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ANALYSIS OF GROUNDWATER QUALITY IN THE AMBULIYAR WATERSHED, TAMIL NADU, INDIA USING GIS

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ABSTRACT

Groundwater is the most important natural resource used for drinking by many people around the world, especially in rural areas. An attempt has been made in this research paper to understand about the groundwater quality of the Ambuliyar watershed in parts of Thanjavur and Pudukkottai districts, Tamil Nadu, India. Groundwater is the major source for domestic and agricultural activities in the area. The water samples were collected from PWD (Public Works Department). These samples were analysed for electrical conductivity, pH, total dissolved solids (TDS) and Hardness and major cat ions like calcium, magnesium, sodium, potassium and anions like bicarbonate, chloride, nitrate and sulfate in the laboratory using the standard methods given by the American Public Health Association (APHA). The groundwater locations were selected to cover the entire study area and attention was given to the area where contamination is expected. Geochemical parameters exceeding permissible limit have been identified in most of the locations indicating higher ionic concentration. TDS, Mg, Na, K, Cl, SO_4 and EC exceed the maximum permissible limit. pH, NO_2, NO_3, Ca, Hardness, HCO_3, CO_3 and F are within the permissible limit of World Health Organisation (WHO, 2008) and Bureau of Indian Standard (BIS, 1991). The results were evaluated in accordance with the drinking water quality standards given by the World Health Organization. The present study reveals that the groundwater distribution pattern and concentration of different geochemical parameters and demarcation of the higher concentration zones were identified and discussed. The spatial interpolation maps for various geochemical parameters were generated using GIS software.

INTRODUCTION

Water is the most vital component of our planet and probably responsible for the existence of life on earth. Among all sources, the rivers are the most important source of fresh water both for human consumption and agricultural / industrial usage. Groundwater is the main source of water that meets the agricultural, industrial and household requirements. Population growth, socio-economic development, technological and climate changes has increased the demand for potable water manifolds in the past few years (Alcamo, *et al*., 2007). One of the internationally accepted human rights is the access to safe drinking water which is the basic need for human health and development (WHO, 2001). The general health and life expectancy of the people is reported to be adversely affected due to lack of the availability of clean drinking water in many developing countries of the world (Nash and McCall, 1995).

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Geographic information system (GIS) is an efficient and effective tool in solving problems where spatial data are important. Therefore, it is widely used for assessment of water quality and developing solutions for water resources related problems (Chaudhary *et al*., 1996). GIS based spatial distribution mapping and suitability of groundwater quality, evaluation for domestic and agricultural purpose was carried out by (Goyal *et al*., 2010). Anbazhagan and Nair (2004) used GIS to represent and understand the spatial variation of various geochemical parameters in Panvel Basin, Maharashtra, India. GIS is to understand the behaviour of various geochemical parameters spatially in Upper Gadilam, River basin of Vizhupuram district and Paravanar basin of Cuddalore district of Tamil Nadu (Aravindan *et al*., 2010) and Shankar *et al*., 2010). Therefore, groundwater quality play a major role for planning water supply, water quality management, public health management and environmental management. In the present study, GIS was used to prepare spatial interpolation of various geochemical parameters with

the aim to evaluate the groundwater quality of the Ambuliyar watershed by amalgamating the groundwater quality data.

Study Area

The Ambuliyar Watershed lies in the districts of Thanjavur and Pudukkottai in the State of Tamil Nadu. It is partly cover Thanjavur district and Pudukkottai districts. It is located between the latitudes 79° 0′ E and 79° 10′ E longitudes and 10° 10′ N and 10° 20′ N latitudes. It covers Survey of India Topographic sheets 58 J/15, J/16, 58 N/3, N/4, N/7 and N/8 on the scale of 1:50,000. Ambuliyar watershed covers total area of about 702.58 km^2 (Fig. 1). The watershed is linear in shape and ends in the Palk Strait in the southeast direction. Physiographically the watershed is flat with gentle slope. Mean annual rainfall of the watershed is 776.74 mm and its ranges between 1108.18 mm and 156.83 mm. Geological formations are ranging in age from Archaean to recent.

MATERIALS AND METHODS

The geochemical parameters of the study area were collected from PWD Taramani, Chennai. Each parameter is soaked in 1:1 HCl for 24 hours were rinsed with distilled water followed by deionized water. At the time of sampling, the sampling bottles were thoroughly rinsed two or three times, using the groundwater to be sampled. The geochemical parameters namely, pH and electrical conductivity (EC) were measured, using digital instruments immediately after sampling.

There were six water samples collected in the study area using 500-ml polyethylene bottles from the borewells during the pre-monsoon period (2012). The groundwater sample bottles were labeled, tightly packed, transported immediately to the laboratory and stored at 4° C for chemical analyses. The sampling preservation and analysis were carried out as per the standard methods prescribed by American Public Health Association (APHA, 1995). The processes were carried out by PWD, Chennai. The results of geochemical parameters are presented in table.

