does not yield sufficient quantities of water to wells. The openings of fissures form avenues for groundwater movement. Solution cavities filled with subsurface water leads potential aquifers. Limestone in the area is dense, compact and posses very little primary porosity. Secondary porosity due to solution, joints, fractures, bedding planes allow percolation of water in deeper horizons. Limestone is almost horizontally bedded with lesser extent of joints/ fractures/ lineaments. The depth of weathering zone is limited and vary in thickness. Chances of deeper percolation in the area exists through the caverns, fractures and joints etc. The zone of weathering characterized by grey yellow soil represents a permeable area of limited extent in the area. High elevated ground having laterite capped mounds the underneath limestone have been chances to retain the water through pisolitic laterites, passes through intergranular spaces which transmit water below to the ground very fast. The bed rock strata of limestone oriented horizontally and only widely jointed cracks and fissures provide chance to circulate water internally in the rock layers. Topographically, the low lying areas occupied by thick soil Mantle and Cavernous limestone stores groundwater further down to make storage in the aquifer which tends conspicuous supply of groundwater for utilization. The Alluvial zones in stream channels are also proved as potential zones of g.w. in the region.

F. OCCURENCE OF G.W. & SWL (WELL INVENTORY)

Well inventory has been carried out in Urla Industrial Area Sector 'A' understand the nature of occurrence and movement of groundwater. In the study area 12 tubewells have been monitored in the month of December, January, February, March, April, May and June.No dug well is encountered in the Urla industrial area sector 'A'. The mode of water exploitation is my hand pump (near sarora village plate) and power pump. The well inventory data includes well diameter, total depth, static water level (SWL), casing height, owner of the well etc. were collected. The static water level were measured in post monsoon i.e. December and during pre monsoon that is June Seasons.The depth of water level were recorded with the help of water level indicator. The depth of tube wells varies from 45.72 m. to 144.78 m. The study revealed that depth of water level in post monsoon ranges from 3.65 to 29.1 m. and pre monsoon ranges from 2.20 to 45. 80 m.

G.WATER SAMPLING AND ANALYTICAL INSTRUMENTATION PROCEDURE-

The parameters like temperature, pH , Ec were determined in the field and the remaining parameters like Sodium(Na+), Potassium(K+) Calcium Magnesium as cations and sulphate chloride chloride nitrate alkaline as anions where analysed in the laboratory of school of studies in chemistry Pandit R S University Raipur. In the study area total 15 water samples have been collected with standard methods of sampling the samples have been taken from surface and ground water both i.e, from water tanks, dug wells and borewells. Before collecting the sample bottles were thoroughly by diluted HCl and distilled water and prelabelled on polylab bottles with cap.

Temperature and pH are determined by the Century (Water analyzer kit Model No.711) temperature electrode, pH electrode and conductivity meter respectively. Sodium and Potassium where determined by Systronics flame photometer. Stock solutions for Sodium 1000 ppm. NaCl has been prepared by dissolving 2.5416 gm. In 1000 ml. distilled water and gradually by diluting it different strength of solution (5,10,20,30,40,100) NaCl for calibration of instrument has been made and stock solution for Potassium 1000 ppm by dissolving 1.9070gm. KCL in 1000 ml. distilled water has been prepared by dissolving and gradually by deleting it different strength of solution calibration of instrument has been made in stock solution for Potassium 1000 PPM by dissolving 1.90 70 gram KCl in 1000 ml distilled water has been prepared by dissolving 2.5416 gram. In 1000 ml. distilled water and gradually by diluting it different strength of solution (5,10,20,30,40,100) KCl for calibration of instrument has been made. Calcium is analysed by the titration method using sodium hydroxide EDTA titrant as reagent, eriochrome blue black R as indicator. Magnesium is determined by calculation method –

$$\text{Mg mg/l} = [Total\ hardness\ (as\ CaCO_3\ mg/l - Calcium\ hardness\ (as\ CaCO_3\ mg/l\ ] \times 0.244$$

Hardness is determined by titration method. Buffer solution pH 10.0 (16.9 of $NH_4Cl + 143\ ml.NH_4OH$ make up 250 ml. distilled water) titrant are used as reagent Eriochrome black T (dissolve 0.5 dye in 100 ml. ethanol) used as indicator.

Alkalinity is measured by titration method 0.02 N (20 ml. 1 NH_2SO_4 and makeup 2000 ml. distilled water) and sodium carbonate solution (dissolve 13.25 gm. of Na_2CO_3 in 250 ml. distilled water) titrant are used as

reagent phenophthelein (dissolve 1 gm. phenophthelein in 100 ml. alcohol and 100 ml. distilled water and add. 0.02 N NaOH) in used as indicator.

