International Journal of Bioresource Science
Citation: IJBS: 4(1): 23-27, June 2017
DOI: 10.5958/2454-9541.2017.00006.8

Quantifying Groundwater Quality Variation Assessment by using Geostatistical Method

Vinod Kumar Tripathi[1] and Amitava Rakshit[2*]

[1]Department of Farm Engineering, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. India
[2]Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. India

*Corresponding author: amitavabhu@gmail.com

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. Geostatistical 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 pH and electrical conductivity (EC). Data were collected from 40 wells in Dwarika Sector, Delhi (*India*). After normalization of data, semi-variograme was drawn. EC values were in the range of 1282 to 2567 μS/cm and pH values were in the range of 7.2 to 8.5. The study elucidates more than 50% of the water samples are not suitable for drinking purposes without any treatment.

Keywords: Geostatistical analysis, spatial variability, interpolation chemical quality

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 (Todd, 1980). During recent years, increasing pollution of water sources has changed exploitation policy of water and soil sources.

Water, next to air is a vital natural resource responsible for the existance and development of life on the earth. Even though our country is one of the wettest countries of the world and has substantial fresh water resources, there is a chronic shortage of safe water especially in some of the major towns where urbanisation has taken place. The shortage varies from mild to acute depending upon the geographical, topographical, climatic, hydrogeological and other factors (Karanth, 1987).

This research has been carried out with the aim of spatial interpolation techniques for mapping Groundwater chemical quality (Ekhtesasi, 2004; Hem, *et al.,* 1989). The accuracy of interpolation methods for spatially predicting soil and water properties has been analyzed in several studies (Robinson, *et al.,* 2006; Hounslow, *et al.,* 1995). Safari (2002) 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 variabl depends on variables type and regional factors which influence this and any selected method for given region can not be generalized to others (Meer, *et al.,* 1993). Nazari *et al.* (2006), used geostatistics method to study spatial variability of Groundwater quality in Balarood plain. Their results showed spherical model is the best model for fitting on experimental variograme of EC, Cl and SO4 variables. Istok, *et al.,* 1998) used kriging method to estimate heavy metals. They found that the mentioned method is the best estimator for spatial prediction of lead. Dagostino, *et al.* (1998) studied spatial and temporal variability of nitrate, using Kriging and cokriging methods in Groundwater. Their results showed that cokriging method has resulted in increasing accuracy to estimate nitrate concentration. Rizzo *et al.* (2000) used geostatistics for analyzing groundwater quality. They used microbial data as auxiliary variable in cokriging method. These researchers' results showed that cokriging method has suitable accuracy to estimate Groundwater quality. Ahmed et al. (2002) used kriging method to estimate TDS in Groundwater and demonstrated accuracy of this method to prediction of TDS. The present study was carried out with the aim of spatial interpolation techniques for mapping Groundwater chemical quality for Dwarika Sector Delhi (*India*).

MATERIALS AND METHODS

Topography of the Study Area

Dwarka is a sub-city, located in the South West Delhi district of the National Capital Territory of Delhi. It is between lat28° 32′ to 28° 38′ North and long 77° 0′ to 78° 8′ East covering a total of 0.00451 sq. km. One of the largest residential areas in Asia, it is supposed to have a "Zero Tolerance" policy towards common misuses of land and the transgressions of any existing laws and regulations, such as encroachments, which are frequently thought to be flouted in other parts of Delhi. It is also frequently referred to as the "Model Township" and is also thought to be the cleanest of all parts of Delhi and nearby townships.

Soil Classification and Distribution

The soils of the Dwarka area are mostly light with subordinate amount of medium texture soils. The light texture soils are represented by sandy, loamy, sand and sany loam; whereas medium texture soils are represented by loam silty loam. Textural classes of soils as revealed from the grain size analyses. The soils that occur in all the blocks are generally suitable for irrigating moderately salt resistant crops such as wheat, barley and mustard.

Climate

The climate of the Delhi region is semiarid type, with three well defined seasons. The cold season begins at the end of November, and extends to in early July and continues upto September. The hot summer extends from the end of March to the end of June. The temperature is usually between 21.1° C to 40.5° C during these months. Winters are usually cold and night temperatures often fall to 6.5° C during the period between December and February. The average annual temperature is 31.5° C based on the records over the period of 70 years maintained by the Meteorological Department. About 87% of the annual rainfall is received during the monsoon months June to September (Rawat and Tripathi, 2015).

Groundwater depth and quality

The data related to groundwater quality were acquired from field woke for the year 2005 covering 40 groundwater sampling points. 40 ground water samples from phreatic aquifer were collected inclean polyethylene bottles from fixed wells established in Dwarika Sector Delhi. Collected samples were analyzed (as per procedure laid down in APHA (1996) 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 with help of GIS (Anbazhagan and Nair, 2004).

