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Geochemical Characteristics of Groundwater from Urmodi River Basin, Satara Disrict Maharashtra India

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Abstract

*Geochemical investigation is useful for better understanding of the status of water quality. The aim of this study to check quality of drinking and irrigation water. The area chosen for present study covering about sixteenvillages in Urmodi River basin, Satara district, Maharashtra (India). Geologically, study area consisting of four lithounits viz. laterites, lithomarge, basalt and red boles. To investigate the hydro geochemical characteristics and evolution of groundwater in Urmodi River basin, sixteen groundwater samples were collected and analysed for eighteen indices. The geochemical results reveal that the Ca>Na>Mg>K and Cl>HCO_3>SO_4>NO_3>CO_3*trend.*The influences of agricultural fertilizers and irrigation practices are the other reasons for increasing NO_3^- ions in the groundwater. According to drinking water quality standards, the groundwater is not suitable for drinking purpose due to high concentration of total hardness and higher amount of Ca^{2+}, Mg^{2+} and NO_3^- at some locations. For irrigation water quality, parameters such as Sodium Adsorption Ratio, Soluble Sodium Percentage and Residual Soluble Carbonate are assessed, which showed overall irrigation qualities of bore wells is suitable for irrigation except sample which is collected from Kaloshi village having coordinates N17°41′ and E 73°56′ with 732 m amsl.*

Keywords: Groundwater, Geochemistry, Water type, Medical Geology, Urmodi river basin, Maharashtra, India.

Introduction

Groundwater quality has become one of the most important aspects in our living environment and chemistry of groundwater has a bearing on human health and on livestock[1]. Human being is using water for drinking, domestic, agriculture and industrial purpose, which is drawn from subsurface. Due to insufficient availability of surface water, to meet the requirement of human activities, groundwater remains only option for the increasing demand of water[2]. In recent years groundwater contamination has been one of the major issues in many countries. Earlier researchers have reported hazards of inorganic elements on human health, which arise naturally and anthropogenically due to improper waste management, groundwater contamination, unnecessary use of fertilizers and insecticides in agricultural area for high yield[2].

Study area: The aim of present study is to assess quality of water for drinking and irrigation purpose. Location map of the study area has depicted in figure 1. Urmodi River is one of the tributary of River Krishna, which covers an area about 413 sq. km. Drainage basin of Urmodi is 5th order stream which rises from Kas plateau about 1260 mts from MSL, near Satara. Kas plateau is lateritic plateau which is famous for various coloured wild flowers blossom every monsoon from mid-July to mid-October. The area of Urmodi basin is bounded by latitudes 17°43'25.8" to 17°28'1.8" N and longitudes 73°48'43.8" to 74°07'33.1" E. It forms part of SOI toposheet 47 G/14, 47K/2 and 47K/3 on the scale 1:50,000. Urmodi flows in NW-SE direction and meet Krishna River at Kashil village of Karad taluka. Climate of study area is tropical with three distinct seasons. Temperature varies in the range 39° C to 45° C in summer and 5° C to 20° C in winter. The monsoon season is spread between periods of mid-June to mid-October. Urmodi river basin receives highest rainfall (about 5000 mm) at western part of the basin where it starts its journey and it is observed that it lowers down (about 600 mm to 700 mm) towards eastern part where it meets to the River Krishna. Urmodi river basin is characterised by different physiographic division like high ranges with flat topography covers the portion of West side of the basin, hilly areas with rugged topography at North and South side with valleys and floodplains. High ranges with flat topography locally called as Sadas or Pathar, include high elevated portion ranging from1111 mts. to 1260 mts. from MSL. Hilly area with rugged topography is present between elevation 962 mts. to 1036 mts. with moderate slopes. Digital elevation map of the Urmodi river basin has depicted in Figure-2.

Geology of the area: Principallystudy area is consisting of four lithounits viz. laterites, lithomarge, basalt and red boles. Most of the part of study area is covered by Deccan basaltic formation, comprising nearly horizontal lava flows of late Cretaceous to early Eocene. The Deccan volcanic province (DVP) is unique in the geology of India because of its prodigious volcanism and its key role in the studies of volcanology. The Deccan volcanic eruption has been in Cretaceous-Tertiary (K/T) period at about

65 Ma[3]. 5, 00,000 sq.km area of the western and central India today covers the basaltic flows. The type of basaltic lava flows occurring in the study area are simple (aatype) and compound (Pahoehoe type). Different structures of basalt are observed in the study area in which spheroidal weathering is common features. Columnar joints are also found at some places which are formed due to contraction of lava during solidification (Figure-3). Top of the lava flows are covered with high level lateritic cap [4]. In the study area lateritic cap is present at a range of 1065 mts. to 1260 mts. amsl (Figure-4). Such duricrust results from impregnation of saprolite (rock weathered in situ) with iron oxides and hydroxides. They have usually been called as laterites [5,6, 7]. Duricrust is general term for hard crust formed at or near ground surfaces. Widdowson interpreted the laterite profile of Bamnoli range Koyana-Patan-Satara region is formed by insitu breakdown of the underlying basaltic lava flows[6]. Laterites are formed due to in situ chemical decay and disintegration of basalt. Circulating groundwater brought about leaching, removal of almost entire lime, magnesia, and alkalis and part of SiO_2, from the parental rock resulting in the concentration of the Al_2O_3, Fe_2O_3 and TiO_2 in the residue. The elements with low ionic potential were depleted and carried away in solution during the process of weathering. The chemical and mineralogical results have shown that the primary minerals are generally not fully dissolved but partially transformed into secondary minerals which are most stable under the intensive weathering condition. The elements in the primary rock minerals are released and show different reaction in the aqueous solution. The elements like Na, K, Mg and Ca do not react with other elements and are removed in the percolating groundwater. The initial dissolution is predominantly promoted by a higher acidity (lower pH) of the water. A high percentage of the dissolved Si is removed but another part reacts with dissolved Al and forms the clay mineral like Kaolinite. The aluminium hydroxide (Gibbsite) is formed if the concentration of dissolved Si is extremely low due to very strong drainage. Al can likewise be removed if gibbsite formation is not arrived. Dissolved Fe is very reactive with hydroxyl ions and forms Goethite and Hematite after oxidation which cause red brown colour to laterite. Sequences of basaltic lava flows commonly include spectacular red interflows strata widely known as 'red bole' which serve as marker bed in between two basaltic lava flows (Figure-5). Boles are recognised on its red colour. The bole beds occur as prominent horizons composed of fine grained earthy material having colours in shades of red to chocolate brown, green, purple grey. Bole are made up of friable earthy clay and it was suggested that boles are made up of that material derived from weathering of neighbouring basalt and volcanic ashes [8]. Colour of bole beds in study area is red to reddish brown. Boulders are also present in some places along with the clay. These boulders geochemistry suggest that many of the boles are weathered pyroclast [6].

