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Evaluating groundwater suitability for the domestic purpose in Jam River Basin, Maharashtra, India,using GIS

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Abstract

Groundwater is an important natural resource for sustenance of life. Evaluation of groundwater quality is crucial for the socioeconomic development of the area because the usefulness of groundwater to humans depends on its chemical status. In the Jam River Basin, the hydrogeochemical properties of groundwater and their suitability for drinking purposes were assessed. A total of 60 representative groundwater samples were collected from bore wells and dug wells during pre and post monsoon season 2021 and analyzed for major cations and anions. The order of dominance of cation and anions were Na > Ca > Mg > K and HCO_3 > Cl > SO_4 > NO_3, respectively. The research area's groundwater quality is primarily regulated by the weathering and evaporation of the study area's rocks. As per BIS standards for domestic water purposes TDS, TH, Ca, Mg and Cl exceed the safe limits in15, 91.66, 50, 61.66, 8.33 % and 11.66, 48.33, 10, 21.66, 8.33% during pre and post monsoon 2021 respectively; therefore, most of samples during post monsoon show that the groundwater is suitable for drinking. ArcGIS was used to create the spatiotemporal distribution maps of the physicochemical parameters. As a result, the majority of the groundwater samples from this study attest to the advantages of using the area's aquifers for drinking water. However, sample numbers 5, 6, 9, 15, 16, 18, 19, 34, and 37 were found to be problematic in the study region and require specific corrective actions in order to be useful.

Keywords: *Groundwater, Hydrogeochemical, Jam River, GIS, domestic*

Introduction

Water is a crucial natural resource for human health as well as for the existence of all species. Aquifer integrity is mostly impacted by contamination from agricultural practices, making groundwater quality a crucial component of sustainable water management. Worldwide, groundwater is a significant supply of water for household, agricultural and industrial needs. On Earth, freshwater makes up 37 Mkm^3; 22% of it is groundwater and 97% of it is usable for human consumption. (Foster, 1998; Mukate *et al.*, 2017). In India, an economy dependent on agriculture, the majority of people live in rural and urban areas and rely on groundwater for irrigation and domestic use. Groundwater quality has declined in India as a result of excessive groundwater extraction without corresponding recharge, excessive agricultural chemical usage and residues of pollutants from fertilizers and pesticides that seep into the ground in numerous regions of the nation. (Goyal *et al.*, 2010; Wagh *et al.*, 2017). Due to intensive agriculture, urbanization, industry, population growth and other factors that raise the risk of groundwater contamination and depletion, groundwater demand has increased. Ion concentrations must be determined in order to evaluate the appropriateness of groundwater for household, agricultural and industrial uses. A good method for determining the processes responsible for groundwater chemistry is hydrogeochemical analysis. (Jeevanandam *et al.,* 2007). The geological environment, natural water flow, rock types, aquifer materials, climatic variation, water's residence period and inputs from the soil during percolation are all factors that affect the water's quality (Tay and Kortatsi, 2008; Todd *et al.*, 1980; Laurent *et al.*, 2010). The spatiotemporal change of ions, geomorphology, hydrogeology, land use pattern, etc. have all been represented using GIS-based interpolation techniques recently (Zolekar and Bhagat, 2015). The literature now in circulation indicates that there has not yet been any scientific oversight of groundwater quality study in the Jam River basin. Therefore, the current study was conducted with the aim of evaluating the acceptability of groundwater for household purposes by validating water quality criteria.

Study Area

The study area lies in Nashik and Ahmednagar district of Maharashtra bounded by latitudes 19^{0}44'27" to 19^{0}52'18" N and longitudes 74^{0}6'28" to 74^{0}25'56" E in the Deccan Plateau, an eastern extension of the Kalsubai range (Fig.1). The high Mhasha Hill in Sinnar Tehsil, Nashik District, is the origin of the Jam River, a tributary of the Godavari River, which it joins near Kopargaon Tehsil, Ahmednagar District. A total of 636.67 square kilometers makes up the basin. In the Ahmednagar district of Maharashtra, it traverses 52.2 Km from Sinnar Tehsil's eastern section to Kopargaon Tehsil's southwest section. The south-west monsoonal winds, which blow from June to September (Sinnar: 568.6 mm, Sangamner: 510.57 mm and Kopargaon: 483.9 mm), are responsible for the region's average annual rainfall (CGWB 2014). The Deccan trap rocks that make up the study area's limited groundwater are weathered, faulted and fractured, causing secondary porosity in the aquifers that are disproportionately distributed (Rai *et al*., 2011). These factors affect how the groundwater moves. This river benefits many communities in Sinnar, Kopargaon and Sangamner tehsil for irrigation and drinking needs. The current study examines the suitability for home use as well as all potential methods of river basin groundwater contamination and their effects on human health.

