Impact of Human Activities on the Quality of Groundwater from Sangamner Area, Ahmednagar District, Maharashtra, India

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Abstract

Groundwater is liable to contamination through anthropogenic and other sources like use of chemical pesticides, addition of industrial waste, domestic and agricultural waste to the water bodies. During last decades, it has been observed that the groundwater gets polluted drastically because of increased human activities. Consequently, the numbers of cases of water born diseases have been seen causing health hazard. The study has been carried out to assess the impact of human activities on the quality of groundwater of Sangamner area, Ahmednagar district, Maharashtra. 21 groundwater samples were collected along the Pravara River and assessed the physico chemical parameters such as P^H, EC, TDS, TH, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, SO_4^{2-} and NO_3^-. The geochemical characteristics of groundwater have been found to be dominated by $Ca+Mg > Na + K - HCO_3 + CO_3$ indicating dominance of cation and anion exchange process. This suggests the contamination of groundwater is due to human activities. On the basis of TDS, the groundwater is slightly moderately saline in character in the discharge zone in the are due to anthropogenic activities. The groundwater from the majority of the samples is not suitable for drinking purposes as compared with standard limit suggested by WHO. This is posing the serious health hazard to the local population. Groundwater salinisation, nitrate pollution, changes in alkalinity, hardness of groundwater and changing nature of geochemical character of groundwater has been identified as the impacts of human activities in the area. Educating the people about water quality surveillance program, infrastructural set up and the importance of public participation about water quality will prevent further degradation of groundwater resources in the area.

Keywords: Human activities, salinisation, nitrate pollution, health hazard, total alkalinity, geochemical character of groundwater.

Introduction

Groundwater is the major source of water for domestic, agricultural and industrial purposes in many countries. India accounts for 2.2% of the global land and 4% of the world water resources and 16% of the world population. It is estimated that one third of the world's population use groundwater for drinking. Therefore, water quality issues and its management options need to be given greater attention in the developing countries. Intensive agricultural activities have increased the demand on groundwater resources in India. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices[1].

In the last two decades, the rapid growth industrialization and urbanization has created negative impact on the environment. Due to industrial, municipal and agricultural waste containing pesticides, insecticides, fertilizer residues and heavy metals with water groundwater has been polluted by leaching process[2]. These pollutants are being added to the groundwater and soil system through various human activities and rapid growth of industrialization which affect the human health directly or indirectly.

The composition of groundwater has also been affected by human activities through changes in land use and intervention in natural flow patterns. The quality of water also depends on agricultural land use pattern. Due to increase in population, uses of chemical fertilizers, pesticides, industrialization and many other anthropogenic factors, water from various sources becoming polluted to a larger extent day by day. Animal and human excrement is also a dangerous cause for water pollution in the under developed countries. Consumption of polluted water directly from the sources may cause water borne diseases like diarrhea, dysentery, typhoid and paratyphoid fever, hepatitis, liver and intestinal infection, skin rash etc. Chemical contamination of drinking water may not cause immediate health problem but their long time intake may be fatal for human health[3]. Several researchers have carried out an extensive work on the quality of groundwater for various anthropogenic activities[4-10].

Sangamner area is experiencing the interplay between natural and human induced factors. These factors in combination have lead to degradation of overall soil and groundwater quality. Because of construction of Bhandardara dam in the source region of Pravara River, the area has been brought under

intensive agriculture. Establishment of co-operative sugar mill and several other allied industrial units without planning of waste water management contributes to adversely affecting the natural groundwater quality of study area. Wide range of human induced factors causing changes in the groundwater quality of study area is not known. Some studies were reported regarding the ground water and soil characteristics of the study area[11-12]. As the population of Sangamner Tahsil is widely dispersed and the majority of people are localized in rural / remote area in the periphery of Pravara river. They suffer from lack of awareness regarding the quality of water, which exposes the variety of health related problems in the area. In view of this, the present work was carried out in Sangamner area.

The Study Area: Sangamner area is located in the northern part of the Ahmednagar district of Maharashtra State. The tahsil lays between 18°36' N to 19° 1'N latitude and 74° 1'W to 74° 56'W longitude. The Sangamner town is located on the confluence of the Mahalungi and the Pravara River. It is a Taluka head quarter which is at a distance of 150 km from Pune, on Pune - Nasik National Highway No. NH-50 (figure 1). The area is drained by the Pravara river which is a tributary of Godavari and has its origin in the hilly region of Western Ghats. Geologically, basalt underlay the Pravara basin, which is characterized by thick alluvium (up to 35 m.). Several dams and weirs have been constructed across Pravara river. Because of construction of Bhandardara Dam in the source region of Pravara River, the valley has been brought under intensive agriculture with sugarcane as a single dominant crop. Subsequent to the establishment of co-operative sugar mill at Sangamner in 1967, the agriculture in the area has witnessed rapid changes in the cropping pattern. In addition to sugar industry several allied industrial units have also come up in the area. The effluents from sugar industry, with little or no treatment have been stored in lagoons and then discharged into the natural stream flowing through the agricultural area for a distance of about 8 to 9 km. This effluent stream finally meets the Pravara River at Sangamner. While flowing through the natural stream, the effluent infiltrates through the soil zone into the nearby dug / bore wells thereby adversely affecting natural groundwater quality.