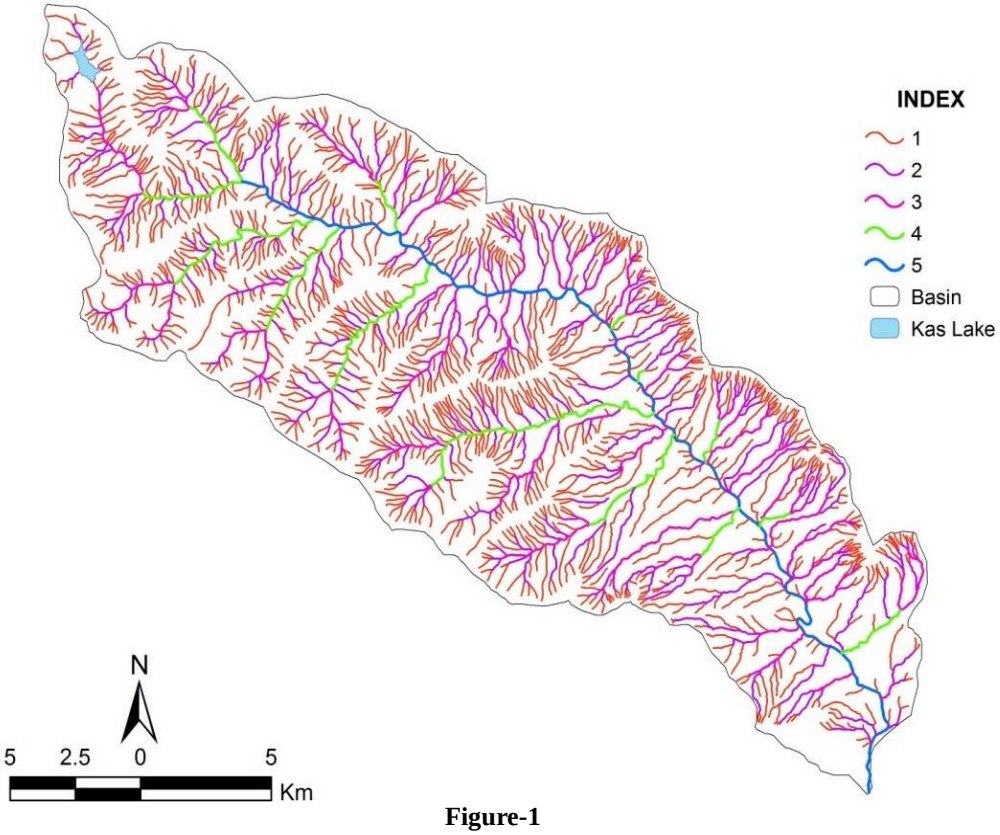

Figure-1
Drainage map of Urmodi river Basin

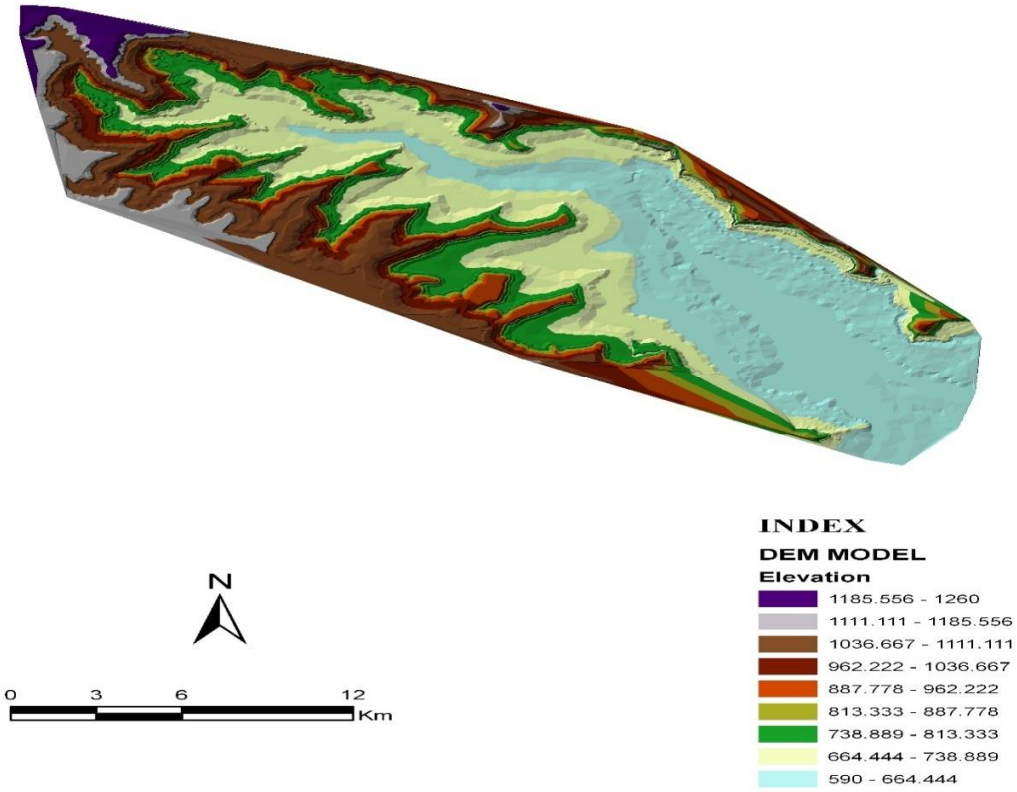

Figure-2
Digital Elevation Model of Urmodi river basin

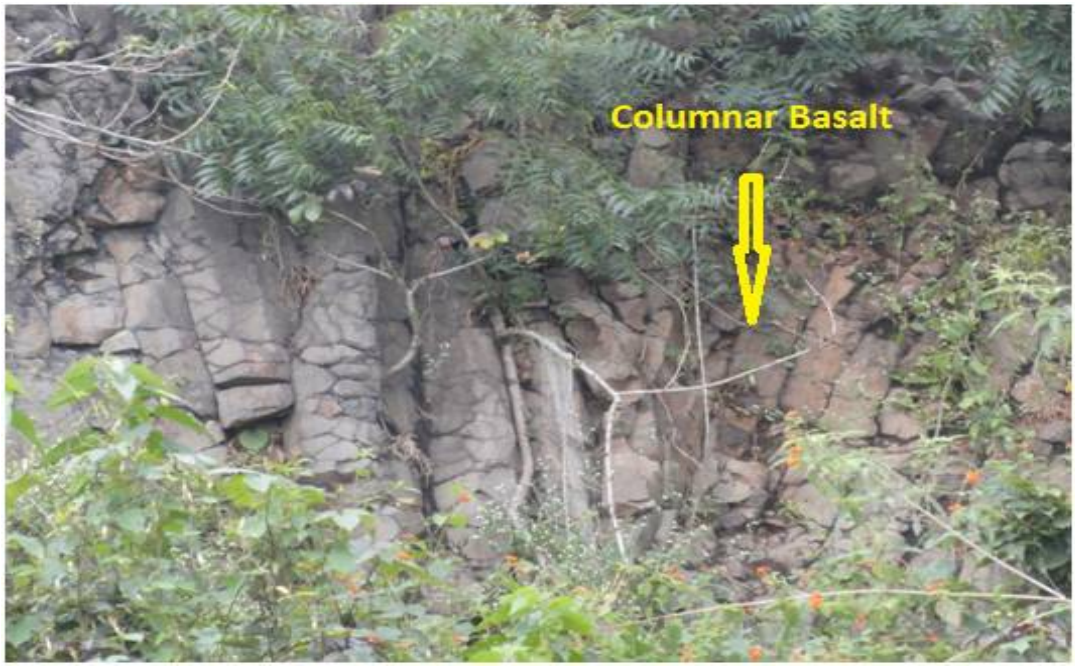

Figure-3
Columnar basalt near Palsavade village

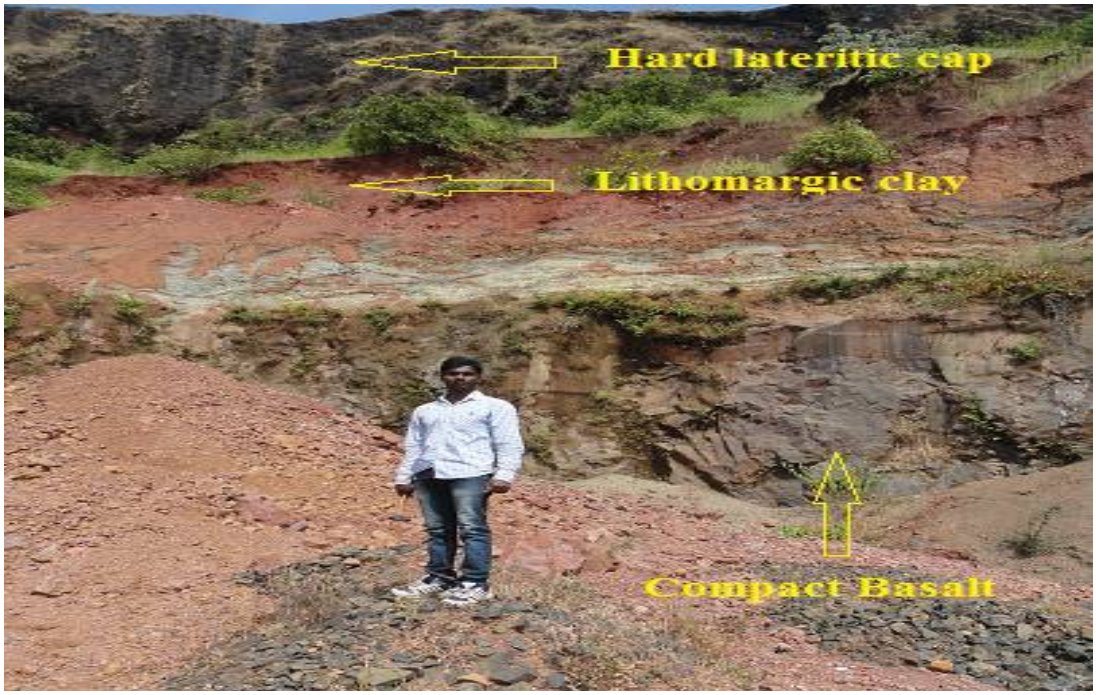

Figure-4
Contact of Laterite, Lithomargic clay and Basalt

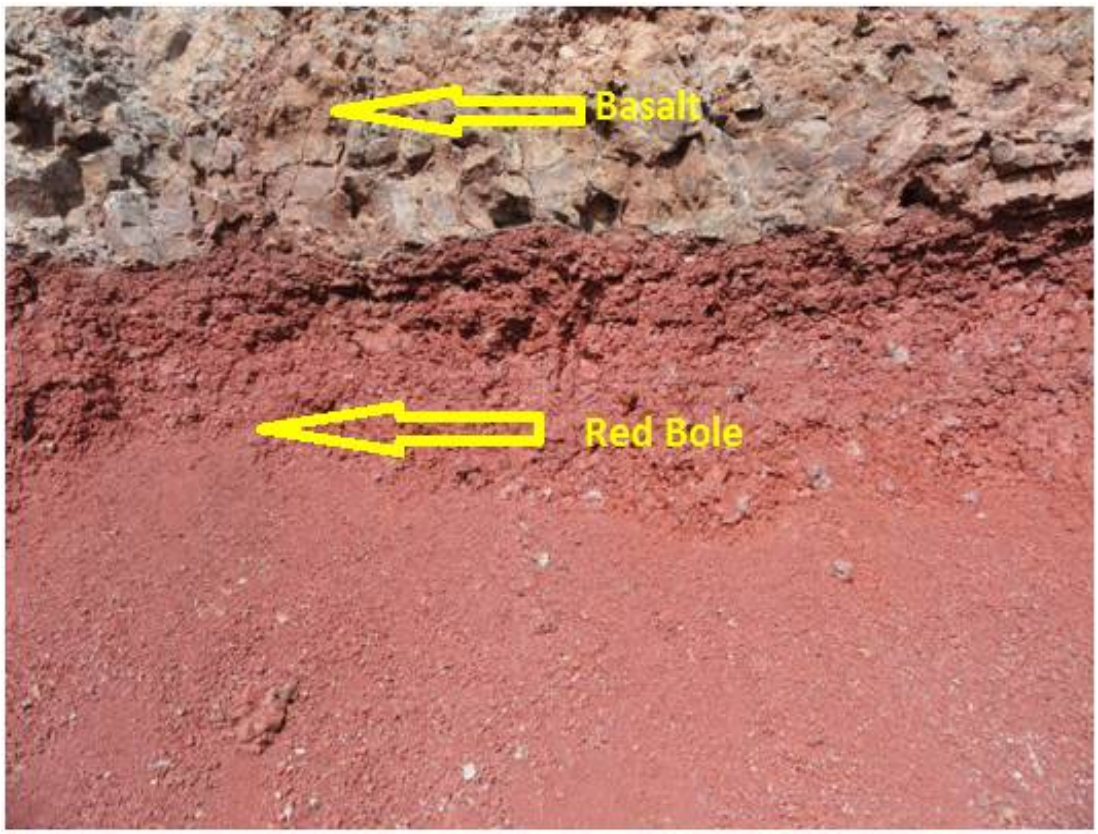

Figure-5
Red bole contact with Basalt near Ajinkyatara Fort, Satara

Methodology

The groundwater samples were collected during the month of February 2014 from catchment area of Urmodi river basin (Table 1). A total 16 water samples were collected. Water samples were collected in well cleaned one litre polyethylene sample bottles. The sample locations were recorded by the Global Positioning System. The analysis of water samples by adopting standard procedure[9]. Major ions like calcium, magnesium and hardness determined by standard EDTA titrimetric method, Chloride determined by standard $AgNO_3$ titrimetric methodand alkalinity determined by standard HCL titrimetric methods. pH, EC and TDS were measured on digital water