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Quality of Ground Water in Aurangabad District (Maharashtra, India) using Geostatistical Method.

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Abstract
Groundwater is one of the major sources of water in arid and semi -arid regions. Groundwater quality data and its spatial distribution are important for the purpose of planning and management. Geo-statistical methods are one of the most advanced techniques for interpolation of groundwater quality. In this study, kriging methods were used for predicting spatial distribution of some groundwater quality parameters such as: pH, Alkalinity, salinity, dissolved oxygen(DO), Biological oxygen demand(BOD),Chloride(Cl), Sulphate (So_{4}),Nitrate(No_{3}), Calcium Hardness(CaH), Magnesium Hardness(MgH), and Total Hardness (TH). Data were collected from fixed eight (08) dug wells and bore wells in Aurangabad district (Maharashtra, India). Use of kriging method on our well sampling results provided valuable insight on the nature of the spatial and temporal variability of groundwater quality parameters.

Keywords: Groundwater quality and interpolation DO, BOD, Geo-statistical methods, spatial distribution.

1. Introduction

Everyone has to access to safe water & Sanitation. clean drinking water has been given priority in the Constitution of India, with Article 47 conferring the duty of providing clean drinking water and improving public health standards to the State. The average availability of water is reducing steadily with the growing population and it is estimated that by 2020 India will become a water stressed nation. Groundwater is the major source of water in our country with 85% of the population dependent on it [1, 2]. The knowledge of the occurrence, replenishment and recovery of potable groundwater assumes special significance in quality-deteriorated regions, because of scarce presence of surface water. In addition to this, unfavorable climatic condition i.e. low rainfall with

frequent occurrence of dry spells, high evaporation and etc. on one hand and an unsuitable geological set up on the other, a definite limit on the effectiveness of surface and subsurface reservoirs During recent years, increasing pollution and losing of water sources have changed exploitation policy of water and soil sources [3].

In this research our aim is to estimate ground water chemical quality using spatial interpolation techniques several studies shown that interpolation technique accuracy is analyzed for soil & water properties. Several research shown that using kriging method to estimate spatial prediction of Groundwater to estimate one variable depends on variables type and regional factors which influence this and any selected method for given region cannot be generalized to others use of geo-statistics method for analyzing Groundwater quality to estimate EC, CL, SO4, NO3, TDS has suitable accuracy to estimate Groundwater quality [4, 5].

The present study was therefore, carried out with the aim of spatial interpolation techniques for mapping Groundwater chemical quality for Aurangabad district (Maharashtra), India.

In Aurangabad district the chemical analysis results show that the ground water in the district is alkaline in nature, while the EC and TDS values show that the ground water in the area is mineralized to medium extent. The concentrations of the major ions indicate that among the cations, the concentration of magnesium ion is highest followed by calcium and sodium while among anions, the concentration of chloride ion is highest followed by bicarbonate and sulphate ions. The results also show that the concentration of nitrate ions in the ground is significant and appearing as major ion.

The geochemical classification of ground water in the area was carried to see the dominance of ions in ground water. In the district, 08 samples were collected all representing the epm percentage of alkaline earths (Ca+Mg), alkali metals (Na+K), weak acids (CO3+HCO3) and strong acids (CI+SO4NO3), in the ground water samples were calculated and samples were broadly classified into 2 classes as given in Table-1 As all the samples are from Basaltic aquifer, the type of water present in these samples should be of Ca-HCO3 type. But the perusal of Table-1 shows that 86% of samples are having Ca-Cl type of water, indicating that the type of water in these samples has been changed from Ca-HCO3 type to Ca-Cl type.

This may be because of percolation of waste and wastewater containing high concentration of strong acid ions (CI+NO3+SO4) to ground water [6].

Table-1: Geochemical Classification of Ground Water Samples.

Sr. No.	Classification	Type	No. of Sampl	% of Sample
1	Alkaline earths (Ca+Mg > 50%) exceeds alkali metals and weak acids (CO3+HCO3 > 50%) exceeds strong acids.	Ca-HCO3	**02**	14
2	Alkaline earths (Ca+Mg > 50%) exceeds alkali metals and strong acids (Cl+SO4+NO3 > 50%) exceeds weak acids.	Ca-Cl	**06**	86
3	**Total**		**08**	**100**

In this paper an attempt has been made to study the Chemical quality of ground water collected from fixed Eight (08) dug wells and bore wells in Aurangabad district (Maharashtra) and its spatial distribution. Special Emphasis has been given to the chemical quality of the Well waters regarding their portability.

