An integrated approach to assess the quality of groundwater in and around Neyveli lignite mine area, Cuddalore District,Tamil Nadu, India

Rumuri Remy, M.V.Mukesh, S.Chidambaram

Department of Earth Sciences, Annamalai University, Annamalai Nagar-608002

Email:urumuri14remy@gmail.com

Contact no: +918220929868

Abstract— In the current study 23 groundwater samples collected in and around Neyveli lignite mine area, Cuddalore district, Tamil Nadu, India to assess groundwater quality by analyzing the major cations (Ca^{2+},Mg^{2+},Na^{+} and K^{+}) and anions (SO_4^{2-}, $HCO_3^{-}$and Cl^{-})besides physico-chemical parameters (namely pH, Temperature, Electrical Conductivity, Total Dissolved Solids).Also, geographic information system-based groundwater mapping in the form of visually communicating contour maps was developed using ArcGIS-9.3to delineate spatial physico-chemical characteristics of groundwater samples. Different parameters of water have been analyzed and are in adherence to Bureau of Indian Standard permissible limit. It reveals that groundwater in and around Neyveli lignite mine area is not polluted and therefore was considered suitable for human consumption.

Keywords— Groundwater quality, physico-chemical parameters, geographic information system, Neyveli lignite mine area.

INTRODUCTION

Medically it has been confirmed that, the average human body is composed of 65% water and dehydration starts just at only 6% loss of body water [1]. Again, it is well established that about two – thirds of the earth surface is occupied by water in liquid, gas and solid forms. Besides, researches have showed that the total volume of water on the Earth surface is about 1400 Km^3 and more than 97% of this is sea water. Notwithstanding these figures, only about 0.8% is fresh water out of which groundwater constitute only 0.6%. Thus, the total easily accessible safe and drinkable surface fresh water is only 0.2% which represents approximately 11.2 km^3 of volume on earth.

Groundwater, though makes up about 0.6% of the water on Earth, it is an important resource for potable water, irrigation, domestic purposes, food production or recreational purposes, and industry [2]. Groundwater dissolves various soil, ground, and rock minerals through the action of chemical weathering and on its traverse through the groundwater system.

Therefore six ions are predominant in most ground waters. These are called the major ions; there are 3 major cations Ca^{2+}, Mg^{2+}, Na^{+}, and 3 major anions HCO_3^{-}, $SO_4^{2-}$and Cl^{-}, with concentrations usually higher than 5 mg/l. Minor ions have concentrations in the range of 0.01 to 10 g/m3; examples are K^{+}, Fe^{2+}, Fe^{+3}, F^{-}, B^{-}, NO_3^{-} and CO_3^{2-} .These ionic species when added together account for most of the salinity that is commonly referred to as total mineralization or total dissolved solids (TDS)[3].

Because groundwater is largely hidden from view, it is often forgotten and subject to contamination by careless humans. The sources of contamination can be classified into anthropogenic and natural causes. Among the notable natural causes include: (1) mineralization of water from dissolved salts present in soil, (2) contamination from dissolved ground emitting gases such as radon, (3) the decomposition of biological products on the ground, etc. Major anthropogenic activities that significantly contaminate ground water include: (1) agricultural activities such as fertilizers and pesticides applications, (2) Precious mineral extractions processes such as mining activities which often involve the disposal of waste rock, tailings deposition, and effluent discharges, (3) sewage and septic tanks discharges, (4) seawater intrusion results from excessive discharge of fresh groundwater in coastal areas, etc. Thus, all these activities lead to increasing content of ionic species in groundwater.

Consequently, groundwater quality assessment is invariably directed towards factors which may lessen the suitability of pumped groundwater with respect to its potability and use in agriculture and industry. The overall goal of a groundwater quality assessment programme, as for surface water programmes, is to obtain a comprehensive picture of the spatial distribution of groundwater quality and of the changes in time that occur, either naturally, or under the influence of man [4].