analysis kit. Sodium and Potassium analysed by spectrophotometer. Nitrate, Phosphate and Sulphate analysis were done by standard calorimetric methods. The chemical characteristics were determined as per the standard methods for examination of water and wastewater [9].All results are compared with standard limit recommended by the Bureau of Indian Standards and World Health Organization [10, 11].

Results and Discussion

The obtained analytical results of drinking and irrigation parameters are depicted in Table-2.

Water Quality Assessment for drinking and domestic Practices: The analytical results of water quality assessment are depicted in Table-2.

pH: Water in the study area is generally acidic in nature with pH ranging from 6.18 to 7.80 with an average of 6.94. In the study period, maximum pH recorded 7.80 at Khodad and minimum value 6.43 at Nisrale village. Analytical results show that the pH values in all the spot is observed below 8.0, this suggests that the water becomes acidic [1].

Total dissolved solids: The total dissolves solids (TDS) indicate the general nature of salinity of water. TDS are a direct measurement of the interaction between groundwater and subsurface minerals. The total dissolved solids (TDS) are the concentrations of all dissolved minerals in water indicate the general nature of salinity of water. The principle component of TDS is calcium, Magnesium, Sodium, Potassium, cations and Carbonates chloride, sulphate and Nitrate inions. The TDS values can change due to solubility of minerals present in the rock. The BIS (Bureau of Indian standards) specifies a desirable limit of TDS is 500 mg/L.It is observed that the 10 water samples shows higher TDS as suggested by BIS[10]. Remaining samples are within the acceptable limit. The lower values are observed in the elevated area and increases towards downstream areas (Table-2). High values of TDS could be due to intensive irrigation. Sources for TDS includes agricultural run-off, sewage, and natural sources such as leaves, silt, and weathering of rocks. These salts affect the growth of plants as also deteriorates the quality of soil, soil structure, permeability and aeration of soil. The TDS values shows that, 6 samples fallsin low to medium salinity zone and 10 in the high salinity zone.