1.1 Topography of the Study Area

Aurangabad district is situated in the north central part of Maharashtra between North Latitude 19° 15' and 20° 40, and East Longitude 74° 37' and 75° 52'. It covers an area of 10,107 sq. km falling in parts of Survey of India. The district is bounded by Jalgaon district in north by Nasik district in West, Ahmadnagar and Beed districts in south and Parbhani and Buldhana districts in east. The world famous Ajanta and Ellora caves are situated in Aurangabad district. There are also a few caves near Aurangabad City. Other monuments of national fame are Bibi-ka-Maqbara and Daulatabad fort. (fig.1)

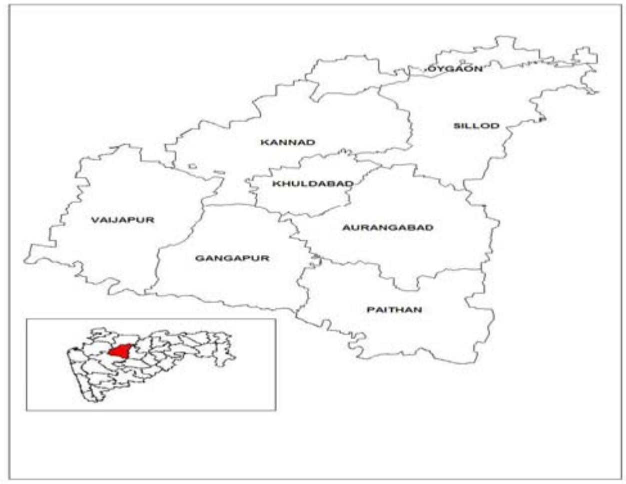

Figure 1. Location map of Aurangabad district of Maharashtra (study area).

The district has been divided in 9 talukas viz., Aurangabad, Kannad, Soygaon, Sillod, Phulambri, Khuldabad, Vaijapur, Gangapur and Paithan talukas. The district has geographical area of 10,107 sq.km. Out of which 814.15 sq.km is occupied by forest whereas cultivable area is 8135.57 sq.km and net area shown is 7150.55 sq.km in 2005-06. Agriculture is the main occupation of the rural people.

1.2 Hydrogeology of the Area

The major part (95%) of the district constitutes a sequence of basaltic lava flows (Deccan Trap) while alluvium occupies a small portion. There are two distinct hydrogeological units in the district i.e. fissured formations (different units of basaltic lava flows) and porous formations (isolated patches of alluvial deposits). The occurrence and movement of ground water is controlled by variation in water bearing properties of these formations. The depth to water levels in premonsoon Shallow water levels within 2 to 5 m bgl are seen in northern parts of the district in parts of Soygaon and Sillod talukas. Water levels within 5 to 10 m bgl are seen almost in entire district occupying entire Khuldabad taluka and major parts of Aurangabad, Gangapur, Kannad and Sillod talukas. Water levels in the range of 10 to 20 m bgl are seen in the form of 4-5 patches scattered in the district occupying major parts of Paithan and Vaijapur talukas and small parts of Aurangabad, Sillod and Kannad talukas.
The depth to water levels during post monsoon ranges between 1.85 (Chauka) and 16.00 (Paithan). The spatial variation of the postmonsoon depth to water levels Shallow water within 5 m bgl are observed in north-south

extended patch along eastern side of the district occupying parts of soygaon, Kannad, Silod and Gangapur talukas and almost entire Aurangabad taluka. water levels within 5 to 10 m bgl are observed in major part of the district in western, southern and north eastern parts of the district, occupying almost entire Vaijapur, Paithan, Kannad and Sillod talukas and parts of Khuldabad and Gangapur talukas[6].

2. Material and Methods

Data Collected samples were analyzed in the laboratory to measure the concentration of the quality parameters. The water quality parameters along with the locations of the tube wells were used for spatial data analysis (SDA), development of semivariogram models and generation of spatial variability maps [7].

2.1 Geostatistical Approach in Development of Spatial Variability Models

For this paper to investigate the spatial correlation of the Aurangabad ground water data sets using Kriging methods And Kriged maps illustrate the spatial relationships. Spatial assessment of groundwater chemistry is important for revealing the correlation between location and the hydro chemical variables in the present study. ILWIS 3.7 software was used to determine kriged maps (Fig. 2 to 13) [10, 11].

