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Seawater Intrusion in Coastal Aquifer from Ratnagiri Area of India and Its Impact on Quality of Irrigation Water

[1]Golekar Rushikesh Baburao*, [2]Dakve Soham Mahendra, [3]Kurdhundkar Shubham Shailesh, and [4]Nivate Sanjana Sanjay

Author's Affiliations:
[1-4] Department of Geology, G.B. Tatha Tatyasaheb Khare Commerce, Parvatibai Gurupad Dhere Arts and Shri. Mahesh Janardan Bhosale Science College. Guhagar. District Ratnagiri 415703, Maharashtra, India

***Corresponding Author: Rushikesh Baburao Golekar,**Department of Geology, G.B. Tatha Tatyasaheb Khare Commerce, Parvatibai Gurupad Dhere Arts and Shri. Mahesh Janardan Bhosale Science College. Guhagar. District Ratnagiri 415703, Maharashtra, India
E-mail: rbgolekar@gmail.com

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Abstract:
An attempt has been made in this work to determine the groundwater quality in parts of Guhagar area of Ratnagiri district, Maharashtra. A total 25 groundwater samples were collected from dug and bore wells, during the winter season (January, 2023) and analyzed its physicochemical parameters like pH, EC and TDS, in order to understand the hydro-geochemistry of the water. Suitability of this water for its utility was verified using Indian standards. The analytical results of the groundwater samples showed that the average value of pH is 6.60 and average value of EC is 431.1 µS/cm while average values of TDS is 215.1 mg/L. The effect of sea water on the fresh water aquifer in this coastal region needs special attention in terms of monitoring and sustainable management. Besides, suitability of water for irrigation is evaluated based on this physicochemical parameter. Also, the suitable crop cultivation is recommended on the basis of quality of irrigation water.

Keywords:*Groundwater, sea water, crops, irrigation, sustainable management.*

1. INTRODUCTION

Coastal aquifers are important source of freshwater supply in coastal regions. Excessive groundwater extraction has led to seawater intrusion and water quality degradation in many coastal aquifers (Bear et al., 1999; Saxena et al., 2003; Mondal et al. 2010, 2011). The salinization of coastal aquifers will deteriorate with the increasing demands for freshwater resources in coastal areas and predicted international sea level rise by 0.1 m to 2 m before 2100 (Pfeffer et al., 2008). Better understanding of seawater intrusion in coastal aquifers and the ability to more precisely prediction of the extent of aquifer salinization is very important for improving water resources planning, development and management in coastal areas. Seawater intrusion in a coastal aquifer is a natural phenomenon that occurs due to flow and salt transportation driven by the density variation between the seawater and fresh groundwater. The seawater intrusion is increased by groundwater extraction and potentially sea level rise as these processes reduces the hydraulic gradient that drives fresh groundwater discharge in to the ocean (Werner and Simmons, 2009; Chang et al., 2011).

As a natural factor, the ocean tide has a greater impact on seawater intrusion (Kim et al., 2005). Therefore, it is essential to determine whether groundwater has been contaminated due to seawater intrusion in the coastal areas. Because domestic and irrigation source in coastal area is groundwater due to the inadequate geographical features. Groundwater quality is drastically decreasing due to seawater intrusion into groundwater. The present study was carried out to identify the seawater ingress in the Guhagar area of Ratnagiri District and its impact on groundwater quality. The main source of drinking water supply in the studied regions is groundwater except one small dam situated near Guhagar Town. Small rivers are flowing in this area but during the dry seasons the most of the rivers were dried. In this situation, water quality assessment and the study of hydrogeochemical processes affecting the groundwater quality in coastal areas will be helpful to promote sustainable development and the management of water resources.