Material and Methods

Twenty one sampling wells were selected along the cross section of Pravara River (figure 1). The cross section passes through entire valley from one water divide to another i.e. from Chandapuri Ghat towards south of Pravara River to Karhe Ghat in the north. By selecting wells along the cross section, it was possible to cover areas from recharge to discharge zone. It included wells located on plateau top, hill slopes and valley floor areas spread on the either sides of Pravara River. The samples were collected in polyethylene bottles of one liter capacity. The care was taken to collect samples after pumping for some time. The pH, electrical conductivity (EC) was measured in the field. The samples were then brought to the

laboratory for further chemical analysis. The analysis was carried out in the laboratory by using the procedures given by APHA[13], using titrimentric methods, the analysis of chloride (Cl), total alkalinity as $CaCO_3$, Calcium (Ca^{+2}) and total hardeness as $CaCO_3$ (TH) was performed. While nitrate, phosphate and sulphate were analyzed by spectrophotometric methods (Hitachi-2000, UV-visible spectrophotometer), the alkali elements like sodium and potassium were detected by flame photometer (Corning 400). Using Stiff Computer program the charge balance error (CBE) was calculated to check the analytical accuracy. The charge balance error up to 10% was considered valid. The data obtained by carrying out the chemical analysis for groundwater is presented in table 1.

Results and Discussion

Physico chemical parameters of groundwater and Human Activities: Physico-chemical parameters like pH, EC, TDS, total alkalinity, cations like calcium, magnesium, sodium and potassium and anions like chloride, sulphate, bicarbonate, nitrate and phosphate and alkali elements like Na and K are some important parameters for assessing the groundwater quality for irrigation and drinking purposes. In this group of parameters the chloride, sulphate, nitrate and phosphate were considered as contaminants because the host rock (basalt) contribute to them in very meager quantities. The very presence of all these parameters in the groundwater therefore, is directly related to the human activities.

pH and Electrical Conductivity: pH of ground waters is related to the dissolved carbonates and bicarbonates, silicates, borates, fluorides and other salts in dissociated forms. High pH values are associated with sodium bicarbonate – carbonate waters. High carbonate cause calcium and magnesium ions to form insoluble minerals leave sodium the dominate ion in solution[14]. Low pH values reflect water containing free acids. This accelerates the release of metals from rocks or sediments in the water. The lower values of pH may cause corrosion in containers and pipeline while higher values may produce sediments, deposits and difficulties in chlorination for disinfection of water. In the study area, the pH values ranges from 7.6 to 8.9 indicating weakly to moderately alkaline nature of groundwater. The higher values of pH have been recorded for the wells (W8, W11, W12, W13, W15, W16 and W20) located near Pravara river and near sugar mill effluent flow. Lower values have been observed in the topographically higher areas and in the hilly terrain of the basin (S.No. W3, W4, W5 and W19). The values reflect abundant supply of CO_2 to the groundwater in hilly terrain due to the presence of vegetation. Further they can also be attributed to the dissolution of carbonates and decomposition of organic matter in the soil.

Electrical Conductivity is an easily obtained parameter that is a good indicator of the amount of dissolved solids in water and thus can be used to detect contaminants in water. As such electrical conductivity measurement makes it possible to obtain information about the extent of mineralization in the

groundwater. In the present study, EC value ranges from 841 to 6310μs/cm (table-1) reflecting fresh to moderately saline character of groundwater. This increase in EC is associated with the human activities because EC values are higher in the downstream part and near to sugar factory area. The lower EC values have been obtained for the wells situated along the slopes of the hills (S.No. W1, W2, W3, W4 and W5) forming undulating topography leading to faster circulation of groundwaters. EC of the samples were in accordance with the TDS values (Table 1) indicating threat of the major cations like Na^+, Ca^{2+}, Mg^{2+} which are present in groundwater along with major anions like chloride, carbonate, bicarbonate and sulphate[15].