Kriging is a general term describing a geo-statistical approach for interpolation at un-sampled locations. This method provides less bias in predictions, so known as best linear unbiased estimator (BLUE). This is because the interpolated or kriged values are computed from equations that minimize the variance of the estimated value. Another advantage of kriging is that it presents the possibility of estimation of the interpolation error of the values of the regionalized variable where there are no initial measurements [8]. The experimental semi-variogram is a graphical representation of the mean square variability between two neighboring points of distance h as shown in Equation (1).

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i + h) - z(x_i)]^2 \qquad (1)$$

Where γ (h) is the semi-variogram expressed as a function of the magnitude of the lag distance or separation vector h, N (h) is the number of observation pairs separated by distance h and is the random variable at location x_i. The experimental variogram is fitted in theoretical model such as Spherical, Exponential, Linear or Gaussian to determine three parameters, such as the nugget (c_0), the sill (c) and the range (A_0). These models are defined as follows [9].

Spherical model:

$$\gamma(h) = c_0 + c\left[1.5\left(\frac{h}{A_0}\right) - 0.5\left(\frac{h}{A_0}\right)^3\right] \qquad h \le A_0 \qquad (2)$$

$$\gamma(h) = c_0 + c, \qquad h > A_0$$

Exponential model:

$$\gamma(h) = c0 + c\left[1 - \exp\left(-3\frac{h}{A_0}\right)\right] \qquad (3)$$

Gaussian model:

$$\gamma(h) = c0 + c\left[1 - \exp\left[-\left(\frac{3h}{A_0}\right)^2\right]\right] \qquad (4)$$

Linear model:

$$\gamma(h) = c0 + h\left(\frac{c}{A_0}\right) \qquad (5)$$

2.2 Interpretation of Kriging Maps

The total dissolved solids (TDS) parameter reflects the level of minerals (such as carbonates, bicarbonates, chlorides, sulfate, phosphate, silica, calcium, magnesium, sodium, and potassium) that are present in water samples in dissolved form. The Average value of TDS values for groundwater samples ranged between 449 to 545 milligrams per liter (mg/l) in all the area Fig. 2.

Distribution of EC is also in average according to the average chemical composition for the period 2010 has been depicted in Fig. 3.

$NO3^-$distribution according to the average chemical composition has been presented in Fig. 4. Kiriging map shows high values of $NO3^-$.

Distributions of HCO_3^- have been shown in Fig. 5. In the cases of HCO_3^- concentration values increase.

Most of the center part of study area has average values of $SO4^{-2}$ concentration which range from 252 to 271 mg/l but high concentration values appear in Fig.6.

From Kriging map (Fig. 7) it is clear that Na+ is randomly distributed over the study area. shows average values of Na+.

Most part of study area is covered by average values of $PO4^{-2}$ is randomly distributed shown (Fig. 8).

K+ distribution according to the average chemical composition has been presented in Fig. 9. Central part of Kiriging map (Fig. 9) shows only normal values ranges of K+.

Fig. 10 shows the distribution of Cl^{-} is randomly distributed over the study area as well as according to the average chemical composition. (Fig. 10) show value of Cl^{-} is the high range.

Ca^{+2} according to the average chemical composition. According to map (Fig. 11) show value of Ca+2 above the average range.

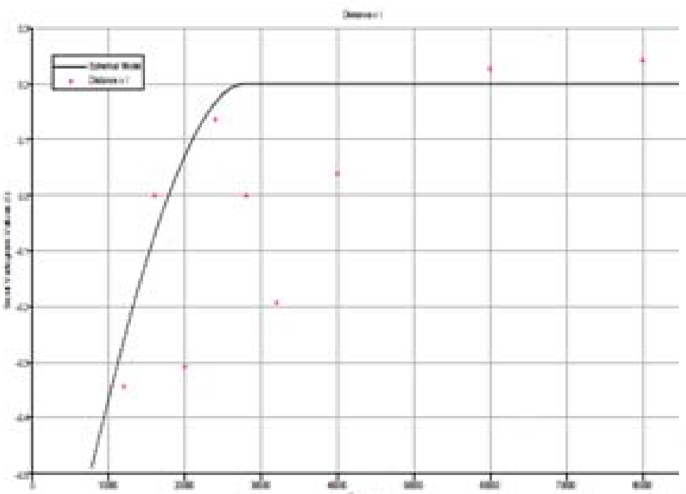

Figure 2. Spatial variability map of TDS (mg/l) over Aurangabad of Maharashtra.

