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Evaluation of Groundwater Quality and its Suitability Assessment for Drinking and Agriculture purposes in Vidarbha Region of Maharashtra, India

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Abstract: **Water is an excellent solvent and can contain lots of dissolved chemicals. Since groundwater moves through rocks and subsurface soil, it has a lot of opportunity to dissolve substances during interaction as it moves. For that reason, groundwater will often have more dissolved substances than surface water will. To assess the groundwater quality of the Vidarbha Region of Maharashtra State, the present study was conducted in the month of May 2019. Total 345 groundwater samples were collected from all the eleven districts of the Vidarbha region and analysed for 11 water quality indicative parameters viz. pH, Electrical Conductance, Total Dissolved Solids, Total hardness, Sodium, Potassium, Total Alkalinity, Chloride, Sulphate, Nitrate and Fluoride. Selected chemical indices were also calculated viz. Calcium Hardness, Sodium Absorption Ratio, Residual Sodium Carbonate, Soluble Sodium Percentage, Permeability Index and Kelly's Ratio. More than 95 percent of the ground water samples were found to be fit for drinking, irrigation and other purposes.**

***Keywords*: Groundwater, Water Quality, Chemical Indices, Suitability Assessment.**

I. INTRODUCTION

Indian Sub - Continent is endowed with a wide variety of geological formations from oldest Achaeans to Recent alluviums and also characterized by different climatic conditions in different parts of the country. The natural chemical content of ground water is influenced by depth of the soils and sub-surface geological formations through which ground water remains in contact. In major part of the country, the quality of the ground water is either within 'very good' or 'good' category, and is suitable for various purposes like drinking, agricultural or industrial purposes. Ground water in shallow aquifers is generally suitable for use for different purposes and is mainly of Calcium Bicarbonate and Mixed type. However, other types of water are also available including Sodium-Chloride water. The quality in deeper aquifers also varies from place to place and is generally found suitable for common uses. There is salinity problem in the coastal tracts.

Maharashtra Pollution Control Board has reported the ground water quality status of the entire state of Maharashtra through the study at 66 locations of the state by calculating Water Quality Index, where groundwater of Nagpur and Chandrapur has reported in the category of 'Poor Water' (MPCB-TERI 2019). Chaudhari et al 2021, have examined groundwater quality in South-West zone of Surat city, Gujarat which is situated on the shoreline, causing the groundwater of the concerned area to be highly affected by seawater intrusion. It is concluded that concentrations of EC, TDS, Cl, SO4, NO3, and F are respectably higher which disintegrates its quality for drinking and other homegrown purposes in the study are. The result of this study indicates that ground water quality occurs in the poor' range as per BIS standards (IS 10500:2012). Durbude et al (2002) mapped the ground water quality parameters in Ghataprabha command area in GIS environment. Varadarajan et al (2003) have studied the hydrochemical characteristics of a Malaprabha sub basin and found the fluoride concentration along the downstream of the sub basin. Tatawat et al. (2008) investigated the quality of ground water for Jaipur city, Rajasthan and its suitability for domestic and irrigation purposes. Laluraj et al. (2005) studied the ground water quality and sea water intrusion of shallow aquifers of coastal zones of Cochin, India.

II. Objective

As a part of study of National Hydrograph Stations, Central Ground Water Board monitors ground water quality of the entire country on regular basis. Central Ground Water Board, Nagpur monitors the WQ of entire state of Maharashtra by collecting water samples from around 2000 dug well across the state. The present study is based on the results of study conducted during May 2019 (Pre monsoon). For the purpose, all the eleven districts of Vidarbha region were selected from where 345 ground water samples were collected during the month of May 2019. The objective of the study was to assess the suitability of ground water of the area for drinking and other purposes.

III. Materials & Methods

Study Area

Vidarbha is the north-eastern region of the Indian state of Maharashtra, comprising Nagpur Division and Amravati Division. It occupies 31.6% of the total area and holds 21.3% of the total population of Maharashtra. It borders the state of Madhya Pradesh to the north, Chhattisgarh to the east, Telangana to the south and Marathwada and Khandesh regions of Maharashtra to the west. Situated in central India (Figure-1). The largest city in Vidarbha is Nagpur followed by Amravati, Akola and Chandrapur. The Nagpur region is known for growing oranges and cotton. Vidarbha holds two-thirds of Maharashtra's mineral resources and three-quarters of its forest resources, and is a net producer of power.

Figure 1: Location of study area selected, Vidarbha Region, Maharashtra State, India

Sampling

The ground water samples were collected from 345 wells of all the eleven districts of Vidarbha region of Maharashtra State, India during the month of May 2019. Standard methods of sampling, preservation and transportation were followed as prescribed by WQAA 2005. The details of the sampling locations are depicted in Figure-2. Numbers of samples collected from each district are presented in Table-2. The collected ground water samples were preserved and transported from water quality monitoring wells to the Chemical Laboratory (Accredited to ISO/IEC- 17025: 2017), Central Ground water Board, Central Region, Nagpur, Maharashtra State for Physiochemical analysis.