Sulphate is measured by Systronics spectrophotometer (Model No. 106) at 410 nm. Conditioning reagent, barium chloride, standard sulphate solution and stock solution 20, 40, 50, 60, 80 ppm. were used.

Fluoride is determined by Orion fluoride electrode. Stock fluoride solution 0.2, 0.4, 0.6, 0.8 ppm. has been used. Nitrate is measured by Systronics spectrophotometer (Model No. 106) at 543 nm. Using NEDA – 1 nephthyl ethylene diamine acid 0.1 gm and sulfanilide acid 0.1 gm and sulfanilide solution 1% and sodium nitrate standard solution 0.1, 0.2, 0.3, 0.5, 0.7, ppm. were used. Chloride is determined by Orion electrode method. Stock sodium chloride solution 50, 100, 150, 200, 250, 300 ppm. has been used.

G. INTERPRETATION OF PIPER'S TRILINEAR DIAGRAM-

Piper (1994) trilinear diagram has been extensively used to understand problems about the geochemical evolution of groundwater. The diagram consists of three distinct field- two triangular fields and diamond - shaped field. In the triangular fields plotted separately, are the percentage epm values of cation, Ca and Mg plotted separately, are the percentage epm values of Cation, Ca and Mg (alkaline earths) and sodium (alkali), and anoins, HCO3 (weak acid) and SO4 and Cl strong acid. The overall characteristics of the water is represented in the Diamond shape field by projecting the position of the plots in the triangular fields. Different type of groundwater can be distinguished by the position there plotting occupy in certain subareas of the Diamond shaped field as follows-

1. alkaline earths exceed alkalies
2. alkalies exceed alkaline earths
3. weak acid exceed strong acid
4. strong acid exceed weak acids week
5. carbonate hardness exceed 50% i.e. chemical properties of the water are dominated by alkaline earths, and weak acid
6. non carbonate hardness exceed 50%
7. non carbonated alkali exceed hardness 50% i.e. chemical properties are dominated by alkalies and strong acid ocean water and many brines plot near the right hand vertex of the sub area.
8. Carbonate alkali exceed 50% here plot the water which are not in ordinately soft in proportion to their content of dissolved solids.
9. No one cation-anion pair exceeds 50%.

The classification obtained from Piper trilinear diagram figure 3 reveals that groundwater fall in 4,5,6,7,8,9 area. On the above basis it is found that the water of the entire study area occurs diamond shape in different area.

H. Water Quality Standards :-

The water quality parameters threshold values (mg / litre) for some industries and water specifications for Domestic / Drinking purposes (WHO standards) is given in Table 3 & 4. The required quality of water, for industries vary with the type of Industries / Technology used / manufacturing processes and product. In industries a large quantity of water is used for cooling purposes. Mostly groundwater is utilized due to its easy availability, uniformity is utilized due to its easy availability, uniformity and low temperature. In general, most of the industries accepted the domestic & drinking water quality standards for their requirements. The threshold values for some industries is given in the table. For the purpose of Steel Rolling Mills the water should be low concentration of chloride (below 150 mg/litre) and silica content with pH value should be above 7.0, the water the water below pH 7.0 is not allowed since it is acidic in nature. For Oil Refiniries and distilleries relatively hard water is used, whereas printing, Textiles and Edible oil, Electroplating industries are sensitive to hardness of water and water supply from municipal Domestic / Drinking water distributary is suitable. In Paper Mills, the turbidity in water should be less than 50 mg / litre and it should be free from heavy metals like Fe etc.

DISCUSSION AND CONCLUSION

The study area is located in Raipur district of Chhattisgarh. The popularly known 'Urla Industrial Area' has 74 Industries. The study area is covered by limestone belonging to the Chhattisgarh Super group. The main source of water includes bore well and A.K.V.N. supply from Kharun river anicut which are used in industries and as well as for drinking purpose. Chemistry of the water indicate that the quality of water of the area has been found suitable for drinking purpose (W.H.O. standard T4) all the samples can be used for drinking purpose, except three samples (1,5,14) which have Cl more than 200 ppm. As a result only except three samples all other samples, can be used for drinking purposes. In irrigation purpose sample number 1, 2, 3, 4, 8, 11 and 12 are suitable. For the domestic purpose sample number 1,2,3,5,7, 9,14 are of soft category (0 to 60 ppm) sample number 4,8,10,11,12 are moderately hard category (61 to 120 ppm) and sample number 13,15 belongs to hard category (121 to 180 ppm). No major chemical contamination is found in UIA. The underlying sedimentary lithologies – limestones are giving better quality responses. The chemical dissolution and reactivity of limestone strata are perhaps main controlling factors for maintaining quality characteristics of water in the region. Piper Trilinear diagram indicates ionic cation and anion interactions and better position of water quality fields. The results can be compared in similar Karshic terrain of other region.