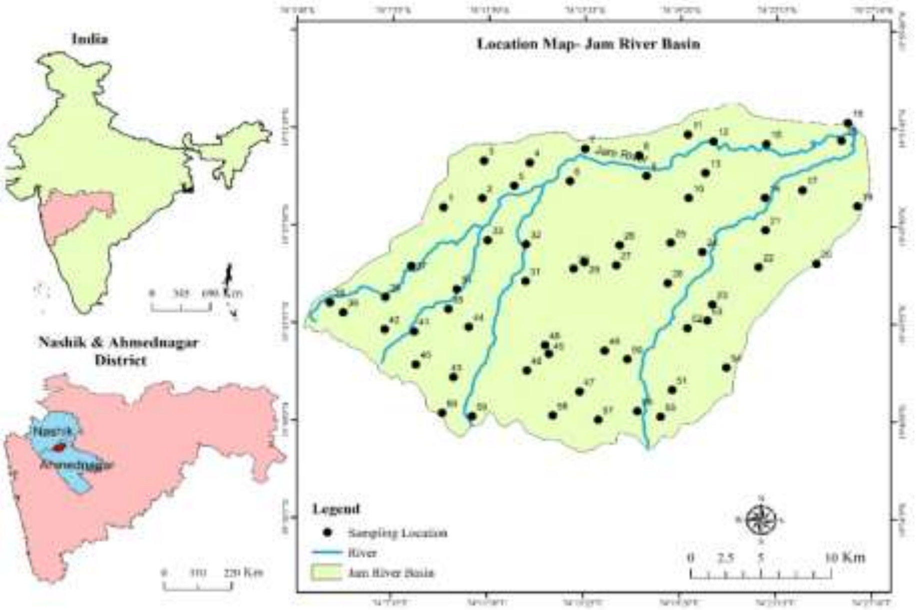

Fig.1 Study area map with groundwater sample locations

Materials and Methods

According to geographic variation, sixty (60) representative ground water samples were obtained for the current study during the pre- and post-monsoon seasons of 2021 from various dug wells and bore wells. GPS (Geographical Positioning System) data was used by Arc GIS software to pinpoint the sites of the water samples. For the purpose of making, it easier to collect representative groundwater sample, the area was divided into grids. Fig.1 depicts a sample location map. To minimise the danger of contamination, groundwater samples were taken in pre-treated plastic cans with a 1 lit. capacity, which were also correctly labelled. A multi parameter tester was used to quantify pH, EC and TDS in situ. Additionally, samples were delivered to an analytical lab for physicochemical investigation using American Public Health Association standard procedures (APHA 2005). In a lab, the major cations and anions were measured. The approach, which consists of the analytical techniques, tools and software used to carry out this work, is given in Table 1. The selected variables have a numerical water quality guideline for drinking that met BIS (2012) requirements and were routinely measured at all sites. Using Arc GIS software, the spatial assessments of several physicochemical characteristics were displayed. The ion balance error is within ($\pm$10%) which confirms analytical accuracy (Table 1).

Table 1. Materials and methods adopted for physicochemical analysis of groundwater

Parameters	Materials and methods
Base map preparation	Survey of India toposheet 47 I/1, 47 I/2, 47 I/5 and 47 I/6 on 1:50000 scale
Geo-coordinates	GPS (Garmin eTrex)
pH and EC	Multi-parameter tester
Cations	
Ca and Mg	Titrimetric method
Na and K	Flame Photometer (Elico CL361)
Anions	
NO_3, SO_4 and PO_4	Spectrophotometer (Shimadzu UV-1800)
Cl and HCO_3	Titrimetric method
TDS	Multi-parameter tester
Spatial distribution maps	Arc GIS 10.8 v (IDW technique)
Ion balance error (IBE)	∑ cations + ∑anions

Results and Discussion

The physicochemical properties of groundwater (n = 60) are summarized in Table 2.

Status of pH, EC, TDS and its seasonal variations

The groundwater for the study had pH levels that ranged from 7.2 to 8.4 with an average of 7.9 during the pre-monsoon season and from 7.1 to 8.7 with an average of 7.6 during the post-monsoon season, showing that the water is typically alkaline. It falls as the water table rises and represents the water's capacity to buffer and withstand a pH change. On the other hand, the lack of rain-fed recharge to the aquifer and the high bicarbonate concentration in groundwater are to blame for the summer's modest pH increase. Throughout the winter, only sample number 34 (1.66%) exceeds the permitted level. The taste of water may change, and alkaline groundwater with an elevated pH commonly exhibits a close association with other ionic elements of water (Wagh *et al*., 2016 a, b). However, alkaline groundwater with a raised pH frequently has no detrimental impact on human health. The central section of the research area (sample numbers 1, 8, 10, 13, 30, 33, 36, 50, 57) will see elevated pH values in 2021 due to the pre-monsoon season. Samples 34, 36, 46, and 50 revealed higher pH values in post-monsoon 2021 (Fig. 2).

According to Morrison *et al*. (2001), the association between electrical conductivity and the total amount of dissolved salts in water shows that there is a higher level of inorganic contamination in the water. One finding demonstrates that the EC values during the winter (1627.62 µS/cm) are lower than those during the summer (1942.14 µS/cm). The higher ground water levels caused by rain-fed recharge during the monsoon season would have diluted the EC values in winter, which could be the cause of the lower EC values. (Fig.3). The idea that the pH is higher during the pre-monsoon season is supported by an increase in EC during this period. The EC value changes depending on the geological occurrence of soluble salts and rises with temperature (Wagh *et al*., 2019). The BIS has not prescribed any safe limit for the parameter EC.