Therefore an attempt has been made in the current study to assess the effects of opencast mining activities on groundwater quality and their variation by defining the principal hydrochemical nature of the groundwater in and around Neyveli lignite mining area.

MATERIALS AND METHODS

Sampling and Physico-chemical Analysis:

Twenty three groundwater samples were collected in 1000-ml polyethylene bottles from hand pump/bore holes during pre-monsoon (April-June 2014) in and around Neyveli lignite mine area. The sampling bottles at the time of sampling were thoroughly rinsed three times, using groundwater to be sampled. The chemical parameters viz. pH, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were measured, using digital instruments immediately after sampling. The bottles were labeled, tightly packed, transported immediately to Annamalai university laboratory, and stored at 4°C for chemical analyses. The specific methods used for physico-chemical parameters analysis of groundwater samples are given below in table.

Table 1 .Methods used for physico-chemical parameters analysis.

Parameters	Methods
SO_4^{2-}	Turbidity method
HCO_3^-	Volumetric titration
Ca^{2+}	EDTA titration method
Mg^{2+}	EDTA titration method
K^+	Flame photometer (Systronics, mk-V/mk-III)
Na^+	Flame photometer (Systronics, mk-V/mk-III)
Cl^-	Volumetric titration
TDS	TDS meter

The results were evaluated to the suitability of drinking water for human consumption and compared with the water quality guidelines of Bureau of Indian Standards (BIS, 2003).

Geo-database creation-GIS model:

The various physico-chemical parameters obtained from analyses are created as attribute database in generating the spatial distribution maps. These attributes data then transformed into a point layer for GIS analysis. Each sample point was assigned by a unique code and stored in the point attribute table. The database file contains the values of all physico-chemical parameters in separate columns along with a sample code for each sampling station. The attribute data were linked to the spatial data and maps showing the spatial distribution were prepared to model the variation in concentrations of the physico-chemical parameters using Inverse Distance Weighted (IDW) raster interpolation technique of Spatial Analyst TM module in ArcGIS 9.3 software. IDW is an algorithm for spatially interpolating or estimating values between measurements. Each value estimated in an IDW interpolation is a weighted average of the surrounding sample points. Weights are computed by taking the inverse of the distance from an observation's location to the location of the point being estimated [5]. In a comparison of several different deterministic interpolation procedures, [5 and 6] found that using IDW with a squared distance term yielded results most consistent with original input data. In the present study, the geospatial attributes data were utilized for the generation of spatial distribution maps of selected water quality parameters.

RESULTS AND DISCUSSION

In order to determine the potability of the groundwater, the quality of physico-chemical parameters of the collected water samples is to be understood in detail. Therefore, the following water quality parameters were selected for the generation of spatial distribution maps using Arc GIS namely pH, EC, TDS, K^+, SO_4^{2-} ,HCO_3^-,Ca^{2+}, Mg^{2+} ,Na^+ and Cl^- (Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10).

A statistics summary of the analytical results of the physical parameters of groundwater samples collected from different sampling sites of Neyveli Lignite Mine area is presented in Table 2 and Table 4. Also, a statistics summary of the analytical data of the chemical parameters of analyzed components in groundwater is presented in Table 2. Comparative analyses of groundwater samples of the study area exceeding the desirable and permissible limits prescribed by BIS [7] for drinking purposes are furnished in Table 4.

Table 2: Summary Statistics of the analytical data of the physical parameters of groundwater samples collected from the study area

Parameters	N	Minimum	Maximum	Mean	Std. Deviation
pH	23	6	7	6.57	0.507
EC	23	76	1277	453.17	380.425
TDS	23	52	867	297.87	242.738

Table 3: Variables, symbols and units

Variable	Symbol	Units
pH	pH	pH units
Conductivity	EC	µS/cm
Total dissolved solids	TDS	mg/L

Table 4: Summary Statistics of the analytical data of the chemical parameters of groundwater samples collected from the study area

