

Physico-chemical Characteristics of Groundwater in Wardha Sub basin, Maharashtra, India

V. P. Nawale¹, M.K.N. Yenkie², D. B. Malpe³

Research Scholar, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur¹.

Professor, Department of Chemistry, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur, India²

Professor, Department of Geology, RTM Nagpur University, Nagpur, India³

ABSTRACT: Physico-chemical characteristics of the groundwater in Wardha sub basin of Maharashtra State of India were studied based on the physico-chemical analysis data for 15 parameters of groundwater samples collected from 90 wells representing shallow and deeper aquifers. The results have shown that the groundwater in the area is alkaline, hard and moderately mineralised in nature. The alkalinity of groundwater is mainly due to the HCO_3^- ions present in the groundwater. Major ions concentrations in groundwater indicated the dominance of $\text{Na}^+ > \text{Mg}^{++} > \text{Ca}^{++} > \text{K}^+$ among the cations while dominance of $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{--} > \text{NO}_3^- > \text{F}^-$ ions among the anions in groundwater. The results further indicate that the HCO_3^- , Na^+ , Mg^{++} and Ca^{++} ions are contributed to groundwater through interaction of aqueous phase of groundwater with minerals present in basalts, sandstones and limestones aquifer media. The study has also indicated that the groundwater chemistry in the area is controlled by the precipitation and ion exchange processes. The influence of anthropogenic activities on the characteristics of the groundwater have revealed from the high concentrations of Cl^- , SO_4^{--} and NO_3^- ions in groundwater. The potability of groundwater in the area is affected mainly due to the high concentrations of parameter TA, TDS, Mg^{++} , TH and NO_3^- in groundwater while the salinity hazard is high as compared to sodium hazard if the groundwater is used for irrigation purpose. The periodic assessment of groundwater quality along with strict measures for disposal of domestic and agricultural waste in the area may help to check the further deterioration of groundwater quality in the area.

KEYWORDS: Physico-chemical Characteristics, Major ions, Groundwater Quality, Anthropogenic activities

I. INTRODUCTION

The groundwater acquires its physico-chemical characteristics due to the amount of dissolved or suspended inorganic or organic material in it. Under natural condition, the physico-chemical characteristics of ground water depend on several factors such as the composition of atmospheric gases, the climatic conditions, physiographical, geological and hydrogeological conditions prevailing in particular area [1]. The evolution in characteristics of groundwater depends on dissolution, ion-exchange, oxidation-reduction, precipitation and several others reactions taking place during the interaction of aqueous phase of groundwater with solid and gaseous phase. The surface and subsurface anthropogenic activities also influence groundwater characteristics existing in particular area. The physico-chemical characteristics changes with time and space [2]. The groundwater quality for the intended use is assessed using the physico-chemical characteristics of groundwater. Several groundwater related studies carried out in different parts of the world to assess and study the water quality and hydro geochemical processes highlights need to first understand the physico-chemical characteristics of groundwater [3-5].

The present study aims at understanding the physico-chemical characteristics of ground water in the WR-7 watershed of Wardha river sub basin of Yavatmal district, Maharashtra, India. The objective of the present work also includes assessment of groundwater quality for human consumption and irrigation based on physico-chemical characteristics.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

II. STUDY AREA

The study area falls in parts of the Survey of India Toposheet No. 55L/16 covering 245 sq.km, area and lies between north latitude 20°05'13" and 20°15' 26" and east longitudes 78° 44' 28" and 78° 58'44" and is shown in figure 1. It represents WR-7 watershed of Wardha river sub basin and includes parts of the Maregaon and Wani Tahsils of Yavatmal district, Maharashtra state, India. The watershed comprised of total 49 habitations out of which 48 are village habitations and 1 town habitation with a population of 53,430 as per census 2011. The land use pattern in the area indicates that, out of the total area, 6% is forest land and 20% are hilly lands while the remaining 74% land is utilised for cultivation, grazing and other purposes. No major industrial units except few limestones, cotton and vegetable oil processing units are located in the area. The Climate of the area is characterised by a hot summer and general dryness throughout the year except during the south-west monsoon season. The normal annual rainfall received by the area is about 897 mm with mean daily maximum and minimum temperature during month of May and December is 45°C and 11°C respectively. The soil in the area is slightly alkaline in nature, clayey loamy in texture and contain calcium carbonate [6]. Geologically the area is underlain by Precambrian Penganga beds consisting of limestone and dolomites, Upper Carboniferous-Permian Gondwanas having sandstone and shale sequence, Cretaceous Lameta beds consisting of limestones and sandstones, Upper cretaceous to lower Eocene Deccan Trap Basalt and Recent Alluvium [7]. Deccan Trap Basalt is the predominant water bearing formation, followed by Gondwana formation having Sandstone and Shale sequence. Penganga and Quaternary Alluvium aquifers are spread in limited areas. The water level fluctuation observed in the area during pre and post monsoon season is 4.60 m bgl and stage of groundwater development is 8% [8].