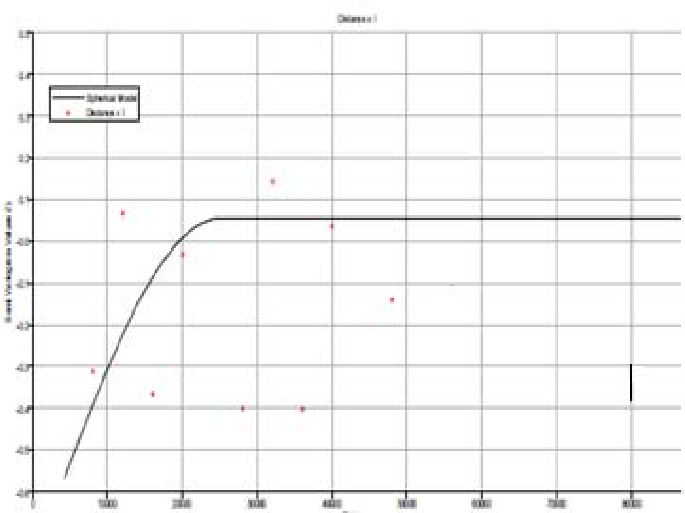

Figure 3. Spatial variability map of EC (dS/m) over Aurangabad of Maharashtra

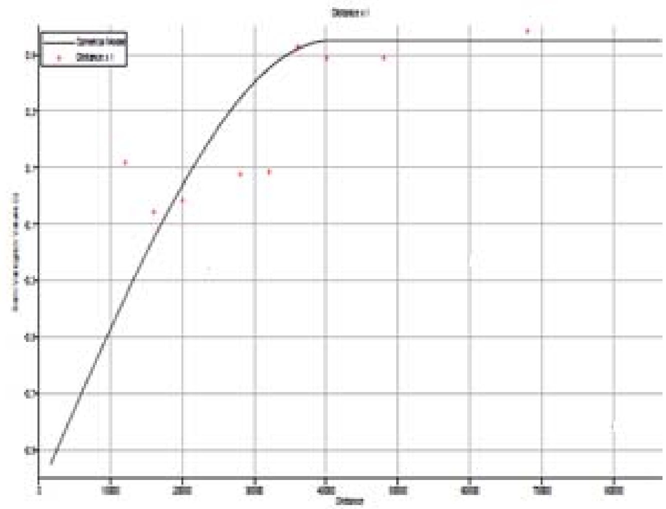

Figure 4. Spatial variability map of $NO3^{-}$ (mg/l) over Aurangabad of Maharashtra

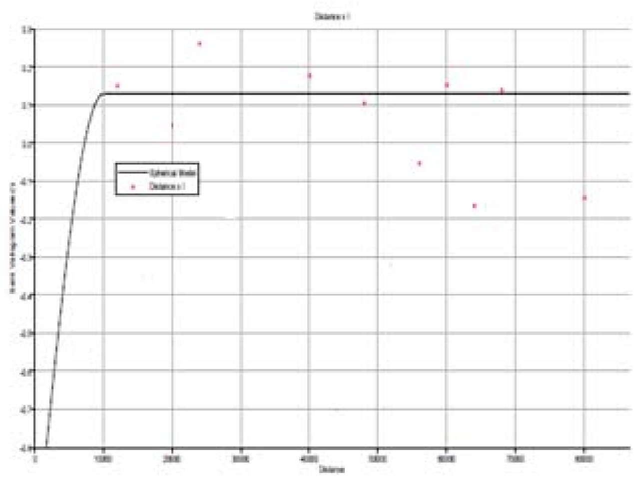

Figure 5. Spatial variability map of $HCO3^{-}$ (mg/l) over Aurangabad of Maharashtra