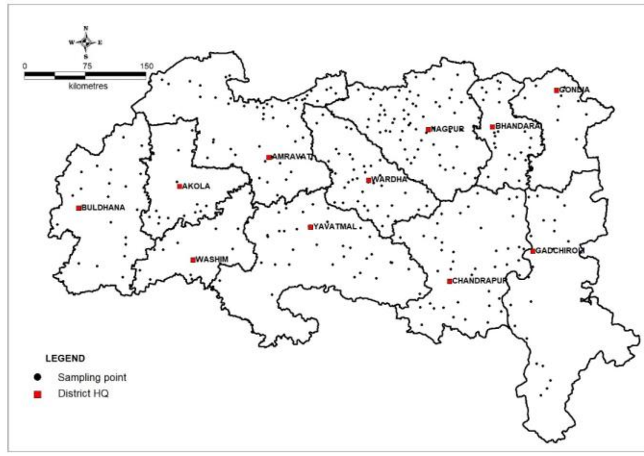

Figure 2: Sampling Locations of Vidarbha Region, Maharashtra State, India (May 2019)

Chemical Analysis

For the chemical analysis of the collected samples, only standard methods of chemical analysis for water samples were followed as prescribed by Standard Methods for Analysis of water and waste water (APHA 2017). The instruments used were as per the accuracy and precision prescribed in the standard procedures. Chemicals of analytical reagent and certified reference grade/ standard reference material were used during the chemical analysis. The quantitative estimations of water quality parameters were carried out by titrimetric, spectrophotometeric, flame photometric methods etc. The ultra-pure distilled water was used for analytical purpose during chemical analysis. Selected water quality indicative parameters were chosen for the chemical analysis of collected water samples, viz. pH, Electrical Conductance (EC), Total Dissolved Solids (TDS), Total hardness (TH), Calcium Hardness (CaH), Total Alkalinity (TA), Sodium (Na), Potassium (K), Chloride (Cl), Sulphate (SO_4), Nitrate (NO_3) and Fluoride (F).

Statistical Analysis

The results of chemical analysis were statistically analysed for several chemical indices such as Residual Sodium Carbonate (RSC), Permeability index (PI), Soluble Sodium Percentage (SSP), Sodium Adsorption Ratio (SAR) and Kelly's ratio (KR). All the parameters are reported in standard units of measurements. Apart from this, some statistical analysis of the reported results were also calculated as described below:

a. Residual sodium carbonate (RSC) of the ground water was calculated by the formula (Eaton 1950; Raghunath 1987):

$$RSC = \left(CO_3^{2-} + HCO_3^{-}\right) - \left(Ca^{+} + Mg^{+}\right)$$

b. Permeability index (PI) of the ground water was calculated by employ equation developed by Doneen (1964) and Raghunath (1987)

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \times 100$$

c. Soluble sodium percentage (SSP) of the ground water was estimated by employ the equation given by Todd (1980):

$$SSP = \frac{(Na + K) \times 100}{(Ca + Na + Mg + K)}$$

d. The sodium adsorption ratio of the ground water was evaluated by employ the formula developed by Richards (1954):

$$SAR = \frac{Na}{\sqrt{Ca + Mg/2}}$$

e. The Kelly's ratio (KR) was determine by using the following expression (Karanth 1987).

$$KR = \frac{Na}{Ca + Mg}$$

For the calculation of all the chemical indices, meq/l values of the parameters were used.

Pictorial presentation

Based upon the outcomes of the chemical analysis, the results were plotted on the study area through software viz. Map Info version 8.5. Distribution of selected water quality parameters across the study area are presented in figures, from 3 to 8. Number of samples falling within specific category of different chemical indices and their percentage have been prepared in the form of pie-charts and presented in figures, from 9 to 13. These pie-charts indicative of the suitability of ground waters as per the category of the chemical indices, which shows that more than 95% of the total samples collected are within the recommended category of classification.

IV. Results and Discussion

The results of the physicochemical analysis are presented as minimum, maximum and average concentration of the WQ parameters in each of the eleven districts of the Vidarbha region, Maharashtra State, in Table-1. The analytical results were compared with BIS standard (BIS 2296: 1982 and 10500: 2012) for evaluation of suitability of ground water for different purposes. Calculated chemical indices such as RSC, PI, SSP, SAR and KI ratios are also presented in Table-1. For each WQ parameters 3-4 categories were created based on their different criteria for suitability assessments and the number of samples within the categories are presented in Table-2.

pH: pH is one of the most significant parameters of ground water. The values of pH were varying from 6.2 to 8.2. Almost all samples of eleven districts of Vidarbha region were within maximum permissible limit prescribed by BIS.

Electrical Conductance (EC): The electrical conductivity is a fast and convenient means of estimating the concentration of ions in water. The values of EC were varying from 139 to 5600 µmho/cm at 25^{o}C. The maximum and minimum EC were recorded in Akola (5600 µmho/cm) and Gondia (139 µmho/cm). Total 60.87% of the samples has EC less than 1000 µmho/cm, 34.20 % samples has EC between 100-2250 µmho/cm and 4.93 % samples has EC above 2250 µmho/cm. As per BIS standard 2296:1982, 4.93 % samples of study area is not suitable for irrigation. Distribution of EC across the study area is presented in Figure-3**.**

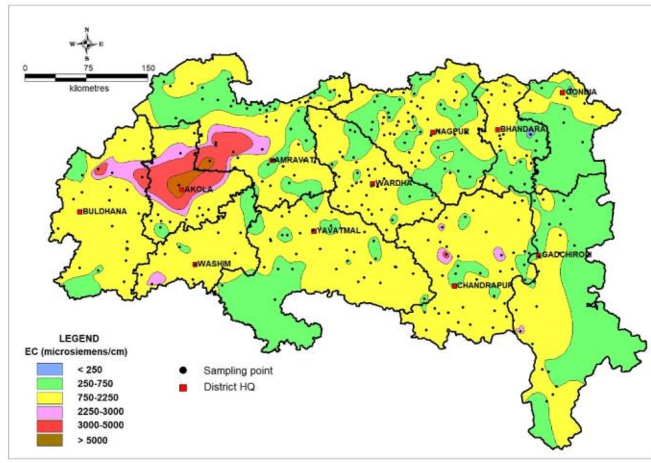

Figure 3: Distribution of Electrical Conductance across the study area, Vidarbha Region, Maharashtra State

