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Ground Water Quality Assessment and Hydrogeological Scenario of Twin City Durg-Bhilai, Chhattisgarh State

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*Abstract:***Groundwater quality varies due to variation in climatic conditions, contact time of water with host rock and inputs from soil during percolation of water. The contaminations of the ground water by industrial effluent and domestic sewage sources are alarming in several parts of the country. Ground water as well as surface water is seriously deteriorated due to rapid industrialization and urbanization. The present study was conducted in the month of May 2021 to assess the suitability of ground water and to address the key contamination issues of the study area with the collection of around 37 samples in the twin city Durg-Bhilai of the Chhattisgarh State. The collected water samples were analyzed for 16 basic parameters and 8 heavy metals following the standard methods of analysis and results were compared with BIS drinking water standard 2012. The analytical result reveals that the most of the analyzed constituents of ground water samples collected are within the BIS prescribed limits and are fit for the drinking purpose. Majority of ground water of Bhilai-Durg twin city belongs to the calcium magnesium bicarbonate (Ca-Mg-HCO3) type and are suitable for various uses like drinking, agriculture etc. However higher nitrate, iron and manganese contents found in few ground water samples in the study, are discussed. Ground water is mostly neutral to mild alkaline in nature. Nitrate contamination in ground water is main issue of concern in the twin city. Exceptionally higher fluoride, Iron and Manganese concentration were found in few locations. Ground water of the study area is mostly suitable for drinking and irrigation.**

I. INTRODUCTION

The contaminations of the ground water by industrial effluent and domestic sewage sources are alarming in several parts of the country. The ground water as well as surface water is seriously deteriorated due to rapid industrialization and urbanization (P.S.V. Shankar et al 2011).The industrial effluents are discharged at various points in the surrounding area. The slag, ore flushing and other chemicals effluents generated from the industries are let out in dumping sites like ponds, lagoons etc. which is discharged in to the surface water drains as a final liquid effluent containing various kinds of pollutant may contaminate the ground water. Several land and water-based man-made activities are causing pollution of this precious resource (P.N. Patil 2012).

Groundwater quality varies due to variation in climatic conditions, contact time of water with host rock and inputs from soil during percolation of water (CGWB 2010). Many processes like hydro geochemical, carbonates & silicates weathering, ion exchange, dissolution, absorption, adsorption have been found responsible to change the chemical composition of groundwater (B.K. Mitra et al 2007).

The purpose of the present study is to understand the ground water scenario and extent of ground water contamination from Bhilai steel plant, NSPCL Thermal power plant and JK Laxmi cement industries and domestic sewage of Bhilai-Durg. Apart from this, attempts have been made towards understanding the hydro-geochemistry of the area and record the effects of this contamination on environment. The area selected to assess the ground water quality is Bhilai-Durg twin city of Chhattisgarh State.

Study Area

The study area Bhilai-Durg urban agglomerate is located in the Durg district of Chhattisgarh. Its geological map and sampling point presented in Fig-1. Geographically it is bounded by latitudes 21° 06' to 21° 16' North and longitudes 81° 14' to 81° 26' East, encompassing a total area of about 215 sq km and area falls in Survey of India topo sheet no. 64 G/11.

The average annual rainfall in Bhilai area is about 1247 mm. Temperature rises from 6 °C in winter to 46 °C in summer. The relative humidity is around 85% during monsoon period and it varies between 30 to 40% during winter season. Bhilai-Durg urban agglomerate also known as Bhilai-Durg twine city situated in West central part of Chhattisgarh state of India. It is situated on the bank of Shivnath River. It is a tributary of Mahanadi. Bhilai is famous for its Bhilai steel plant (BSP) and was established in 1959 with the help of the USSR. The plant was setup at 10 km away from Durg city along Howrah Mumbai rail line for the production of steel. Now a days, it is one of biggest steel plant of the Asia. To meet the demand of the raw material for making the steel, a huge quantum of iron ore and other industrial required material are transported in this area. Accordingly, a big town ship established in this area. Thus, the city facing both industrialization and urbanization load on the natural sources.