Cationic constituents in groundwater and Human activities: Calcium and Magnesium: Groundwater with high calcium content is undesirable for household uses such as washing, bathing and laundering because of consumption of more soap and other cleaning agent. Ca is an important nutrient for human health but in balanced amount. Constant use of Ca rich well water for drinking purposes may lead to kidney stones or gall bladder stones or joint pains in population. Calcium and magnesium are the dominant cations in the groundwater from the study area followed by sodium and potassium. On the average Ca^{2+} + Mg^{2+} in equivalent units accounts for 75% of the sum of cations. On the individual basis, Ca content ranges from 18 to 723 mg/l. Similarly the minimum concentration of Mg is 26 mg/l and maximum 870 mg/l. It is observed that concentration of Ca and Mg increases from recharge to discharge zone. The wells situated on alluvial terraces and along the course of river (S. No. W9, W18 and W20,) show higher values of calcium and magnesium. Magnesium salts have laxative effect particularly when present as magnesium sulphate.

Sodium and Potassium: Human activities can have a significant influence on the concentrations of sodium in surface and groundwaters. The re-use of water for irrigation commonly leaves a residue, which is much higher in sodium concentration than was in the original water. This is possibly the important source of high concentration of Na in the area. Excessive amount of sodium in drinking water has been recognized as risk factor in hypertension and high blood pressure (WHO, 1979)[16]. The sodium content in groundwater ranges from 58 to 522 mg/l. Sodium concentration in the groundwater is the result of chemical weathering of plagio clase feldspar present in the basalt. Apart from the natural sources, human activities have significant influence on the concentration of sodium in the groundwater[17]. In the area, however, higher Na^+ concentration is the combined effect of geological source as well as evaporative concentration towards the Pravara River (S.No. W11, W12, W13, W14, W15, W16, W17 and W18). Apart from these sources mixing of sugar mill effluents from sugar factory has influenced the concentration of sodium in groundwater from the area.

Potassium in the groundwater is derived from rainwater, geological sources, fertilizers and other anthropogenic activities.

The geological source of potassium is silicate minerals like orthoclase, microcline, nepheline, lucite and biotite in igneous and metamorphic rocks and sylvite, carnallite and niter from sedimentary rocks [18]. However, these sources are absent in the study area as it is chiefly characterized by basalt. As compared to sodium, K concentrations are negligible in the groundwater, which varies from 0.4 to 2.8 mg/l in the study area.

Iron and Manganese: Fe and Mn both are essential constituents of plant and animal metabolism. Availability of both iron and manganese in igneous solution is strikingly affected by environmental condition i.e. charge in the degree of oxidation and reeduction. Three natural conditions that have been found to produce high levels of iron and manganese in ground water are aquifers located crystalline bed rock, swamps and organic material, interbeded with alluvial sediments located near areas of groundwater discharge[19].

The Iron is also present in the environment due to human activities. Industrial wastes and mine drainage waters are two common anthropogenic sources of iron. The ground water containing iron at concentration greater than 2 mg/l cause straining of clothes and plumbing fixtures and impart bad taste and colour to water. Normally Fe is only slightly toxic but excessive intake can cause siderosis and damage to organs though excessive iron storage [20]. Iron in higher concentration may also cause vomiting. Again its deficiency causes anemia and shortness of breath. On the other land, the incidence of Mn toxicity is rare because Mn is rapidly excreted in the kindney. The problem of excess Mn is similar with iron. The Fe and Mn concentration in the ground water of study area are negligible and are within the limit of WHO[16].

Anionionic constituents in groundwater and Human activities: Chloride: Most chloride in groundwater is present as sodium chloride but chloride concentration may exceed the sodium due to base exchange phenomenon. Abnormal concentration of chloride in the groundwater may result due to pollution from sewage, salt of tree like coconut and leaching of saline residues from the soil[21]. In the study area there is no significant primary source of chloride. This is because the basaltic as well as alluvial aquifer lithology does not possess the chloride bearing minerals. Hence the possible sources of chloride could be precipitation and anthropogenic in origin such as fertilizers and recycling of water due to irrigation. In the present study, chloride content varies from 20 to 2490 mg/l. The highest values of chloride are found in the wells (S.No. CW14, CW18 and CW20) located in the vicinity of storage of sugar mill effluent and other allied industries. Contribution of chloride could be due to mixing of waste waters. The remaining groundwater samples are within the maximum permissible limit[22]. (ISI, drinking water specification, Reaffirmed 2009). The chloride at higher concentration can damage metallic pipes and structures and hampers agricultural crops.