Total dissolved solids (TDS): It is a natural pollutants in the ground water and it imparts color, total alkalinity and conductivity to the natural water. The optimum value of 2000 mg/L is acceptable according to BIS-2012 guideline. The values of TDS were varying from 90 to 3640 mg/L. Higher TDS in water is harmful for sufferer of kidney and heart diseases (Al-hadithi 2012). Total 38.26 % samples has TDS less than 500 mg/L, 59.42% samples has TDS between 500-2000 mg/L and 2.32% samples have TDS above 2000 mg/L. 2.32% samples of study area are not suitable for drinking as per BIS 10500:2012 standard. Distribution of TDS across the study area is presented in Figure-4.

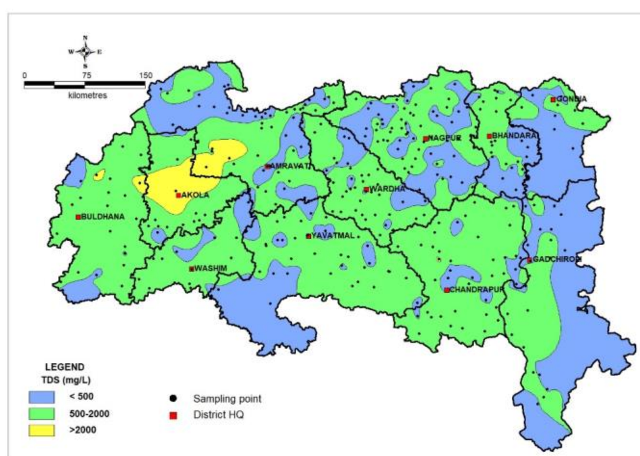

Figure 4: Distribution of TDS across the study area, Vidarbha Region, Maharashtra

TABLE 1

Results of Chemical and Statistical Analysis of Ground Water Samples of Vidarbha Region, Maharashtra, India.*

District (No of Samples)	Statistical Values ↓	pH	EC	TDS	TH	Na	K	TA	Cl	SO4	NO3	F	CaH	SAR	RSC	SSP	PI	KR
Akola (14)	Min	7.3	555	361	122	15	0.4	119	15	16	13	0.1	40.9	0.68	-13.00	14.7	12.4	0.17
	Max	7.9	5600	3640	729	508	3.1	1023	670	263	76	0.9	281.1	7.02	1.93	63.7	33.2	1.76
	Avg	7.6	1739	1131	298	125	1.2	322	151	75	40	0.3	98.1	2.68	-2.09	36.3	25.3	0.67
Amravati (54)	Min	7.2	390	254	128	7	0.1	131	8	1	2	0.4	25.6	0.35	-20.97	8.3	11.2	0.09
	Max	8.2	4490	2919	500	620	3.3	494	742	190	37	1.7	337.3	20.20	3.13	83.5	50.4	5.05
	Avg	7.8	1261	819	222	85	1.2	275	143	43	21	0.8	107.9	2.69	-1.19	34.3	33.1	0.67
Bhandara (22)	Min	6.8	350	228	36	19	1.8	95	7	12	4	0.0	63.1	0.53	-13.18	14.5	6.4	0.13
	Max	8.1	2001	1301	377	89	51.3	303	256	43	37	0.7	542.9	4.68	-0.85	55.3	33.3	1.17
	Avg	7.6	906	589	170	49	16.7	190	83	24	18	0.2	240.7	1.90	-5.60	32.1	20.7	0.47
Buldhana (22)	Min	7.4	612	398	148	44	0.9	143	50	20	7	0.0	97.1	0.64	-11.72	14.1	21.5	0.16
	Max	8.1	3530	2295	1327	206	45.1	845	496	356	76	1.1	1068.0	3.44	-0.81	47.7	35.7	0.86
	Avg	7.7	1637	1064	496	103	11.2	464	174	85	36	0.7	351.0	2.20	-3.93	35.3	28.7	0.55
Chandrapur (41)	Min	7.5	395	257	148	14	0.1	113	17	12	7	0.0	56.2	0.62	-2.96	16.6	20.8	0.16
	Max	8.1	2343	1523	750	83	29.3	654	184	94	44	1.6	449.7	3.48	1.64	46.9	40.0	0.87
	Avg	7.7	1036	673	295	57	9.0	314	76	38	27	0.5	161.3	2.05	-0.84	34.4	31.5	0.51
Gadchiroli (24)	Min	7.4	443	288	87	11	0.6	24	27	7	6	0.4	49.1	0.31	-3.74	7.7	6.6	0.08
	Max	7.9	2209	1436	439	81	19.8	280	311	62	43	1.1	165.1	3.62	0.68	50.0	34.9	0.90
	Avg	7.6	1080	702	217	37	4.7	132	111	32	29	0.7	80.2	1.78	-1.25	30.4	19.5	0.44
Gondia (14)	Min	7.4	139	90	41	6	0.9	18	12	6	2	0.3	20.4	1.21	-3.85	26.8	4.9	0.30
	Max	7.9	1465	952	304	101	58.8	232	144	79	47	1.2	196.7	6.46	-0.17	63.5	32.6	1.62
	Avg	7.6	755	491	159	49	18.3	121	72	41	29	0.7	94.0	2.98	-1.96	43.5	18.8	0.75
Nagpur (63)	Min	7.8	431	280	148	10	0.6	172	12	10	4	0.0	97.1	0.35	-3.27	8.3	18.2	0.09
	Max	8.1	1253	814	474	58	16.5	375	169	154	47	0.2	270.8	1.61	1.09	29.1	44.4	0.40
	Avg	7.9	833	541	297	33	4.8	265	63	52	29	0.1	158.4	0.97	-0.49	20.1	31.5	0.24
Wardha (39)	Min	7.5	453	294	163	19	0.6	184	14	12	4	0.0	35.3	0.58	-2.75	13.0	20.2	0.14
	Max	8.0	2187	1422	775	202	10.5	767	171	200	38	0.8	485.5	8.89	1.19	69.0	46.4	2.22
	Avg	7.7	1055	686	326	69	3.5	338	73	67	16	0.5	156.8	2.37	-0.37	31.0	31.7	0.59
Washim (15)	Min	7.3	694	451	66	29	0.7	65	25	3	11	0.0	35.8	1.40	-9.44	26.9	9.8	0.35
	Max	7.8	2502	1626	255	253	50.9	351	256	130	38	3.5	138.0	25.41	-0.42	86.4	30.8	6.35
	Avg	7.5	1231	800	178	94	12.3	173	105	38	28	0.5	98.7	6.46	-3.13	48.5	19.1	1.61
Yavatmal (37)	Min	7.4	503	327	173	17	0.5	65	21	11	5	0.3	56.2	0.70	-3.80	15.2	9.4	0.17
	Max	7.8	1954	1270	673	74	11.1	607	161	108	53	1.5	250.4	3.15	3.88	46.4	34.5	0.79
	Avg	7.6	910	591	304	42	2.4	233	74	45	33	0.8	128.7	1.44	-0.69	25.8	23.8	0.36