Parameters	N	Minimum	Maximum	Mean	Std. Deviation

SO_4^{2-}	23	5	34	14.74	7.436
HCO_3^-	23	24	464	186.17	128.519
Ca^{2+}	23	12	148	58.04	28.124
Mg^{2+}	23	2	57	21.30	13.109
K^+	23	0	7	1.70	1.743
Na^+	23	1	162	61.26	54.100
Cl^-	23	53	408	175.04	102.672

Table5: Comparative Analyses of the Groundwater samples of the study area exceeding the desirable and permissible limits

Parameters	BIS 2003		No. of samples exceeding desirable limit	No. of samples exceeding permissible limit
	Desirable limit	Permissible limit		
pH	6.5-8.5	8.5-9.2	-	-
EC (µS/cm)	-	1500(WHO)	-	-
TDS (mg/L)	500	2,000	4	-
Ca^{2+} (mg/L)	75	200	5	-
Mg^{2+} (mg/L)	30	100	4	-
SO_4^{-2} (mg/L)	200	400	-	-
Cl^- (mg/L)	250	1,000	6	-
$*Na^+$ (mg/L)	50	200	12	-

pH is most important in determining the corrosive nature of water with optimum range between 6.5 to 8.5.The maximum permissible limit is 8.5 and may be extended up to 9.2 in the absence of alternate water source. In the present investigation during the pre-monsoon period, the values of pH in the groundwater samples collected from the study area ranged between 6.73 and 7.93(Fig.1). The pH values of all the samples are within the desirable limit of BIS (2003).

The Electrical Conductivity (EC) of water at 25°C ranged from 76 to 1277 µS/cm during pre-monsoon period and maximum of 1277 µS/cm with a mean value of 453.17 µS/cm (Table 2).EC is measured in microsiemens per centimeter and is a measure of salt content of water in the form of ions [9].A higher concentration is recorded in the southeastern part of the study area as shown in Fig.2.

Figure 1.Spatial distribution of pH

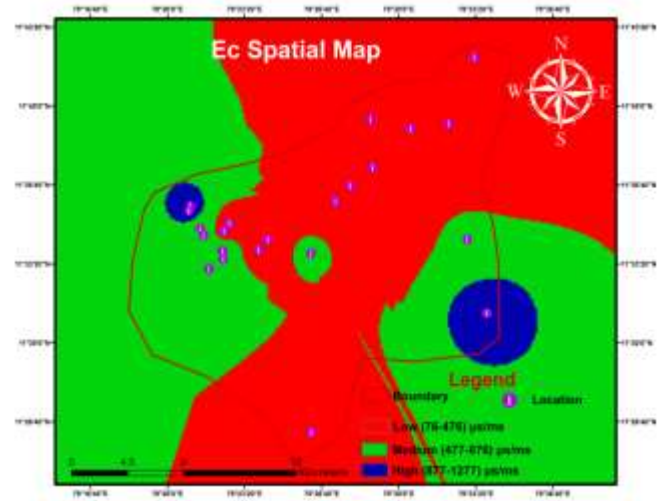

Figure 2. Spatial distribution of EC

The TDS values in the study area varies from 52 to 867 mg/L, which indicates a variation of degree of water quality due to entering of mobile charged ions into groundwater system. Four samples exceed the desirable limit of BIS standard but are within the permissible limit. The spatial distribution of TDS is shown in Fig 3 and a maximum is observed on the southeastern and northwestern part of the study area.

The concentration of K^+ in the study area varied from 0 to 7 mg/L during pre-monsoon period. The spatial distribution of K^+ is shown in Fig 4 for and a maximum concentration of Potassium is observed at the centre part of the study area.