RESULTS AND DISCUSSION

General Parameters

PH: The pH value of groundwater samples varies from 7.7 (Arsarkulam sample location) to 8.5 (Arayapatti sample location) with an average of 8.2 indicating alkaline nature as per BIS (1991) standards. Almost all samples fall within the recommended limits (6.5 to 8.5) for human consumption. The pH indicates the strength of the water to react with the acidic or alkaline material present in the water. It controls by carbon dioxide, carbonate and bicarbonate equilibrium. The combination of CO_2 with water forms carbonic acid, which affects the pH of the water. More than 8.2 pH value has been noticed in the northeast, northwest, west and the southwest parts of the study area. At the same time less than 8.2 pH value has been identified in the north, central, south and southeast parts. Even though the study area has recommended limits for human consumption (Fig. 2).

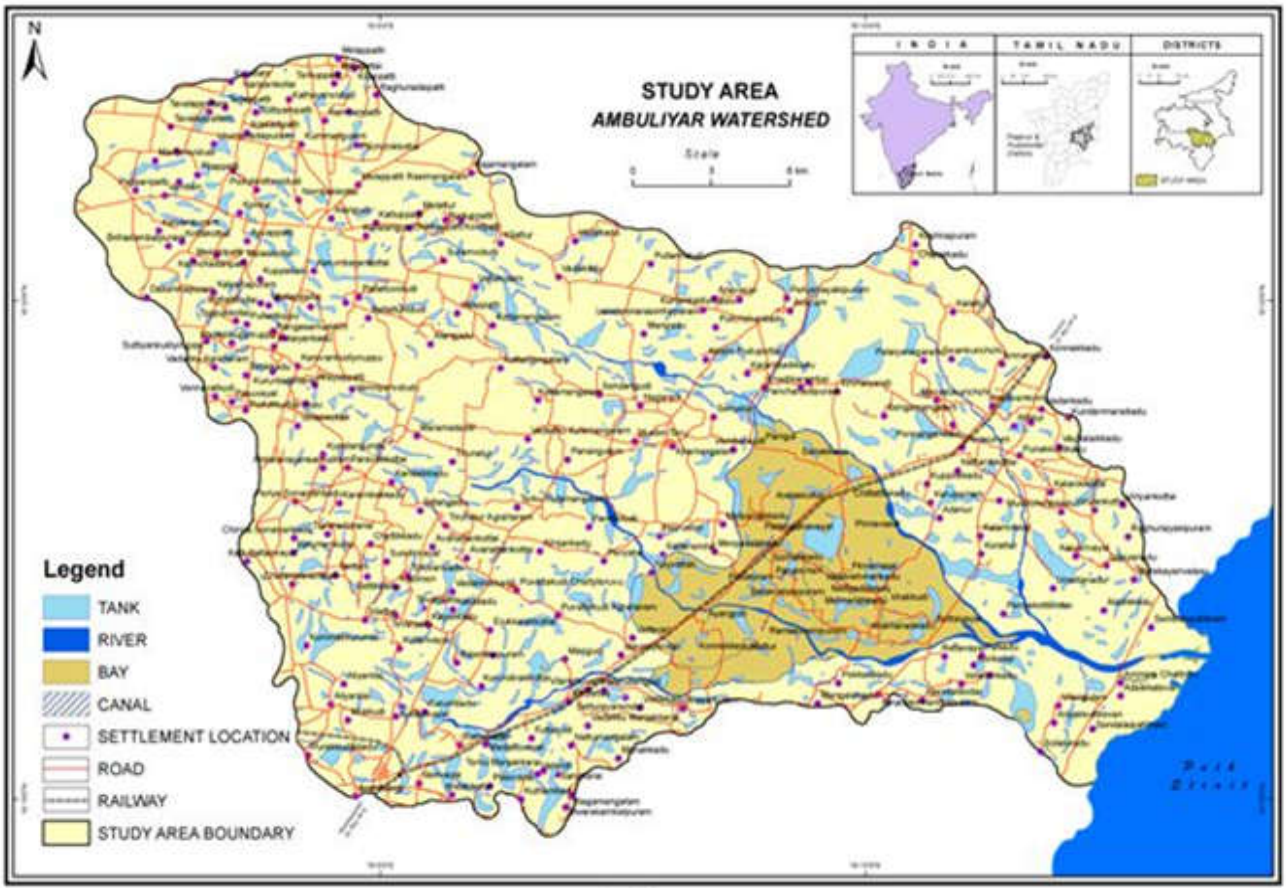


Fig.1. Key Map of Ambuliyar Watershed, Tamil Nadu

Table. Geochemical Parameters of the Ambuliyar Watershed

Sl. No.	Sample Location	pH	EC	TDS	HAR	Ca	Mg	Na	K	HCO3	CO3	SO4	Cl	NO_2& NO_3	F
1	Peravurani	8.4	660	372	170	24	26.73	72	3	107.34	2.53	30	124	6	0.3
