Spatial Variability of Ground Water Quality in Mathura District (Uttar Pradesh, India) with 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: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, TDS, EC, F^{-}, $HCO3^{-}$, $NO3^{-}$, Cl^{-}, $SO_4^{2-}$and PO_4^{2-}. Data were collected from 13 wells in Mathura district (Uttar Pradesh, India). After normalization of data, semi-variogram was drawn. For selecting suitable model for fitness on experimental semi-variogram, residual sum of squares (RSS) value was used. Use of geo-statistics (i.e., kriging) on our well sampling results provided valuable insight on the nature of the spatial and temporal variability of groundwater quality parameters. In analysis, found high values of NO_3^{-} (=104.77 mg/l), K^{+} (=141.51 mg/l), PO_4^{-2} (=2.99 mg/l) and high F^{-} value with a maximum of 4.6 mg/l (at Shahpur) are observed in ground water samples.**

Keywords-component; Geo-statistical methods, Spatial distribution, Interpolation and Ground water quality

I. INTRODUCTION

Water is essential for sustenance of life. 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 [1]. During recent years, increasing pollution and losing of water sources have changed exploitation policy of water and soil sources.

This research has been carried out with the aim of spatial interpolation techniques for mapping Groundwater chemical quality [2, 3]. The accuracy of interpolation methods for spatially predicting soil and water properties has been analyzed in several studies [4, 5]. Safari [6] used kriging method to estimate spatial prediction of Groundwater in Chamchamal plain in west of Iran. Results showed that suitable method of geostatistics 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 [7]. Nazari et al. [8], used geo-statistics method to study spatial variability of Groundwater quality in Balarood plain. Their results showed spherical model is the best model for fitting on experimental variogram of EC, Cl and SO_4 variables. Istock and Cooper [9] used kriging method to estimate heavy metals. They found that the mentioned method is the best estimator for spatial prediction of lead. Dagostino studied spatial and temporal variability of nitrate, using kriging and co-kriging methods in Groundwater [10]. Their results showed that co-kriging method has resulted in increasing accuracy to estimate nitrate concentration. Rizzo and Mouser [11] used geo-statistics for analyzing Groundwater quality. They used microbial data as auxiliary variable in co-kriging method. These researchers' results showed that co-kriging method has suitable accuracy to estimate Groundwater quality. Ahmad [12] used kriging method to estimate TDS in Groundwater and demonstrated accuracy of this method to prediction of TDS. Gaus [13] studied pollution of Bangladesh Groundwater in view of heavy metal. They used disjunctive kriging method to estimate arsenic concentration and to prepare risk map. Their results showed that 35milion people are exposed in high concentration of Arsenic (50ppm) and 50 million people are exposed in 10 ppm. Finke et al [14] used simple kriging to estimate water surface changes in Netherlands and introduced it as a suitable method for mapping of water surface. Barca and Passarella [15] used Disjunctive kriging and simulation methods to make nitrate risk map in 10, 50 (mg/l) thresholds, in Modena plain of Italy. Their results showed that Disjunctive kriging method is the suitable method to study deterioration level of Groundwater. The present study was therefore, carried out with the aim of spatial interpolation techniques for mapping Groundwater chemical quality for Mathura district (Uttar Pradesh), India.

In Mathura district water logging and salinity in ground water have become a universal problem. The large quantity of ground water is of no use due to its high salinity. Most of the ground water in Mathura district of Uttar Pradesh (U.P) occurs under unconfined and semi-confined condition whereas near surface it is found under water table condition. The general quality of ground water is found to be brackish with 85 per cent of the water samples having Total Dissolve Salt (TDS) Values above 1000 mg/l and with a max value of 6692 mg/l observed at Jacchoda. The ground water varies in chemical character from Cl^- dominated to that of HCO_3^- dominated type. The alkalis, (Na and K) are the dominating cations in 62 per cent of the analyzed samples whereas in the remaining 38 per sent of the samples alkaline earths (Ca and Mg) dominate. High values of NO_3^- and K^+ with a maximum of 108 and 110 mg/l respectively have been found at Chaumuhan. Highest PO_4^{-2} value of 10 mg/l has been observed in the well water of Adampur. Very high F^- value of 4.6 mg/l is found. In the well water of Shahpur the amount of F^- has been observed as high as 4.6 mg/l. In this paper an attempt has been made to study the chemical quality of ground water collected from fixed 13 dug wells in Mathura district (U.P) and its spatial distribution. Special emphasis has been given to the chemical quality of the well waters regarding their portability.