Geostatistical approach in development of spatial variability models

Kriging is a general term describing a geostatistical approach for interpolation at unsampled 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 regionalised variable where there are no initial measurements. The spatial dependence is quantified using semivariogram. The experimental semivariogram is a graphical representation of the mean square variability between two neighbouring points of distance h as shown in Eq. (1).

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

Where γ (h) is the semivariogram 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 (Goovaerts, 1999).

Spherical model:

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

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

Exponential model:

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

Gaussian model:

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

Linear model:

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

RESULTS AND DISCUSSION

Variation in EC values are presented in Fig. 1. The range of EC values are from 1282 to 2567 μS/cm. In Dwarika Sector Delhi water shortage and salinity in groundwater have become a big problem. The large quantity of groundwater is of no use due to its high salinity. Most of the groundwater in Dwarika Sector of Delhi (*India*) occurs under unconfined and semi-confined condition whereas near surface it is found under water table condition. The general quality of groundwater is found to be brackish with 85 percent of the water samples having Total Dissolve Salt (TDS) Values above 1000 mg/l and with a maximum value of 6692 mg/l observed at Jacchoda. The total dissolved solids (TDS) parameter reflects the level of minerals (such as carbonates, bicarbonates, chlorides, sulfate, phosphate, silica, calcium, magnesium, sodium, and potassium) 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 than (3758 mg/l).

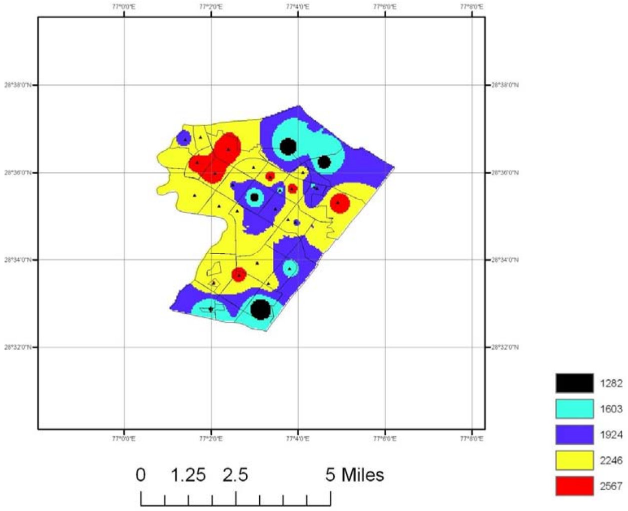

Fig. 1: Spatial variability map of EC over study area

In general the quality of groundwater is found to be brackish with 85 percent of the water samples having TDS values more than 1000 mg/l. (Fig.1) WHO (Pebesma, *et al.*, 1997; Ayers, *et al.*, 1985) has recommended 1000 mg/l TDS for potable water (WHO, 1984). The TDS values varied from 570 to 6692 mg/l with an average value of 2697 mg/l 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 (Dutta, 2003; Yadav, *et al.*, 1993; Paliwal, 1976). 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.

Variability of pH by using Kriging maps shows the ranges from 7.2 to 8.5. Low values at Jhinganala, Balded and Bisawar side area as Fig. 2, upper left and lower right part shows higher values of pH. In these region values were more than 7.0. pH slightly higher than 7.0 is better for human life. Generally pH value smoothly moves from Sahar to Barsana area. Highest Ph value has been observed in the well water of Adampur. Special emphasis is required for chemical quality of the well waters regarding their potability. Ground water associated with high pH value should not be used for potable purposes or suitable defluoridization technique such as Nalgonda technique, blending with low pH water ion exchange and chemical treatment etc. should be adopted to keep pH concentration of water samples within limits.