TDS is a key component in determining whether water is suitable for drinking and irrigation due to its ionic components. TDS before the monsoon varies from 217 to 4590 mg/l, while TDS after the monsoon varies from 79 to 4109 mg/l. (Fig.4). The conclusion drawn regarding higher EC values at this time of year is supported by an increase in TDS during the summer. The BIS has established a TDS permissible maximum of 2000 mg/l.

Table 2: Physico-chemical characteristics of groundwater from Jam River basin

	Pre monsoon season				**Post monsoon season**			
Parameter	Min.	Max.	Average	Standard Deviation	Min.	Max.	Average	Standard Deviation
pH	7.2	8.4	7.9	0.32	7.1	8.7	7.6	0.31
EC	337	7780	1942.14	1499.07	111	6390	1627.62	1392.17
TDS	217	4590	1158.51	949.90	79	4109	987.70	882.18
Na^+	23.21	1120.99	276.89	329.10	8.24	890.4	193.60	225.64
K^+	0.00	17.16	2.02	2.61	0.00	6.26	1.60	1.37
Ca^{2+}	63.12	537.07	223.17	93.49	40.48	352.70	132.92	59.43

Mg^{2+}	21.87	410.8	137.6	73.81	1.21	417.96	79.25	71.96
TH	400	3245	1227.16	629.73	268	1760	716.06	381.30
Cl^-	17.04	1710.2	389.57	387.89	65.32	1668.5	469.19	355.08
HCO_3^-	150	800	422.41	134.44	150	1225	450.32	205.13
SO_4^{2-}	13.77	1224.19	243.33	276.17	37.49	516.61	167.48	103.16
PO_4^{2-}	0.02	1.92	0.96	0.63	0.01	1.11	0.37	0.38
NO_3^-	0.82	66.71	25.86	15.84	3	75.67	29.18	19.91

Note: All major ions and TDS are expressed in mg/lit while pH on scale and EC in µS/cm.

Table 3: Critical parameters exceeding the permissible limit in the Jam River basin

Parameters	Indian Standards, drinking water – specification BIS: 10500:2012		Sample exceeding permissible limit in premonsoon (May 2021)	Sample exceeding permissible limit in postmonsoon (November 2021)
	Desirable Limit	Permissible Limit	%	%
pH	6.5 to 8.5	No relaxation	Nil	1(1.66)
TDS	500	2000	9(15)	7(11.66)
Ca^{2+}	75	200	30(50)	6(10)
Mg^{2+}	30	100	37(61.66)	13(21.66)
Cl^-	250	1000	5(8.33)	5(8.33)
F^-	1	1.5	Nil	Nil
SO_4^{2-}	200	400	6(10)	2(3.33)
NO_3^-	45	No relaxation	8(13.33)	15(25)
TH, (as $CaCO_3$)	300	600	55(91.66)	29(48.33)

Note: All major ions and TDS are expressed in mg/lit while pH on scale

The maximum permissible level (Table 3) established by the drinking water standard (BIS, 2012) was found to be surpassed by 15% of the pre-monsoon samples (sample numbers 5,6,9,15,16,18,19,34,37) and 11.66% of the post-monsoon samples (sample numbers 5,9,11,15,16,18,19).