Figure 3.Spatial distribution of TDS

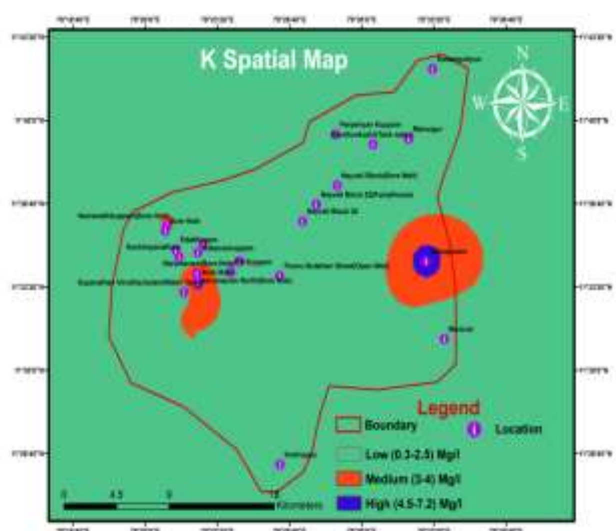

Figure 4.Spatial distribution of K

The concentration of SO_4^{2-} in the study area ranges from 5 to 30 mg/L, which are below the recommended limit of SO_4^{2-} for BIS drinking water. The spatial distributions of SO_4^{2-} concentration is given in the Fig.5.

The concentration of HCO_3^- in the study area ranges from 24 to 464 mg/L. The carbonates (HCO_3^- and $CO_3^{2-)}$ which are dominated ions in the groundwater; they are result from the CO_2 that is released from the decay of organic matter and root respiration in soil zone. The higher content of carbonates indicates an intense weathering of rocks, which favors an active mineral dissolution [8].

$$CO2 + H2O \rightarrow H_2CO_3$$

$$H_2CO_3 \rightarrow H_2 + HCO_3$$

$$HCO_3 \rightarrow H+ + CO_3$$

The spatial distribution of HCO_3 is given in Fig.6 and the maximum concentration of bicarbonate observed on Eastern part area.

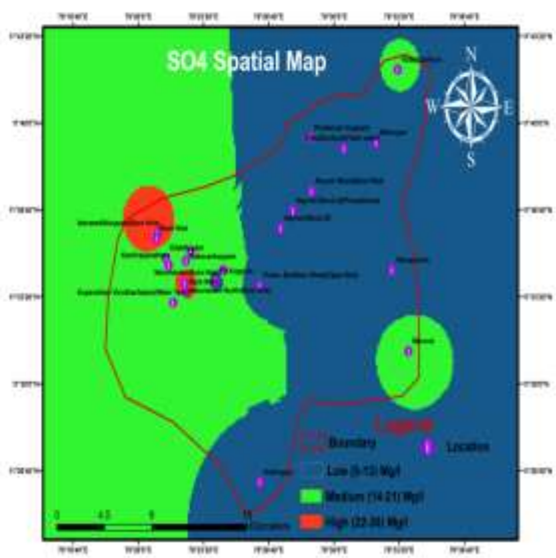

Figure 5.Spatial distribution of $SO_4{}^{2-}$

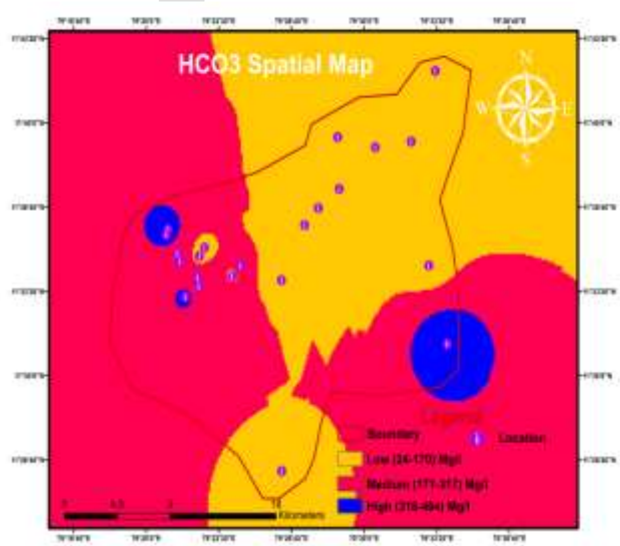

Figure 6.Spatial distribution of HCO_3^-

The concentration of calcium ranges from 12 to 148 mg/L during pre-monsoon period with an average mean value of 58.04 mg/L.Five sample exceeds BIS desirable limit of 75 mg/L (Table 5). The Calcium maximum value is trending from the Eastern to Western (Fig.7).