The aim of present study is to assess the groundwater quality and its deterioration in coastal aquifer in Guhagar area of Ratnagiri District, Maharashtra (India) by examining the physicochemical characteristics. A total 25 wells have been selected for the purpose of water sampling in and around Guhagar Town. A total 25 water samples were collected from different zones from the during the winter season (January, 2023). Samples were analysed for its physicochemical parameters (i.e., pH, EC, TDS).The study area is a coastal territory which lies between Guhagar Town in the South (Latitude 17.47 N to 17.51 N) and (Longitude 73.18 E to 73.19 E). The location map of the study area has depicted in Figure 1. The present study area is receiving rainfall from southwest monsoon during the period of June to September, July being the recipient of maximum rainfall. October and November months receive late showers from retreating monsoon. Such variation in rainfall has an important bearing on groundwater level fluctuations. The average annual rainfall of the Guhagar area is 2745 mm. The hottest month is May, its mean monthly temperature being 32.7°C and the coldest month is January, its mean monthly temperature being18.6°C. The annual average evaporation is 158 mm. The maximum humidity of over 80% is experienced in the rainy months that seldom lower down to 60% due to proximity of sea. The data thus suggests that the area experiences per-humid to humid type of climate (IMD 1972; NBSS 1995; Uamrikar and Thigale, 2007).