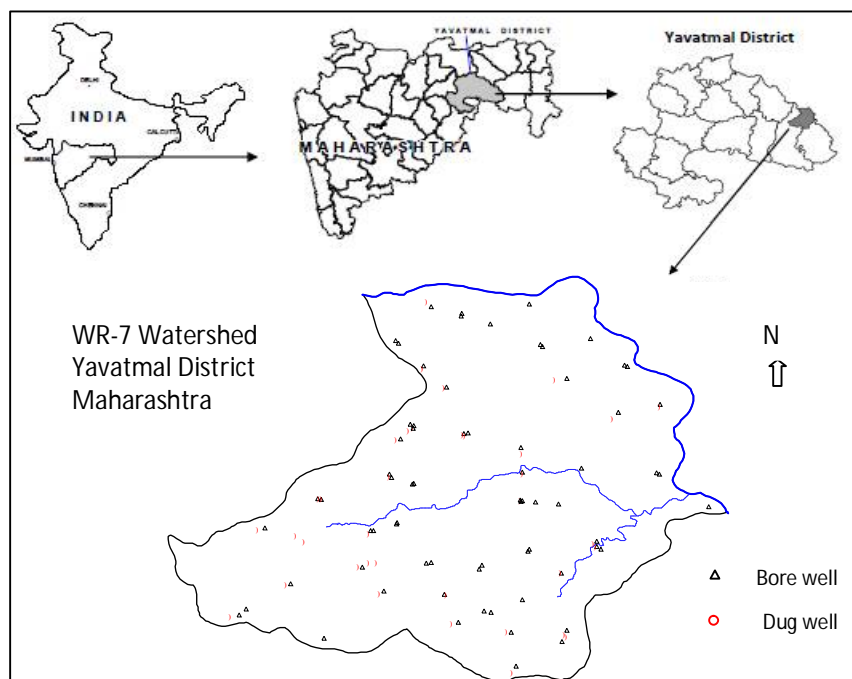


Figure 1: Location Map of Study Area

III. MATERIALS AND METHODS

Ground water samples were collected in the month of November 2011 from 90 ground water structures comprising of 30 dug wells representing shallow aquifer and 60 bore wells fitted with hand pump representing deeper aquifer. Figure 1 shows the location of bore wells and dug wells selected for study. The depth of wells tapping shallow aquifer were less than 15 m below ground level (bgl) while borewells depths ranges from 15 to 107 m bgl. The elevation of the wells located ranges from 190 to 260 m amsl with average elevation of 218 m amsl. Out of the 90 wells, 29 wells were

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

tapping the limestone aquifer while 44 wells were tapping the basaltic aquifer and 12 wells were tapping sandstones. The rest 5 wells were representing the Alluvium formation. The samples were analysed for nearly 15 parameters viz. pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), total alkalinity(TA), calcium (Ca⁺⁺), magnesium (Mg⁺⁺), sodium (Na⁺), potassium (K⁺), carbonate (CO₃⁻), bicarbonate (HCO₃⁻), chloride (Cl⁻), sulphate (SO₄⁻), nitrate (NO₃⁻) and fluoride (F⁻). The sampling, preservation and analysis techniques were followed as per American Public Health Association (APHA) manual of the Standard Methods for examination of Water and Wastewater [9].

IV. RESULTS AND DISCUSSION

The experimental results obtained after analysis were first checked for correctness by using charge balance error [9]. The principle of neutrality requires that sum of the cations must equal to sum of anions. The error in a cation-anion balance is calculated as

$$\% \text{ balance error} = [(\sum \text{Cations} - \sum \text{Anions}) / (\sum \text{Cations} + \sum \text{Anions})] \times 100$$

The cations and anions are expressed in meq/L. The % balance error calculated for the entire groundwater samples were found well within the acceptable limit of 5% and the data was used for interpretation purpose. The descriptive statistics giving minimum, maximum, mean concentration of the each parameter analysed along with standard deviation in groundwater samples is presented in Table 1. The physico-chemical characteristics acquired by the groundwater in the area based on the concentration of the each parameter as shown in Table 1 are described below.