* Units of all chemical parameters is mg/L except pH, EC is expressed in µS/cm. Statistical parameters has no units.

TABLE 2

Classification* of samples in the selected categories of WQ parameters for the study area.**

Parameters	Categories ↓ / No. of Samples→	*AKO* 14	AMR 54	BHN 22	BUL 22	CHD 41	GDC 24	GND 14	NGP 63	WRD 39	WAS 15	YMT 37
pH	6.5-8.5	14	54	22	22	41	24	14	63	39	15	36
	6.0-9.0	0	.0	0	0	0	0	0	0	0	0	0
	6.0 - 8.5	0	0	0	0	0	0	0	0	0	0	1
EC	< 1000	10	37	13	7	21	14	12	44	21	9	22
	1000-2250	1	12	9	12	17	9	2	19	18	5	15
	> 2250	3	5	0	3	3	1	0	0	0	1	0
TDS	< 500	2	26	10	4	10	13	7	28	12	5	15
	500 - 2000	10	25	10	16	30	11	7	35	27	10	22
	> 2000	2	3	2	2	1	0	0	0	0	0	0
TH	<200	9	21	16	3	11	16	10	18	5	9	7
	200 - 600	3	32	6	16	29	8	4	45	33	6	29
	> 600	2	1	0	3	1	0	0	0	1	0	1
Cl	< 250	12	49	20	19	39	22	14	62	39	14	37
	250 - 600	1	3	2	3	2	2	0	1	0	1	0
	600-1000	1	2	0	0	0	0	0	0	0	0	0
SO4	> 400	14	53	22	22	41	24	14	63	39	15	37
	400 - 1000	0	1	0	0	0	0	0	0	0	0	0
	> 1000	0	0	0	0	0	0	0	0	0	0	0
NO3	> 20	1	22	13	6	17	7	3	32	12	3	2
	20-50	9	32	9	15	24	17	11	31	27	12	34
	>50	4	0	0	1	0	0	0	0	0	0	1
F	> 1.0	14	48	22	17	31	19	12	62	35	14	26
	1.0 - 1.5	0	5	0	5	4	5	2	1	4	0	10
	> 1.5	0	1	0	0	6	0	0	0	0	6	1
PI	> 75 %	2	2	0	0	1	0	0	0	0	0	0
	75 - 25 %	5	39	6	13	23	6	4	47	27	5	22
	< 25 %	7	13	16	9	17	18	10	16	12	10	15
SSP	< 50	8	38	20	18	32	18	10	51	30	11	32
	> 50	6	16	2	4	9	6	4	12	9	4	5
SAR	<10	14	53	22	22	39	24	14	61	39	13	37
	10 to 18	0	0	0	0	2	0	0	1	0	1	0
	18-26	0	0	0	0	0	0	0	1	0	1	0
	> 26	0	1	0	0	0	0	0	0	0	0	0
RSC	< 1.25	13	42	22	22	37	24	14	58	35	15	36
	1.25 -2.5	1	11	0	0	2	0	0	4	4	0	0
	> 2.5	1	0	0	0	2	0	0	1	0	0	1
KR	> 1.0	12	45	20	21	34	24	10	58	35	10	37
	1.0 - 2.0	2	5	2	1	5	0	4	3	3	2	0
	< 2.0	0	4	0	0	2	0	0	2	1	3	0

* Number of samples in a particular category. ** AKO-Akola, AMR-Amravati, BHN-Bhandara, BUL-Buldhana, CHD-Chandrapur, GDC-Gadchiroli, GND-Gondia, NGP-Nagpur, WRD-Wardha, WAS-Washim and YMT-Yawatmal.