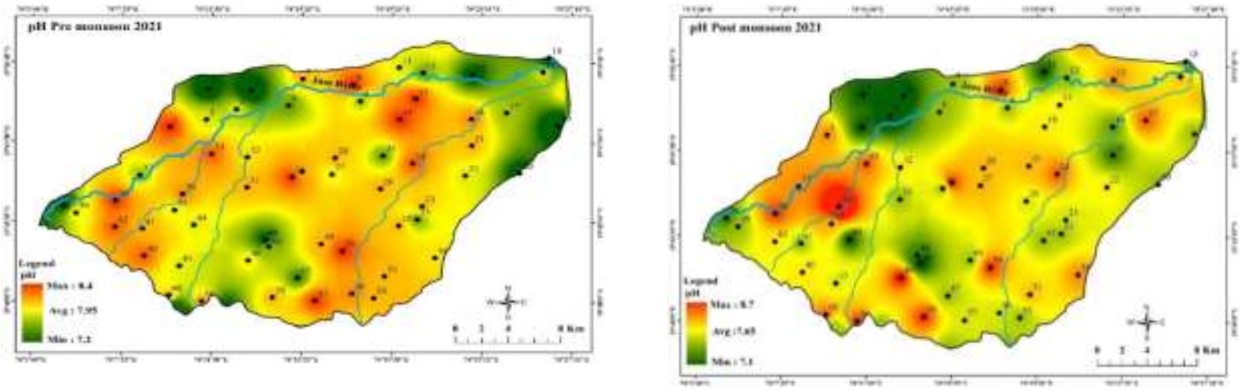

Fig. 2 Variations of pH in Pre and Post monsoon season

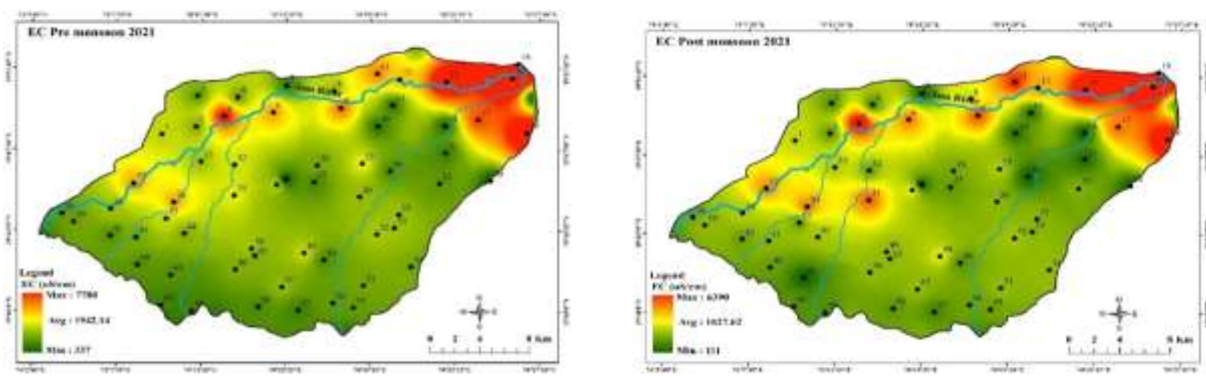

Fig. 3 Variations of EC in Pre and Post monsoon season of 2021

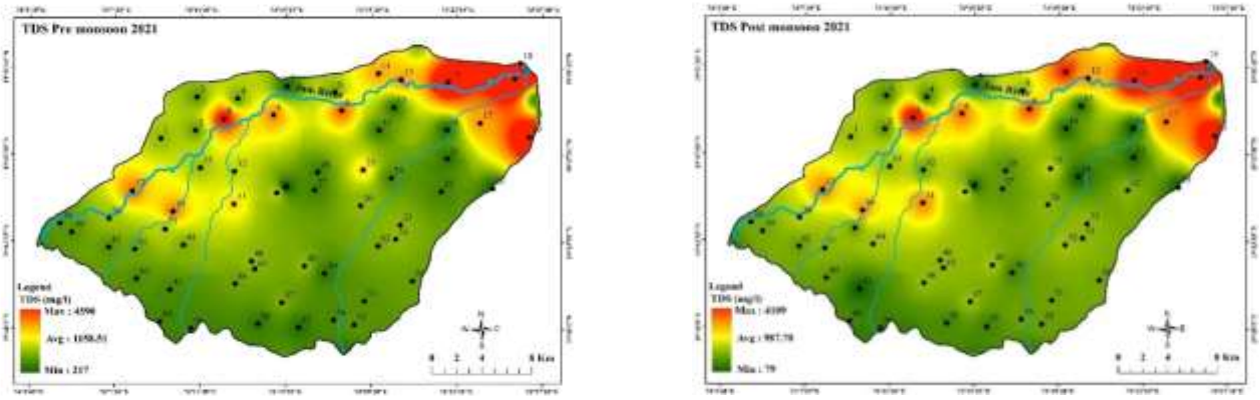

Fig. 4 Variations of TDS in Pre and Post monsoon season of 2021

The results are probably close to the mean because the standard deviation figures for the winter are lower than those for the summer. The increased TDS is believed to be caused by salt percolation, agricultural inputs and the dissolving of minerals from the basaltic aquifer. In the lower catchment area of the Jam River Basin, which is home to an intensive agricultural zone, high concentrations of TDS will be seen during both the pre-monsoon and post-monsoon seasons of 2021.

Status of cationic constituents and its seasonal variations

Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} are the four important cations found in groundwater. The calcium content of the groundwater varies from 63.12 to 537.07 mg/l in the summer and from 40.48 to 352.70 mg/l in the winter, respectively. According to BIS (2012), the maximum amount of calcium that should be present in drinking water is 200 mg/l. Calcium levels are higher in the pre-monsoon period as compared to both before and after the monsoon. (Fig.5). Table 3 reveals that 50% samples (sample numbers 1 to 6, 11, 12, 15 to 24, 27, 33 to 37, 43, 46, 48, 52, 55, 57) and 10% samples (sample numbers 5, 11, 15, 20, 35, 39) in pre-monsoon had above the allowable level specified by drinking water standard (BIS, 2012). Therefore, if these well waters are regularly consumed, the populace may develop kidney stones or joint ache.

The magnesium level varies from 21.87 to 410.8 mg/l and 1.21 to 417.96 mg/l, respectively, throughout the pre-monsoon and post-monsoon seasons. The BIS has established 100 mg/l as the acceptable level for magnesium. The maximum permissible limit (Table 3) established by the drinking water standard has been exceeded in 61.66% of the pre-monsoon samples (samples 1, 5, 13, 15, 16, 18, 25, 27, 33, 34, 43, 45) and 21.66% of the post-monsoon samples (samples 5, 9, 11, 15, 16, 18, 25, 27, 33, 34, 43, 45), respectively (BIS, 2012). The water becomes too hard to drink when calcium and magnesium levels are too high. Despite being one of the most important electrolytes in the body, magnesium may also be associated with a lower incidence of osteoporosis. Magnesium has a high solubility, is widely distributed in the crust of the earth and high quantities can cause diarrhea in humans (Hem, 1991). The magnesium that basalt rocks release into the groundwater is diluted by rainwater recharge (Pawar *et al.*, 2008). Magnesium's spatiotemporal maps revealed that the north of the study area contains a substantial amount of the element. The magnesium hotspots are located during and after the rainy season in dense agricultural areas. (Fig.6).

