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CALCIUM AND CHLORIDE VARIABILITY ASSESSMENT IN THE SEMI-ARID REGION - A CASE STUDY

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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. 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 Ca^{2+} and Cl^{-}. Data were collected from 40 wells in Dwarika Sector, Delhi (*India*). After normalization of data, semi-variograme was drawn. The study elucidates more than 50 per cent of the water samples are not suitable for drinking purposes without any treatment.

Keywords: Geostatistical Analysis, Spatial variability, Interpolation Chemical Quality.

1.0 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 [18]. During recent years, increasing pollution and lossing of water sources have changed exploitation policy of water and soil sources. Water, next to air is a vital natural resource responsible for the existence and development of life on the earth. Even though India 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 [1.1].

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Calcium and chloride is used in concrete mixes to accelerate the initial setting, but chloride ions lead to corrosion of steel bar, so it should not be used in reinforced concrete. The anhydrous form of calcium chloride may also be used for this purpose and can provide a measure of the moisture in concrete. It is included as an additive in plastics and in fire extinguishers, in wastewater treatment as a drainage aid, in blast furnaces as an additive to control scaffolding (clumping and adhesion of materials that prevent the furnace charge from descending), and infabric softener as a thinner.

This research has been undertaken with the aim of spatial interpolation techniques for mapping calcium and chloride variability. The accuracy of interpolation methods for spatially predicting soil and water properties has been analyzed in several studies [9,14]. Safari [15] used kriging method to estimate spatial prediction of Groundwater in Chamchamal plain in west of Iran [6, 8]. 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. Nazari et al. [12] 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 SO_4 variables. I stock and Cooper [10] used kriging method to estimate heavy metals and found that spherical model is the best estimator for spatial prediction of lead. Dagostino et al.[5] studied spatial and temporal variability of nitrate, using kriging and cokriging methods in groundwater. Barca and Passarella [3] showed that disjunctive kriging method is the suitable to study deterioration level of Groundwater. In Dwarika Sector Delhi water shortage and salinity in ground water have become a big problem. The large quantity of ground water is of no use due to its high salinity. The present study was therefore, carried out by using spatial interpolation techniques for mapping groundwater quality.

2.0 Material and Methods

2.1 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 lat 28° 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.

2.2 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 sandy 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 [19].

2.3 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 [13].

2.4 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 in clean polyethylene bottles from fixed wells established in Dwarika Sector Delhi. Collected samples were analyzed (as per procedure laid down in APHA [2]) 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 G.I.S [1,16].

2.5 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 regionalized variable where there are no initial measurements. The spatial dependence is quantified using semivariogram [17]. The experimental semivariogram is a graphical representation of the mean square variability between two neighbouring points of distance h as shown in Eq. (1).

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

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 [7].

Spherical model:

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

$$\gamma(h)=c_0+c, \qquad h>A_0 \tag{2}$$

Exponential model:

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

Gaussian model:

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

Linear model:

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

3.0 Results and Discussion

Calcium is often present at a significant concentration in natural waters. It is easily precipitated and in particular react with soap to make it difficult to remove scum. Calcium is an essential element required for good health and its daily requirement varies from 0.7-2.0 gm. Insufficient amount of calcium may induce adverse physiological effects. On the contrary excess amount of calcium in body results in formation of urinary bladder stone and irritation in urinary passage. Bureau of Indian Standards (IS:10500, 2012) have recommended the highest desirable limit of 75 mg/l and maximum permissible limit of 200 mg/l. Calcium concentration in groundwater of the study area ranged from 152 to 499 mg/l (Fig. 1). It was observed that Barsana, Palsangaon, Sahar, Chavmuhan, Vrindavan, Jachhoda and Jhinganala show value of Ca^{+2} in below the average value while Sonkh shows value of Ca^{+2} above the average value. Distribution of calcium has been depicted in Fig. 1.