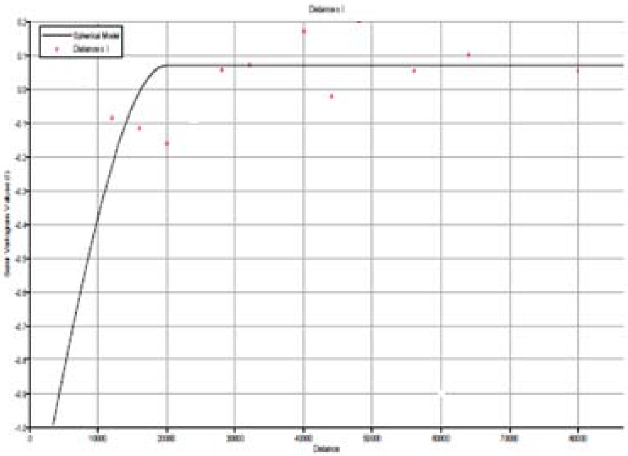

Figure 6. Spatial variability map of $SO4^{-}2$ (mg/l) over Aurangabad of Maharashtra

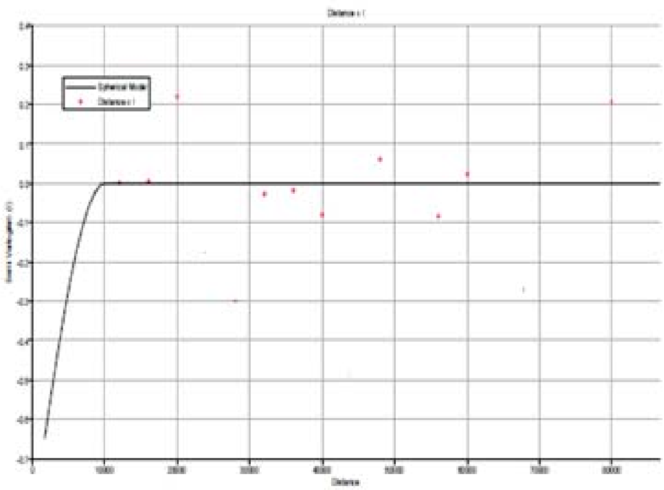

Figure 7. Spatial variability map of Na+ (mg/l) over Aurangabad of Maharashtra

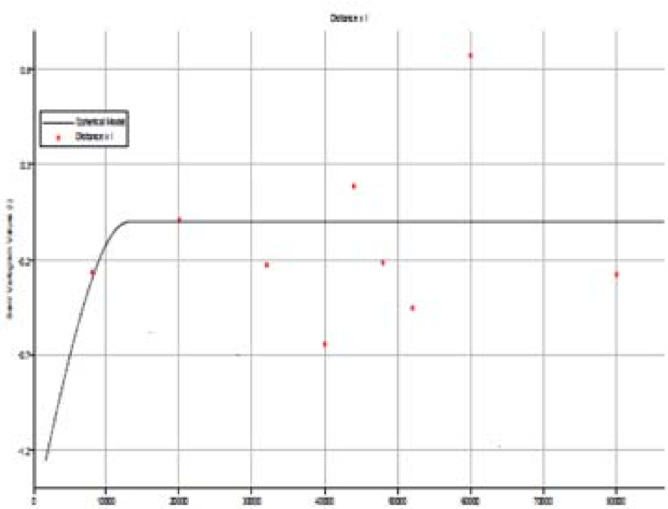

Figure 8. Spatial variability map of $PO4^{-}2$ (mg/l) over Aurangabad of Maharashtra