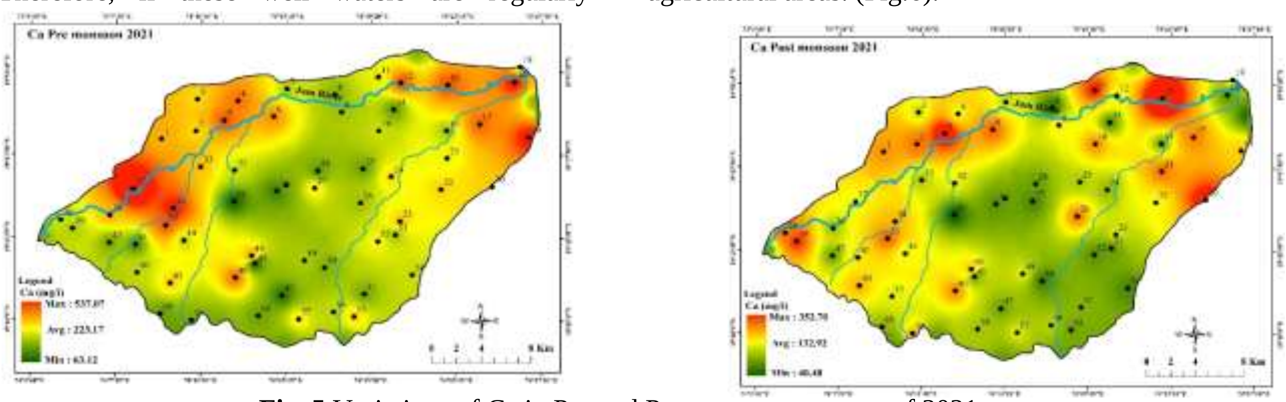

Fig. 5 Variations of Ca in Pre and Post monsoon season of 2021

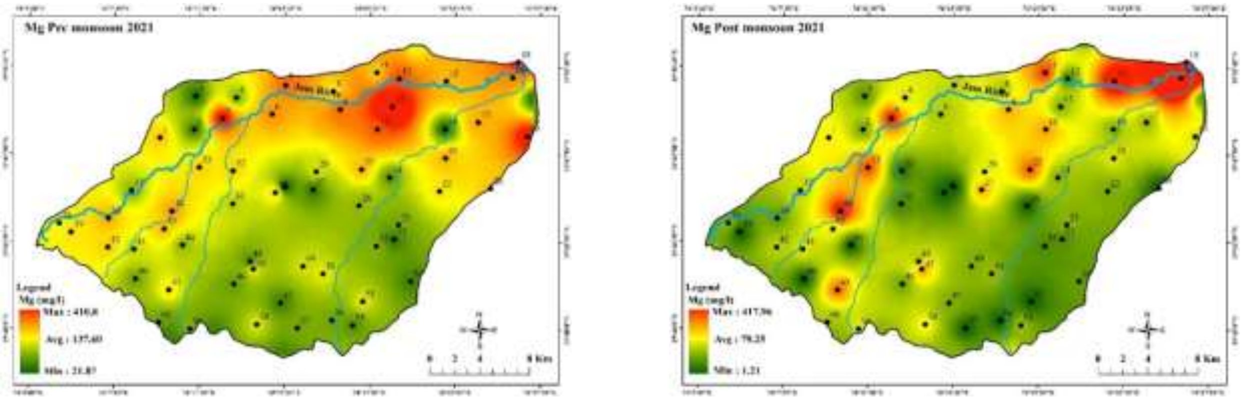

Fig. 6 Variations of Mg in Pre and Post monsoon season of 2021

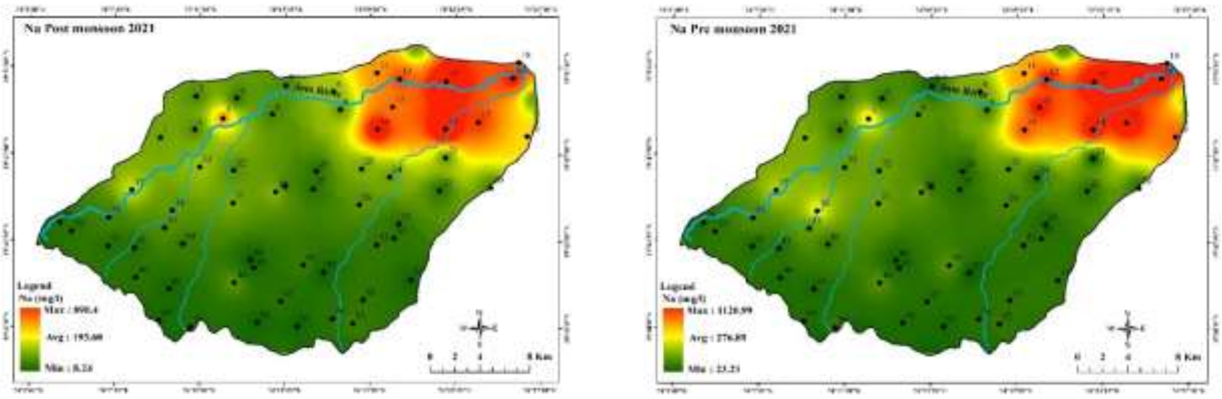

Fig. 7 Variations of Na in Pre and Post monsoon season of 2021

The sodium content of the groundwater varies from 23.21 to 1120.99 mg/l in the pre-monsoon season and from 8.24 to 890.4 mg/l in the post-monsoon season. WHO (1979) established a recommended sodium level of 200 mg/l. It has been determined that in pre- and post-monsoon samples, 31.66% of samples (sample numbers 1, 5, 8, 10 to 19, 30 to 34, and 37) and 23.33% of samples (sample numbers 5, 8, 10 to 19, 33, and 37), respectively, above the permitted limit. The salt imbalance in tap water has been connected to a number of potentially lethal ailments. The likelihood of experiencing hypertension, high blood pressure, hyperosmolarity, vomiting, cerebral and pulmonary odema, arteriosclerosis and muscle stiffness and twitching has been demonstrated to increase with salt consumption (Prasanth *et al*., 2012; Varade *et al.*, 2014). The level of sodium is high during the pre-monsoon season. (Fig.7). The potassium levels are extremely low, notwithstanding a slight increase during the pre-monsoon season. The major influence on the K content is the use of K-rich fertilizers.

The acceptable limit for total hardness in drinking water is 600 mg/l (BIS, 2012). The ranges of total hardness during the pre- and post-monsoon seasons are 400 to 3245 mg/l and 268 to 1760 mg/l, respectively. The variation in hardness between winter and summer