2	Mangottai	8.4	470	253	170	28	24.3	19	18	170.84	4.03	5	46	1	0.2
3	Nagaram	8.2	1320	821	145	20	23.08	205	55	170.8	0	125	259	11	0.55
4	Alangudi	8.2	480	280	130	30	13.36	48	4	78.747	1.17	21	92	5	0.07
5	Arsarkulam	7.7	2400	1415	760	120	111.78	168	59	128.1	0	206	574	25	0.26
6	Arayappatti	8.5	440	232	180	38	20.65	16	3	160.08	4.75	8	39	1	0.17

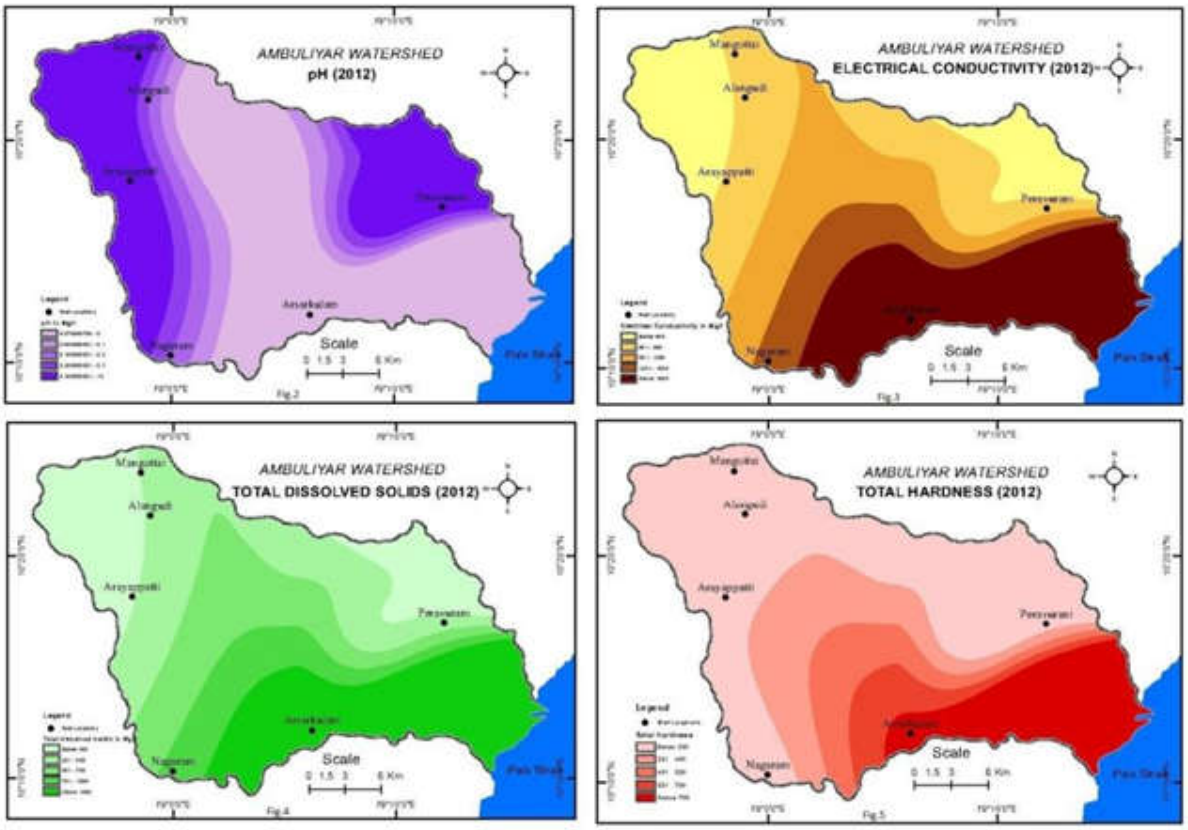


Fig.2 Map for pH, EC, TDS and TH

Electrical Conductivity: The electrical conductivity value ranges from 440 (Arayapatti) to 2400 (Arsarkulam) µs/cm at 25° C. A high salt content (high EC) in irrigation water leads to formation of saline soil. This affects the salt intake capacity of the plants through their roots. High salinity water cannot be used on soil with restricted drainage. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil (Saleh, *et al*., 1999). Electrical conductivity value is very high in the south and the southeast parts mainly Arasarkulam sample location has 2400, which is located in the south part of the study area. Moreover very low electrical conductivity has been observed in the northeast and northwest parts of the study area (Fig. 3).