Table-1
Details of water sampling location along with their coordinates

Sample No.	Type of water	Location	Latitude (decimal)	Longitude (decimal)	Elevation (m) amsl
1	Bore well	Nisrale	N17°31′	E 74°5′	603
2	Bore well	Nagthane	N17°33′	E 74°03′	625
3	Bore well	Ganeshwadi	N17°32′	E 74°01′	683
4	Bore well	Dolegaon	N17°36′	E 74°01′	638
5	Bore well	Kari	N17°38′	E 73°54′	707
6	Dug well	Karandi	N17°37′	E 73°57′	709
7	Bore well	Atit	N17°31′	E 74°31′	714
8	Bore well	Kashil	N17°28′	E 74°05′	591
9	Bore well	Majgaon	N17°32′	E 74°03′	609
10	Bore well	Shendre	N17°37′	E 73°57′	644
11	Bore well	Bharatgaon	N17°36′	E 74°02′	645
12	Bore well	Maskarwadi	N17°41′	E 73°55′	645
13	Bore well	Kaloshi	N17°41′	E 73°56′	732
14	Bore well	Loharwadi	N17°39′	E 73°54′	718
15	Dug well	Songaon	N17°38′	E 73°59′	664
16	Bore well	Khodad	N17°30′	E 74°05′	608

Table-2
Physico-chemical and irrigation water quality parameters of water samples from Urmodi river basin
(All values are in mg/L, except pH, EC in µS/cm and SSP in %)

Sample ID	pH	EC	TDS	Alkalinity	Hardness	Ca	Mg	Na	K	NO_3	PO_4	SO_4	Cl	CO_3	HCO_3	SAR	RSC	SSP
1	6.43	616.00	400.00	238.00	200.00	55.00	15.00	32.00	0.00	12.01	0.28	161.00	19.93	0.00	238.00	1.38	-1.36	25.74
2	6.61	1047.20	680.00	255.00	340.00	88.00	29.00	58.00	0.00	42.05	0.15	227.00	37.73	0.00	255.00	1.92	-3.97	26.95
3	7.18	893.20	580.00	375.00	315.00	70.00	34.00	71.00	0.50	36.04	0.08	178.00	33.62	0.00	375.00	2.44	-2.17	32.74
4	6.87	1016.40	660.00	360.00	390.00	93.00	38.00	44.00	11.00	39.04	0.15	96.00	119.03	0.00	360.00	1.36	-3.81	19.63
5	6.84	847.00	550.00	320.00	245.00	72.00	16.00	84.00	0.50	32.03	0.31	53.00	120.63	0.00	320.00	3.27	-1.39	42.44
6	6.77	770.00	500.00	300.00	250.00	61.00	24.00	27.00	45.00	16.02	0.63	95.00	63.21	0.00	300.00	1.04	-1.72	18.83
7	6.96	831.60	540.00	290.00	165.00	58.00	5.00	111.00	0.50	12.01	0.04	111.00	85.66	0.00	290.00	5.26	-0.12	59.11
8	6.18	1262.80	820.00	475.00	355.00	96.00	28.00	127.00	0.20	35.16	0.04	73.00	186.92	0.00	475.00	4.11	-1.88	43.55
9	6.61	215.60	140.00	84.00	66.00	18.00	5.00	9.00	0.00	21.02	0.04	43.00	16.38	0.00	84.00	0.68	-0.39	22.85
10	7.05	1185.80	770.00	365.00	495.00	120.00	48.00	41.00	0.00	27.03	0.02	266.00	60.79	0.00	365.00	1.12	-5.92	15.10
11	6.92	1047.20	680.00	370.00	310.00	86.00	23.00	119.00	0.30	19.61	0.07	198.00	99.85	0.00	370.00	4.12	-2.12	45.33
12	7.29	1370.60	890.00	540.00	560.00	132.00	56.00	106.00	0.00	38.18	0.03	70.00	275.12	0.00	540.00	2.73	-5.26	28.99
13	7.63	1386.00	900.00	252.00	52.00	18.00	2.00	145.00	0.00	16.51	0.05	127.00	57.90	0.00	252.00	12.12	1.71	85.45
14	7.05	431.20	280.00	164.00	96.00	26.00	7.00	40.00	0.00	4.88	0.05	93.00	7.88	0.00	164.00	2.52	-0.07	47.92
15	6.81	754.60	490.00	345.00	330.00	78.00	33.00	17.00	0.00	15.68	0.03	193.00	25.85	0.00	345.00	0.57	-2.81	9.99
16	7.80	785.40	510.00	205.00	230.00	42.00	30.00	87.00	1.40	13.81	0.03	53.00	169.13	0.00	205.00	3.51	-2.31	45.13
Maximum	7.80	1386.00	900.00	540.00	560.00	132.00	56.00	145.00	45.00	42.05	0.63	266.00	275.12	0.00	540.00	12.12	1.71	85.45
Minimum	6.18	215.60	140.00	84.00	52.00	18.00	2.00	9.00	0.00	4.88	0.02	43.00	7.88	0.00	84.00	0.57	-5.92	9.99
Average	6.94	903.79	586.88	308.63	274.94	69.56	24.56	69.88	3.71	23.82	0.13	127.31	86.23	0.00	308.63	3.01	-2.10	35.61
STDEV	0.41	321.99	209.08	112.62	142.84	33.44	15.68	42.52	11.34	11.75	0.16	68.33	73.62	0.00	112.62	2.79	1.97	19.12

Alkalinity: The alkalinity of water is the capacity to neutralize acid. In natural waters alkalinity is caused by CO_2. High alkalinity indicates highly productive water. As per the BIS, permissible limit of alkalinity is 200 mg/L. All the samples shows values are greater than the BIS limit. The data observed in the table 2 is ranged from 84 mg/L to 540 mg/L. The maximum value of total alkalinity is observed 540.00 mg/L at Muskarwadi (Table 2). Most of the water samples showsalkalinity values beyond the BIS limit except 02 samples at Loharwadi and Majgaon. This suggests that 14 water samples are not suitable for drinking purposeas per alkalinity parameters.