Sulphate: The major source of sulphate in the groundwater is rainwater, sulphur minerals and sulphides of heavy metals from

igneous and metamorphic rocks. Gypsum, anhydride from sedimentary rocks, soil amendments, fertilizers and burning of fossil fuel are also important sources of sulphate[23]. The sulphate varies from 8 to 184 mg/l. Higher concentration of sulphate is observed in the downstream part and in the vicinity of sugar mill effluents which could be due to excessive use of fertilizers or use of soil amendments (S.No. C11, C12, C13, C18 and C20). Since the study area is intensively irrigated, the frequent use of sulphate rich fertilizers can be considered as a potential source of the sulphate ions in the groundwaters. In addition to this, sulphates can be added to the groundwater from the breakdown of organic substance in the soils, leachable sulphate present in the fertilizers and human influences[24]. Lower values of sulphate have been reported from the upstream part characterized steep valley wall scarps and non – irrigated agricultural area (CW1, CW2, CW3, CW4, CW5, CW6, CW7, CW8 and CW10). The sulphate content of groundwaters in the study area are within the maximum permissible limit specified by drinking water and WHO [16]. If sulphate in groundwater exceeds the limit, a bitter of medicinal taste may render the water unpleasant to drink and causes diarrhea and dehydration (Dept of public health and Environment, Washington, County).

Phosphate: Phosphate in the groundwater may occur due to decomposition of organic matter, sewage disposal, industrial and agricultural effluents, domestic waste water, detergents and fertilizers [23]. The rocks containing mineral like apatite and rock phosphate further contribute phosphate to the groundwater. In industries, sodium tripolyphosphate is used for the prevention of precipitation of $CaCO_3$ which also contribute phosphate to the groundwater. The rocks in which most of the P is bound, are generally insoluble and hence phosphate concentration in the freshwater is generally less than 1 ppm [25]. In the present study phosphate concentration varies from 0.25 to 0.82 mg/l which were within the limit. Excess of phosphate nutrients encourages the over abundance of plant life and results in environmental damage called as eutrophication. If phosphate is consumed in excess, phosphate gas is produced in gastro – intestinal tract on reaction with gastric[26].

Total Alkalinity: The alkalinity in natural water system is due to carbonates, bicarbonates and hydroxides. These constituents are the results of dissolution of minerals in the soil and atmosphere. Carbonate and bicarbonates may originate from the microbial decomposition of organic matter also [27]. The concentration of bicarbonate is directly linked with alkalinity of water. There is no adverse effect of alkalinity but the bicarbonate present in alkaline water can release F^- from CaF_2 present in the soils with the simultaneous precipitation of $CaCO_3$ due to high rate of evapotranspiration caused by semi – arid climate. Hence the association of HCO_3^- and F^- is called as alkalinity factor[15]. The relation can be represented as follows

$$CaF_2 + 2HCO_3^- \longrightarrow CaCO_3 + 2F^- + H_2O + CO_2$$
$$CaF_2 + 2NaHCO_3 \longrightarrow CaCO_3 + 2Na^+ + 2F^- + H_2O + CO_2$$
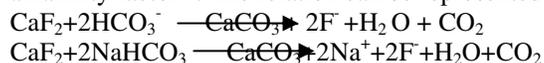
In the present study, the total alkalinity was found in the range 294 to 1498 mg/l. The high bicarbonate concentration observed

in the wells (S. No. W11, W12, W13, W18 and W19) close to sugar mill effluents flow is possibly due to flat topography, providing sufficient length of time for the aquifer material to interact with the groundwater.

Nitrate Pollution and Human activities: Nitrate is not derived primarily from the minerals in rocks that make up groundwater reservoir. Instead, nitrate enters the groundwater from another part of nitrogen cycle on the earth that includes atmosphere, hydrosphere and biosphere. The greatest contribution of nitrate in groundwater is from decaying organic matter, sewage and animal waste and nitrogen fertilizer[23]. Urine deposited by grazing stock is the principal source of nitrate in the irrigated area. Many researchers investigated the different sources of nitrogen pollution[28-32].

The nitrate concentration in the area observed from the Table 1 that minimum concentration as low as 8 mg/l and maximum as high as 92 mg/l. The high values of nitrate are observed in the irrigated area which can be attributed to excessive use of chemical fertilizers in the sugarcane cultivating tract. It is also significant to note that area which is thickly populated with residential colonies and industrial sector have high nitrate concentration. The groundwater samples (W4, W9, W17, W18 and C19) near Sangamner town as well as sugar factory region have elevated concentration of nitrate. Around sugar factory areas mixing of effluents with groundwater is responsible for high order of nitrate values. It is also observed that nitrate pollution is localized to certain areas in the rural belt. An excreta of animals gets accumulated and is leached by rainfall causing higher nitrate pollution of groundwater. The extent of such groundwater pollution depends on bio gradation, soil and rock strata characteristics through percolation takes place.