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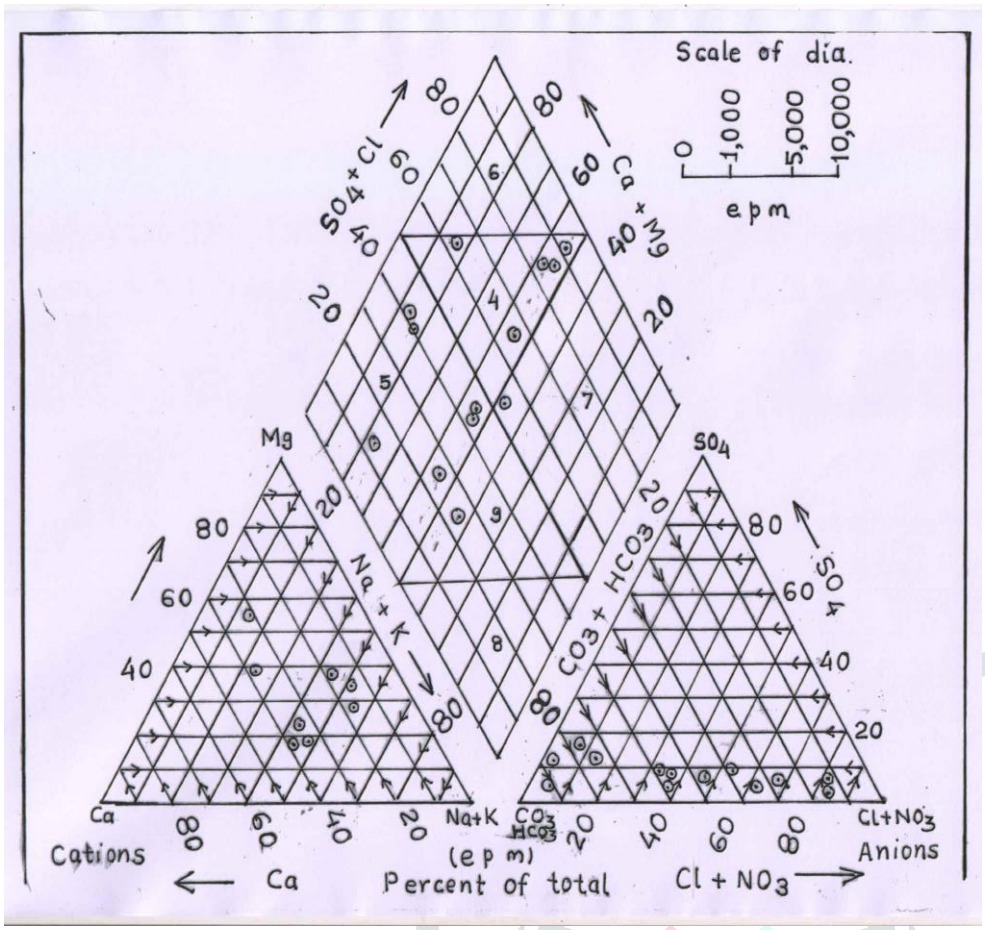
Scale of dia.
0
1,000
5,000
10,000
epm
SO4+Cl
Ca+Mg
Mg
Na+K
SO4
CO3+HCO3
Ca
Cations
Na+K
CO3
HCO3
Cl+NO3
Anions
(epm)
Percent of total
Ca
Cl + NO3

Table

Geological succession (generalized)

Age	Group/formation	Lithology
Recent	Laterite/Alluvium	Medium grained laterite Sand alluvium fine grained
Proterozoic	CHHATTISGARH SUPERGROUP CHANDRAMUR FORMATION →Deodongar sand stone →Raipur limestone	Platy ferrugenous brownish red sand stone Stromatolitic pink and grey coloured thick bedded jointed lime stone. (KARSTIC)

Table .