Geology and Hydrogeology

The area is underlined by the lime stone and Ferrugious Sandstone of Chandi formations of Raipur group of Chhattisgarh super group. The upper part is karstified up to aquifer of the area. The western part along Shivnath River covered with ferruginous sandstone. The lateritic capping exposed in few small locations. The depth of bore wells drilled in this rock type varies about 20 to 200 mbgl. The casing length lowered varies from 6.00 to 30.0 m, which also represents the weathered thickness in this formation. Geological map and sampling point study area Bhilai-Durg urban agglomerate presented in Fig.1. The discharge varies place to place from 0.27 to 17 lps.Pre-monsoon the depth to water (DTW) level observed during pre-monsoon period in the month of May is presented in Fig-2.

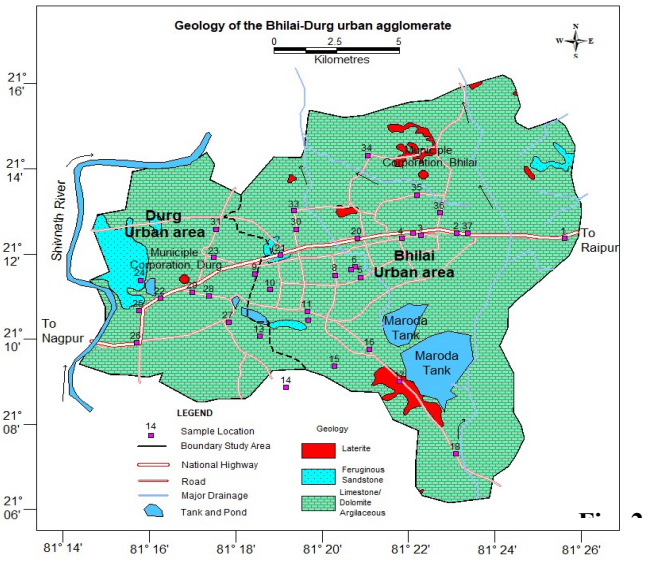

Figure 1: Geological map and sampling locationsin study area Bhilai-Durg urban agglomerate

The depth to water level during pre-monsoon period is ranges between1.78 to 15.10. m bgl. In most of the area the water level lies in the range of 5 to 10 m bgl. The depth to water levels more than 10 m bgl is observed in North, north-western & north-eastern including Udiyapara, Shalendra nagar, Ambedkar nagar, Ahmad nagar, Mochi Mohalla, Sardar para, Indian Convent School, Yadav Mohalla, Ganesh Mandir Area in Bhilai urban area and Karidih Para, Kasaridih, Mill Para, Katulbod in Durg urban area. The shallow water levels 0 to 5 m bgl are observed in the south western part around Maroda Tank.Post-monsoon**.**The depth to water level measured during the post-monsoon period in the month of November is presented in Fig-3. The depth to water level during post-monsoon period is ranges between 1.24 to 6.5 m bgl. In most of the area the water level lies in the range of 3 to 5 m bgl. The depth to water levels more than 5 m bgl is observed in North, north-western and central part of the area running north to south in a strip. The shallow water levels 0 to 3 m bgl are observed in the south eastern part of the area around Maroada Tank.

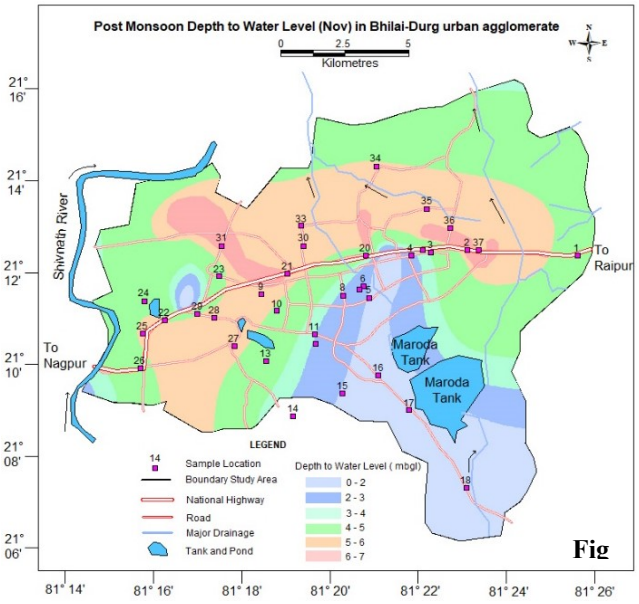

Figure 2: Post-monsoon the depth to water (DTW) level observed in the month of November.