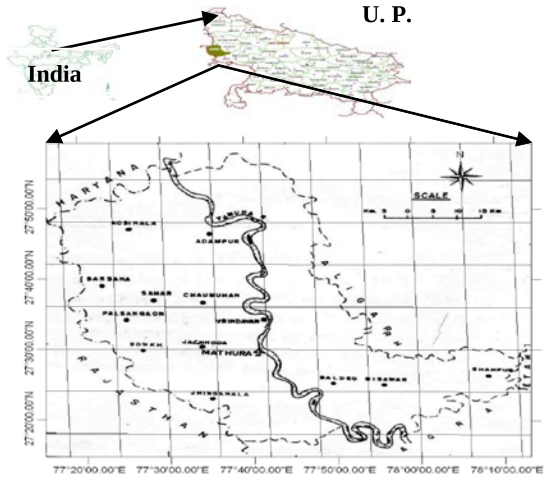

Figure 1. Location map of Mathura district of Uttar Pradesh (study area)

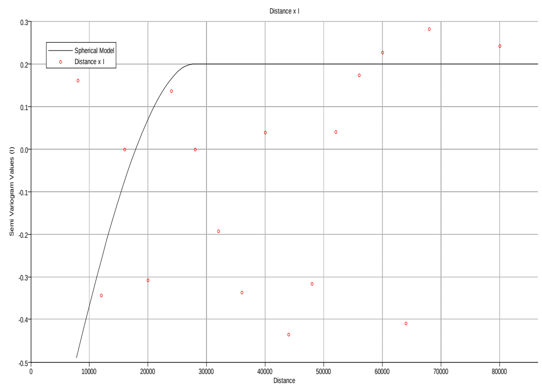

Figure 2. Spatial variability map of Ca^{+2} (mg/l) over Mathura district of Uttar Pradesh.

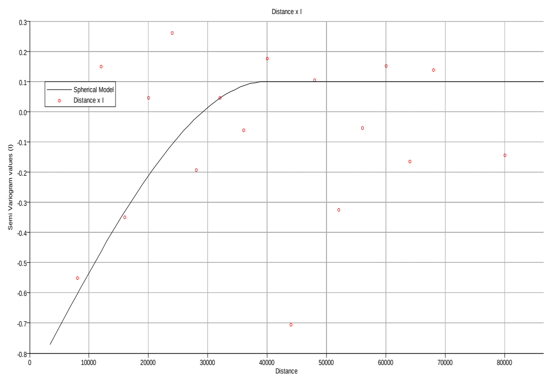

Figure 3. Spatial variability map of Cl^- (mg/l) over Mathura district of Uttar Pradesh.

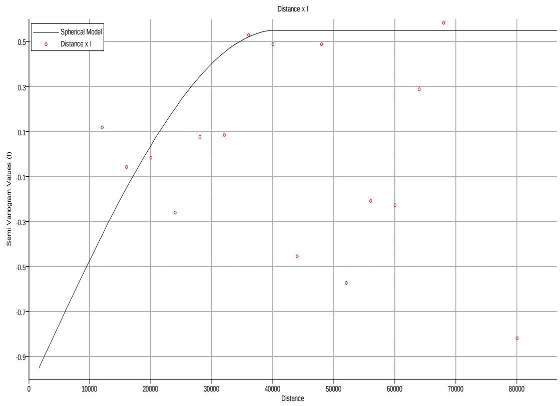

Figure 4. Spatial variability map of EC (dS/m) over Mathura district of Uttar Pradesh.

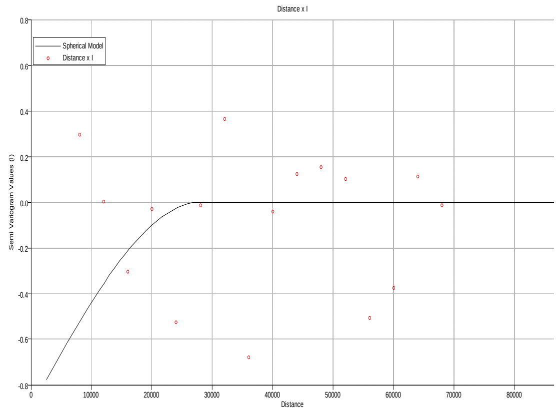

Figure 5. Spatial variability map of F^- (mg/l) over Mathura district of Uttar Pradesh.

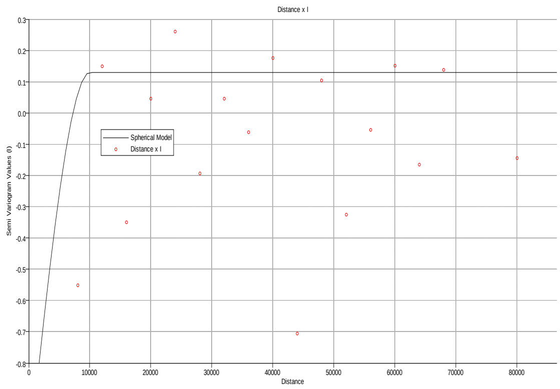

Figure 6. Spatial variability map of $HCO3^-$ (mg/l) over Mathura district of Uttar Pradesh.

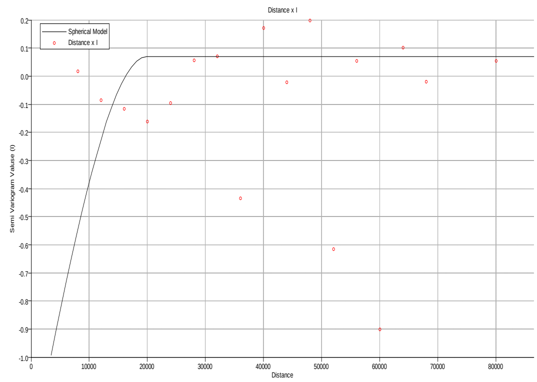

Figure 7. Spatial variability map of K+ (mg/l) over Mathura district of Uttar Pradesh.