CONCENTRATION OF CHEMICAL CONSTITUENTS IN WATER OF INDUSTRIAL BELT

Chemical Analysis Data for Urla as measured in laboratory (values in ppm.)

S. No.	Sample No.	Location	Ca	Mg	TH	Na	K	Cl	SO_4	NO_3	F	HCO_3-CO_3	TDS
01	01	Sarora pond	36	68	104	38	61	204	21	0.0916	0.345	192	146.25
02	02	Rajesh strips	48	52	100	18	20	174	18	0.0697	0.256	36	370.5
03	03	Raipur rotacast	44	28	72	19	20	0.0	19	0.0702	0.285	56	414.05
04	04	Active chemical	68	72	140	18	25	46	20	0.0688	0.129	48	344.5
05	05	Kisan steel	12	16	28	32	26	217	37	0.0686	0.663	132	682.85
06	06	Shukla wood	184	28	212	18	19	155	23	0.0695	0.431	68	566.8
07	07	Jagdamba flour mill	12	12	24	31	21	09	36	0.0684	0.540	68	570.7
08	08	Vandana plastic division	112	40	152	152	19	20	19	0.0689	0.342	216	434.85
09	09	Goyal pipe	16	12	28	28	21	33	20	0.0685	0.532	100	677.95
10	10	Mohata pipe	108	44	152	152	27	96	29	0.0731	0.588	88	520.0
11	11	Bhimsaria doors	116	40	156	156	19	0.0	12	0.0756	0.696	56	323.05
12	12	Jasmin tools	120	44	164	164	19	26.0	10	0.0734	0. 389	24	425.75
13	13	Premiere laminates	168	44	212	212	19	73.0	33	0.0738	0.414	60	632.45
14	14	Achholi pond	52	64	116	116	49	239	22	0.0703	0.260	76	716.95
15	15	Ashirwad chouk D.W.	132	60	192	192	20	179	04	0.0688	0.194	20	880.1

Table No. 4

Drinking water standards

Chemical constituents	WHO international standards 1971		Indian standards Institution 1983	
	Highest desirable	Maximum permissible	Highest desirable	Maximum permissible
Total hardness as CaCO3	500 100	1500 500	500 300	1500 600
Calcium ppm	75	200	75	200
Magnesium ppm	< 30 if SO4 is 250 ppm, upto 150 ppm if SO4	150	30	100
Chloride ppm	is < 250 ppm	600	250	1000
Floride ppm	200	0.8 – 1.78	0.6 – 1.2	1.5
SO4 ppm	0.6 – 0. 9 200	400	150	upto if Mg does not eceed 30 ppm
NO3 ppm	-	45	45	No relaxation

(After Karanth,1998)