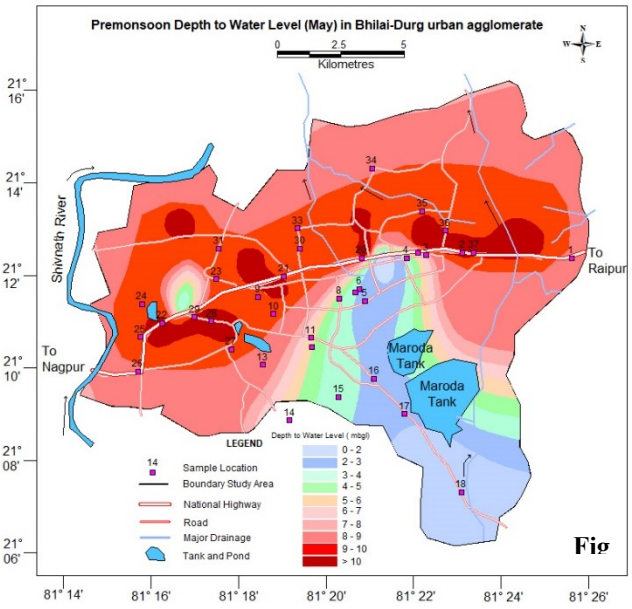

Figure 3: Pre-monsoon the depth to water (DTW) level observed in the month of May.

II. MATERIALS AND METHOD

The quality of ground water is one of the most important criteria, which determines its suitability for various uses like drinking, irrigation, industrial purpose etc. Thirty seven water samples (N=37) were collected from various locations in and around Durg-Bhilai city during the month of May 2021. The location of samples are presented in Fig-1. All Thirty seven ground water samples were collected from hand pumps and dug wells situated in different parts of the study area. Sample bottles were rinsed with ground water to be sampled. Purging has been done by pumping the wells for the sufficient time. There after the samples were collected in pre-cleaned polyethylene bottles in two sets. In case of significant turbidity, the suspended matter was filtered and preserved for further processing. The non-acidified samples were collected for analyzing physicochemical parameters and another set of samples for heavy metals analyses were separately acidified.

The collected samples were brought to the chemical laboratory of Central Ground Water Board, Raipur for the analysis of physical and chemical parameters by the standard methods (APHA 23rd Edition, 2017). Heavy metals like iron, manganese, copper, chromium, zinc, lead, arsenic and uranium concentration was measured by ICP -MS (Thermo Fisher). The analytical results were compared with the drinking water standards of Bureau of Indian standard. To assess the suitability of ground water for irrigation purposes chemical indices i.e. sodium soluble percentage, sodium adsorption ratio, residual sodium carbonate, percent sodium, Kelley ratio, magnesium ratio, permeability index were computed.

III. RESULTS AND DISCUSSION

In the present study assessment of ground water quality for physico-chemical characteristics and heavy metals occurrence were studied in and around twin city of Durg-Bhilai. The chemical analysis result of groundwater was evaluated against drinking water quality standard (BIS 10500, 2012 & WHO 1984). The chemical quality of the ground water samples has mainly been laid on the determination of some inorganic parameter viz. pH, electrical conductivity, alkalinity, chloride, sulphate, nitrate, phosphate, fluoride, calcium, magnesium, total hardness, sodium, potassium and heavy metals i.e. iron, lead, manganese, copper, zinc, and chromium (N. Manivasagam, 1984). This gives idea about general hydrochemistry and their applications for drinking/domestic, agriculture and industrial proposes. The correctness of the chemical analysis result is checked for ionic charge balance by calculation of the conductivity and major ions i.e. Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-} , HCO_3^{-}, Cl^{-}, SO_4^{2-} and F^{-} (Freeze and Cherry, 1979). It is observed that computed error in all the chemical analysis results are within ± 10%. The analysis result of physicochemical parameters and heavy metals were computed for statistical parameters and presented in Table-1.