The pollution of groundwater by nitrate is one of the most serious issues of environmental concern in the study area, considered in context of agriculture pollution. Agricultural pollution source in the study area are intensive farming practices, particularly fertilization, livestock rising and plant protection. Besides agriculture, there are many other sources of pollution and it is difficult to distinguish the share of agriculture on nitrate pollution of groundwater.

Excess nitrate (>50mg/l) in the drinking water cause health risks such as conversion of hemoglobin to methemoglobin, which depletes oxygen levels in the blood. Additional consequences among people who consumed drinking water containing high level of nitrate enlargement of the thyroid gland, increased incidence of 15 types of cancer and two types of birth defects and even hypertension were reported [33]. Increasing rates of stomach cancer caused by increasing nitrate intake have been reported [34]. Such types of health problems are not yet detected in the area.

Hardness of groundwater and Human activities: Hardness generally represents the concentration of calcium and

magnesium ions because these are the most common polyvalent cations. Other ions such as iron and manganese may also contribute to the hardness of water but are generally present in much lower concentration[2].

On the basis of hardness (table 1), the groundwater from the study area can be classified into four categories [23] summarized in table 2.

It is observed from table 2 that 3 samples (14.3%) shows very hard category while 7 Samples (33.33%) belong to extremely hard class I, 8 samples (38.1%) belongs to extremely hard class

II and remaining 3 samples (14.3%) to extremely hard Class III in the area. The samples having extremely hard class III type of water are observed in the wells near the sugar mill effluents flow. This elevated hardness is related to human activities. However, this problem is expected to be solved by softening of groundwater. The higher concentration of Ca and Mg in groundwater in the study area may be due to presence of Ca and Mg in the sedimentary rocks. However, there is no adverse health effect on human being due to Ca and Mg. In contrast, the results of a number of studies have suggested that water hardness may protect against diseases[35].

Table-1
Physico – chemical analysis for ground water from Sangamner area, Ahmednagar district, Maharashtra

S. No.	WT	pH	EC	TDS	Na	K	Ca	Mg	Cl	HCO$_3$	SO$_4$	NO$_3$	PO$_4$	Fe	Mn	TH
W1	12.12	8.2	890	569	61	0.4	38	26	24	300	8	11	0.32	15	298	196
W2	12.12	8.2	1046	669	59	0.6	44	28	20	294	12	16	0.30	12	320	218
W3	7.58	8	1174	751	58	1	49	45	32	340	14	28	0.29	12	308	298
W4	9.39	8.2	1824	1167	83	0.8	79	50	102	380	22	88	0.28	12	320	394
W5	22.73	8	1746	1117	72	1.2	62	55	94	374	21	64	0.36	14	310	360
W6	19.70	8.3	2720	1740	152	0.6	38	102	200	425	44	68	0.30	10	364	522
W7	25.15	8.4	3330	2131	108	0.8	115	114	320	325	72	70	0.82	52	298	748
W8	19.70	8.7	3650	2336	163	0.4	72	132	360	300	78	60	0.32	18	300	712
W9	22.12	8.3	6310	4038	46	1.98	128	160	850	445	116	82	0.26	11	311	988
W10	22.12	8	2850	1824	252	1	86	78	350	435	82	92	0.30	14	554	547
W11	21.21	8.3	5280	3379	448	0.8	28	160	698	620	136	58	0.32	18	552	728
W12	6.67	8.7	5550	3552	562	0.6	18	130	712	665	150	62	0.29	16	500	561
W13	12.12	8.6	5450	3488	598	0.4	62	114	818	690	138	76	0.29	14	408	634
W14	15.45	8.3	6150	3936	518	1	74	218	1148	485	120	58	0.26	15	400	1090
W15	1.52	8.5	2640	1689	318	2.8	60	90	520	470	72	38	0.32	15	468	534
W16	1.52	8.6	3710	2374	278	0.8	100	158	748	400	70	62	0.31	13	615	902
W17	25.76	7.6	3040	1945	362	0.6	82	72	460	460	76	84	0.31	16	584	512
W18	17.58	7.7	4440	2841	522	0.6	723	870	2490	1498	184	102	0.33	40	880	5402
W19	21.21	8	5120	3276	398	0.4	86	248	992	612	100	76	0.30	12	762	1248
W20	7.88	8.9	3325	2161	198	0.4	382	390	1790	422	132	8	0.25	18	650	2644
W21	1.52	7.8	1937	908	238	0.4	125	116	420	355	81	62	0.27	12	520	812
Avg.	12.04	7.8	3376	2194	262	83	117	160	626	490	82	60	.3	17	462	955
Max.	25.76	8.9	6310	4038	522	2.8	723	870	2490	1498	184	92	0.82	52	880	5402
Min.	1.52	7.7	890	569	58	0.4	18	26	20	294	8	8	0.25	11	298	196

Note: 1. All values of the constituents are in ppm / mg/l, except pH and EC (μS/cm). 2. Values of Fe and Mn are in ppb, 3. W-Dugwell, TH - Total hardness, 4. Water Table (WT) depth is in meters.