Table 1: Descriptive Statistics of Physico-chemical Analysis Data of Groundwater Samples

Parameter	Minimum	Maximum	Mean	Std. Dev.
Temperature in °C	22.0	30.5	28.0	1.6
pH	7.1	8.0	7.5	0.2
EC in µS/cm at 25°C	670	4550	1628	756
TDS in mg/L	357	2721	930	467
TA as CaCO ₃ in mg/L	135	785	437	115
TH as CaCO ₃ in mg/L	55	1490	368	185
Ca ⁺⁺ in mg/L	12	178	36	22
Mg ⁺⁺ in mg/L	6.1	294	68	39
Na ⁺ in mg/L	2	920	182	145
K ⁺ in mg/L	0.5	168	22	26
CO ₃ ⁻ in mg/L	BDL	BDL	BDL	BDL
HCO ₃ ⁻ in mg/L	165	958	534	140
Cl ⁻ in mg/L	18	550	134	122
SO ₄ ⁻ in mg/L	7	950	102	147
NO ₃ ⁻ in mg/L	0.1	360	118	95
F ⁻ in mg/L	0.01	3.1	0.90	0.52

*BDL- below detectable limit

Temperature

Temperature plays an important role in controlling the reactions taking place between water and solid or gaseous media. The solubility of gases will be affected by the partial pressure and temperature [10]. In the study area, the temperature of groundwater ranges from 22.0°C to 30.5°C with mean temperature of 28 °C. The temperature of groundwater normally increases as the depth increases. In study area, the average temperature observed at shallow depth is 26.4°C and at deeper depth is 28.9°C indicating a difference of 2.5°C.

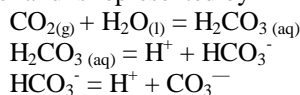
International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

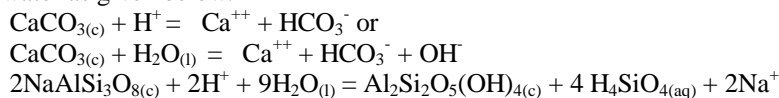
pH

The results show that the pH of groundwater ranges from 7.1 to 8.0 in the area with mean value of pH 7.75 indicating that the ground water is alkaline in nature. The pH of water is mainly controlled by the reaction of dissolved carbon dioxide with water and is represented by



The H^+ ion produced in second and third phase influences pH of water. The observed pH of water is an indicator of the status of equilibrium existing in the above reactions. The ratio $[\text{HCO}_3^-]:[\text{H}_2\text{CO}_3]$ will be near to 100:1 at pH 4.4 and ratio $[\text{HCO}_3^-]:[\text{CO}_3^{2-}]$ will have the similar value at pH 8.3. The range of pH in study area indicates that the pH of groundwater is controlled by second phase reaction.

In study area, the interaction of aqueous phase of groundwater with the mineral phase producing or consuming H^+ influences pH of water as given below.



Several other reactions like dissociation of acidic solutes such as H_2PO_4^- , $\text{H}_2\text{S}_{(aq)}$ and HSO_4^- producing H^+ ions, precipitation reactions like conversion of iron(III) into iron hydroxide ($\text{Fe}(\text{OH})_3$) and oxidation reduction reactions such as interaction of water with pyrite (FeS_2) can also influence the pH of water [2].

Electrical Conductivity and Total Dissolved Solids

The EC and TDS of groundwater is mainly due to the dissolved ions or dissolved solids in groundwater. The mean value of EC 1628 $\mu\text{S}/\text{cm}$ and TDS 930 mg/L indicates that the groundwater in the area is moderately mineralized and water has spent sufficient time in interacting with solid and gaseous media present in the area. A plot of EC in $\mu\text{S}/\text{cm}$ on y-axis versus TDS in mg/L on x-axis is shown in figure 2. The figure 2 reflects that the EC and TDS are both related with each other by well-defined relationship.

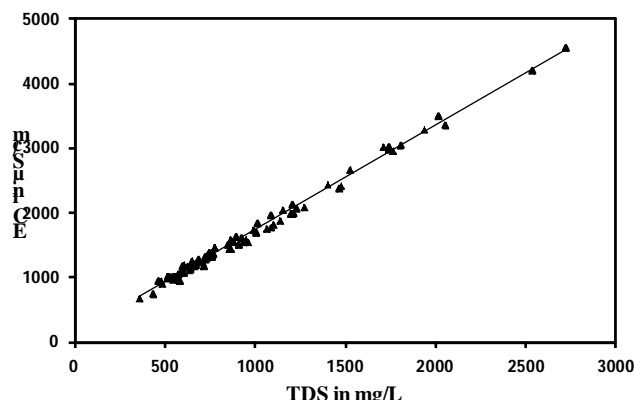


Figure 2: Relations between EC and TDS of Groundwater

The mean concentrations of major ions such as Ca^{++} , Mg^{++} , Na^+ , K^+ , HCO_3^- , Cl^- , NO_3^- and SO_4^{--} indicate that these ions dissolved in groundwater are contributing to the EC of water. It further reflects that among the cations, the dominance of $\text{Na}^+ > \text{Mg}^{++} > \text{Ca}^{++} > \text{K}^+$ while among the anions, the dominance of $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{--} > \text{NO}_3^- > \text{F}^-$ ions in groundwater.