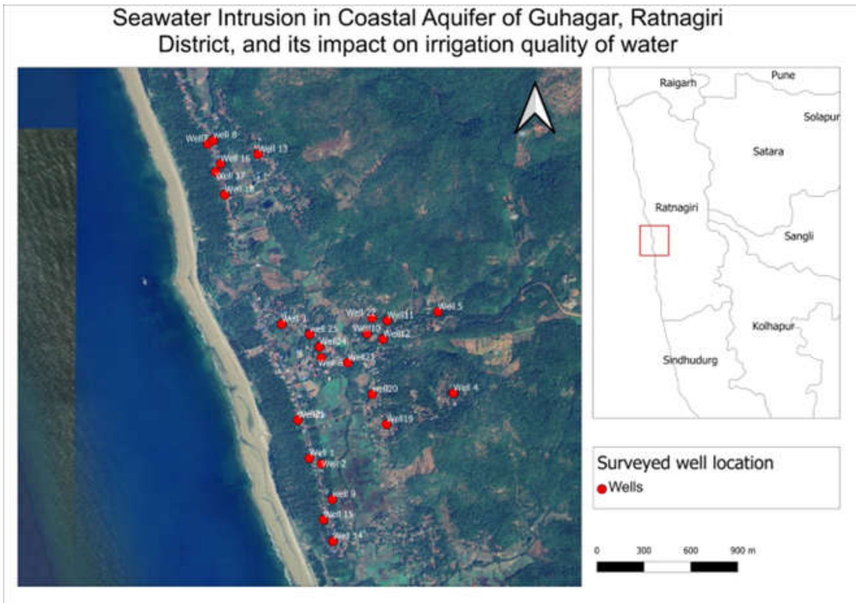


Figure 1: Location map of the study area

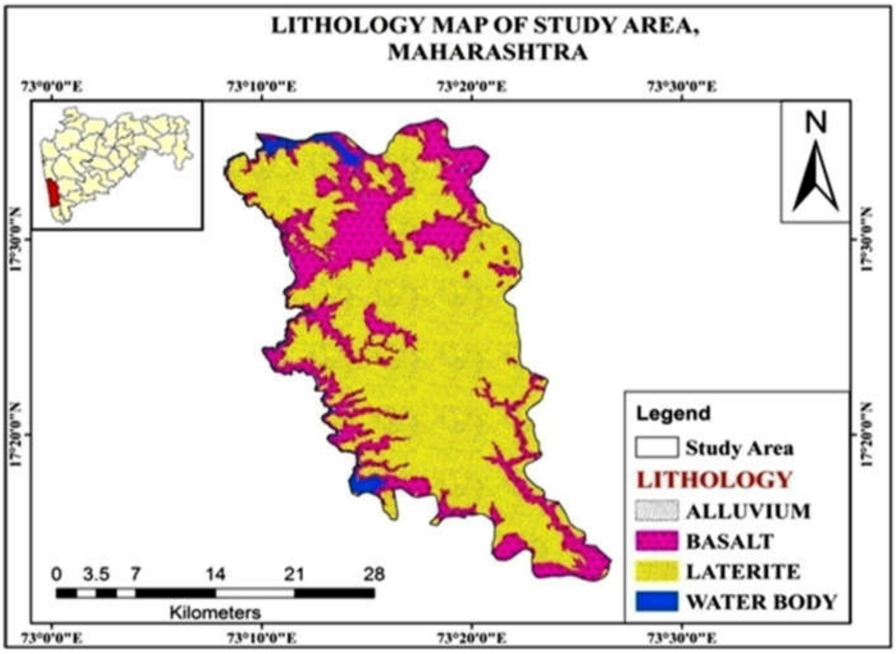


Figure 2: Geological map of the study area

Geologically study area is mostly covered by the basaltic lava flows of the Continental Tholeiitic Province of India (Deccan Volcanic Province), of the upper Cretaceous to Miocene Period. At a number of places, laterite cappings on basalt occur at various altitudes. The basalt is massive, compact and fine grained with occasional presence of vesicles. The Quaternary (Holocene) sediments were found along the coast. These sediments are found in consolidated and unconsolidated calcareous sands and contain molluscan shells in varying proportions. These sediments are fine grained to medium grained and rounded to sub rounded in character (Herlekar and Sukhatnkar, 2011). Beaches are represented by sand, spit by beach rock, flats by mud and uplifted abrasion platforms by colluvium and alluvium (Uamrikar and Thigale, 2007). Geological map of the study area is depicted in figure 2.

Hydrogeological environments in the study area are mostly found as unconfined aquifer system. Water bearing rock formation in the top section is more often weathered basalts while higher altitude areas usually have hard basalts. In general, the aquifer consists of weathered jointed and fractured basalts. Groundwater level in the study areas was shallow and some of the well's groundwater level below the mean sea level (Uamrikar and Thigale, 2007). In the field investigation, it was found that total depth of the wells is shallow and it is around 16 meters below ground level (bgl). According to the results, there is a clear variation of the groundwater table during dry and wet seasons. Elevation of the groundwater table varies from 2 to 7 m above the mean sea level (m.amsl) in the study area.

2. METHODOLOGY

A total 25 wells locations have been selected for water sampling and which depicted in Table 1 along with its co-ordinates. For the purpose of present study, a total of 25 water samples were collected from different location in Guhagar town, Ratnagiri District, Maharashtra (India). The samplings have been carried out on in the month of January 2023. In this regard, it is difficult to specify the exact sampling depth so that we assumed groundwater samples are mixed over the whole vertical section where wells are selected as sampling sites (James, 2020). Representative well location has depicted in field photographs number 01 and 02. The analysis of the influence of seawater on the groundwater quality was based on physicochemical parameters such as electrical conductivity (EC), total dissolved solids (TDS) and pH. The pH measured with a with pH meter (Hach), the EC and TDS measured on EC meter. The present work is useful to recognize the impact of quality of water on productivity. Based on the obtained results and field observationsfew suggestive measureswere recommended to control the salinity hazard problem in the studied area.

3. RESULTS AND DISCUSSION

Hydrochemical characterization

All analytical results of the water samples from the study area are depicted in Table 1. Obtained results of water quality parameters have been compared with Bureau of Indian Standards (BIS) for drinking water. The analytical results of the groundwater samples showed that pH ranges from 5.77 to 7.33 with an average value is 6.60 (Fig. 3). EC was found ranged from 95to 997 μS/cm with an average value is 431.1 μS/cm (Fig. 4). TDS concentration ranges between 48 and 481 mg/L with average of 215.1 mg/L (Table 2).