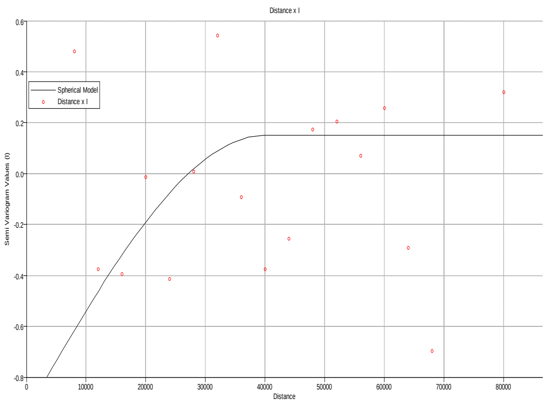

Figure 8. Spatial variability map of Mg+2 (mg/l) over Mathura district of Uttar Pradesh.

A. Topography of the Study Area

Mathura district is bordered by Haryana state in the north and by Rajasthan state in the west. It is between lat 27°14' to 27°58' North and long 77°17' to 78° 12' East in the toposheet No 54E and 54I of Survey of India covering a total of 3797 sq. km. (Fig.1). Yamuna River is the major perennial river in the area which enters north of Mathura district near Shahpur and leaves it in SSE direction near Akos. Yamuna river divides Mathura district in two physiographic units Yamuna and trans Yamuna. Agra canal is another surface water resource used in the area under study.

B. Hydrogeology of the Area

Ground water occurs under unconfined and semi-confined condition. Near surface of the ground water in the area is under water table along Yamuna river, is grater then rest of the area which is under canal command. The depth to water table varies from 1.8 mbgl (meter below ground level) to 17.47 mbgl during pre-monsoon period and from 1.39 mbgl to 17.18 mbgl during post monsoon. The general direction of flow of ground water is from NNW to SSE. Sinha [16] observed that the Yamuna river is effluent in nature, while Agra canal is influent. The influent Seepage from canal as well as its distributaries has modified the general direction of flow of ground water flow.

Assessment of spatial correlation in hydro chemical variables is an important tool in the analysis of groundwater chemistry. This paper investigates the spatial correlation of the Mathura ground water data sets using Kriging methods [17, 18]. Spatial assessment of groundwater chemistry is important for revealing the correlation between location and the hydro chemical variables in the present study. ILWIS 3.3 software was used to determine kriged maps (Fig. 2 to 13). Examples are given of the type of semi-variogram found in the study area, while Kriged maps illustrate the spatial relationships found. The semi-variogram analysis of the geo-statistical assessment revealed that for the data set the spatial correlation has a relatively short range. The sill is difficult to analyze because of a spatial trend in the data, leading to an increase of the semi-variance almost immediately after the sill has been reached [17, 18].

II. MATERIALS AND METHODS

Thirteen water samples were collected from phreatic aquifer in clean pre-rinsed 100ml plastic (polyethylene) bottles. 2-3 drops of toluene were added in each bottle to prevent microbial growth. Samples were analyzed for total salt (EC dSm-1), cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) and anions (Cl^{-}, F^{-}, HCO_3^{-}, NO_3^{-}, CO_3^{-2}, SO_4^{-2} and PO_4^{-3}).

A. Groundwater Depth and Quality Data Acquisition

The data related to groundwater quality were acquired from field woke for the year 2007 covering 13 groundwater sampling points. 13 ground water samples from phreatic aquifer were collected in clean polyethylene bottles from fixed wells established in Mathura district, U.P (Fig. l). Collected samples were analyzed [19] 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 semi-variogram models and generation of spatial variability maps with help of G.I.S [20, 21].

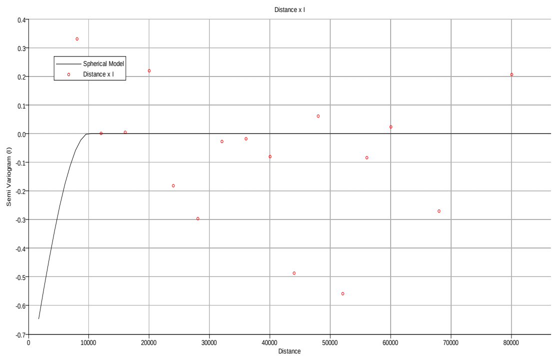

Figure 9. Spatial variability map of Na+ (mg/l) over Mathura district of Uttar Pradesh.