The contribution of individual ion to EC of groundwater was calculated from the mean concentrations of these ions [11] and shown below in figure 3. The figure clearly indicate that HCO_3^- , Mg^{++} , Na^+ , Cl^- , NO_3^- , SO_4^{--} and Ca^{++} ions are contributing maximum to EC in the increasing order. Among the cations, Mg^{++} , Na^+ followed by Ca^{++} ions are

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

major contributors to EC while among anions, HCO_3^- and Cl^- followed by SO_4^{2-} and NO_3^- ions are contributing maximum.

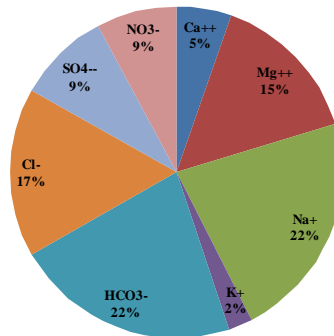


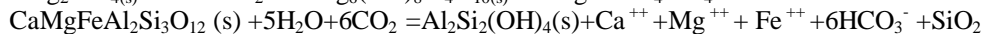
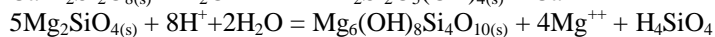
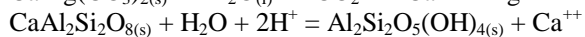
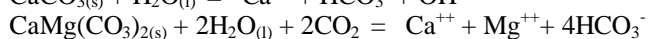
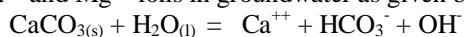
Figure 3: Contributions of Individual Ions towards EC of Groundwater

Total Alkalinity (TA), Carbonate and Bicarbonate

The average total alkalinity of groundwater of 437 mg/L as CaCO_3 shows that the groundwater in the area has gained sufficient capacity to neutralize the acids. The source of alkalinity in groundwater in the area is mainly the carbon dioxide dissolved in water and mineral calcite present in calcareous rocks. The concentration of CO_3^{2-} ion in groundwater was found in traces while that of HCO_3^- ion ranges from 134 to 909 mg/L with mean value of 494 mg/L. The range of pH from 7.2 to 8.3 in groundwater in the area suggests that under such pH condition, bicarbonate concentration in groundwater will be maximum. Overall, the bicarbonates present in the water are mainly contributing to total alkalinity of water. However, silicates, phosphates, borates etc. present in groundwater can also contribute to the alkalinity. Among all the anions analyzed in groundwater, HCO_3^- is the most dominant anion in groundwater.

Total Hardness (TH), Calcium and Magnesium

The total hardness of groundwater in the area ranges from 55 to 1490 mg/L as CaCO_3 with mean value of 368 mg/L reflecting that the groundwater in the area is very hard in nature [12]. The sources of hardness in groundwater are mainly the salts of calcium and magnesium present in groundwater. The concentrations of Ca^{++} and Mg^{++} in groundwater were found in the range of 12 to 128 mg/L and 6.1 to 294 mg/L with average concentration of 36 and 68 mg/L respectively. The geogenic source of calcium and magnesium in the study area are mainly the minerals present in the basalts, sandstone, limestone and dolomites. The reaction between the aqueous phase of water with the minerals yield Ca^{++} and Mg^{++} ions in groundwater as given below.



A plot of TH in mg/L as CaCO_3 on x-axis versus Ca and Mg in mg/L on y-axis was prepared to study the contribution of individual ions towards TH and shown in figure 4. The figure indicates that both calcium and magnesium contributes for hardness of water however the contribution of magnesium salts towards hardness is more as compared to the calcium salts in groundwater.

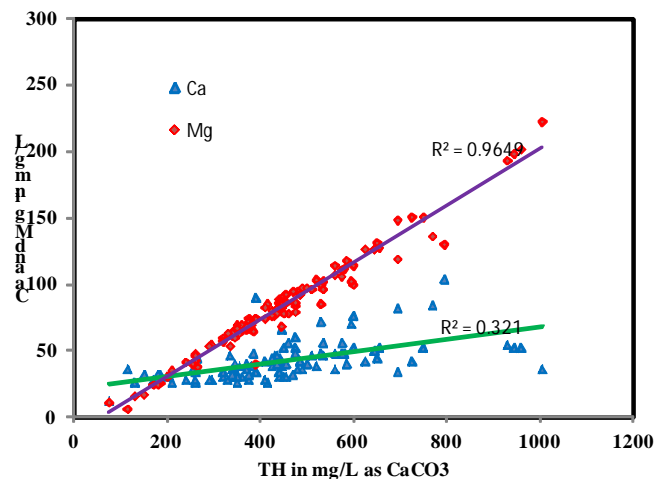
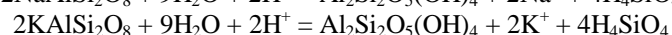
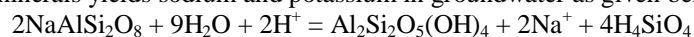