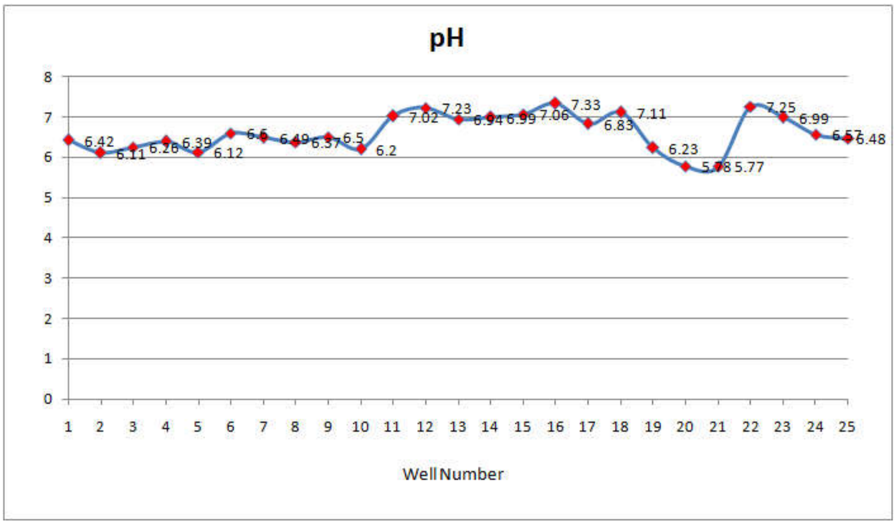


Figure 3: pH in water samples from the study area

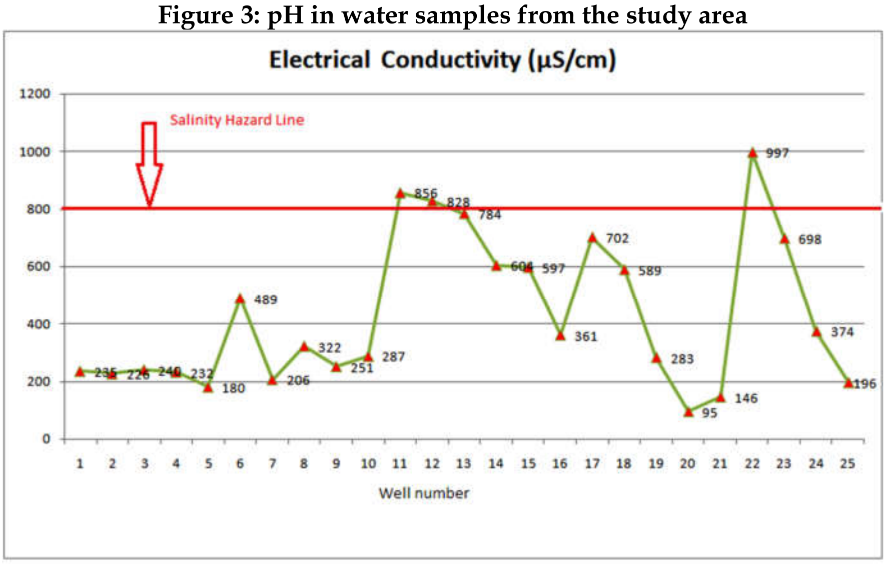


Figure 4: Electrical conductivity of water samples from the study area

The pH of groundwater sample measures its hydrogen ion concentration and indicates whether the sample is acidic, neutral or basic. Majority of the groundwater samples from the study area shows acidic and neutral nature. This suggests that this category of water where the pH values ranged between 5.0 to 8.0 is most suitable for cultivation of betel nut (George and Robert, 2006). Detay and Carpenter (1997) has been categorized drinking water based on values of electrical conductivity which shows level of mineralization (Table 2). According to this classification majority of groundwater samples from the study area falls under weakly and slightly mineralized water category.

Table 1: Details of the selected well for the present study along with analytical results