Calcium: It is good for building bones. 99 % of calcium is found in bones and teeth and 1 % in bloods, Muscles, nerves. Calcium regulates physiological functions. In the human body it is found as calcium carbonate, calcium phosphate, calcium fluoride and calcium sulphate. Proper adsorption of calcium is

obstructed by presence of fats and Oxalic acids. Deficiency in calcium causes changes in bones and muscles.Ca in water samples ranged from 18 to 132 mg/L with an average of 69.56 mg/L whereas BIS limit is 75 mg/L suggesting that the most of water sample is good for drinking purpose. Higher values are observed in downstream direction of Urmodi River, lower values are in elevated area and hard rock area.

Magnesium: Magnesium is required for carbohydrate metabolism. About 20 % of Mg is present in tissues, 70% in bones. Deficiency of magnesium is similar to that of potassium they are due to renal diseases, diabetics and chronic alcoholism as result there is loss of Ca and K damaging the Kidney. Magnesium concentrations ranged from 2.00 to 56.00 mg/L, with an average of 24.56 mg/L. This suggests that the 11 water samples are within the acceptable limit (30 mg/L) as per BIS drinking water standards. In present study, the maximum magnesium value perceived 56.00 mg/L at Maskarwadi village and minimum magnesium value perceived 2.00 mg/L around Kaloshi village. In Urmodi river basin area, value of calcium and magnesium resemble the general trend reported earlier in Indian context. The values of magnesium always lower than the calcium (Table-2).

Sodium: The most important element required for living organisms, sodium is the principal cation in the extracellular fluid, about 50 % is present in the bones, 40 % in extracellular fluids and 10 % in tissues. Deficiency of sodium causes excessive sweating, chronic diarrhoea, muscular weakness and exhaustion, chronic renal diseases, adhesion diseases, and over dehydration. Excessive sodium has an effect on heart functions.In Urmodi basin water samples, Na ranges between 0.39 to 6.25 mg/L with an average of 3.01 mg/L, suggesting that the Na concentration is good for all the water samples. The maximum value of sodium was recorded 6.25 mg/L at Kaloshi and the minimum value of recorded 0.39 mg/Kg at Majgaon Village.

Potassium: Potassium is used to prevent acidosis which is most important cation. Excessive use of alcohol coffee, sugar leads to potash deficiency. Potash deficiency is also causes to nephritis, diabetic acidosis, diarrhoea, palpitation, nervous shaking and body tiredness. In Urmodi river basin area Potassium in water samples ranged from 0 to 1.15 mg/L with an average of 0.11 mg/L suggests that the all water samples are within the permissible limits. The maximum value of Potassium is at Karandi and the minimum '0' at 7 places like, Nagthane, Majgaon, Shnedre, Maskarwadi, Kaloshi, Loharwadi and Songaon villages.

HCO_3 and CO_3: Bicarbonate and carbonate represents the major sum of alkalinity. The relatively higher concentration of bicarbonate with respect to chloride suggests the intense chemical weathering taking place in the area. The maximum value of bicarbonate is 540 mg/L at Maskarwadi and minimum bicarbonate is 84 mg/L at Majgaon with an average 308.63 mg/L.

Chloride: This cation is present as chloride salt in the body fluid. Deficiency of chloride give rise to hypertension or enema, heat cramps, loss of hairs or loss of appetite.The chloride concentration in the analysed water samples varies from 7.88 to 275.12 mg/L with an average of 86.23 mg/L in Urmodi river basin area. Chloride value in the 15water samples from the study area is less than 250 mg/L, which suggests, water is suitable for human consumption. On the other hand Maskarwadiwater sampleis not suitable for drinking because its Cl value is greater than 250 mg/L.

Sulphate: The Sulphate concentration in the analysed water samples varies from 0.9 to 5.54 mg/L with an average of 2.65 mg/L. The maximum value of Sulphate is 5.54 mg/L at Shendre Village and minimum Sulphate is 0.9 mg/L at Majgaon village. Sulphate is naturally occurring anions in all kinds of natural waters. In area under investigation, the maximum value recorded at non command and minimum value recorded at command area due to dilution factor. High concentrations of sulphate stimulate the action of sulphur reducing bacteria, which produces a gas highly toxic to fish life.

Nitrate: The health concern for high level nitrate in drinking water is risk especially for infants. The source of nitrate is usually seepages from fertilized soil, decaying of plant materials and flooding of the area during monsoon and getting contaminated with fecal material (human waste) a common habit of the villagers. Presence of nitrate in water is related to stomach upset, dehydration, etc. Urmodi, area water analysis indicate that the nitrate value extended from 4.88 mg/L to 42.05 mg/L. The observation recorded during study show maximum value of nitrate 42.05 mg/L at Nagthane and on other hand, minimum value 4.88 mg/L at Loharwadi village. Nitrate occurs in various dissolved forms as dissolved molecular nitrogen, inorganic nitrogen as ammonia nitrite and organic nitrogen as amino acid proteins etc. The major source of nitrogen in water is due to bacteria and cyanobacteria which fix atmospheric nitrogen along with surface and subsurface drainage.