Figure 4: Relations between TH and Ca⁺⁺ & Mg⁺⁺ ions in Groundwater

The geochemical behavior of calcium and magnesium is different from each other. Under natural condition, the concentrations of calcium may be higher than the magnesium and the ratio of Ca:Mg may be more than 1.0 but the concentration of calcium may get reduced during the circulation of water due to the precipitation and ion exchange. The magnesium may remain in the aqueous phase of water as the effect of hydration is much greater than larger ion of calcium and may not precipitate or take part in ion exchange reaction [2]. In the study area, the average Ca:Mg ratio in groundwater found to be 0.53 which is significantly low and indicate that the concentration of calcium in groundwater as compared to magnesium might have been reduced because of the precipitation and ion exchange reaction. The low Ca:Mg ratio may also be due to the enrichment of magnesium in groundwater from anthropogenic sources. The concentrations of bicarbonate, chloride, sulphate and nitrate ions in groundwater shows that the temporary hardness of water is due to the bicarbonates of Ca and Mg while permanent hardness of water is due to chlorides, sulphates and nitrates of Ca and Mg. The dominance of carbonate ion among anions indicates that the groundwater is having more temporary hardness than the permanent hardness.

Sodium and Potassium

The groundwater in the study area was found to have the concentrations of sodium and potassium in the range of 2 to 920 mg/L and 0.5 to 168 mg/L with mean value of 182 and 22 mg/L respectively. The concentration of sodium is significantly higher than the potassium in groundwater. The average composition of igneous and sedimentary rocks indicates that sodium and potassium occur as major elements in these rocks. However, sodium is slightly more abundant than potassium in igneous rocks while potassium is more abundant as compared to sodium in sedimentary rocks [13]. In study area, the igneous rock basalt and sedimentary rocks such as sandstone, limestone and dolomites are present. Among the sedimentary rocks sandstone, shales will have more concentrations of potassium and sodium as compared to carbonate rocks. The feldspar minerals constitute 60% of igneous rocks and the interaction of aqueous phase of water with these minerals yields sodium and potassium in groundwater as given below.



The potassium feldspars are more resistant to chemical attack than the sodium feldspars. However, the K⁺ liberated from silicate mineral structures have strong tendency to be reincorporated into solid weathering product especially in clay minerals while the Na⁺ has reverse tendency to remain in solution. Therefore, the groundwater normally has concentration of K⁺ lower than the Na⁺. In the study area, the average concentration of potassium is nearly 10 times lower than the sodium in groundwater. The hydro-chemical behaviour of K⁺ also suggests that it is more involved in biosphere as compared to Na⁺. Potassium is an essential element for both plants and animals. In sedimentary rocks, Na⁺

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

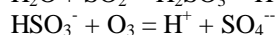
may be present in unaltered mineral grains or in the form of sodium salt deposited with the sediment or left in them by saline water. The sodium ion is having ionic radius more than 1 angstrom and is not strongly hydrated. Sodium normally does not get precipitate like calcium as carbonate during circulation and cation exchange processes in groundwater systems normally try to extract divalent ions such as Ca^{++} from solution and replace them with monovalent ion like Na^+ . Hence, the groundwater sometimes may be enriched with sodium than calcium. The sodium may also occur in groundwater from anthropogenic sources as large numbers of salts are used by human beings in their daily life and manufacturing of different products. The agricultural activities can contribute potassium to groundwater if potassium fertilisers are extensively used. The potassium ions assimilated by plants can also become a source of potassium in groundwater after organic decay and leaching from soil [2].

Chloride

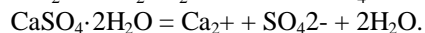
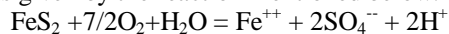
The chloride in groundwater of study area ranges from 18 to 550 mg/L with average concentration of 134 mg/L. It is the second most dominant anion in water after bicarbonate ion followed by sulphate and nitrate ions. The igneous and sedimentary rocks present in the area do not contribute significantly chloride to groundwater [13]. The chemical behavior of chloride ion suggest that it do not significantly takes part in oxidation or reduction reaction, do not get significantly adsorbed on mineral surface, do not forms salts of low solubility and plays few vital biochemical roles. It can enter into groundwater without any retardation and can be used as tracer [14]. As many salts and compounds containing chlorides are utilized in manufacturing, treatment of water and for daily use by the people living in urban and rural areas, it is possible that the domestic and industrial waste and wastewater generated in such area is rich in chloride content. In the study area, presence of significant and high concentration of chloride in groundwater indicates that it is originated from surface anthropogenic activities and getting percolated to groundwater without any hindrance.