Well Number	Latitude	Longitude	Depth of Well (m)	Diameter of well (m)	Water level (m bgl)	pH	Electrical Conductivity (µS/cm)	Total Dissolved Solids (mg/L)	Use of well water	Lithology
1	17.48	73.19	12	3.7	1.4	6.42	235	122	Coconut, betel nut	Lateritic Soil, Compact Basalt
2	17.48	73.19	10	3	1.4	6.11	226	111	Coconut, betel nut	Lateritic Soil, Compact Basalt
3	17.48	73.19	11	3.5	2	6.26	240	123	Coconut, betel nut	Lateritic Soil, Compact Basalt
4	17.48	73.19	16	2.4	4	6.39	232	115	Coconut, betel nut	Lateritic Soil, Compact Basalt
5	17.48	73.19	12	2.8	3.3	6.12	180	89	Domestic use	Lateritic Soil, Compact Basalt
6	17.48	73.19	10	2.7	2.9	6.6	489	240	Not used	Lateritic Soil, Compact Basalt
7	17.48	73.19	7	3	1	6.49	206	102	Coconut, betel nut	Lateritic Soil, Compact Basalt
8	17.48	73.19	7	3	4	6.37	322	160	Coconut, betel nut	Lateritic Soil, Compact Basalt
9	17.49	73.18	8	3	1.8	6.5	251	127	Coconut, betel nut	Lateritic Soil, Compact Basalt
10	17.49	73.18	8	4	2	6.2	287	142	Coconut, betel nut	Lateritic Soil, Compact Basalt
11	17.49	73.18	8	2.7	4	7.02	856	450	Coconut, betel nut	Lateritic Soil, Compact Basalt
12	17.47	73.19	6	3.3	4.4	7.23	828	412	Coconut, betel nut	Lateritic Soil, Compact Basalt
13	17.47	73.19	5	3.4	4.4	6.94	784	387	Coconut, betel nut	Lateritic Soil, Compact Basalt
14	17.48	73.18	5	3.3	3.4	6.99	604	311	Coconut, betel nut	Lateritic Soil, Compact Basalt
15	17.47	73.19	7	1.5	4.4	7.06	597	294	Coconut, betel nut	Unconsolidated Siltstone
16	17.47	73.19	5	3.2	2.7	7.33	361	183	Coconut, betel nut	Lateritic Soil, Compact Basalt
17	17.47	73.19	5	2.5	5.6	6.83	702	344	Coconut, betel nut	Unconsolidated Siltstone
18	17.47	73.19	7	2	4.9	7.11	589	298	Coconut, betel nut	Lateritic Soil, Compact Basalt
19	17.48	73.19	6	3	2.2	6.23	283	142	Coconut, betel nut	Lateritic Soil, Compact Basalt
20	17.48	73.18	7	2.9	5.2	5.78	95	48	Coconut, betel nut	Lateritic Soil, Compact Basalt
21	17.48	73.18	9	2.5	6.5	5.77	146	74	Coconut, betel nut	Lateritic Soil, Compact Basalt
22	17.51	73.18	4	2.8	2	7.25	997	481	Coconut, betel nut	Lateritic Soil, Compact Basalt
23	17.51	73.18	7	2.5	4.5	6.99	698	341	Coconut, betel nut	Unconsolidated Siltstone
24	17.49	73.18	6	3	3.5	6.57	374	186	Coconut, betel nut	Lateritic Soil, Compact Basalt
25	17.48	73.19	11	6.5	5	6.48	196	97	Coconut, betel nut	Jointed Basalt

Latitude and longitude values in decimals of degree minutes

Table 2: Relation between water conductivity and mineralization (After Detay and Carpenter, 1997)

EC (µS/cm)	Mineralization	Number of samples	% of samples
< 100	Very weakly mineralized water	1	4
100-200	Weakly mineralized water	3	12
200-400	Slightly mineralized water	11	44
400-600	Moderately mineralized water	3	12
600-1000	Highly mineralized water	7	28
> 1000	Excessively mineralized water	Nil	Nil

Salinity hazards

Electrical conductivity depends on water's capacity to convey an electric current, which is used for indicating the total concentration of ionized constituents present in natural water. Electrical conductivity is a good measurement of salinity hazard to crops as it reflects the TDS in groundwater. Salts in soil or water reduce water availability to the crop to such an extent that yield is affected. A salinity problem exists if salt accumulates in the crop root zone to a concentration that causes a loss in yield. In irrigated areas, these salts often originate from a saline, high water table or from salts in the applied water. Yield reductions occur when the salts accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in a water stress for a significant period of time. If water uptake is appreciably reduced, the plant slows its rate of growth. The plant symptoms are similar in appearance to those of drought, such as wilting, or a darker, bluish-green colour and sometimes thicker, waxier leaves. Symptoms vary with the growth stage, being more noticeable if the salts affect the plant during the early stages of growth. In some cases, mild salt effects may go entirely unnoticed because of a uniform reduction in growth across an entire field. Salts that contribute to a salinity problem are water soluble and readily transported by water. A portion of the salts that accumulate from prior irrigations can be moved (leached) below the rooting depth if more irrigation water infiltrates the soil than is used by the crop during the crop season. Leaching is the key to controlling a water qualityrelated salinity problem. Over a period of time, salt removal by leaching must equal or exceed the salt additions from the applied water to prevent salt building up to a damaging concentration. The amount of leaching required is dependent upon the irrigation water quality and the salinity tolerance of the crop grown.