samples is higher as a result of the leaching of calcium and magnesium bicarbonate during recharging. For almost all cations, the summertime has significant standard deviation values. The study reveals that the maximum permissible limit, which is set by the drinking water standard, was exceeded by 91.66% (sample numbers 1, 5 to 13, 15 to 29, 31 to 60), and 48.33% (sample numbers 1, 5, 7 to 9, 11, 15, 16, 18 to 21, 28, 33, 34, 36, 37, 39, 41, 43 to 46, 48, 49, 51 to 54) in the pre-monsoon and post-monsoon, respectively (Table 3). (BIS, 2012). As a result, it is found that most samples in the downstream section of the irrigated area have overall hardness values that are greater than permitted.

Status of anionic constituents and its seasonal variations

The groundwater contains the anions HCO_3^-, Cl^-, SO_4^{2-}, F^-, PO_4^{2-} and NO_3^-. Chloride can be found in both natural and artificial sources, such as household appliances, various human activities, septic tanks, fertilizers, waste and landfill leachate (Loizidou and Kapetanio, 1993). The Cl^- value fluctuates from 17.04 to 1710.2 mg/l and 65.32 to 1668.5 mg/l, respectively, throughout the pre-monsoon and post-monsoon seasons. The maximum permissible level (Table 3), which is determined by the drinking water standard of 1000 mg/l (BIS, 2012), has only been surpassed in a tiny number of samples. The bulk of anion species have low winter standard deviation values. In 8.33% of samples (sample numbers 5, 6, 10, 15, 16) taken during the pre-monsoon and 8.33% of samples (sample numbers 5, 6, 12, 15, 16) taken during the post-monsoon, the allowed limit for chloride is surpassed.