Sulphate

The average sulphate content in groundwater of study area is 102 mg/L. The sulphate in groundwater may appear from the atmospheric precipitation. The rainwater interacts with sulphur dioxide gases in presence of other gases in the atmosphere and produce sulphate ions while hydrogen sulphide gas dissolved in water also yields sulphate as given in the reaction below.



The igneous and sedimentary rocks may contain sulphur bearing minerals in the form of metallic sulphide or as metallic sulphate in the evaporites which when undergo weathering in contact with aerated water may give rise to sulphate ions in solution as given by the reaction mentioned below.



The domestic wastewater is normally rich in sulphate content and can act as a potential source of sulphate in groundwater. In study area, the possibility of occurrence of sulfur bearing minerals in the rocks belonging to Gondwana formation cannot be ruled out. The gypsum may also be associated with dolomite and limestone rocks belonging to Penganga formation and can contribute sulphate to groundwater [13]. The emission of sulphur dioxide in atmosphere through industrial activities in the area is less and hence the contribution of sulphate through atmospheric precipitation to groundwater may not be significant. But the runoff generated after rainfall collecting contaminants from soil and domestic wastewater can yield significant amount of sulphate in groundwater. This can also be revealed from the appearance of sulphate in groundwater to the level of 950 mg/L.

Nitrate

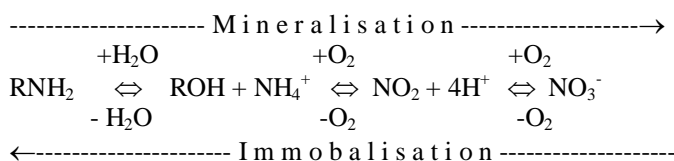
The concentration of nitrate in groundwater of study area ranges from 0.1 to 360 mg/L with average value of 118 mg/L indicating that the groundwater in the area is rich in nitrate content. The nitrate in groundwater is also appearing as major anion in water after bicarbonate and chloride ion. The chemical behavior of NO_3^- ion shows that it is highly electronegative and does not get adsorbed in the process of percolation like chloride ions as the adsorbent on the way are mostly electronegative. Nitrate salts are highly soluble as it forms electrovalent compound with ions like Na and K

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

etc. It remains in groundwater without retardation unless reducing condition is developed for denitrification or by ion exchange some time [2]. The process of tying of nitrogen in organic form is called immobilization and its slow release from organic to inorganic form is mineralization.



There are many sources of nitrogen such as atmospheric precipitation, domestic waste and wastewater, agricultural activities and geological media through which nitrate may be appearing in groundwater. The igneous rocks contain nitrogen in very small quantities [13]. Rankama and Sahama (1950) have suggested that possibly ammonical form of nitrogen may be present and very little could be present as nitrate in the rocks [15]. The nitrogen present in the atmosphere in the different form can be converted into the oxidised form by the reaction caused by lightning, photochemical oxidation in the stratosphere and chemical oxidation of ammonia. The nitrate concentration in rainwater was reported up to 3.7 mg/L in the past [16]. In the study area, the average nitrate concentration of 118 mg/L in groundwater indicates that the atmospheric precipitation and geological media have played limited role in contributing nitrate to groundwater. It was observed during field investigations that the disposal of domestic waste/wastewater is carried out through unlined drains and nalas in residential area. It was also observed that the farmers are storing the animal manure in the area without impervious lining. The fertilizers extensively used for agricultural purpose were also found to have rich in nitrate salts/compounds. The wells monitored were found to lie in close proximity of these sources of nitrate in study area. Overall, the improper disposal of domestic waste and wastewater and agricultural activities are playing significant role in contributing nitrate to groundwater.

Fluoride

The fluoride in groundwater of study area ranges from 0.01 to 3.1 mg/L with average fluoride of 0.90 mg/L in groundwater. Only 12 samples were found to have F⁻ more than 1.5 mg/L. The fluoride in groundwater may be appearing from the dissolution of fluoride bearing minerals present in the area although the possibility of contribution of fluoride from anthropogenic sources such as use of phosphate fertilisers for agriculture purpose cannot be ruled out.

Groundwater Quality for Drinking and Irrigation Purpose

The groundwater quality of study area for drinking purpose was assessed based on the percent compliance of groundwater samples with acceptable limit prescribed by the Bureau of Indian Standards (BIS) in its Drinking Water Specifications IS 10500:2012 [17] for the parameters pH, TDS, TA, TH, Ca⁺⁺, Mg⁺⁺, Cl⁻, SO₄⁻, NO₃⁻ and F⁻ and shown in Table 2 given below.