Magnesium ion concentration ranges from 2 to 57 mg/L during pre-monsoon period with average mean value of 21.30 mg/L (Fig.8).Magnesium is an essential ion functioning of cells in enzyme activation, but at higher concentration, it can cause laxative effect upon people after consumption[10].Four samples exceeds BIS desirable limit of 30 mg/L (Table 5).

The concentration of Na^+ in the study area ranges from 1 to 162 mg/L with a mean average value is 61.26 mg/L during the pre-monsoon period and twelve samples exceeds the recommended permissible limit of 200 mg/L (Table 5, Fig.9).This is because of the silicate weathering of soil salts stored by the influences of evaporation and anthropogenic activities [11, 12 and 13].

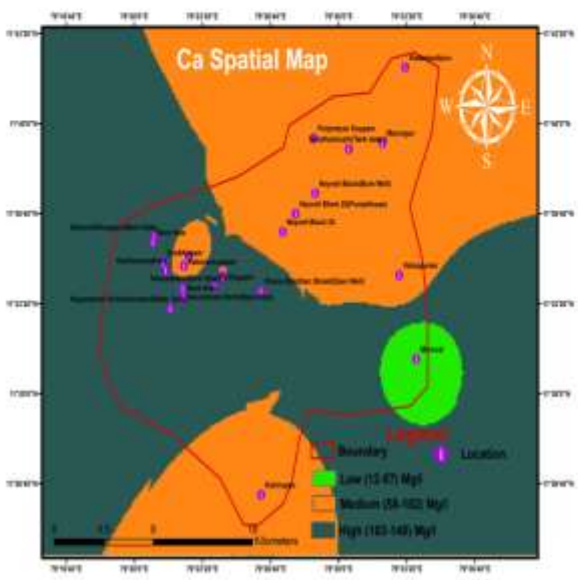

Figure7.Spatial distribution of Ca

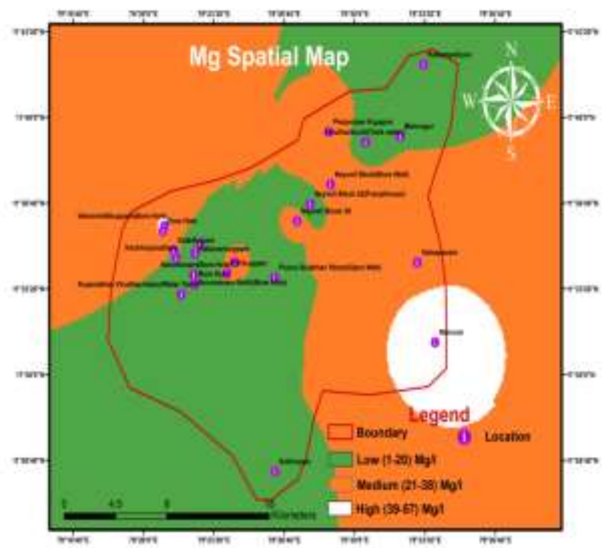

Figure 8.Spatial distribution of Mg

The concentration of Cl^- varied from 53 to 408 mg/L with a mean average value of 175.04mg/L during the pre-monsoon period and six samples exceeds the recommended permissible limit of 200 mg/L (Table 5, Fig.10).High chloride in groundwater samples may be due to the pollution from chloride rich effluents of sewage and municipal waste[14].