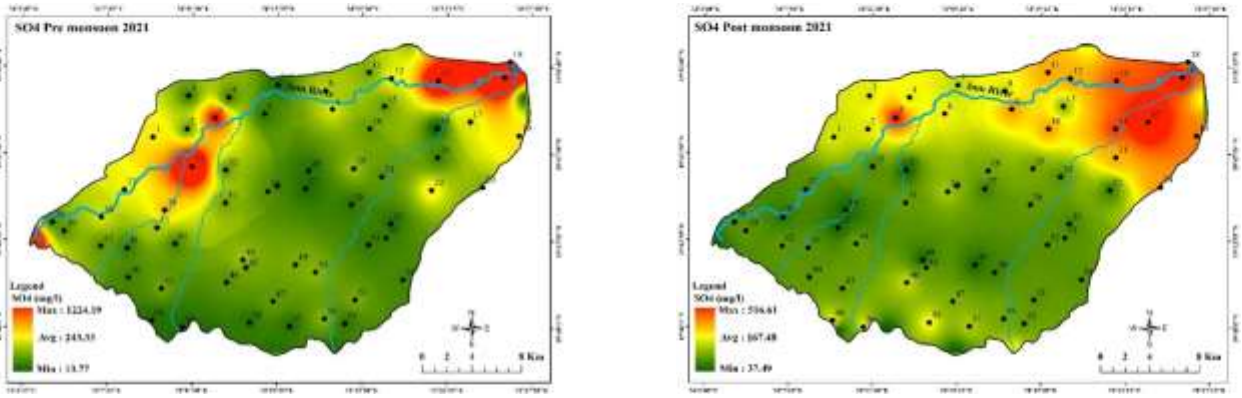

Fig. 8 Variations of SO_4 in Pre and Post monsoon season of 2021

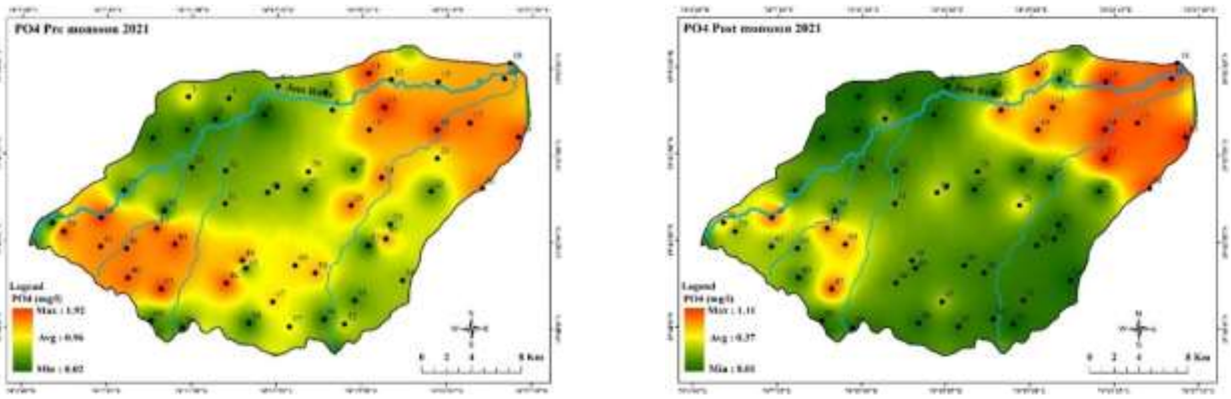

Fig. 9 Variations of PO_4 in Pre and Post monsoon season of 2021

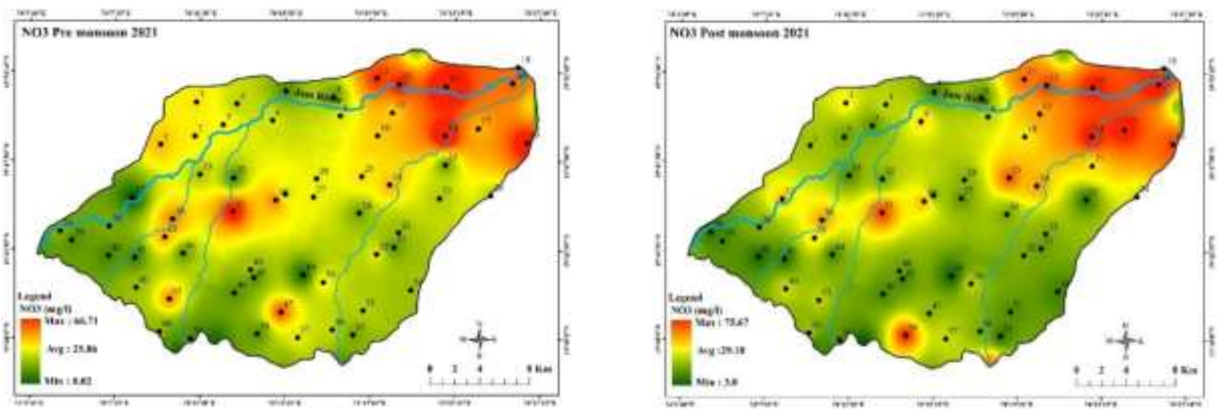

Fig. 10 Variations of NO_3 in Pre and Post monsoon season of 2021

Groundwater containing 13.77 to 1224.19 mg/l of SO_4^{2-} before the monsoon and 37.49 to 516.61 mg/l of SO_4^{2-} after the monsoon. (Fig.8). The BIS has established that the permissible maximum sulphate concentration is 400 mg/l. Human activities may be to blame for the elevated sulphate concentration during the pre-monsoon season. Only 10% (sample numbers 5, 15, 16, 18, 33, 34) and 3.33% (sample numbers 16, 17) of samples exceed the permitted limit during the pre- and post-monsoon seasons, respectively (Table 3). The amount of sulphate released into groundwater by gypsum-containing fertilizers used to change the physicochemical properties of soil (Todd, 1980). Higher sulphate concentrations in water, which also have a cathartic impact on people's bodies, may cause the alimentary canal to malfunction (Deshmukh, 2011).