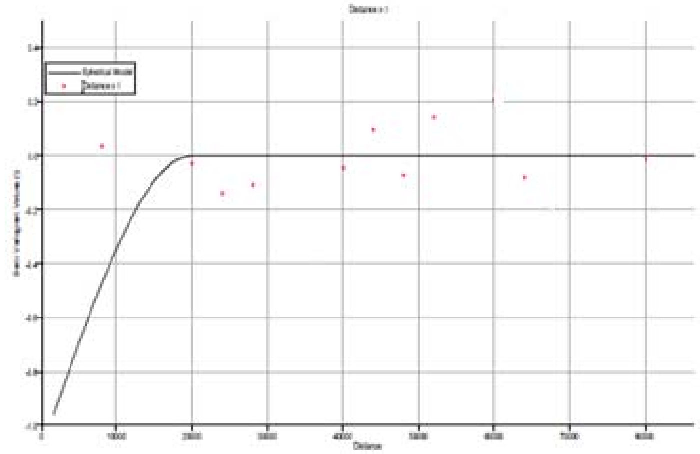

Figure 9. Spatial variability map of K+ (mg/l) over Aurangabad of Maharashtra

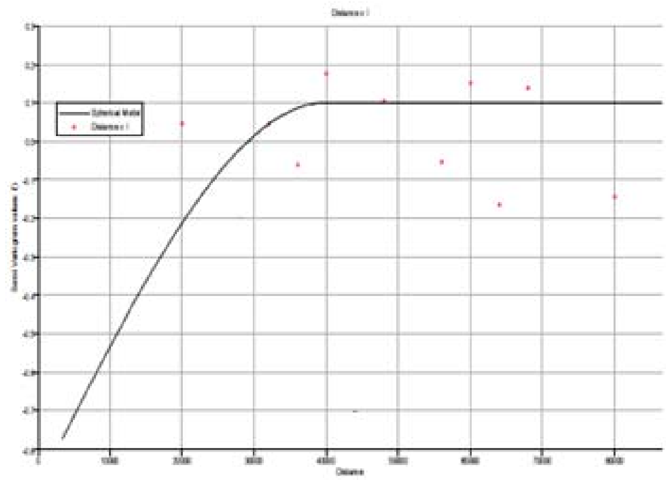

Figure 10. Spatial variability map of Cl^{-} (mg/l) over Aurangabad of Maharashtra

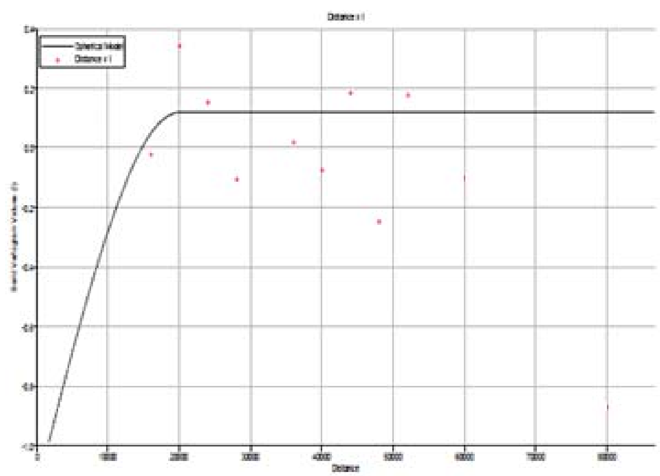

Figure 11. Spatial variability map of Ca^{+2} (mg/l) over Aurangabad of Maharashtra

2.3 Interpretation Semivariograms

The semivariograms parameters nugget, sill and range for the data sets are summarized in Tables 3 . In general the semivariograms can be modeled with a spherical semi-variogram up to lag distances of 40000 m. At larger distances the trend effect starts to dominantly. An up to medium distance low value of correlation effect was found. There was a substantial nugget affect indicating large variability at very short distances and this may be attributed to both aquifer characteristics and errors in the chemical analysis.

3. Results and Discussion

The suitability of ground water for drinking purpose is determined keeping in view the effects of various chemical constituents in water on the biological system of human being. The classification of ground water samples was carried out based on the desirable and maximum permissible limits as given for the parameters viz., TDS, TH, Ca, Mg, Cl, SO4 and NO3 is given .The detailed observations for the Physico-chemical analysis of groundwater are given in the table 2.

pH: The pH of the groundwater samples ranged between 7.5 to 8.0, which is well within the permissible limits of WHO standards [12]. The maximum pH (8.0) was recorded in the sample collected at sampling station Aurangabad and minimum (7.5) was recorded at khultabad. All the samples have been found to have pH values well within the limits prescribed by WHO for drinking water.

Alkalinity: The alkalinity was reported to occur between 289 mg/l to 344 mg/l. The highest alkalinity values were reported at sampling station Aurangabad and lowest was at soygaon. Almost all the samples were found have values exceeding the WHO permissible limits of 200mg/l.

Chlorides: The chlorides were estimated in the samples understudy, the maximum value was 290 mg/l at Aurangabad and minimum recorded value was 239 mg/l at sillod. Except for sillod all the groundwater samples were found to have chlorides in access of the permissible limit of 250 mg/l.

Salinity: The salinity was calculated based on the chloride concentration and it has shown a similar pattern with maximum value at Aurangabad (545.20 mg/l) and minimum at sillod (449.32 mg/l).

Sulphate: the sulphate in the assessed ground water sample range between 252.90 mg/l to 280 mg/l. the highest sulphate concentration is found at sillod and lowest was at phulambri. At all the sampling station sulphate concentration is exceeding maximum permissible limit of WHO.