Table-2
The Classification of groundwater in the study area on the basis of total hardness after Hem (1991)[23]

Category	Total Hardness (mg/l)	Location with samples No.
Very hard	>300	W1, W2, W3 = 3 **(14.3%)**
Extremely hard Class I	300-600	W4, W5, W6, W10, W12, W15, W17 = 7 **(33.33%)**
Extremely hard Class II	600-1200	W7, W8, W9, W11, W13, W14, W16, W21 = 8 **(38.1%)**
Extremely hard Class III	>1200	W18, W19, W20 = 3**(14.3%)**

Groundwater salinisation and Human activities: The dissolved solids originate from the weathering of rocks, soil and dissolving lime, gypsum and other salts sources as water percolates through them. Groundwater quality changes as the water flows through the subsurface, geological environment increasing dissolved salts and major ions[27]. Increase in the concentration of dissolved salts such as sulphate, chlorides, bicarbonates of Ca, Mg and sodium in the groundwater attributable to both natural as well as well as human induced factors, leads to the process of salinisation[36]. As salinity increases, the proportion of all these salts increases. This induced salinisation is caused by the mismanagement of irrigation i.e. human activities. TDS indicate the general nature of water quality of salinity. The groundwaters with TDS ranging from 400 to > 3000 mg/l are called saline[23.] Hem (1991) has classified the water into four categories on the basis of TDS. By using this criterion groundwater from the study area is classified and summarized in table 3.

Table-3
Groundwater salinity classification of the study area on the basis of TDS (after Hem, 1991)

Nature of water	TDS (mg/l)	Location and No. of Samples
Fresh Water	> 1000	W1, W2, W3, W21 **= 04 (19.04 %)**
Slightly saline	1000 – 3000	W4,W5,W6,W7,W8,W10,W15,W16,W17,W18,W20 **= 11 (52.38%)**
Moderately saline	3000 – 10000	W9, W11, W12, W13, W14, W19 **= 06 (28.57%)**
Very saline	10,000 – 35,000	Nil
Brine	> 35,000	Nil

It is observed that in the recharge zone (S. No. W1 to W3), wells belong to fresh water class (TDS<1000mg/l), the wells (W4, W5, W6, W7, W10, and W12) which are in the intermediate part between recharge and discharge areas belongs to slightly saline water class. On the contrary, the wells (S. No. W11, W13, and W 14) are situated on the both sides of river representing discharge zone are moderately saline in character. The wells (S. No. W16, W17, W18, W19 and W 20) located in the recharge zone near Karhe Ghat are expected to represent fresh water class. However, interestingly, all of them show slightly saline water characters. This is possibly due to contamination of the wells by mixing of sugar mill effluent. These wells are located in the down gradient direction of the effluent storage pond (lagoons) of sugar factory besides being in close proximity to the effluent carrying stream. Due to mixing of effluents into the wells, saline water characteristics have been developed. As mentioned earlier the ground water is slightly to moderately saline in character in the discharge zone. This is possible because of alluvial lithology, flat topography and intensive irrigation practices that have lead to the problem of salinization. The observations further show that the area with

TDS below 1000 mg/l lies in the recharge zone, which is predominantly non-irrigated agricultural region and located on the plateau and hilltop. Therefore, absence of saline waters or presence of fresh water in this part is possible due to the faster circulation of ground water attributable to physiography. On the contrary, in the discharge zone, flat topography responsible for sluggish groundwater flow conditions has lead to higher residence time and greater rock-water interactions. In addition to this, intensive irrigation and excess use of fertilizers have lead to higher salinity in the area.