Figure 9.Spatial distribution of Na^+

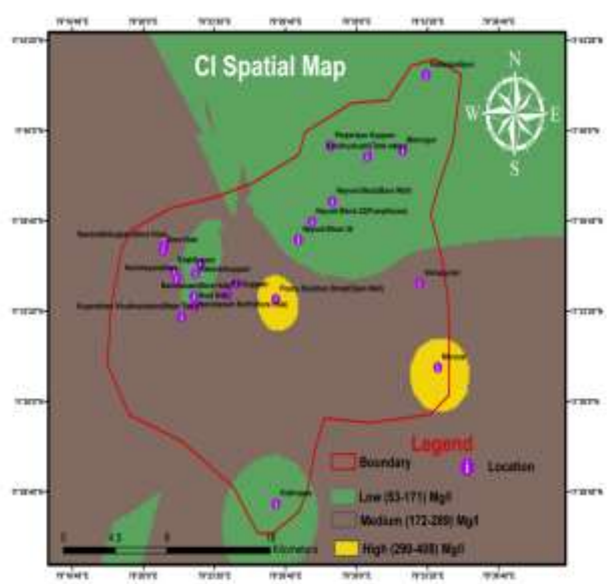

Figure 10.Spatial distribution of Cl^-

ACKNOWLEDGMENT

I want to thank the Professor and Head from the Department of Earth Sciences, Annamalai University, Tamil Nadu, for permitting to carry out the research project. In addition, I owe my special gratitude to Dr.M.V.Mukesh and Dr.T.Ramkumar. Many thanks for field and laboratory analysis work to research scholars.

CONCLUSION

The spatial distribution maps of selected water quality parameters namely pH, EC, TDS, TH, Ca^{2+}, Mg^{2+} ,Na^{+} , K^{+} ,HCO_3^{-},Cl^{-} and SO_4^{2-} were developed by using GIS. Therefore, it is inferred from the study that the majority of groundwater quality parameters in and around Neyveli lignite mine are within the desirable and permissible limits of BIS (2003) .It is generally concluded that groundwater quality is good for drinking purposes. Further research should be conducted in both wet and dry seasons to obtain more information pertaining to physico-chemical parameters in many groundwater samples within the study area, so as to determine the effect of seasonality.

REFERENCES:

[1]. Popkin BM, D'Anci KE, Rosenberg IH, *Water, Hydration and Health*, **2010**; 68(8):439-458.

[2]. Bozeman. Only a Drop to Drink on Earth. Adapted from: "A Drop in the Bucket" in Project WET: Curriculum and Activity Guide. *The Watercourse and the Council for Environmental Education*, **1995**.

[3] Prof. Dr. Ir. F. De Smedt, *Groundwater Hydrology* **2009**, pp.38.

[4]. Wilkinson and Edworthy, 1981.Water Quality assessments.

[5]. Burrough PA, McDonnell RA, Principles of geographical information systems for land resources assessment. Oxford University Press, New York, **1998**.

[6]. Mathes ES, Rasmussen TC, Hydrogeol J, **2006**, 14, 1493–1507.

[7]. BIS, *Indian standard drinking water specifications IS10500:1991, edition 2.2 (2003–2009). Bureau of Indian Standards, New Delhi,* **2003.**

[8]. Methods for Chemical Analysis of water and Wastewater, EPA-600/4-79-020, USEPA. Method 9253.

[9]. Karanth KR, *Ground water assessment development and management*, **1987,** 217–275.

[10]. Garg VK, Suthar S, Singh S, Sheoran A, Meenakshi Garima, Jai S, *Env Geol*, **2009**, 58, 1329–1340.

[11]. Meyback M, *American Journal Science*, **1987**, 287, 401–428.

[12]. Stallard RF., and Edmond JM, *Journal of Geophysical Research*, **1983**, 88, 9671–9688.

[13]. Subba Rao N, *Environmental Geology*, **2002**, 41, 552–562.

[14]. Ravikumar, P., Venkateshraju, K. and Somashekar, R. K**. 2010**. Major ion chemistry and hydrochemical studies of groundwater of Bangalore South Taluk, India, Environ Monit Assess. 163: 643-653.