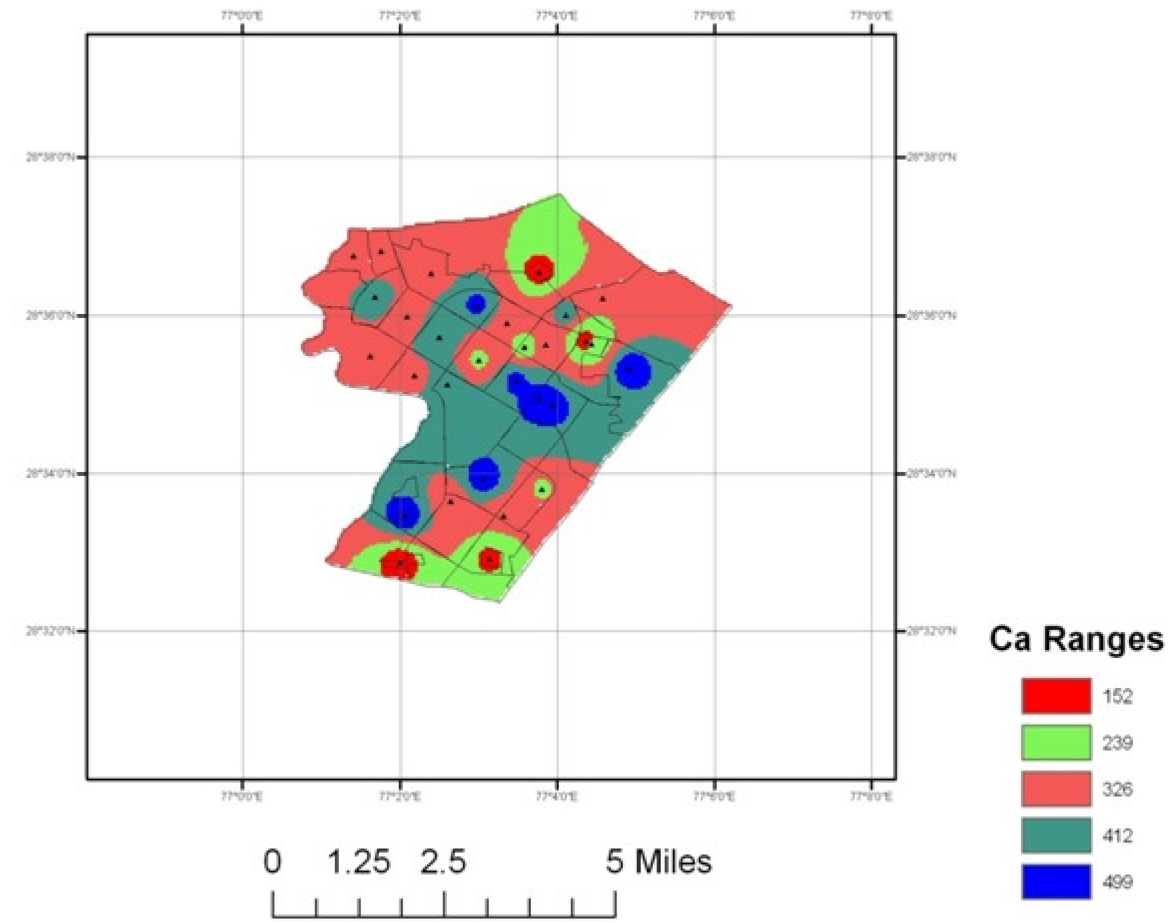

Fig.1 Spatialvariability map of Ca^{+2} over Dwarika Sector Delhi

Chloride distribution in the study area has been presented in the Fig. 2. Highest concentration (560 mg/l) was observed in central region. It was about two times higher than maximum desirable limit (250 mg/l). Lower part of Kiriging map (Fig. 2) shows above average value. It comes to groundwater from chlorapatiterock mineral. Chloride salts, being highly soluble and free from chemical reactions with minerals of reservoir rocks, remain stable once they enter into solution. Most chloride in groundwater is present as sodium chloride, but the chloride content may exceed due to base-exchange phenomena. High chloride content of groundwater is likely to originate from pollution sources such as domestic effluents, fertilizers, septic tanks and from natural sources such as rainfall, the dissolution of fluid inclusions. Increase in chloride level is injurious to people suffering from diseases of heart or kidney [20]. When the excess chloride concentration is present with excess sodium concentration it may cause congestive heart failure. The ground water samples collected from Sonkh and Chaumuhan show that it is Ca-Mg-Cltype, 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.