Geochemical characters of groundwater and Human activities: In order to visulise the variations with space and time in terms of hydro – chemical facies of the groundwater from the study area, the chemical data were plotted on Piper Trilinear diagram [37]. It is observed from the figure that out of 21 samples, 20 samples (nearly 95%) belong to Ca+Mg>Na+K and one sample (W12) show Na+K> Ca+Mg cation hydrochemical facies. Similarly, 8 samples (38%) belong to HCO_3+CO_3 > $SO_4+Cl + NO_3$ while 13 samples (61.90%) shows $SO_4 + Cl+NO_3$ > $HCO_3 + CO_3$ anion hydrochemical type (Table 3). This indicates that majority of samples Ca + Mg > Na + K - SO_4 + Cl+ NO_3 > HCO_3 + CO_3 chemical type of water. It is interesting to note that in the recharge zone, the groundwater predominantly belongs to Ca+Mg-HCO_3 +CO_3 type that gradually passes through Ca + Mg - SO_4 + Cl type to finally Na + K- SO_4 + Cl type in the discharge zone. This type of chemical evolution of ground water has exhibited the properties of ground water ranging from fresh water to slightly saline to moderately saline in nature. This further suggests that in the recharge area groundwater with Ca + Mg - HCO_3 + CO_3 facies reflects input of salts from the weathering of rocks. On the other hand, Na + K- SO_4 + Cl type of facies are indicating proportionately higher input of anions and cations from anthropogenic activities. The domestic use of water, effluents from sugar cane factory and intensive agriculture practices involving excess use of chemical fertilizers contribute these anions and cations in significant quantities. Thus evolution of groundwater types HCO_3^- to Cl^- +SO_4^{2-} itself is evidence increasing of contamination of groundwater due to human activities.

Conclusion

Unplanned human activities and poor management of irrigation water besides the overuse of chemical fertilizers deteriorated the ground water quality in the study area. Physico – chemical parameters like pH, EC, Ca^{2+}, Mg^{2+}, Na^+, K^+,Cl^-, SO_4^{2-}, Fe, Mn, NO_3^- and PO_4^{3-} are used for assessing the groundwater quality. The higher values of pH have been observed for the area close to river channel and near the flow of sugar mill effluent and other allied industries. The EC of groundwater also show higher values on the same locations as pH due to poor drainage conditions and mixing of sugar mill effluents. The calcium and magnesium are dominant cations followed by sodium. Human activities have a significant influence on the concentration of sodium in groundwater. Mixing of sugar mill effluents from