Phosphorus: Phosphorous is also known as body energisers.It is major anions in intracellular fluids, which is good for teeth, bones, brains and nerves in combination with calcium. 80 % of phosphates are in bones and teeth 10 % in muscles and bloods. The deficiency they lead to general weakness, retarded, growth deficient nerve and brain function.Phosphate is an element required for all aspects of cellular metabolism, respiration, cell division, growth, synthesis of protein and incorporation in all living tissues. Both organic and inorganic phosphorus occurs in water.The phosphorus concentration in the analysed water samples varies from 0.02 to 0.63 mg/L with an average of 0.13 mg/L.The phosphate and nitrate are the important nutrients for the growth of aquatic flora and phosphorus has often

suspected to be the limiting nutrient in primary production in fresh water so called as 'sub optimum' element.

Water Quality Assessment for Agricultural: Assessment of the suitability of ground water and water for agricultural purpose is mainly based upon the estimation of parameters like Salinity hazards, SAR, SSP and RSC.

Salinity hazards: Electrical Conductivity (EC) is an indirect measurement of ionic strength and mineralization of natural water. EC range from 215.60 to 1386 μS/cm with an average of 903.79 μS/cm was observed in the study area. Table-2 shows all the water samples are within the acceptable limits as per WHO standards [11].The salinity hazard diagram shows that, 12 samples falls in high salinity zone; 01 in the low salinity zone and 03 samples in medium salinity zone (Figure-6).

Sodium Absorption Ratio (SAR)

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad (1)$$

Where, all the ions are expressed in meq / L

If SAR ratio less than 10, it is very good quality of water for irrigation purposes[12]. SAR values in the water samples from the study area ranged from 0.57 to 12.12 suggest that all the water samples falls in excellent category except Kaloshi village.

Residual soluble Carbonate (RSC): When sum of the carbonates and bicarbonates is in excess of calcium and magnesium, it may be the possibility of complete precipitation of Ca and Mg [12]. To quantify the effects of carbonates, it is essential to highlight the results of residual sodium carbonate (RSC) which has been computed by the following equation[13].

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

Where, all the ions are expressed in meq / L

Water having RSC values greater than 5 meq/L is considered harmful for plant growth, while greater than 2.5 meq/L is not considered suitable for irrigation purpose[1]. This suggests that the water in the basin is suitable for cultivation of plants and vegetables (Table-2).

Soluble Sodium Percentage (SSP): The soluble sodium percentage calculated by using following formula[14],

$$SSP = (Na \times 100) / (Ca + Mg + Na) \quad (3)$$

Where, all the ions are expressed in meq / L

Na % is defined as the ratio of sodium to the total cations in meq/L. Water with Na % greater than 50 may result in sodium accumulations that will cause a breakdown in the water's physical properties. It is observed that, the SSP values are lower than 50 in all the water samples from the area under study except Kaloshi (85) and Atit village (59).

Graphical representation of water quality data: The most common methods of graphical representation of the chemical analytical data are tabular form. The determination of ionic concentration of groundwater recorded in different units. However certain chemical aspects are not covered by tabular representation and therefore the use of various diagram has been adopted for this purpose. Different methods of graphical representation such as piper plot and USSL diagram.

Several workers namely Piper have used triangular diagram[15]. The importance of piper's trilinear diagram has been widely recognized in groundwater studies. The diagram consisting three distinct fields with two triangular fields and one diamond shaped fields. The percent epm values of different constituents of water are represented by three points in which cation and anions grouped separately and are plotted in lower left and right triangles respectively then the anions and cation are combined to show a single point diamond shape fields, which throws height on the hydro chemical facies classification. Piper Trilinear diagram (Figure-6 and Table 3) shows that the majority of groundwater samples of the study area are of Ca-Na-Cl-HCO_3 type.

US Salinity Laboratory diagram: US Salinity Laboratory proposed irrigational specifications for evaluating the suitability of water for irrigation use. The USSL diagram relates SAR, expressing the alkalinity hazard, to EC (salinity hazard). The EC in irrigation water can be classified into low (C1), medium (C2), high (C3) and very high (C4) salinity zones. The sodium hazard is classified, in terms of classification of irrigation water, as low (S1, <10), medium (S2, 10-18), high (S3, 18–26) and very high (S4, >26). The irrigation water quality was assessed with the methods introduced above. The SAR value in water samples range between 0.57 and 12.12, suggesting low to medium sodium hazard as per the USSL classification. In the present study, the values of SAR and EC were plotted on a US Salinity diagram (Figure-7). The results show that most of the water samples belong to the category C3S1 which indicates that although these samples have low to medium alkalinity hazard, they are not suitable for irrigation under ordinary conditions, because they have high salinity hazard. However, they may be used for salt tolerant plants on permeable bed with special management practices.

Coefficient correlation of major elements in water: For determination of relationship of physicochemical parameters of groundwater, correlation coefficient is a normally used to recognize the correlation between two variables. It is simply a measure to exhibit how well one variable predicts the other. The correlation matrices for 17 variables were prepared and presented in Table 4and illustrate that EC and TDS show good positive correlation with EC and Cl, EC and Ca, EC and HCO_3.TDS and Cl also exhibit high positive correlation. However Mg and K, K and CO_3 were the negative correlation pairs.