Table 2: Groundwater Quality for drinking Purpose

Parameter	BIS Acceptable limit (IS 10500:2012)	Percent Compliance
pH	6.5 – 8.5	100
TDS in mg/L	500	6
TA as CaCO ₃ in mg/L	200	1
TH as CaCO ₃ in mg/L	200	10
Ca ⁺⁺ in mg/L	75	98
Mg ⁺⁺ in mg/L	30	13
Cl ⁻ in mg/L	250	87
SO ₄ ⁻ in mg/L	200	89
NO ₃ ⁻ in mg/L	45	32
F ⁻ in mg/L	1.0	69

It is clear from the above table that the pH in all the groundwater samples is in compliance with the acceptable limit given by BIS while Ca⁺⁺, SO₄⁻ and Cl⁻ content in majority of samples (> 85%) are also in compliance with the

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

acceptable limit. However, less than 10% of groundwater samples were found in compliance with the acceptable limit for the parameter TA, TDS, TH. The Mg^{++} content in only 13% of sample was found within the acceptable limit. The above classification of groundwater samples shows that the groundwater quality for drinking purpose in the area is mainly affected due to the high concentrations of the parameters namely TA, TDS, Mg^{++} , TH and NO_3^- . It is also revealed that F⁻ in groundwater in 69% samples is in compliance with acceptable limit of 1.0 mg/L. The people using groundwater for drinking purpose without treatment in the area are at the risk of getting affected by the diseases caused by the high concentrations of these parameters in groundwater.

The suitability of groundwater for irrigation purpose was assessed based on the EC and sodium adsorption ratio (SAR) values of groundwater samples using the US Salinity diagram [18] and shown in figure 5 given below. The SAR is given as

$$SAR = [Na / (\sqrt{Ca + Mg/2})]$$

Where, the concentration of Na, Ca and Mg ions is in meq/L.

The figure 5 shows conductivity values on x-axis while SAR values on y-axis giving salinity hazard (C1: Low, C2: Medium, C3: High, C4: Very High) and sodium hazard (S1:Low, S2:Medium, S3:High and S4:Very High). The US Salinity diagram for classification of groundwater for irrigation purpose shows that the maximum number of samples fall in the region of S1 (SAR<10) and C3 (EC 750-2250 $\mu S/cm$) indicating that the sodium hazard is low and salinity hazard is high if groundwater is used for irrigation purpose. The diagram also shows that the groundwater in few wells is unsuitable for irrigation purpose as the sodium (SAR>18) and salinity hazard (EC>2250 $\mu S/cm$) is high if the groundwater in these wells is used for irrigation purpose.

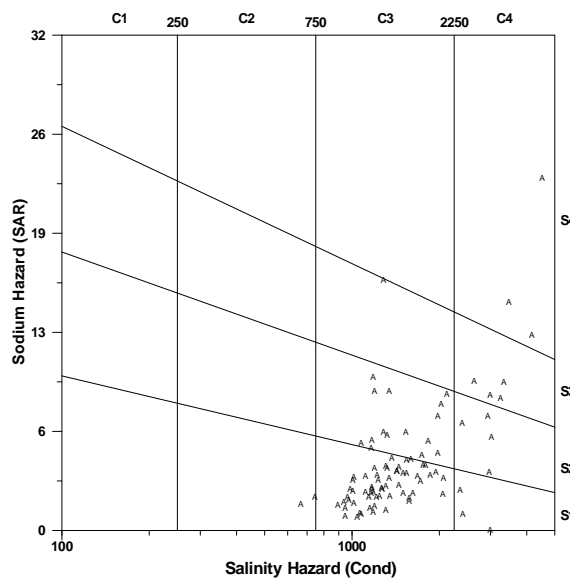


Figure 5: US Salinity Diagram

V. CONCLUSIONS AND RECOMMENDATIONS

The outcome of the study indicate that the physico-chemical characteristics acquired by the groundwater in WR-7 watershed of the Wardha River Sub basin of Yavatmal District Maharashtra are influenced by the hydrogeochemical conditions existing in the area as well as the surface anthropogenic activities. The degree of mineralisation of groundwater has indicated that the groundwater has spent sufficient time in interacting with aquifer media. The alkalinity of the groundwater is mainly due to the bicarbonate ion present in groundwater while the total hardness is due to mainly the salts of magnesium as compared to calcium salts. The high concentrations of Na^+ and Mg^{++} ions as