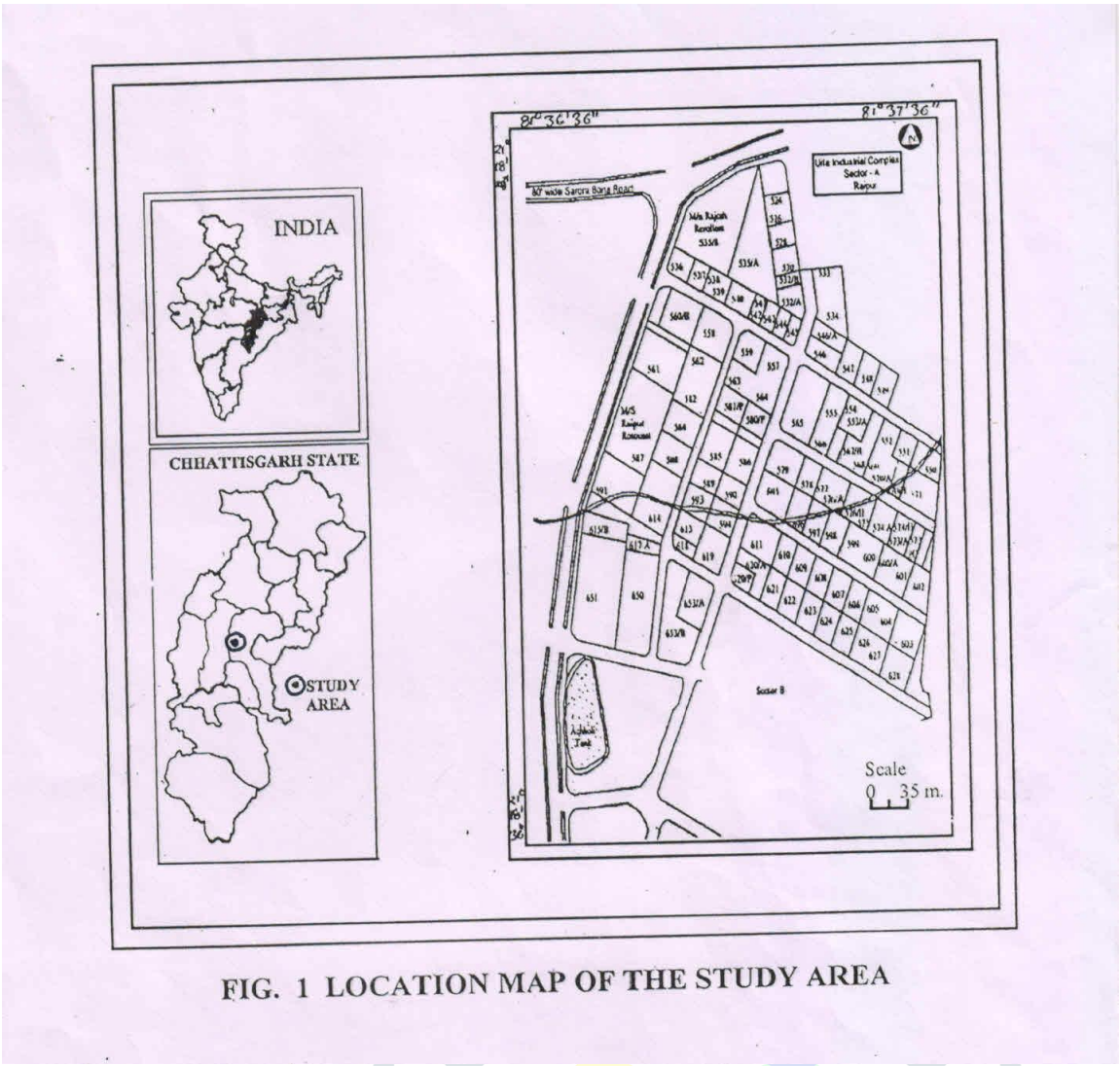

FIG. 1 LOCATION MAP OF THE STUDY AREA

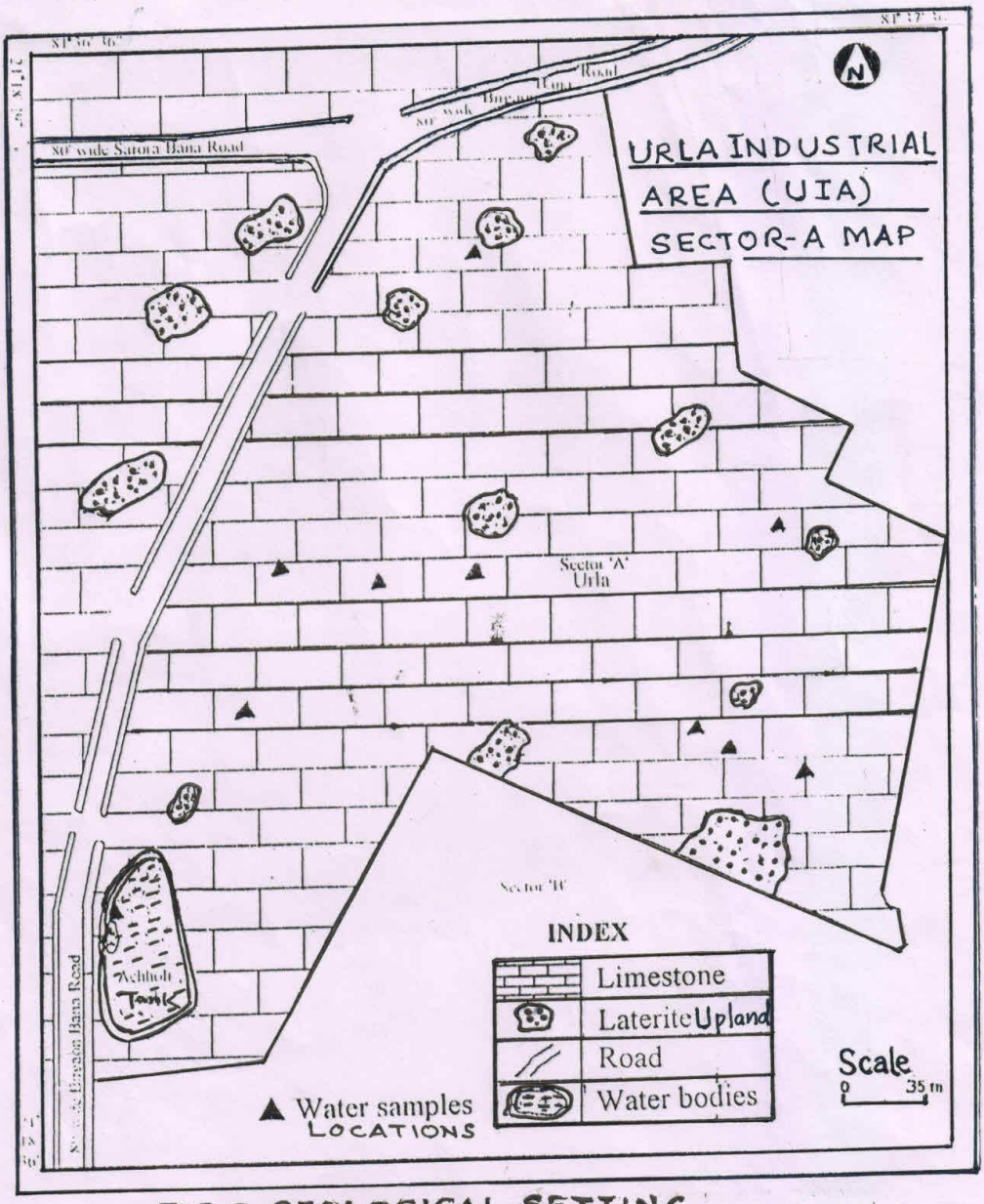

FIG.2 GEOLOGICAL SETTING

Table – 5

Water Quality in UIA

(Based on pipers diagram)

Category	Trilinear Field Area	Characteristics Properties	% of Water Samples	Commulative %
I	4	Strong Acid exceeds weak acids	26.67	26.67
II	5	Carbonate hardness exceeds 50%	53.35	80.02
III	6	Non Carbonate Hardness exceeds 50%	06.66	86.68
IV	7	Non Carbonate alkali exceeds hardness 50%	06.66	93.34
V	9	No one cation – anion exceeds pair 50%	06.66	100.00

Table – 4

Water Quality for Industries (Threshold Values in mg/l)

S No.	Constituents / properties	Food	Confectionary	Cooling	Boiler	Textiles
1.	Colour	10	-	-	-	-
2.	Taste	High	Low	-	-	-
3.	Turbidity	10	-	50	1	0.3
4.	Odour	Low	Low	-	-	-
5.	Hardness	85	100	-	50	-
6.	Total Dissolved Solids (TDS)	850	100	-	50	-
7.	Alkalinity	250	-	-	-	-
8.	Iron	0.2	0.2	0.5	-	0.00
9.	Manganese	0.2	0.2	0.5	-	0.00

REFERENCES –

1. ALPHA, AWWA, WPCF, 1989; Standard Methods for examination of water & waste water 17th edition 219p.

2. Bouwer; H, 1978; Ground Water Hydrology, Mc Graw Hill Publication, New York, 480p