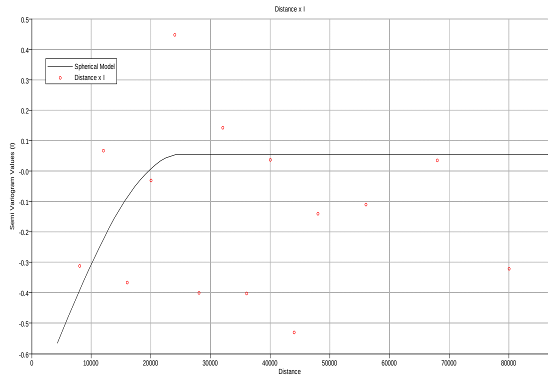

Figure 10. Spatial variability map of NO3¯ (mg/l) over Mathura district of Uttar Pradesh.

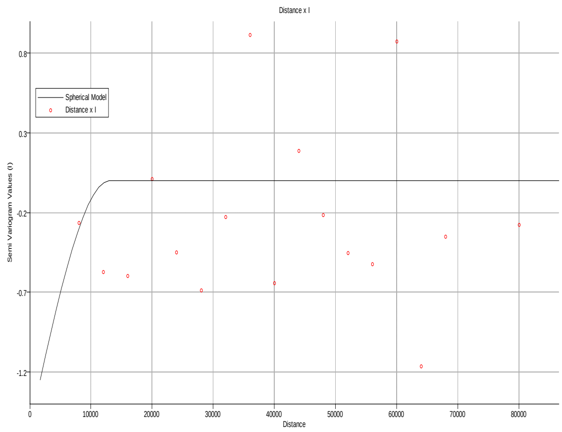

Figure 11. Spatial variability map of PO4¯2 (mg/l) over Mathura district of Uttar Pradesh.

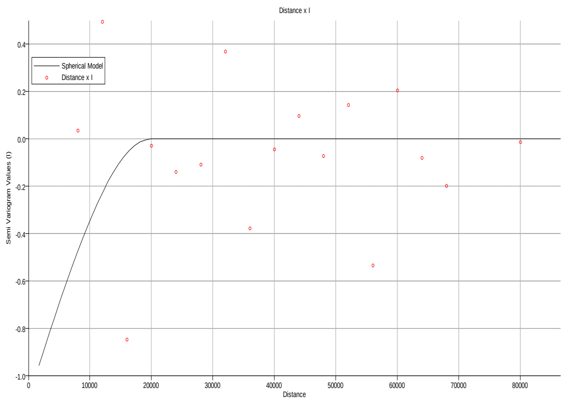

Figure 12. Spatial variability map of SO4¯2 (mg/l) over Mathura district of Uttar Pradesh.

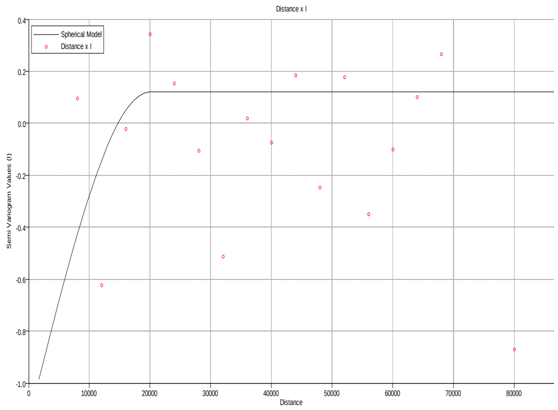

Figure 13. Spatial variability map of TDS (mg/l) over Mathura district of Uttar Pradesh.

B. Geostatistical Approach in Development of Spatial Variability Models

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. The spatial dependence is quantified using semi-variogram [22]. 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 $z(x_i)$ is the random variable at location x_i.

The experimental variogram, $\gamma(h)$ 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 [23].

Spherical model:

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

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

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:

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

C. Interpretation of the Resulting Semivariograms and Kriging Maps

1) Semivariograms

The semivariograms parameters nugget, sill and range for the data sets are summarized in Tables 3 and depicted through the graphs (Fig 14 to 25). 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 [24].

2) Interpretation of Kriging Maps

Fig. 2 shows the distribution of Ca^{+2} according to the average chemical composition during the year 2007. According to map (Fig. 2) Barsana, Palsangaon, Sahar, Chavmuhan, Vrindavan, Jachhoda and Jhinga nala show value of Ca^{+2} in average range while Sonkh shows value of Ca^{+2} above the average range.

Cl^- distribution according to the average chemical composition of the period 2007 has been presented in Fig. 3. Central part of Kiriging map (Fig. 3) shows only normal values ranges of Cl^- while the upper part shows average to high values of Cl^-.

Distribution of EC according to the average chemical composition for the period 2007 has been depicted in Fig. 4.

For the year 2007 the F^- distribution according to the average chemical composition is given in Fig. 5. Most part of study area falls in the region where the average values of F^- is 3 mg/l. Boundary of study area at right side in Kiriging map shows normal values (0.977 mg/l) of F^-.

Distributions of HCO_3^- have been shown in Fig. 6. In the cases of HCO_3^- concentration values increase from right to left smoothly.

From Kriging map (Fig. 7) it is clear that K^+ is randomly distributed over the study area. Sonkh and Jhinga nala shows average values of K^+.

Most part of study area is covered by average values of Mg^{2+}. Only some upper left and lower left part show lower values of Mg^{2+} (Fig. 8).