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

compared to Ca^{++} ion in groundwater reflect that the precipitation and ion exchange processes are controlling the groundwater chemistry in the area. The interaction of groundwater with the minerals present in the rocks basalts, sandstone, limestones existing in the area are contributing the ions Ca^{++} , Mg^{++} , Na^+ , K^+ and HCO_3^- to groundwater. However, the presence of high concentrations of Cl^- , SO_4^{--} and NO_3^- ions in groundwater reflects that the characteristics of groundwater is getting altered due to the percolation of domestic and agricultural waste and wastewater in groundwater in the area. The assessment of groundwater quality for drinking purpose have shown that the groundwater quality for drinking purpose is mainly affected due to the high concentrations of the parameter TA, TDS, Mg^{++} , TH and NO_3^- in groundwater. The study also shows that the salinity hazard is more if the groundwater is used for irrigation purpose. The remedial measures such as periodic assessment of groundwater quality along with disposal of domestic and agricultural waste with proper treatment may help to stop the further deterioration of groundwater quality in the area.

Acknowledgement

The authors are thankful to the Director, Laxminaryan Institute of Technology; RTM Nagpur University, Nagpur for his kind support and providing necessary laboratory facilities during the research work.

REFERENCES

- [1] Handa B. K., "Natural Waters, their Geochemistry, Pollution and Treatment with a Chapter on the Use of Saline Water", Central Ground Water Board, Ministry of Agriculture & Irrigation, Govt. of India, Technical Manual No.2, 246 p, 1975.
- [2] Hem, J. D., "Study and Interpretation of the Chemical characteristics of Natural Waters", US Geological Survey Water-Supply Paper 2254, US Department of Interior, Third Edition, 253 p., 1985.
- [3] UNICEF and WHO, "Drinking Water Equity, safety and sustainability", Thematic report on drinking water, 61 p, 2011.
- [4] Chang, J. and Wang, G., "Major ions chemistry of groundwater in the arid region of Zhangye Basin, northwestern China. Environmental Earth Sciences", Vol.61(3), pp.539-547, 2009.
- [5] Arumugam, K. and Elangovan, K., "Hydrochemical characteristics and groundwater quality assessment in Tirupur region, Coimbatore District, Tamil Nadu, India", Environmental Geology, v.58(7), pp.1509-1520, 2009 .
- [6] CGWB, "Report on Reappraisal Hydrogeological Surveys in parts of Wardha and Penganga subbasins., Yavatmal and Wardha districts, Maharashtra", Central Ground Water Board, Ministry of Water Resources, Government of India, 1996.
- [7] GSI, "Report on Geology in parts of Wani Tehsil of Yeotmal District and Warora Taluka of Chanda District in Topo Sheet 55I/16", Geological Survey of India, Ministry of Mines, Government of India, pp. 1-65, 1965.
- [8] GSDA and CGWB, "Report on the Dynamic Ground Water Resources of Maharashtra (2011-2012)", Groundwater Surveys and Development Agency (GSDA), Govt. of Maharashtra & Central Ground Water Board (CGWB), Ministry of Water Resources, Government of India, 909 p., 2014.
- [9] APHA, "Standard methods for the examination of water and waste water", American Public Health Association, Washington, DC, 21st Edition, pp.10-161, 2005.
- [10] Garrels, R. M. and Christ, C. L., "Solutions, Minerals and Equilibria". Harper & Row, New York, 437 p. 1965.
- [11] Rossum, J. R., "Checking the accuracy of water analyses through the use of conductivity", American Water Works Association Journal, 67:204., 1975.
- [12] Durfor, C N and Becker, Edith, "Public water supplies of the 100 largest cities in United States 1962", US Geological Survey Water-Supply Paper 1812, 364 p., 1964.
- [13] Horn, M. K., and Adams, J. A. S., "Computer-derived geochemical balances and element abundances", Geochimica et Cosmochimica Acta, Vol.30, p.279-297, 1966.
- [14] Kaufman, W.J., and Orlob, G.T., "Measuring groundwater movement with radioactive and chemical tracers", American Water Works Association Journal, v.48, p. 559-572, 1956.
- [15] Rankama and Sahama, "Geochemistry", Chicago University, Chicago Press, 912 p. 1950.
- [16] Kakkar, Y.P., Lal, R., Kumar, A., Singh, B. and Dass, J., "Chemistry of ground water in north-western India (Punjab, Haryana, Himachal Pradesh, Jammu & Kashmir, Union Territory of Delhi and Chandigarh)", Central Ground Water Board, Ministry of Water Resources, Government of India, Chandigarh, 87p. 1987.
- [17] BIS, "Indian Standard Drinking Water-specification (Second Revision) IS 10500:2012", Bureau of Indian Standards, New Delhi, India, 11 p., 2012.
- [18] US Salinity Laboratory Staff, "Diagnosis and improvement of saline and alkali soils", US Department of Agriculture Handbook No. 60, 160p. 1954.