Total Hardness (TH): The Hardness in natural water is due to calcium and magnesium with bicarbonate, carbonate, sulphate and other species. The resultant of hardness is scale in utensils and in boilers etc. soap scum's sources are dissolved calcium and magnesium from soil and aquifer surround by limestone or dolomite (Muthukumaravel, 2010). The values of TH were varying from 35.7 to 1327.0 mg/L, which were recorded in Bhandara and Buldhana districts respectively. The desirable value of TH is 200 mg/L. However, the optimum value of 600 mg/L is acceptable according to BIS 2012 guideline. The effect of this hardness can be seen as deposited scale when such waters are heated and when groundwater using as a drinking water source with high hardness create gastrointestinal problems in human being (CPCB, 2007). Total 36.23% samples have TH less than 200 mg/L, 61.16% samples have TH between 200 - 600 mg/L and 2.61% samples have TH above 600 mg/L. 2.61% samples of study area are not suitable for drinking as per standard. Distribution of TH across the study area is presented in Figure-5.

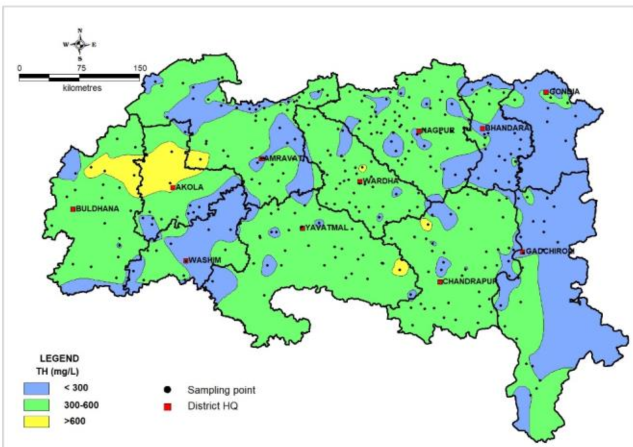

Figure 5: Distribution of Total Hardness across the study area, Vidarbha Region, Maharashtra

Chloride (Cl): Chlorides in natural and raw waters generally come from rocks, the sea, sewage and agricultural and industrial effluents. Fresh water concentrations of chloride are normally less than 40 mg/L and can be as low as 2 mg/L in waters, which have not been subject to pollution. The Cl ion is an essential constituent and found in water from natural as well as anthropogenic activities. The value of chloride was varying from 7.4-742.0 mg/L, which were recorded in Bhandara and Amravati districts respectively. The desirable value of Cl is 250 mg/L and optimum value of 1000 mg/L is acceptable according to BIS 2012 guideline. Chloride concentrations over 100 mg/L give the water a salty taste. The 94.78% samples showing Cl less than 250 mg/L, 42.90% samples showing Cl between 200-600 mg/L and 0.87% showing above 600 mg/L, hence only 0.87% samples of study area is not suitable for drinking as per the BIS standard. Distribution of Chloride concentration in the groundwater samples across the study area is presented in Figure-6.

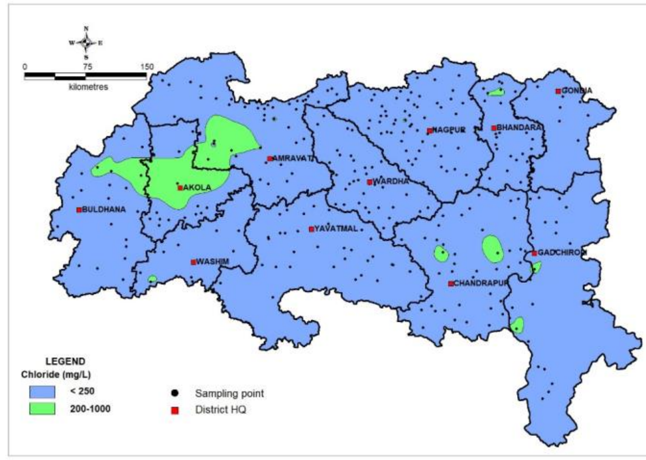

Figure 6: Distribution of Chloride across the study area, Vidarbha Region, Maharashtra State

Sulphate (SO_4) : Natural water contains sulphate ions and the majority of these ions are also soluble in water. Many sulphate ions are produce by oxidation process of their ores, they also present in industrial waste water (Dohare 2014).The value of SO_4 was varying from 1.0 to 356.1 mg/L. The maximum and minimum SO_4 was recorded in Buldhna (356.1 mg/L) and Amravati (1.0 mg/L). The desirable value of SO_4 is 200 mg/L and optimum value of 400 mg/L is acceptable according to BIS 2012 guideline. The WHO (1996) also recommended maximum allowable concentration of 400 mg/L. Sulfate gives a bitter or medicinal taste to water if it exceeds a concentration of 250 mg/l and also contributes to the corrosion of distribution systems WHO (2004). The 97.39% samples showing SO_4 less than 200 mg/L, 2.32% samples showing SO_4 between 200 - 400 mg/L and 0.29% showing above 400 mg/L, hence only 0.87% samples of study area is not suitable for drinking as per standard (BIS 10500:2012). Distribution of Sulphate concentration in the groundwater samples across the study area is presented in Figure-7.