An increase from Chaumuhan to Barsana while a decrease Na^{+} distribution falls down from Jachnoda to Jhinga nala has been revealed in respect of Na^{+} concentration (Fig. 9).

Average value of NO_3^{-} (Fig. 10) is randomly distribution over the study area and higher value find out at upper left side, some lower part shows lower values.

Kriging maps shows concentration of PO_4^{-2} ranges from 0.058 to 2.99 mg/l. Low values at Jhinga nala, Balded and Bisawar side area as Fig. 11, upper left part shows average range value (1.050 mg/l) and Barsana area side shows higher values. Generally PO_4 value smoothly moves from Sahar to Barsana.

Most of the center part of study area has average values of SO_4^{-2} concentration which range from 332 to 989 mg/l but high concentration values appear around Barsana and low concentration in well water of Shahpur as in evident from the Kriging map (Fig. 12).

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 TDS values for groundwater samples ranged between 545 to 3,758 milligrams per liter (mg/l). In most part of study area (South Eastern part), it is below 545 mg/l but in West and North West part the TDS is more then (3758 mg/l) (Fig. 13).

III. RESULTS AND DISCUSSION

In general the quality of ground water is found to be brackish with 85 per cent of the water samples having TDS values more than 1000 mg/l. (Fig.13) WHO [25, 26] has recommended 1000 mg/l TDS for potable water [27]. The TDS values varied from 570 to 6692 mg/l (Table-1) with an average value of 2697 l/mg water of such high TDS values may be laxative effects on human beings. As most of the water samples under study have high TDS values it becomes necessary to study the relative abundance of cations and anions in each water sample and thus knowing the water types [28, 29, 30].

It is observed that for the well waters of Bisawar, Sahar, Shahpur and Vrindavan Na^{+} and HCO_3^{-} are the dominant cations and anions contributing a maximum of 80 per cent and 82 per cent respectively of the total cations and anions. Hence the type of water for these wells is Na-HCO_3 type. The well waters collected from these wells are almost fresh with TDS ranging from 771-1017 mg/l (Table- 1).

TABLE 1. RANGE WISE DISTRIBUTION OF MAJOR ANIONS AND CATIONS OF DIFFERENT TYPES OF WATER IN SHALLOW GROUND WATER SAMPLES OF MATHURA DISTRICT OF UTTAR PRADESH.

Sl. No.	Location	Sample no	TDS (mg/l)	HCO_3 (mg/l)	Cl^- (mg/l)	SO_4 (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Water Types
1	Brsawar	4	771-1017	536-897	43-133	0-164	30-112	16-83	200-267	5-9	Na-HCO_3
2	Sahar	--	--	--	--	--	--	--	--	--	--
3	Shahpur	--	--	--	--	--	--	--	--	--	--
4	Vnndavan	--	--	--	--	--	--	--	--	--	--
5	Baldeo	1	570	567	22		24	83	42	25	Mg-HCO_3
6	Adampur	1	1696	1403	230		200	74	253	100	Ca-Mg-HCO_3
7	Kosi Nala	1	2714	830	557	912	90	107	840	7	Na-SO_4-Cl
8	Sonkh	7	1585-4800	413-483	553-1869	144-240	148-442	124-271	200-460	7-120	Ca-Mg-Cl
9	Chaumuhan	--	--	--	--	--	--	--	--	--	--
10	Palsonga	1	6231	702	1784	2304	268	570	1240	13	Ca-Mg- SO_4-Cl
11	Jhinga Nala	3	1370-6692	358-872	426-2301	192-1682	88-172	70-210	270-2000	17-110	Na-Cl
12	Jacchoda	--	--	--	--	--	--	--	--	--	--
13	Barsana	--	--	--	--	--	--	--	--	--	--
14	Mathura (Range)	13	570-6692	259-1403	22-2071	0-2304	24-268	16-570	47-2000	5-120	--
15	Mathura (Average)	13	2697	674	782	502	141	144	592	39	--

TABLE 2. HIGH VALUES OF VARIOUS CONSTITUTENTS IN SHALLOW GROUND WATER SAMPLES OF MATHURA DISTRICT OF UTTAR PRADESH.

Sl.No	Location	EC (dS/m)	F (mg/l)	NO_3 (mg/l)	K (mg/l)	PO_4 (mg/l)
1	Kosi Nala	4050	1.6	34	7	-
2	Palsongan	2008	1.0	102	13	-
3	Sahar	1150	3.4	7	5	0.5
4	Adampur	2531	1.8	93	100	1.0
5	Shahpur	1510	4.6	6	9	1.0
6	Sonkh	6418	22	12	120	0.2
7	Jacchoda	9988	1.8	52	80	0.5
8	Barsana	2045	0.9	108	110	5.0
9	Chaumuhan	2366	1.8	10	7	i.o
10	Vrindavan	1500	l.l	92	9	1.0

TABLE 3. NUGGET, SILL AND RANGE VALUES FOR THE AVERAGE VALUES OF THE ARCHIVE DATA SET (TIME PERIOD 2007).