Nitrates: The ground water sample assessed have been found to contain nitrate in a range of 39.20 mg/l to 46.90 mg/l. the highest nitrate concentration was recorded at paithan and lowest was found soygaon . However all the ground water sample assessed have shown nitrate concentration exceeding the WHO prescribed limits of 10 mg/l.

Dissolved oxygen (DO): the concentration of DO in the groundwater sample assessed aried between 2.10 mg/l to 4.90 mg/l . the highest was recorded at sillod and lowest at aurangabad.

Biological oxygen demand (BOD): the BOD requirement of the assessed water sample range between 6.5 mg/l to 8.3 mg/ l. the highest BOD was at khultabad and lowest BOD requirement was at sillod.

Calcium Hardness (CaH): the CaH values ranged between 162 mg/l to 229 mg/l with the highest being at Aurangabad & lowest at soygaon. All the assessed ground water sample were found to exhibit CaH values exceeding the WHO prescribed limit of 75 mg/l.

Magnesium Hardness (MgH): the MgH values ranged between 43.43 mg/l to 57.58 mg/l with the highest being at sillod and lowest at gangapur. All the assessed ground water samples were found to exhibit MgH value exceeding the WHO prescribed limit of 30 mg/l.

.**Total Hardness (TH):** the TH values ranged between 412 mg/l to 376 mg/l with the highest being at Aurangabad & lowest being at phulambri. All the assessed groundwater samples were found to exhibit TH value exceeding the WHO prescribed limits of 200 mg/l.

In most of the cases. However, the concentration of nitrate is found more than Maximum permissible limit (MPL) at nine (09) locations (78%) indicating high influence of anthropogenic activity in the vicinity of the wells, causing nitrate contamination. Therefore, it can be concluded that the ground water quality in most of the monitored wells is not suitable for drinking purpose due to high nitrate Concentration

Table 2. Physico-chemical analysis of ground water at Aurangabad district (mg/l)

Sr.no	**Location**	**pH**	**Alk.**	**Cl**	**Sal.**	**So_4**	**No_3**	**DO**	**BOD**	**CaH**	**MgH**	**TH**
	Standard	**6.5-8.5**	**200**	**250**	**------**	**150**	**10**	**----**	**----**	**75**	**30**	**200**
1	Aurangabad	8.00	344	290	545.20	270.10	41.20	2.10	8.10	229	44.65	412
2	Gangapur	7.90	296	281	528.28	259.40	42.40	3.80	7.70	221	43.43	399
3	Kannad	7.60	298	271	509.48	258.90	40.80	3.60	7.90	199	48.56	398
4	Khultabad	7.50	300	278	522.64	271.20	44.30	3.00	8.30	176	50.26	382
5	Paithan	7.90	312	277	520.76	262.10	46.60	4.10	7.20	196	50.51	403
6	Phulambri	7.90	293	281	528.28	252.90	46.90	4.60	6.80	165	51.48	376
7	Sillod	7.70	295	239	449.32	280.80	41.70	4.90	6.50	191	53.19	409
8	Soygaon	7.50	289	259	486.92	261.60	39.20	3.90	7.70	162	57.58	398
9	Vaijapur	7.75	297	245	456.20	283.60	41.40	4.55	6.70	198	52.10	411

TABLE 3. NUGGET, SILL AND RANGE VALUES.

Parameters	Unit	TDS mg/l	HCO_3^- mg/l	Cl^- mg/l	SO_4^{2-} mg/l	NO_3^- mg/l	PO_4^{3-} mg/l	F^- mg/l	EC dS/m	Na^+ mg/l	K^+ mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l
Nugget	$(Unit)^2$	-0.1	-0.49	-0.9	-0.94	-0.8	-1	-0.9	-	-0.58	-0.99	-0.8	-0.7
Sill	$(Unit)^2$	0.5	0.9	0 .3	0.86	0.13	0.17	0.18	0 x102	0.05	0.19	0.19	0
Range	m	28000	22050	18500	38000	20000	34300	40900	29700	35000	27230	21400	32500

4. Conclusions

The proposed methodology requires the definition of factorial variables, to identify the physico-chemical processes that affect groundwater, for subsequent analysis of the spatial distribution of these variables using geo-statistical estimation techniques. The geo-statistical techniques constitute a useful tool for the study of spatial variability in groundwater chemistry.

Geo-statistical methods are one of the most advanced techniques for interpolation of groundwater quality.

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