PO_4^{2-} values range from 0.02 to 1.92 mg/l in pre-monsoon groundwater and from 0.01 to 1.11 mg/l in post-monsoon groundwater. The sources of phosphorus are inorganic phosphate found in soil and phosphate fertilizers. Eutrophication is an issue in the aquatic environment caused by an excess of phosphorus. According to the phosphate spatio-temporal maps, the north-east region and a few isolated patches in the research area saw elevated phosphate concentrations during the pre- and post-monsoon seasons. (Fig.9). Bicarbonate (HCO_3^-) levels before and after the monsoon in this study vary from 150 to 800 mg/l and 150 to 1225 mg/l, respectively. Since the aquifer lithology is where HCO_3^- originates, it's probable that the reason HCO_3^- was higher in the winter was due to the impact of CO_2 on the basic building blocks of soil and rock. In the study, post-monsoon nitrate concentrations are higher than pre-monsoon nitrate concentrations due to leaching. In pre- and post-monsoon samples, the NO_3^- value ranges from 0.82 to 66.71 mg/l and 3.0 to 75.67 mg/l, respectively (Fig.10).

Table 4 Groundwater classification based on TDS values (Davies and DeWiest 1966)

Sr. No	Classification Category	Range (mg/l)	Pre 2021		Post 2021	
			No. of samples and (%)	Sample Numbers	No. of samples and (%)	Sample Numbers
1	Desirable for drinking	<500	11 (18.33%)	7, 10, 13-14, 20-21, 28-29, 50, 57-58	17 (28.33%)	3-4, 7, 10, 13-14, 20-21, 24, 28-29, 43, 57-60
2	Permissible for drinking	500-1000	32 (53.33%)	1-4, 8, 22-24, 26-27, 33, 36, 38-49, 51-56, 59-60	30 (50%)	1-2, 8, 22-23, 25-27, 30, 32-33, 35-36, 38-42, 44-49, 51-56

Samples with TDS levels less than 500 mg/l in 18.33% and 28.33% of them demonstrate their acceptability for drinking in the pre and post-monsoon seasons of 2021, according to Davies and DeWiest's categorization (1966) (Table 4). While groundwater samples from 53.33% and 50% of the population in the pre and post-monsoon seasons of 2021 indicated TDS values between 500 and 1000 mg/l, which are acceptable for drinking. According to Tiwari and Singh (2014), extended residence durations in an aquifer body, parent rock components that have weathered and the presence of soil salts all contribute to the high TDS concentration in groundwater. The primary source of TDS in the study area is weathered basalts. In the pre and post-monsoon seasons of 2021, the shallow aquifers represented by sample number 16 had maximum TDS concentrations of 4590 and 4109 mg/l, respectively, rendering it unfit for drinking.

Table 5 Classification of groundwater based on TH (CaCO3) (Sawyer and McCarty, 1967

Sr. No	Classification Category	Range (mg/l)	Pre 2021		Post 2021	
			No. of samples and (%)	Sample Numbers	No. of samples and (%)	Sample Numbers
1	Soft	<75	--	--	--	--
2	Moderately hard	75-150	--	--	--	--
3	Hard	150-300	--	--	6 (10%)	30, 50, 57-60
4	Very hard	>300	60 (100%)	1-60	54 (90%)	1-29, 31-49, 51-56

As classified by Sawyer and McCarty (1967), In the post-monsoon seasons of 2021, 10% of the groundwater samples (i.e., 150–300 mg/l) belong to the hard water category. Additionally, in 2021's pre and post-monsoon seasons, respectively, 90% and 100% of samples, respectively, show very hard water class (>300 mg/l) (Table 5). In the home, a high total hardness can lead to corrosion in the pipes, encrustation in the water supply system and other issues. Consuming water with such a high TH content may cause urolithiasis and cardiovascular disease (Dzik, 1989).

Conclusion

The groundwater quality of Jam River basin, Nashik and Ahmednagar district was evaluated for domestic purpose. Groundwater in the research area is hard and alkaline by nature, according to the interpretation of the hydrogeochemical analysis results of 60 representative groundwater samples collected from dug wells and bore wells. Na > Ca > Mg

> K and HCO_3 > Cl > SO_4 > NO_3 are the cation and anion dominance orders, respectively. Based on the total hardness (TH), the groundwater is categorized as being moderately hard to very hard. As per BIS standards for domestic water purposes TDS, TH, Ca, Mg and Cl exceed the safe limits in 15, 91.66, 50, 61.66, 8.33 % and 11.66, 48.33, 10, 21.66, 8.33% during pre and post monsoon 2021 respectively; therefore, most of samples during post monsoon season show that the groundwater is suitable for drinking. Additionally, it has been noted that samples 5, 6, 12, 15, and 16 are not acceptable for drinking since they exceed the chloride (Cl) maximum allowed limit (1000 mg/l) set by BIS. This high concentration can be the result of household garbage. The research area's high magnesium concentration causes an increase in salinity and is likely to have negative consequences on crop productivity. The excessive application of chemical fertilizer, the inorganic pollution load in groundwater, and salt evaporation are to blame for the increased EC. The high levels of Cl, NO_3 and TDS are caused by the intensive local agricultural and human inputs. Groundwater quality in the northeastern region is significantly impacted by anthropogenic inputs, particularly agriculture. As a result, the current research demonstrates that the most of groundwater samples are suitable for home uses. Few aquifers, nevertheless, are problematic and require specific corrective action. Local government representatives in Nashik and Ahmednagar district (Jam River basin) may find it easier to identify vulnerable and suitable groundwater resource management regions with the use of the study's findings.

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