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	$(Unit)^2$	-0.8	-0.49	-0.9	-0.88	-0.8	-1	-0.9	- 1.1x102	-0.58	-0.99	-0.8	-0.7
Sill	$(Unit)^2$	0.1	0.1	0	0.53	0.13	0.09	0.18	0 x102	0.05	0.19	0.19	0
Range	m	40000	28064	28640	38000	10000	19900	19900	20000	25000	13000	39000	10000

Ground water samples collected from Baldeo exhibit Mg-HCO_3 type water with Mg and HCO_3 constituting 65 per cent and 92 per cent of the total cations and anions respectively the water is very fresh and much useful for potable purposes.

In the ground water sample collected from Adampur, HCO_3^- (Fig. 6) is the major anion constituting 74 percent of the total anions and among the cations Ca^{+2} and Mg^{+2} (Fig. 2 and 8) together constitute 54 per cent of the total cations, thus showing the quality of water to be Ca-Mg- HCO_3 type. The water found here is slightly saline.

Na-SO_4-Cl type of water is found in ground water sample collected from Kosi Nala. Na constitutes 73 per cent of the total cations whereas SO_4^{-2} and Cl^- together constitute 71 per cent of the total anions. It is a mixed type of water with TDS value 2714 mg/l. The water of this well is also slightly saline.

The ground water samples collected from Sonkh and Chaumuhan show that it is Ca-Mg-Cl type, Ca and Mg are found to be present in almost equal ratios with a maximum of 67 per cent of the total cations whereas Cl^- alone constitutes a maximum of 81 percent of the total anions. The values of TDS was between range from 1585 to 4800 mg/l indicating that the water is slightly to moderately saline.

Ca-Mg-SO_4-Cl type of water is found in ground water sample collected from Palsongaon. Again it is a mixed type of water. The dominant cations Ca^{+2} and Mg^{+2} constitute a maximum of 53 per cent of the total cations and among the anions SO_4^{-2} and Cl^- constitute a maximum of 43 per cent and 45 per cent of the total anions restively. The water is labeled as moderately saline.

Water samples collected from 3 wells situated in Jhinga Nala. Jacchoda and Barsana exhibit Na-Cl type water with the dominant cation Na^+ constituting a maximum of 77 per cent of the total cations, where as dominant anion Cl^- constitutes a maximum of 75 per cent of the total anions. The well water of Jhinga Nala and Jacchoda was found moderately saline whereas in the Barsana well water it was slightly saline.

It is observed that the water samples collected from Adampur. Jacchoda, Barsana are highly rich in NO_3^-, K^+ and PO_4^{-2} values with a maximum of 108, 110 and 10 mg/l respectively (Table-2), which clearly indicates recharge of water through return irrigation flow due to indiscriminate use of excessive fertilizer. High values of NO_3^- (Fig. 11) in well waters of Palsongan (102 mg/l), Vrindavan (92 mg/l) and of K^+ in Sonkh (120 mg/l), however may be due to localised contamination [31, 32].

High F, values (Fig. 5) at Kosi Nala, Sahar, Adampur, Jacchoda and Chaumuhan with a maximum of 4.6 mg/l at Shahpur are harmful for potable purpose and may cause health hazard. Since F^- >1.5 mg/l in water is not suitable for drinking purpose [33, 34].

IV. DISCUSSION AND RECOMMENDATION

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 [35, 36].

It is observed that 85 per cent of the water samples under study are brackish in nature and cannot be used for drinking purposes because of high salinity. High values of NO_3^-, K^+ and PO_4^{-2} are observed in ground water samples of some of the location showing its recharge through return irrigation flow and some localized contamination. High F value with a maximum of 4.6 mg/l at Shahpur is harmful for potable purpose as it may cause mottling of teeth and be hazardous for health [33].

It is recommended that-

1.The brackish water associated with salty taste should be blended with fresh water so that unused water could be brought in to use for potable purposes.

2.Excessive use of fertilizer both phosphatic and potassic should be avoided.

3.Ground water associated with high F value should not be used for potable purposes or suitable defluoridization technique such as Nalgonda technique, blending with low F^- water ion exchange and chemical treatment etc. should be adopted to keep F^- concentration of water samples within limits.

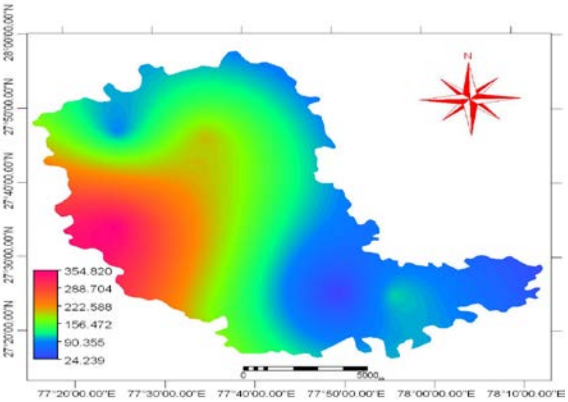

Figure 14. Spatial variability map of Ca^{+2} (mg/l) over Mathura district of U.P.