The analytical results revels that the pH value in collected groundwater samples varies from 7.0 to 9.0 with an average of 7.5 which indicates that ground water is mostly neutral to mild alkaline in nature. Exceptionally high pH value 9.0 was recorded in one location at Kasaridhi where the ground water have more alkaline in nature and not suitable for the drinking purpose. Other than Kasaridhi in rest of the locations, the pH is within the permissible limits as prescribed by BIS (IS: 10500-2012). The electrical conductivity values of the collected samples was observed from 157 to 1672 µS/cm at 25 °C with average conductivity value 904 µS/cm at 25 °C. The lowest electrical conductivity value was observed 157µ S/cm at Sector 6 water sample and highest conductivity is recorded 1672 µS/cm at Pullgaon Chowk hand pump. The conductivity value is converted in total dissolve solids and compared with BIS limits and found within the range (500 – 1500 mg/l) as per the BIS standards. Total Hardness in ground water is observed between 25 to 480 mg/l with the average concentration 249 mg/l. The water of the study area is soft to moderately hard in nature. The BIS permissible limit of hardness is 300 – 600 mg/l and hardness in water of the study area is recorded within BIS prescribed limit. The calcium concentration varies from 4 to 136 mg/l with the average concentration 73.6 mg/l. That indicates calcium concentration in ground water is below the acceptable limit.

The magnesium concentration varies from 3.6 mg/l to 52.8 mg/l with the average concentration 15.6 mg/l. Acceptable and maximum permissible limit for Magnesium is 30 and 100 mg/l respectively, according to BIS. The sodium concentration varies between 5.7 and 200 mg/l with the average of 47.4 mg/l in the collected samples. Exceptionally higher sodium concentration, 200 mg/l was recorded in Kasaridhi area i.e. above the WHO's highest recommended value i.e. 200 mg/l for the drinking water. BIS does not have any standard for the sodium content in drinking water. The potassium concentration is reported in the range from 0.2 to 11.3 mg/l with the average concentration of 2.2 mg/l. The highest concentration 41.0 mg/l of potassium is recorded in Durg and Ruwabandha dug well. In rest of the water samples the potassium concentration is recorded < 10.0 mg/l. Carbonate ions are not present in any of the ground water samples. Bicarbonate is dominating anion in the study area, which varies from 73 to 573 mg/l with the average concentration 236.7 mg/l.

The total alkalinity was observed within the BIS prescribed range i.e. 200–400 mg/l. The Sulphate concentration in ground water samples of the study area varies from 3.2 to 82.6 mg/l with the average concentration 42.6 mg/l. It is observed that the sulphate concentration in all the water samples collected from the study area is below the BIS acceptable and maximum permissible limits i.e. 200 - 400 mg/l for drinking water. Nitrate contamination in ground water is main problem observed in the Durg – Bhilai twin city. In 12 locations i.e. Bhilai 3, Sector 1, Borsi, Navai, Uttai, Supela, Ganjmandi, pullgaon chowk, Green chowk Kohka, Madartersa nagar where high nitrate content 55.4, 58, 47.7, 70.6, 74.6, 51.4 73.6, 67.9, 74.6, 66.8 and 55.6 mg/l recorded respectively against the BIS Standard of 45 mg/l for the drinking purpose.

Consumption of water with high concentration of nitrate (> 45 mg/l) may lead to blue baby syndrome (Kar et.al, 2002 & BIS, 1997 & 2010). High nitrate in hand pumps indicate that pollution has leached in deeper levels of groundwater as well. Distribution of nitrate in ground water of Bhilai-Durg urban agglomerate is presented in Fig. 4. The fluoride concentration varies from 0.01 to 1.6 mg/l with the average concentration 0.3 mg/l. In most of the area the fluoride concentration is below the BIS prescribed range. Exceptionally high fluoride concentration is observed 1.6 mg/l at Kasaridhi i.e. beyond the maximum prescribed concentration (1.5 mg/l) set by BIS. High concentration of fluoride causes dental fluorosis (disfigurement of the teeth). At the same time, a concentration less than 0.8 mg/l results in 'Dental caries'. Hence, it is essential to maintain the fluoride concentration between 0.8 to 1.0 mg/l in drinking water (B. K. Handa 1997, V. K. Saxsena & S. Ahamad, 2003).