sugar factory has enhanced the concentration of sodium. Amongst the anions, chloride, sulphate and nitrate are mainly affected by human activities. The high values of nitrate are observed in the irrigated area which can be attributed to excess use of chemical fertilizers in the sugarcane cultivating tract. Around sugar factory areas, mixing of effluents with groundwater is responsible for high order of nitrate values. High intake of nitrate in drinking water cause serious health hazards in humans. Elevated hardness is observed near the flow of sugar mill effluent which is related to human activities. Salinisation of groundwater is attributable to both natural as well as human induced factors in the area. TDS indicating the groundwater salinity is found to be higher due to contamination of the wells by mixing of sugar mill effluents. The alluvial lithology, flat topography and intensive irrigation practices responsible for sluggish groundwater flow condition has lead to higher residence time and greater rock water interactions. This the promotes higher salinity in the area. On the basis of piper's Trilinear diagram, the ground water from the area can be predominantly classified as Ca+ Mg> Na+K cation hydrochemical type. The area close to river channel or near sugar mill effluent has exhibited Na+K-SO$_4$ + Cl type of water. This indicate that groundwater have higher input of anions and cations from anthropogenic activities. There is an urgent need to create public awareness on the sources, causes and prevention of groundwater pollution and also the consequence of impact of pollution on human health, which would be a key factor for sustainable development of the area.
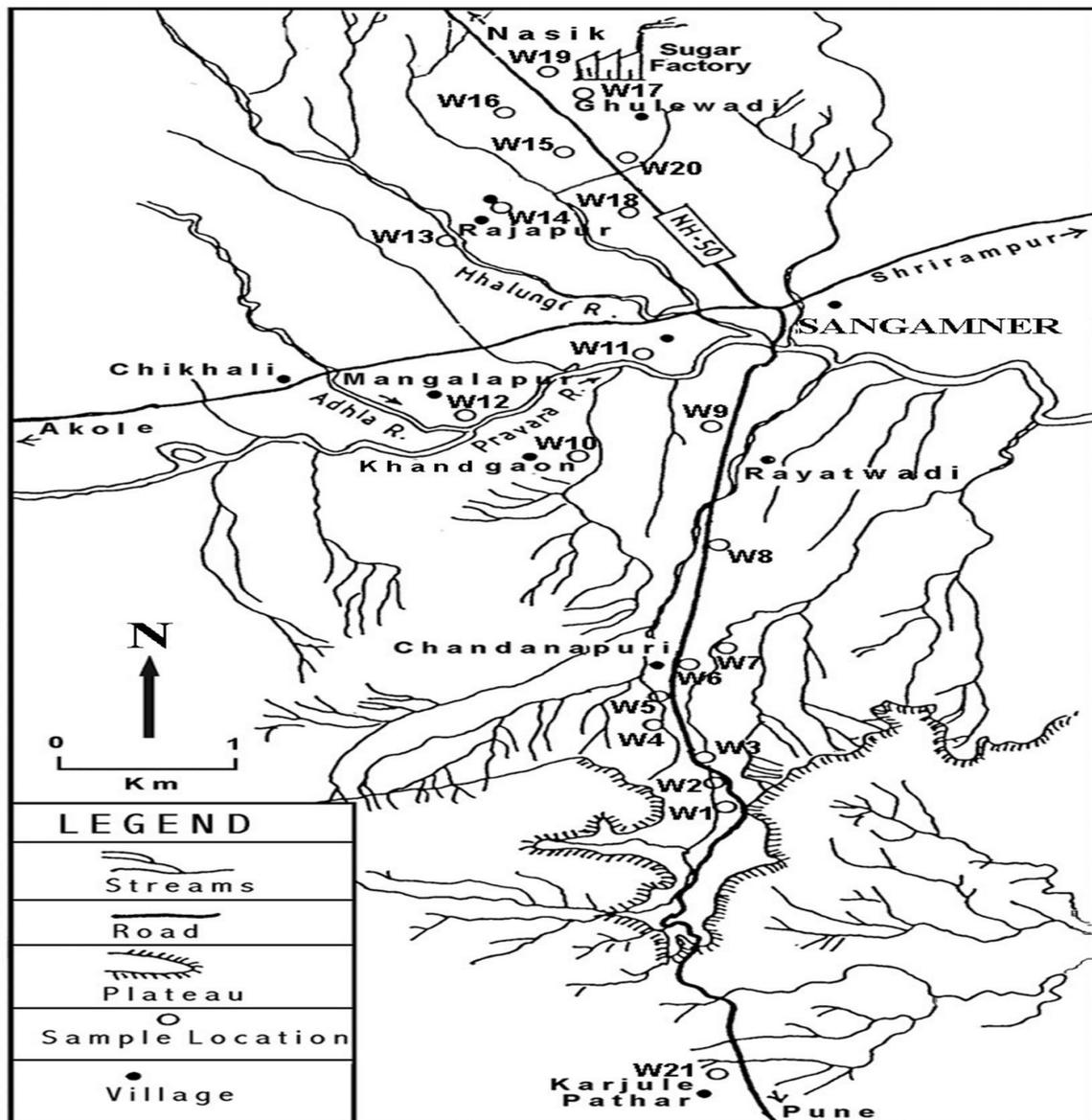

**Figure-1**
Location map showing sampling well in the study area
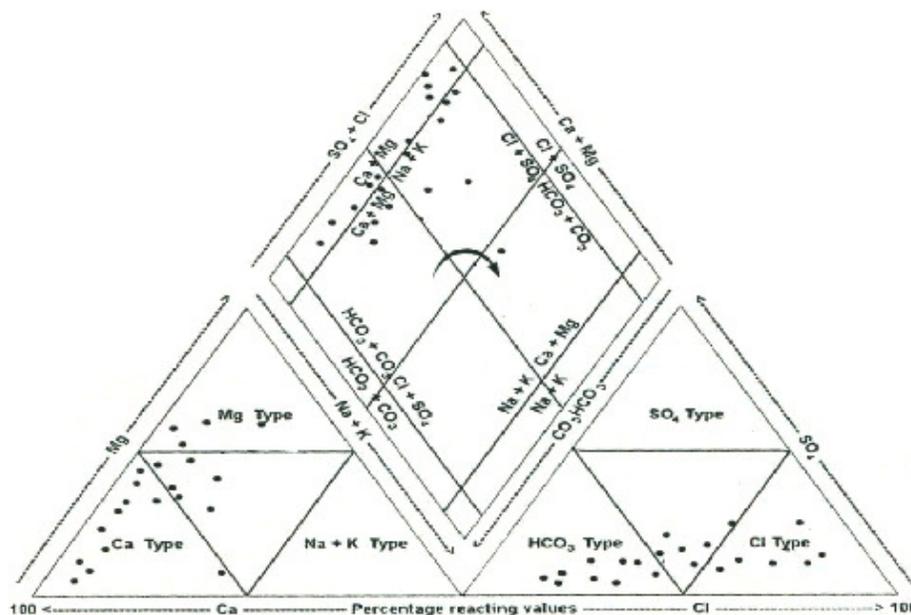
Figure-2
Geochemical character of groundwater from the study area

Acknowledgement

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