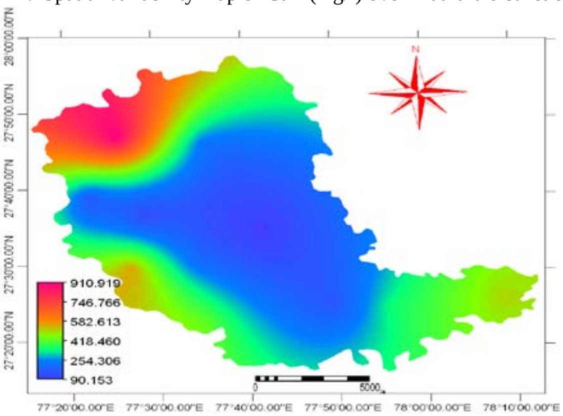

Figure 15. Spatial variability map of Cl^- (mg/l) over Mathura district of U.P.

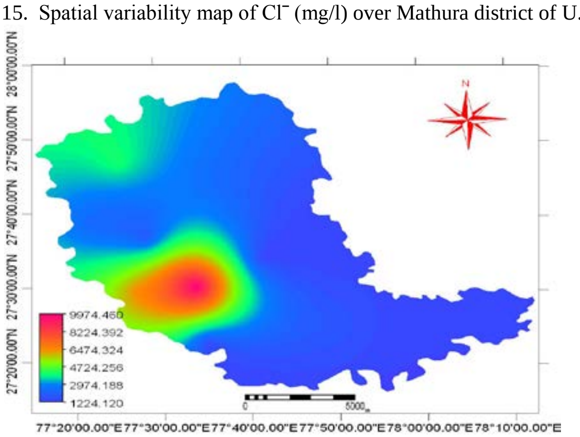

Figure 16. Spatial variability map of EC (dS/m) over Mathura district of U.P.

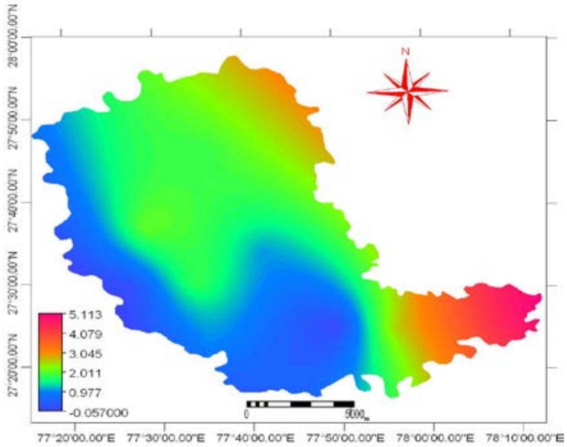

Figure 17. Spatial variability map of F^- (mg/l) over Mathura district of U**.P.**

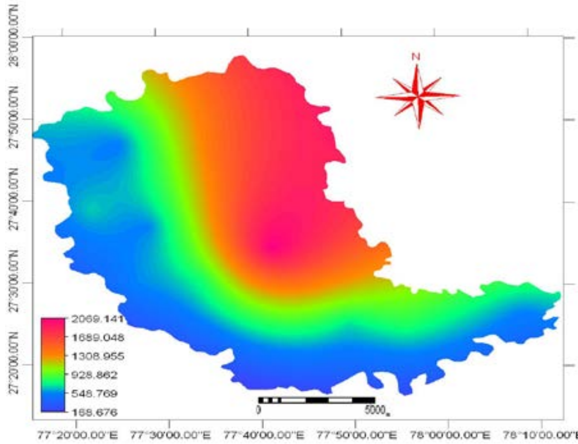

Figure 18. Spatial variability map of $HCO3^-$ (mg/l) over Mathura district of U.P.

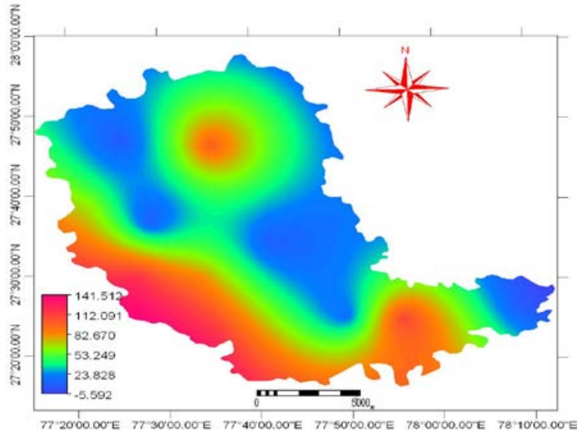

Figure 19. Spatial variability map of K^+ (mg/l) over Mathura district of U.P.

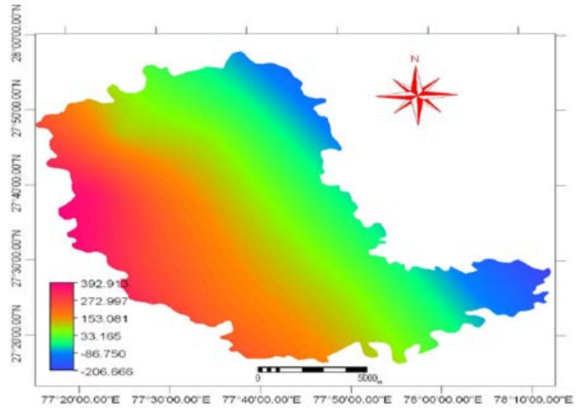

Figure 20. Spatial variability map of Mg^{+2} (mg/l) over Mathura district of U.P.