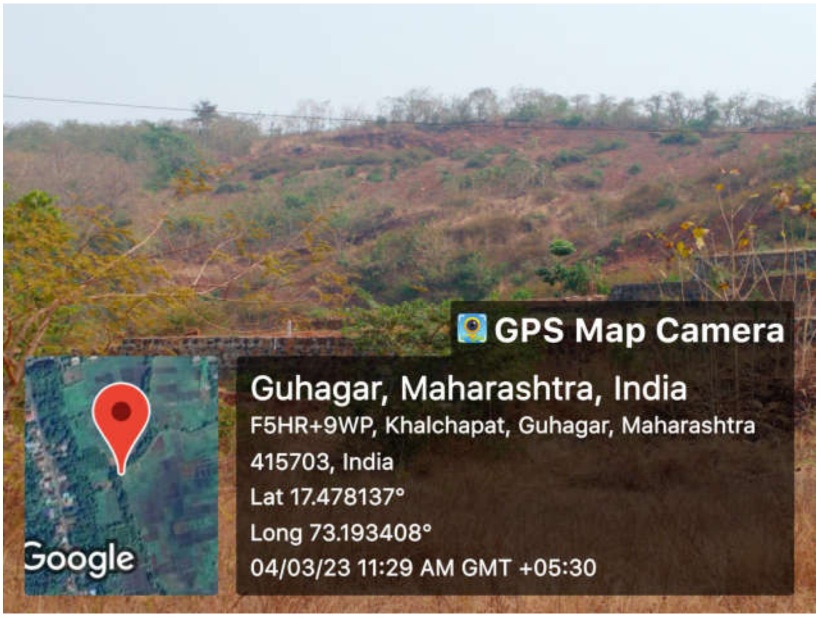
Relationship of quality of water on productivity of the crops

The study area renowned for cultivation of coconut trees, betel nut and mango trees. In the present study, pH, electrical conductivity and Total dissolved solids were analysed in groundwater samples from 25 selected wells from Guhagar Town. The Betel nut plants in many types of soils varying in texture from laterite to loamy. Also, betel nut plants prefer soil with medium texture and sandy clay and loamy soils. And also needs high moisture retains. The pH of the soil for betel nut is in range from 5.0 to 8.0 is good for better crops yields. Betel nut is also not salt tolerant so need low saline soil for better crop yield. Betel nut crops not sustaining in waterlogged soil. The obtained results from the study area suggest that pH of water samples from the study area is good for betel nut plants. Field survey proven that the betel nut from the study area is very healthy and it has high yield. This suggests that the study area is most feasible for the cultivation of betel nut where the pH of irrigation water is ranged from 5.00 to 8.00.

Coconut can be grown in soil with pH of 5.2 - 8.6. Proper supply of moisture either through well distributed rainfall or irrigation and sufficient drainage are essential to high yield of coconut. The obtained results from the study area suggest that pH of water samples from the study area is good for coconut nut plants. The coconut production is good when supply of saline waterthrough irrigation. In the studied area slightly, saline water is found in well number 11, 12, 13, 14, 15, 17, 18, 22 and 23. These wellsare mostly in unconsolidated sedimentary rock formation as well as near from the coast. This suggest that where the irrigation water is slightly saline recommend that for cultivation of coconut instead of betel nuts in this area. Mango grows well on wide variety of soils, such as lateritic, alluvial, sandy loam and sandy. The loamy, alluvial, well-drained, aerated and deep soils (2-2.5 m) rich in organic matter with a pH range of 5.5-7.5 are ideal for mango cultivation. The obtained results from the study area suggest that pH of water samples from the study area is good for cultivation of Mango plants.The electrical conductivity in the irrigation water above 800 µS/cm can reduce the growth and quality of mango tree seedlings. Well number 11, 12 and 22 were found that beyond the permissible limit of electrical conductivity this suggest that this well water is unfavourable for the irrigation for the mango as well as for betel nut because betel nut is not salinity tolerant and it leads to decrease the crop productivity of the mango as well as betel nuts. This well water will be beneficial for cultivation of coconut instead of Mango and betel nuts because of coconut is salt tolerant plants.