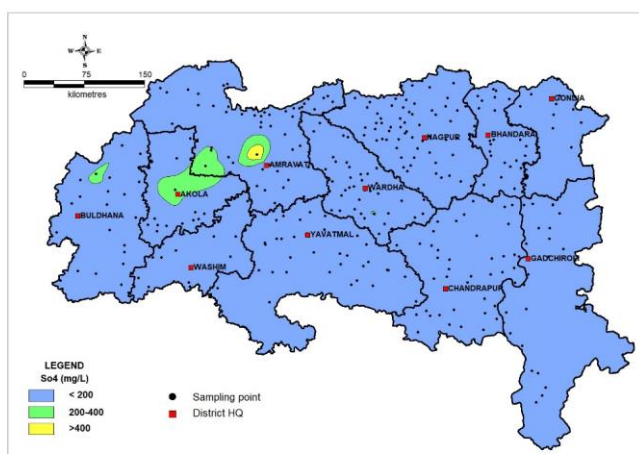

Figure 7: Distribution of Sulphate across the study area, Vidarbha Region, Maharashtra

Nitrate (NO_3): Nitrate is present in untreated water and mainly it is a form of Nitrate, Nitrite and Ammonia. Nitrate is produced from chemical and fertilizer factories, matters of animals, decline vegetables, domestic and industrial discharge (Darwisha 2011). The value of NO_3 was varying from 2.0 to 76.3 mg/L. The desirable value and optimum value of NO_3 is 45 mg/L according to BIS 2012 guideline. The maximum and minimum NO_3 was recorded in Buldhana (76.3 mg/L) and Amravati (2.0 mg/L). The 34.20% samples showing NO_3 less than 20 mg/L, 64.06% samples showing NO_3 between 20 - 50 mg/L and 1.25% showing above 50 mg/L, hence 34.20% samples of study area is fit for Class A (Drinking water source without conventional treatment but after disinfections), 64.06% (Drinking water source with conventional treatment followed by disinfections) samples showing NO_3 for Class B and remaining only 1.74% is not suitable for all class (BIS 2296:1982).

Total Alkalinity: The major sources of bicarbonate contain organic matter in the aquifer that is oxidized to produce carbon dioxide, which help dissolution of minerals (Khashogji and El Maghraby 2013).The fossil carbon of the calcite and dolomite is also contribute bicarbonate ions in the aquifer. This weathering of this type rocks enhance the groundwater in calcium, magnesium and bicarbonate ions. (Gastmans et al. 2010). The value of HCO_3 was varying from 17.8 to 1023.1 mg/L. The maximum and minimum SO_4 was recorded in Akola (1023.1 mg/L) and Amravati (17.8 mg/L). Bicarbonates combine with Ca and Mg produce high hardness of water and converting soft water in to hard water, which creates gastrointestinal problems in human. Distribution of Total Alkalinity concentration in the groundwater samples across the study area is presented in Figure-8.

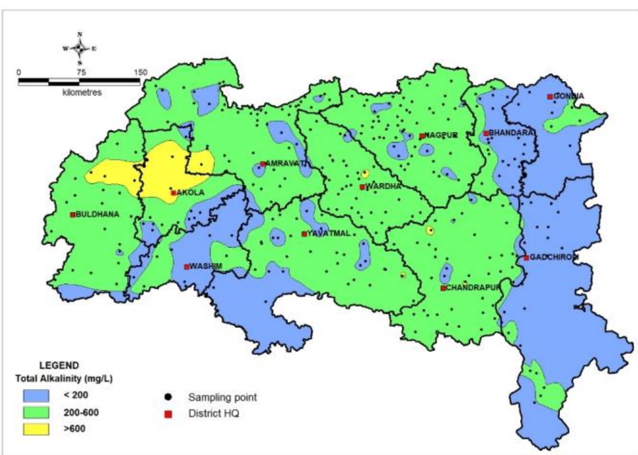

Figure 8: Distribution of Total Alkalinity across the study area Vidarbha, Maharashtra State

Fluoride (F) : It is well known that small amounts of Fluoride (less than 1.0 mg/l) have established to be helpful in reducing tooth decay. The value of F was varying from 0.00 to 3.51 mg/L. The desirable value of F is 1.0 mg/L and optimum value of 1.5 mg/L is acceptable (BIS 10500: 2012). The maximum and minimum F was recorded in Washim (3.51 mg/L) and Bhandara, Buldhana (0.0 mg/L). High concentrations such as 1.5 mg/l of F and above have resulted in staining of tooth enamel and Fluorosis. The 86.96 % samples showing F less than 1.0 mg/L, 10.43 % samples showing F between 1.0 – 1.5 mg/L and 2.61% showing above 1.5 mg/L, hence only 2.61% samples of study area is not suitable for drinking as per the BIS standard.

Sodium (Na) : All natural water contain sodium ions (Na+) is one of the major element occur in the earth. The high concentrations of sodium are normally associated with pollution from industrial waste, sewage effluent and sea water intrusion. The sodium concentrations are less than 200 mg/L in drinking water as recommended (WHO 1996). The sodium concentrations in the ground water samples were varying between 5.7 to 620.0 mg/L. The maximum and minimum sodium was recorded in Amravati (620.0 mg/L) and Gondia (5.7 mg/L). When high concentration sodium water utilize for irrigation purpose, it can have a negative effect on soil structure by deflocculating it, which can affect plant growth and various types of crops are sodium sensitivity. The 84.64% samples showing sodium less than 100 mg/L, 10.43% samples showing sodium between 100 - 200 mg/L and 4.93% showing above 200 mg/L, hence only 4.93% samples of study area is not suitable for drinking as per standard (WHO 1996).