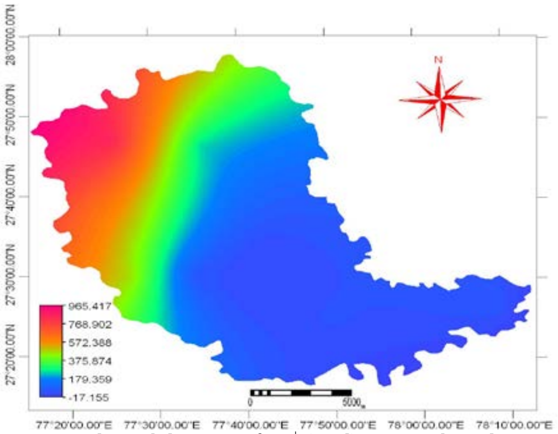

Figure 21. Spatial variability map of Na^+ (mg/l) over Mathura district of U.P

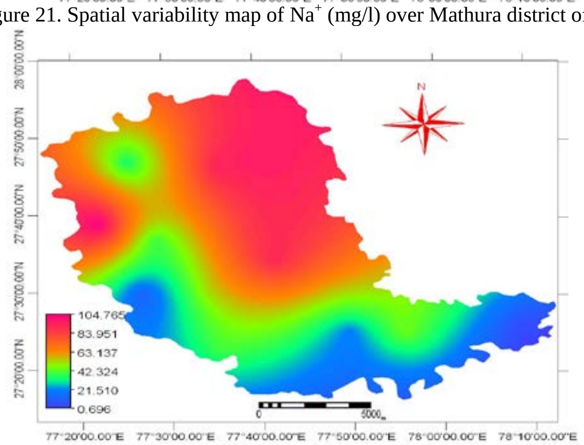

Figure 22. Spatial variability map of NO_3^-(mg/l) over Mathura district of U.P

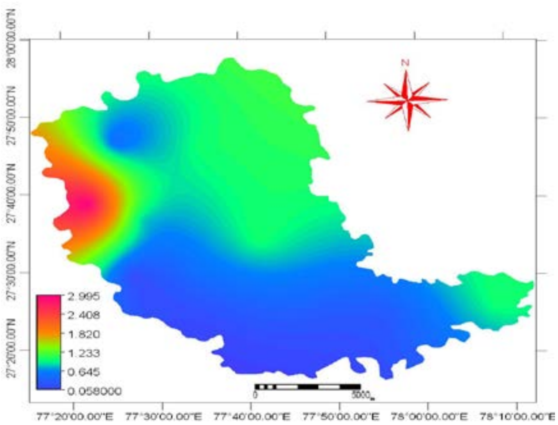

Figure 23.Spatial variability map of PO_4^{-2}(mg/l)over Mathura district of U.P.

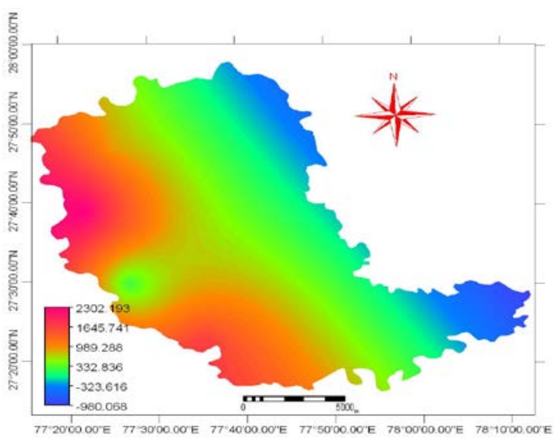

Figure 24. Spatial variability map of SO_4^{-2} (mg/l) over Mathura district of U.P

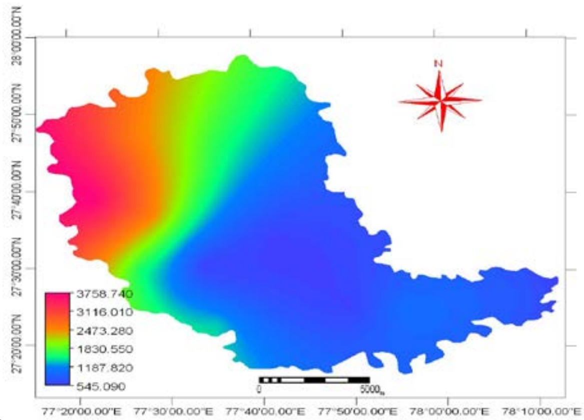

Figure 25. Spatial variability map of TDS (mg/l) over Mathura district of U.P.

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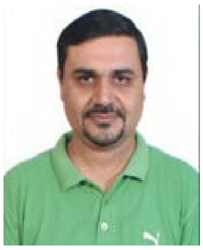

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