3. Dutt; N.V.B.S. 1964; A Suggested Succession of the Purana Formation of the Southern Part of Chhattisgarh, M.P. Rec. Geol. Surv. Ind., Vol. 93 pt. II pp 143-148

4. Das; D.P. Kundu A, etal 1992, Lithostratigraphy & Sedimentation of Chhattisgarh Basin, Indian Minerals, Vol. 46, No. 3&4, July – Dec., pp 271-288.

5. Hem; J.D. , 1970 study and interpretation of Chemical Characteristics of Natural Water, 2nd ed. U.S.G.S. Water Supply paper 1473, 363 p.

6. I.S.I 10500, 1991; Indian Standard Drinking water specifications.

7. Karanth; K.R., 1997; Ground water Assessment Development & Management Tata McGraw Hill Publishing Company Limited New Delhi 226p

8. Murti; K.S., 1987; Stratigraphy and Sedimentation in Chhattisgarh Basin Purana Basin of Peninsular India (ed. B.P. Radhakrishanan); Geol Soc. India Member 6, pp 239-260

9. Piper, A.M., 1944; A graphic procedure in the geochemical interpretation of water analyses, Trans. Amer Geophysical Union, V.25, pp 914-928

10. Schinitzer; W.A., 1971; Das Jung Prakam Barium Indians “Purana System” Erangler Geolo. 85, 44p

11. World Health Organisation 1971; International Standard for Drinking Water, “ UNESCO”, Paris.