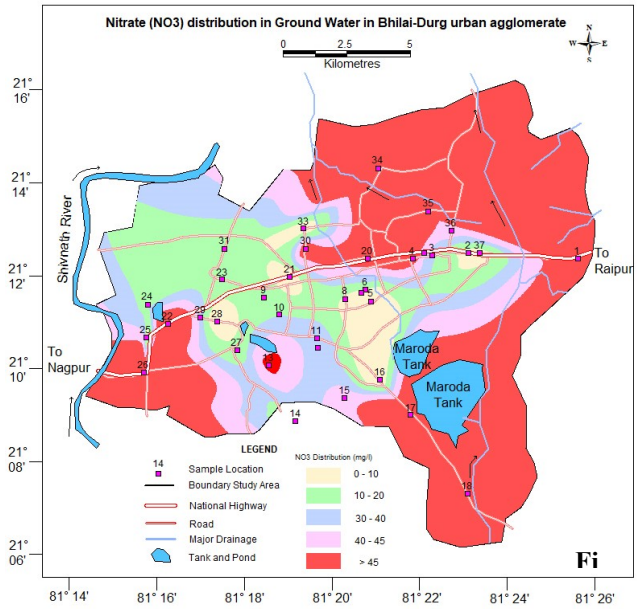

Figure 4: Nitrate distribution in ground water of Bhilai-Durg urban agglomerate.

Heavy Metals

Heavy elements viz. iron, manganese, copper, chromium, zinc, lead, arsenic and uranium were determined in ground water samples collected. The concentration of trace elements along with location was summarized in Table 1. The result of heavy metal revels that chromium concentration observed very low in all the ground water samples collected from Bhilai – Durg Urban Agglomerate. It is recorded below the recommended limit set by BIS for drinking.

Iron is an essential nutrient for human, animals and plants. However, excessive concentration in water can stain clothes etc. or causes excessive bacterial activity in pipes (Hem, J.D., 1985). In seven locations, higher iron (> 1 mg/l) was recorded viz. Sector 6A market, Sector 7, Sector 9, Ruwabahdha, Navai, Pullgaon Chowk and Samridhi bazar. The maximum acceptable concentration of Iron in drinking water is 1.0 mg/l recommended by the BIS. Distribution of Iron content in ground water samples is presented in Figure 5.

Higher Manganese concentrations (> 0.3 mg/l) was recorded at three locations in the study area viz. Sector 6 A-market, Nayapara ward and Samridhi bazar. In rest of the location manganese was recorded low. The acceptable limit for Manganese is 0.1 mg/l and maximum permissible limit is 0.3 mg/l recommended by BIS for the drinking water. Symptoms of Manganese poisoning consist of cough, nasopharyngitis, bronchitis, pneumonia, headache, lethargy progressing to marked weakness flower extremities, slurred speech, sexual impotence and mental retardation (J.D. Hem, 1985).Copper, Zinc and Arsenic were found below the permissible limit for drinking purposes. No uranium content was observed in ground water of twin city.

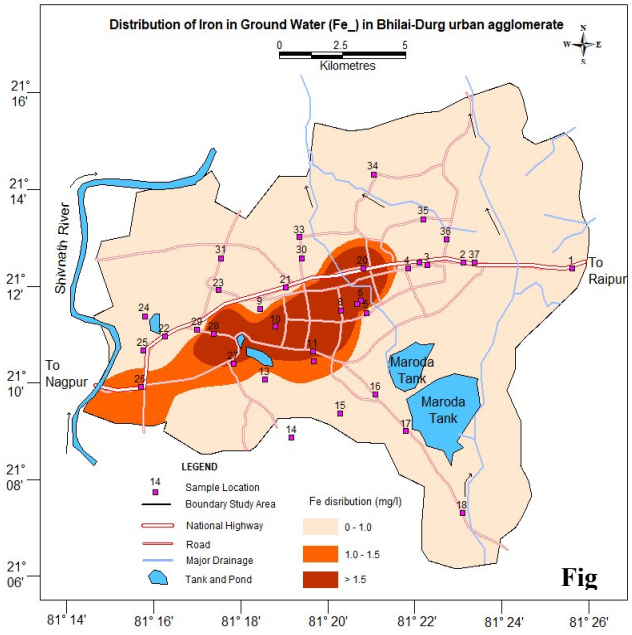

Figure 5: Iron distribution in ground water of Bhilai-Durg urban agglomerate

Hydrochemistry of Water

The Piper tri-linear plots of the major cations and anions in ground water of the twin city is presented in Figure-6. This plot suggests that among the cationic species, the bivalent cations calcium and magnesium (Ca and Mg) dominate and on the other hand, bicarbonate (HCO_3) is the major anion showing dominance over others. Thus, majority of water samples of Bhilai- Durg twin city belongs to the calcium magnesium bicarbonate (Ca-Mg-HCO_3) type. Whereas in few locations mix kind of water is observed. In few locations high sulphate content was recorded in study area may be dissolution of gypsum naturally occur in the twin city.