Potassium (K): The concentration of K in natural waters is normally less than 10 mg/L. The main sources of potassium in ground water include Sea water, brine water, rainwater, weathering of potash, use of potash fertilizers and use of surface water for irrigation). The BIS has not included Potassium in drinking water standards, However the European Union Standard has specified guideline level of 10 mg/l (CPCB, 2007). The Potassium concentration in the ground water samples were found in the range of 0.1 to 58.1 mg/L. The maximum and minimum Potassium were recorded in Gondia (58.1 mg/L) and Chandrapur & Amravati (0.1 mg/L). The increased exposure to potassium could result in considerable health effects in people with kidney disease or heart disease (WHO, 2007) and highly concentrated potassium ground water is not fit for irrigation. The 82.61% samples showing Potassium concentrations less than 10 mg/L, 8.12% samples showing Potassium concentrations between 10 - 20 mg/L and 9.28% showing above 20 mg/L, hence 17.40% samples of study area is not suitable for drinking as per standard as per European Union Standard.

Permeability Index (PI) : PI values also show that the groundwater is fit for irrigation. Doneen (1964) classified in to three classes that is Class I (> 75 %), Class II (25–75 %), and class III (< 25 %). Class I and Class II waters are categorized as good for irrigation with 75 % or more of maximum permeability. Class III waters are unsuitable with 25 % of maximum permeability. The value of PI was varying from 4.3 to 50.4 %. The maximum and minimum SO4 was recorded in Amravati (50.4 %) and Gondia (4.3) in year 2019. Sodium plays significant role in assess the groundwater quality for irrigation because sodium causes an increase in the hardness of soil as well as a reduction in its permeability (Tijani 1994; Nagarajan et al. 2010). The 41.5% samples showing PI less than 25, 57.06% samples showing PI between 25 - 75 and 1.44 % showing above 75% , hence 41.5% samples of study area is not suitable for irrigation. The pictorial presentation of range wise classification is expressed in Figure 9.

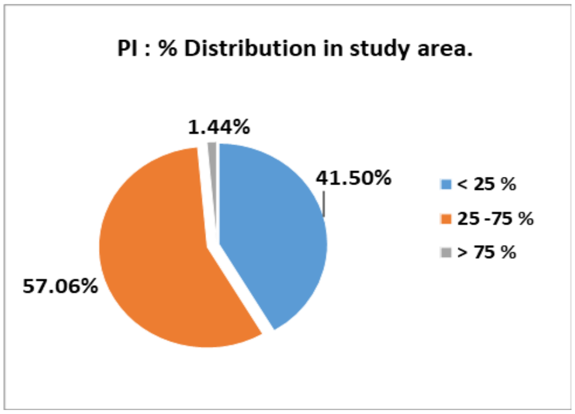

Figure 9: Percent distribution of PI across the study area

Soluble Sodium Percentage (SSP): This term is also known as the sodium percentage (Na %). It is helpful in characterize soft water, because a high value designate a soft water and a low value designate a hard water. It is indicative of the sodium (alkali) hazard but is not as satisfactory a compute of this hazard as is the SAR. The values of SSP below 50 indicate good quality of water and above 50 shows that the water is unsafe for irrigation (USDA 1954). The value of SSP was varying from 7.7 to 86.4. The maximum and minimum SSP was recorded in Amravati (86.4**)** and Gondia (7.7). The 77.68 % samples showing SSP less than 50 % and 22.32 showing above 75%, hence 22.32 % samples of study area is not suitable for irrigation. The pictorial presentation of range wise classification is expressed in Figure 10.

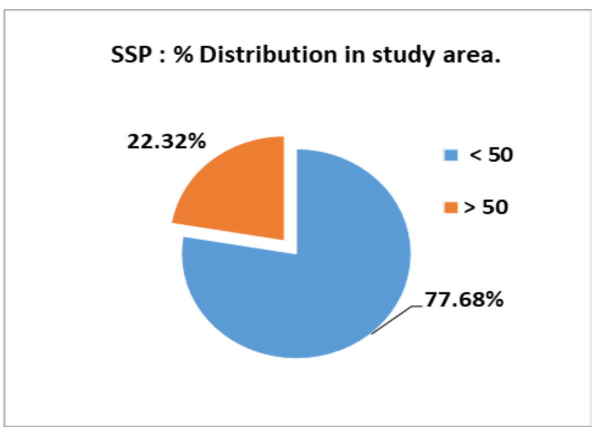

Figure 10: Percent distribution of SSP across the study area

3.17 Sodium Adsorption Ratio (SAR): The SAR using for express the sodium hazards. Sodium concentration is significant in categorize the water for irrigation purpose as sodium concentration can reduce the soil permeability and soil structure (Todd 1980). The waters having SAR values < 10 are considered excellent, 10–18 as good, 18–26 as fair, and above 26 are unsuitable for irrigation use (USDA 1954). The value of SAR was varying from 0.30 to 25.4. The maximum and minimum SAR was recorded in Washim (25.4**)** and Gadchiroli (0.30) in year 2019. The 97.97 % samples showing SAR less than 10, 0.87 % samples showing SAR between 10–18, 1.16 % showing between 18-16 and no sample showing SAR above 26, hence 41.5 % samples of study area is not suitable for irrigation. High values of SAR imply a hazard of sodium ultimately damages the soil structure (Khan and Abbasi 2013). The pictorial presentation of range wise classification is expressed in Figure 11.