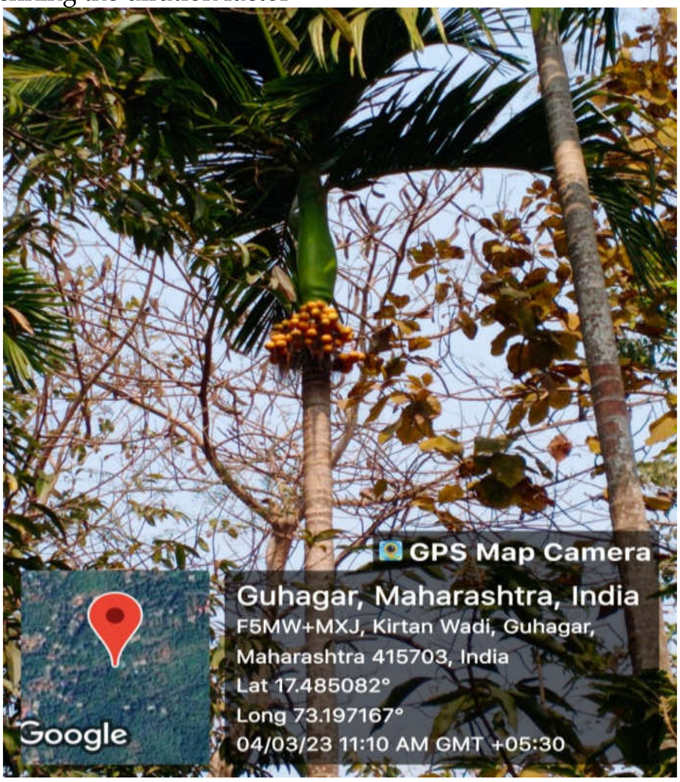
Field photograph 1: (Well Number 09)

Field photograph 2: (Well Number 18)



Field Photograph 3: Excavation of tophills in the study area which prove the decarsing the planation and incarese urabanisation which lead to decres the groundwater recahrge which will effect the quality of water in terms of incarese the salinity ingress in natural

Field Photograph 4: Speedily conversion of forest and barren land into non-agricultural land it will be decrease the recharge rate of rainwater in the area and ultimately it will increase the salinity of groundwater due to declining the dilution factor



Field Photograph 5: Healthy plants of betel nuts in the area under study which reflect that the good quality of water

Field Photograph 6: Non cultivation of rice crops surrounding areas of the well which will ultimately decrease the recharge rate of rainwater in the area and ultimately it will vulnerable to increase the salinity of groundwater.

Significant field observations

1. Excavation of hills in the study region which is proven that the decreasing plantation and increasing urabanisation which leads to decline the groundwater recharge and ultimately effect the water quality in terms salinity (Field photograph 3).
2. Speedily conversion of forest land into non-agricultural land it will be decrease the recharge rate of rainwater in the study area and ultimately it will increase the salinity of groundwater (Field photograph 4).
3. Healthy plants of betel nuts in the area under study which reflect that the good quality of water of its cultivation (Field photographs 5).
4. Rice crops is help to increase the recharge of rainwater into ground but since last few years the studied region cultivation of rice crops is declined in the surrounding areas of the well which will ultimately decrease the recharge rate of rainwater in the area and ultimately it will increase the salinity of groundwater due to declining the dilution factor (Field photograph 6).

4. CONCLUSIONS

This work is demonstrated the hydro-geochemical characteristics of coastal aquifers of Guhagar area of Ratnagiri District in the State of Maharashtra from India. The overexploitation of the coastal aquifers is allowed the salinization process at a faster rate and therefore affected the quality of soil and growth of plants and crops. Therefore, it is essential to have successful conservation and well managed plan to protect the coastal aquifers of this region from salinization process. Few conventional methods have been recommended for conservation and protection of the coastal aquifers of this region from salinization process. Reduction of pumping from wells is the simplest, direct and cost-effective method to maintain the groundwater balance in aquifers. New varieties of salinity tolerant crops should be introduced for cultivation in these areas. It is also needs to change the cropping patterns. Most of the farms are empty after harvesting of Kharif (Monsoon) crops and therefore, needs to Rabbi (winter) crops should be cultivated based on suitability of local climate and soil types.

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