Ground Water Quality for Irrigation Purposes

To evaluate the quality of ground water of Bhilai-Durg twin city for the irrigation purpose some chemical indices i.e. soluble sodium percentage, sodium adsorption ratio, residual

sodium carbonate, percentage of sodium, Kelley ratio, magnesium ratio and permeability index were calculated (E.M. Eaton, 1950, L.A. Richards, 1954, W.P. Kelly 1940) and summarized in Table-2. Wilcox diagrams is presented in Figure-7.

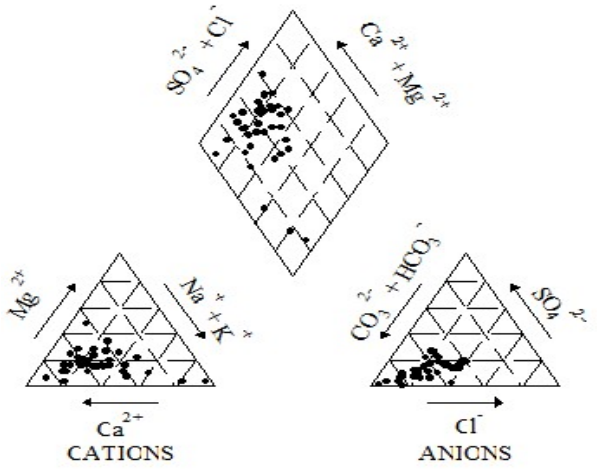

Figure 6: Piper trilinear plots of Bhilai-Durg twin city

Wilcox Diagram

The Wilcox diagram reflects that most of the groundwater of Bhilai- Durg twin city falls under the excellent to good category and suitable for irrigation purpose. While at some locations groundwater comes under doubtful category and suitable only for limited crops. The water samples collected from Kasardhi falls in unsuitable category and ground water is not good for irrigation purpose.

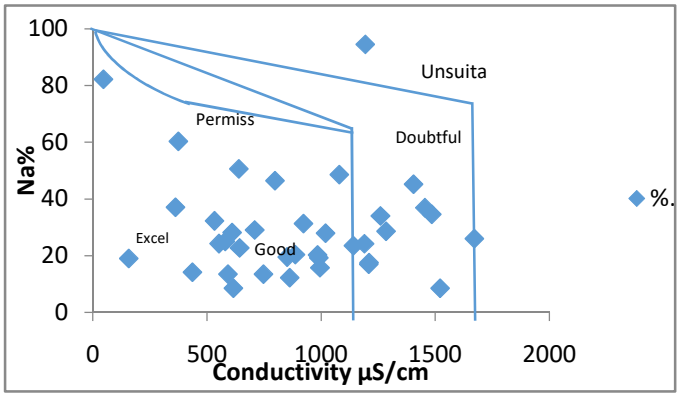

Fig-7 Wilcox diagram of water samples of Bhilai- Durg twin city

TABLE 1
Analytical results of groundwater samples, Durg-Bhilai area*

Parameters	Min	Max	Mean	SD	BIS Permissible limit	BIS Acceptable limit
pH	7.00	9.00	7.50	0.30	6.50	8.50
EC µ S/cm	157.00	1672.00	904.30	372.10		
TH	25.00	480.00	249.10	97.90	300.00	600.00
Ca	4.00	136.00	73.60	29.70	75.00	200.00
Mg	3.60	52.80	15.60	10.40	30.00	100.00
Na	5.70	200.00	47.40	37.40	-	-
K	0.20	11.30	2.20	3.00	-	-
CO3	0.00	0.00	0.00	0.00	-	-
HCO3	73.20	573.40	236.70	79.20	-	-
Cl	7.10	145.60	64.80	39.00	250.00	1000.00
SO4	3.20	82.60	42.60	23.50	200.00	400.00
NO3	0.00	74.60	28.50	25.90	45.00	No Relaxation
F	0.00	1.60	0.20	0.30	1.00	1.50
Cr	0	0.00198	0.00072	0.00055	0.05	No relaxation
Fe	0	0.0053	0.00073	0.00114	0.001	No relaxation
Mn	0	0.00203	0.00013	0.00043	0.0003	No relaxation
Cu	0	0.00011	0	0.00002	0.0001	0.0015
Zn	0	0.00373	0.0006	0.00077	0.005	0.015
As	0	0.00714	0.00029	0.00116	0.01	No relaxation
Pb	0	0.00577	0.00173	0.00154	0.01	No relaxation
U	0	0.00397	0.00086	0.00079	0.03	No relaxation