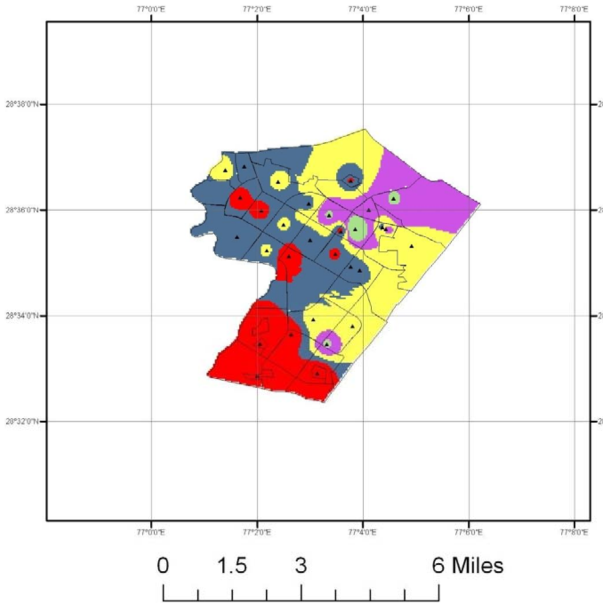

Fig. 2: Spatial variability map of pH over study area

CONCLUSION

Assessment of groundwater quality of Dwarka is vital because it is the only major source to fulfill the demand of domestic and industrial sector. Greater attention is required on continuous decline in water level and quality due to rapid urbanization and industrialization. In the present study geostatistical approach has been applied to access the spatial distribution of calcium and its associate chloride. It has been observed that more than half of the water samples under study cannot be used for drinking purposes because of higher concentration. The important reason for higher values was localized contamination. Attention should be paid by the planners and policy makers to limit the contamination for better public health protection.

REFERENCES

Anbazhagan, S., and Nair, A.M. 2004.Geographic information system and groundwater quality mapping in Panvel Basin, Maharashtra, India. *Environmental Geology*, **45**(6): 753–761.

Ahmed, S., 2002. Groundwater monitoring network design: Application of Geostatistics with a few Case studies from a granitic aquifer in a semiarid region. In: Groundwater Hydrology. Sherif, M.M., V.P. Singh and M. Al-Rashed (Eds.). Balkema, Tokyo, Japan, 2: 37-57.

APHA. 1996. Standard methods for examination of water and waste water 19th ed. Washington DC.

Ayers, R.S. and Westcot, D.W. 1985. Water Quality for Agriculture F AO Handbook 29.

Dutta, P.S. 2003. Water Quality problems of Delhi region (Annual report of DST Project).

Ekhtesasi, M.R, 2004. Morphometric and morphodynamic study of wind erosion facies of Yazd-Ardakan plain and determination of indicator of this process for function in desertification evalution models, Ph.D Thesis, Faculity of Natural Resources, Tehran University.

Goovaerts, P. 1999. Geostatistics in soil science: State-of-the-art and perspectives. *Geoderma*, **89**:1-45.

Hem, J.D., 1989. Study and Interpretation of the Chemical Characteristics of Natural Water, (Third Edition), U.S Geological Survey Water-Supply Paper 2254, United States Government Printing Office 1989.

Istok, J.D. and R.M. Cooper, 1998. Geostatistics Applied to Groundwater Pollution. III: Global Estimates. *Journal of Environmental Engineering*, **114**(4): 915-928.

Karanth, K. R. 1987. Groundwater assessment, development and management.New Delhi: Tata McGraw-Hill.

NazariZade, F. and F. Arshadiyan Behnaz and Zand Vakily Kamran, 2006. Study of spatial variability of Groundwater quality of Balarood Plain in Khuzestan province. The first congress of optimized exploitation from water source of Karoon and Zayanderood Plain. Shahrekord University, Persian Version, pp: 1236-1240.

Meer, F. Van der. 1993. Introduction to geostatistics (GOL 38) Lecture Note, ITCMSc Environmental Systems Analysis and Monitoring Module, ESM.

Pebesma, E.J. and de Kwaadsteniet, J.W. 1997. Mapping groundwater quality in the Netherlands. *J. Hydrol.* **200**, 364-386.

Paliwal, K.V and Yadav, B.R. 1976. Water quality and crop production in union territory of Delhi. IARI Technical Bulletin No.9.

Rawat, K.S., and Tripathi, V.K. 2015. Hydro-chemical Survey and Quantifying Spatial Variations of Groundwater Quality in Dwarka, Sub-city of Delhi, India. Journal of The Institution of Engineers (India): Series A, June 2015, **96**(2), 99-108.

Robinson, T.P. and G. Metternicht, 2006. Testing the performance of spatial interpolation techniques for mapping soil properties.*Computer and Electeronics in Agriculture*, **50**: 97-108.

Safari, M., 2002.Determination filtration network of Groundwater using geostatistic method. M.Sc Thesis.

Tarbiyat Modares University Agricultural Faculty, Persian Version.

Todd, D.K., 1980. Groundwater hydrology. John Wiley and Sons, New York.Microbial Community Fingerprinting at a Waste Disposal Site, pp: 1-11.

World Health Organization (WHO) 1984. Guidelines for drinking water quality Vol. I, Geneva.

Yadav, B.R. and Khera, M.S. 1993. Analysis of irrigation water, edited by Dr. HLS Tandon Pamposh Enclave, New Delhi.