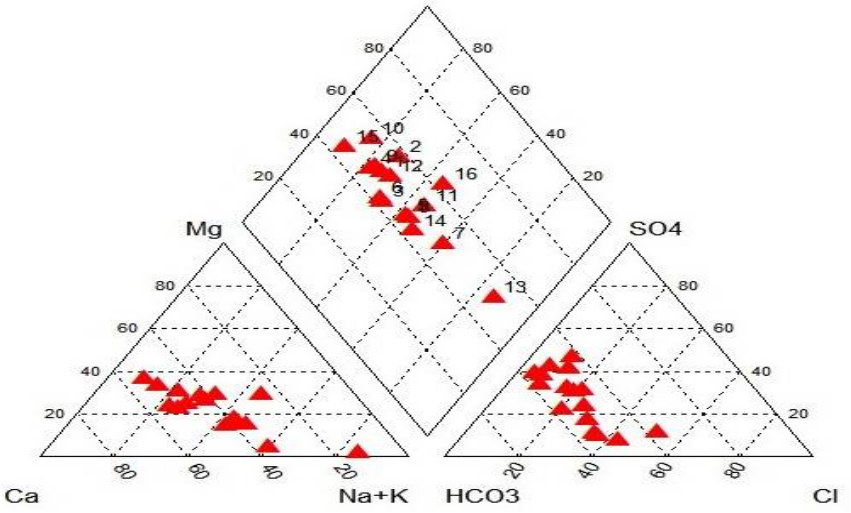

Figure-6
Piper Trilinear diagram of water samples from Urmodi river basin

Table-3
Water type from the area under study

Sample ID	Water Type	Sample ID	Water Type
1	Ca-Na-HCO3-SO4	9	Ca-HCO3-SO4
2	Ca-Na-Mg-SO4-HCO3	10	Ca-Mg-HCO3-SO4
3	Ca-Na-Mg-HCO3-SO4	11	Na-Ca-HCO3-SO4-Cl
4	Ca-Mg-HCO3-Cl	12	Ca-Na-Mg-HCO3-Cl
5	Na-Ca-HCO3-Cl	13	Na-HCO3-SO4-Cl
6	Ca-Mg-HCO3-SO4-Cl	14	Na-Ca-HCO3-SO4
7	Na-Ca-HCO3-Cl-SO4	15	Ca-Mg-HCO3-SO4
8	Na-Ca-HCO3-Cl	16	Na-Mg-Ca-Cl-HCO3

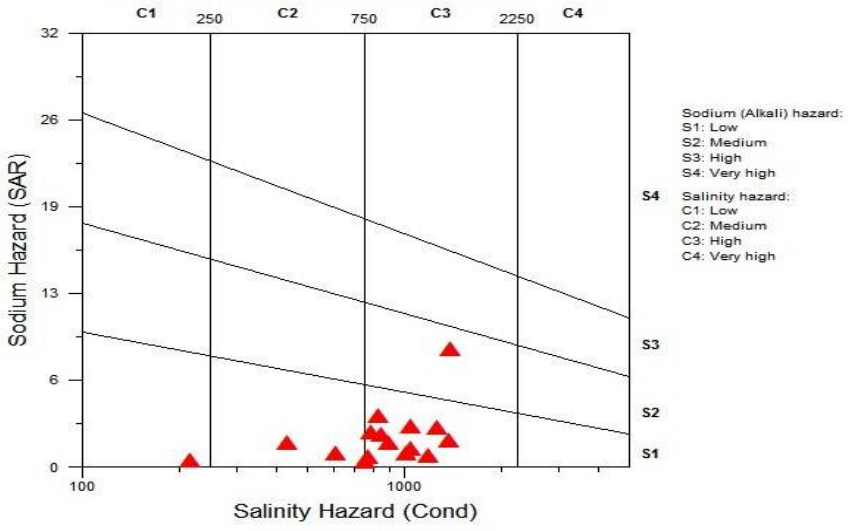

Figure-7
US Salinity Laboratory diagram of water samples from Urmodi river basin

Table-4
Coefficient correlation of water quality data of Urmodi river basin

	pH	**EC**	**TDS**	**Alkalinity**	**Hardness**	**Ca**	**Mg**	**Na**	**K**	**NO3**	**PO_4**	**SO_4**	**Cl**	**$CO_3 + HCO_3$**
pH	1.00													
EC	0.23	1.00												
TDS	0.23	1.00	1.00											
Alkalinity	-0.07	0.76	0.76	1.00										
Hardness	-0.07	0.58	0.58	0.82	1.00									
Ca	-0.20	0.62	0.62	0.85	0.97	1.00								
Mg	0.09	0.50	0.50	0.72	0.96	0.87	1.00							
Na	0.33	0.69	0.69	0.43	0.03	0.11	-0.07	1.00						
K	-0.10	-0.09	-0.09	0.01	0.00	-0.03	0.05	-0.30	1.00					
NO_3	-0.20	0.53	0.53	0.58	0.66	0.67	0.61	0.15	-0.10	1.00				
PO_4	-0.29	-0.18	-0.18	-0.07	-0.09	-0.06	-0.10	-0.31	0.83	-0.05	1.00			
SO_4	-0.09	0.26	0.26	0.15	0.34	0.37	0.29	-0.14	-0.16	0.10	-0.13	1.00		
Cl	0.21	0.58	0.58	0.67	0.56	0.55	0.52	0.57	-0.04	0.42	-0.15	-0.44	1.00	
$CO_3 + HCO_3$	-0.07	0.76	0.76	1.00	0.82	0.85	0.72	0.43	0.01	0.58	-0.07	0.15	0.67	1.00

Conclusion

The total dissolved content in the groundwater from the area under study shows a general increasing trend from higher elevation to lower elevation. The sequence of major cations and anions dominance in groundwater geochemistry in the study area have the order of Ca > Na > Mg > K and Cl > HCO_3> SO_4> NO_3> CO_3. According to the measured EC and calculated SAR values, groundwater in the command area is characterized by limited harmful effect on plants in the higher elevation area to a moderate harmful effect for plants in the lower elevated area.

Some management practices that should be taken into consideration for sustainable development of water resources in the study area were discussed as follows: i. Plant selection: A crop that suits the water quality should be selected. ii. Irrigation methods: Drip irrigation should be adopted for more effective irrigation without excessive waste of water. iii. At some places like Maskarwadi, Kaloshi Atit and Majgaon villages water is not safe as per BIS norm. So that proper treatment should be taken for drinking as well for agriculture water.

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