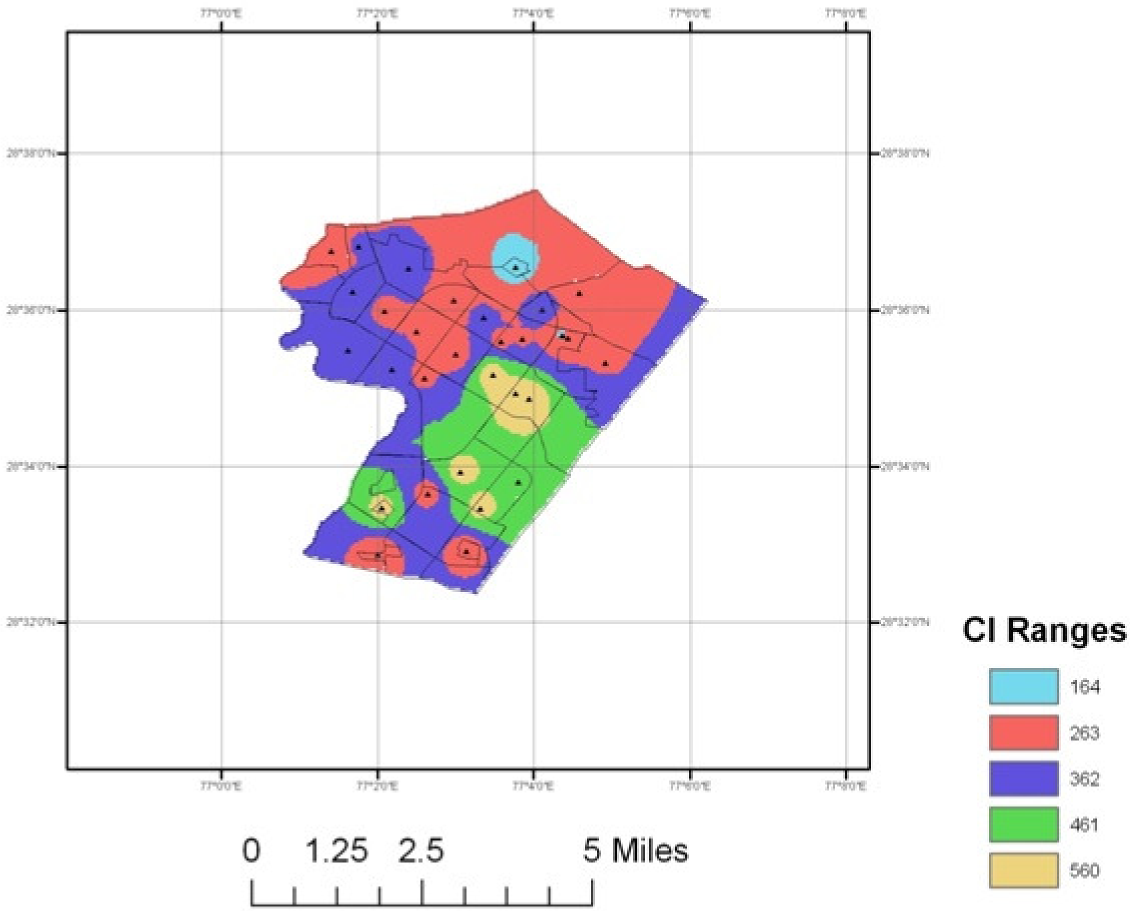

Fig.2 Spatialvariability map of Chloride over Dwarika Sector Delhi

4.0 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.

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