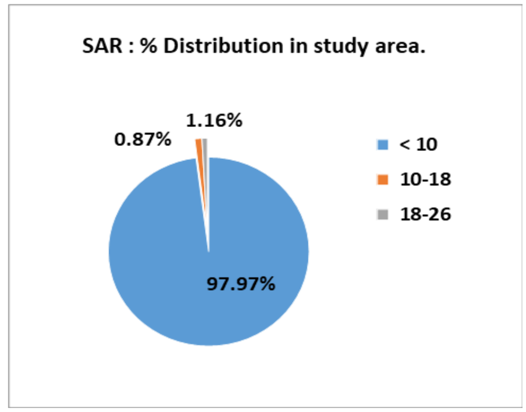

Figure 11: Percent distribution of SAR values across the study area

3.18 Residual Sodium Carbonate (RSC): The waters having RSC values < 1.25 are considered good water quality, 1.25 - 2.5 the water is marginally suitable as good, above 2.5 unsuitable for irrigation use (USDA 1954). The value of SAR was varying from 0.30 to 25.4. The maximum and minimum RSC was recorded in Wasim (25.4**)** and Gadchiroli (0.30) in year 2019. The 92.17% samples showing RSC less than 1.25, 6.38 % samples showing RSC between 1.25 - 2.50, 1.45% showing RSC above 2.5, hence 41.5% samples of study area is not suitable for irrigation. RSC established the hazardous consequence of carbonate and bicarbonate on the quality of water for agricultural use (USSL 1974). The pictorial presentation of range wise classification is expressed in Figure 12.

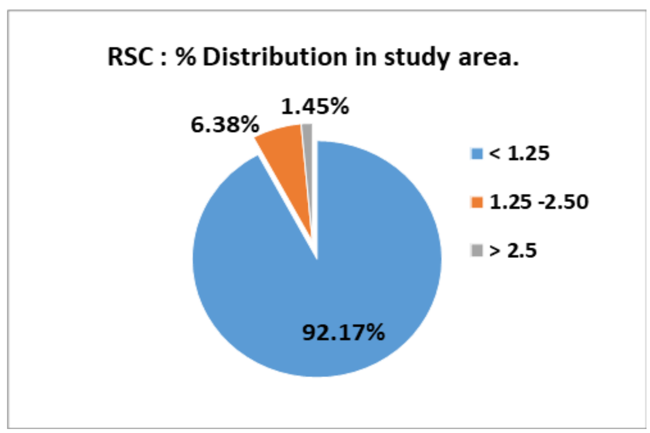

Figure 12: Percent distribution of RSC values across the study area

The Kelly's Ratio (KR): KR is indicative of water for irrigation purpose. The Water having KR valus is less than 1.0 is suitable, 1.0 – 2.0 is marginal suitable and above 2.0 is unsuitable (Karanth 1987) for agricultural purpose due to alkali hazards. The value of KR was varying from 0.08 to 6.35. The maximum and minimum SAR was recorded in Wasim (6.35**)** and Gadchiroli (0.08) in year 2019. A Kelly's ratio of more than one indicates high concentration of sodium in ground water**.** The 88.70 % samples showing KR less than

1.0, 7.83% samples showing KR between 1.0–2.0, 3.48% showing KI above 2.0, hence 3.48% is unsuitable for agricultural purpose. The pictorial presentation of range wise classification is expressed in Figure 13.

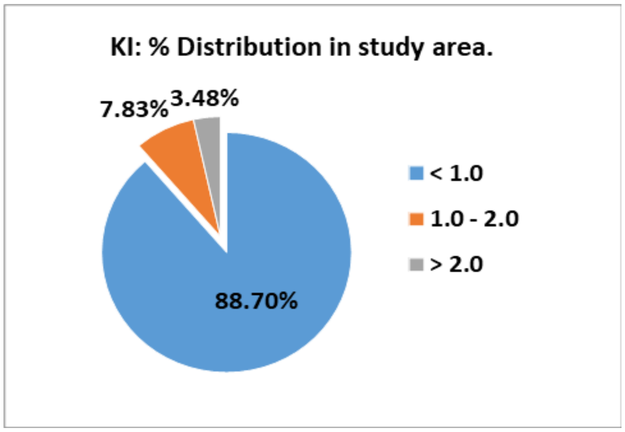

Figure 13: Percent distribution of KC across the state

V. Conclusions

The study of Physico-chemical parameters has been performed to appraise factors regulating ground water quality in an area with irrigation as well as a main use of eleven districts of Vidhbaha area (Maharashtra).

The 4.93 % samples is not suitable for irrigation with reference to EC, 2.32 % samples of study area is not suitable for drinking with reference to TDS, 2.61 % samples is not suitable for drinking as per standard with reference to TH, 1.45 % is not suitable for drinking with reference to Ca, the 14.88 % samples of is not suitable for Class A of designated use classification with reference to CaH (Calcium Hardness), 0.87 % samples is not suitable for drinking with reference to Mg, 0.87 % samples is not suitable for drinking with reference to Cl, 0.29 % samples is not suitable drinking with reference to SO_4, 1.74 % samples are is not suitable for all class designated use classification with reference to NO_3, 2.61 % samples is not suitable for drinking with reference to F, 4.93 % samples for drinking with reference to Na, 17.40 % samples is not suitable for drinking with reference to K, 41.5 % samples is not suitable for irrigation with reference to PI, 22.32 % samples is not suitable for irrigation with reference of SAR, 1.45 % samples of study area is not suitable for irrigation with reference to RSC. 3.48 % is unsuitable for agricultural purpose with reference to KR. The remaining % ground water samples are suitable for drinking and irrigation use.

It is concluded from the study, significance number of ground water samples of Vidharbha area (Maharashtra) are above the limit and not suitable for the drinking and irrigation. Hence it is need to pay attention to improve water quality of Vidharbha area by using suitable ground water recharge techniques in the area.

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