* All parameters are expressed in mg/L except pH (No unit) and EC (μS/cm)

TABLE2
Chemical Indices of ground water of Durg-Bhilai area

Locations	S S P%	SAR	RSC	%Na	K I	Mg^{+2}	P I
1	31.24	1.53	-1.68	31.39	0.45	20.84	55.43
2	46.25	2.40	0.31	46.48	0.86	20.31	74.57
3	13.33	0.50	-1.09	13.51	0.15	18.68	46.92
4	8.43	0.27	-1.10	8.60	0.09	6.90	46.56
5	28.04	1.06	0.52	28.24	0.39	37.54	68.09
6	17.16	0.32	0.00	19.03	0.21	24.76	93.02
7	13.21	0.44	1.22	13.57	0.15	31.44	62.14
8	28.73	1.06	0.42	29.13	0.40	36.85	69.13
9	13.99	0.40	0.31	14.24	0.16	13.19	66.16
10	33.54	1.06	0.81	37.15	0.50	40.61	86.13
11	27.66	0.94	-0.49	32.34	0.38	23.11	65.90
12	33.57	1.90	-3.97	34.68	0.51	29.32	50.10
13	18.26	0.80	-2.28	20.34	0.22	21.33	44.10
14	15.69	0.70	-2.88	15.82	0.19	18.38	40.14
15	36.26	2.05	-1.88	36.95	0.57	24.38	57.36
16	27.90	1.25	-0.09	28.01	0.39	15.22	59.27
17	12.04	0.49	-2.28	12.27	0.14	27.44	39.87
18	19.07	0.84	-2.88	19.29	0.24	21.66	42.80
19	24.46	0.89	-0.79	25.04	0.32	26.07	59.00
20	19.48	0.79	-2.28	20.44	0.24	26.17	45.88
21	60.30	3.65	0.01	60.36	1.52	23.91	83.68
22	8.43	0.36	-4.15	8.54	0.09	51.63	30.82
23	48.54	2.49	-0.99	50.64	0.94	14.13	71.83
24	23.99	1.15	-2.78	24.30	0.32	22.17	46.46
25	48.48	2.72	1.02	48.67	0.94	42.55	76.60
26	25.84	1.52	-4.34	26.03	0.35	45.52	43.56
27	19.38	0.81	-0.50	19.58	0.24	5.20	51.66
28	28.42	1.43	-3.28	28.68	0.40	19.80	48.17
29	94.60	17.46	8.90	94.61	17.52	59.70	127.96
30	33.98	1.80	-1.98	34.07	0.51	22.73	55.96
31	16.85	0.75	-3.18	17.06	0.20	26.23	40.13
32	23.37	1.06	-2.17	23.54	0.31	35.78	48.29
33	24.20	0.81	0.01	24.31	0.32	30.98	66.74
34	22.34	0.81	-1.59	22.78	0.29	19.80	52.49
35	17.50	0.84	-4.09	17.57	0.21	12.68	37.88
36	44.79	2.66	-0.68	45.27	0.81	29.37	67.04
37	0.00	0.00	0.00	82.23	0.00	19.83	56.66

IV. CONCLUSION

As per ground water resources estimation 2017, the study area is categorized under 'Semi-Critical' with stage of ground water extraction 86.8%. The increase in ground water utilization in the last 15 years for agricultural activities through adoption of bore wells has resulted in a fourfold increase in ground water draft from 2004 to 2017. Thus the stage of ground water development has galloped from 20.43% to 86.8%, which is alarming situation and that is why the quality of groundwater needs to be addressed.

Nitrate, Fluoride and Manganese contamination at Kasaridih is a major area of concern, although the area is residential in nature and no agricultural activities are carried out. In some locations higher iron and Manganese concentration were recorded for which intensed sampling of ground water and further study is recommended. Majority of ground water of Bhilai- Durg twin city belongs to the calcium magnesium bicarbonate (Ca-Mg-HCO_3) type. Ground water mostly suitable for drinking and irrigation purpose in Bhilai-Durg twin city.

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