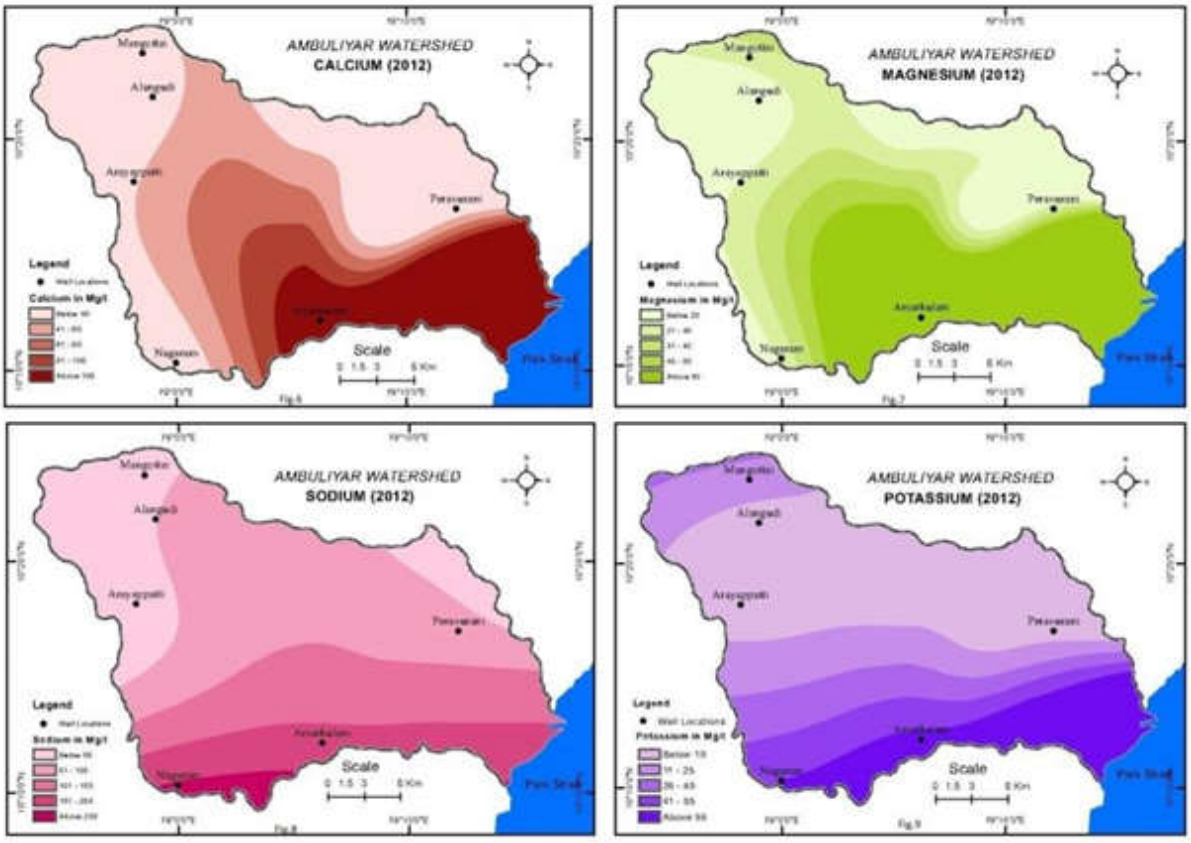
Total Dissolved Solids: TDS which indicates total dissolved ions in the water and it varies between 232 and 1415 mg/L. Most of the groundwater samples from the study area recorded, greater values than the permissible limit (1,000 mg/L) due to successive action of weathering and dilution processes. Ascertain the suitability of groundwater for any purpose, it is essential to classify based on the TDS values (Davis and DeWiest 1966) and displayed spatially in the southeast part of the study area is unfit for drinking and irrigation purposes particularly in Arsarkulam water sample, which is located in the south part of the study area. According to the TDS values, almost the same trend has been observed from the EC values (Fig. 4).

Total Hardness: The total hardness is an important parameter of water quality whether it is to be used for domestic, industrial or agricultural purposes. The total hardness ranges between 130-760 mg/l. While WHO and Indian standards permit any value less than 500mg/l. Arasarkulam water sample have very high value compare to other water samples of the study area (Fig. 5).

Chemical Characteristics of Groundwater

Calcium (Ca) and Magnesium (Mg): The concentration of Ca is varied between 20 and 120 mg/L, while concentration of Mg is varied from 20.65 to 111.78 mg/L. Calcium is also participate in cation exchange equilibrium at aluminosilicate and other mineral surfaces. Solubility equilibrium models have been used widely in studying the chemical behaviour of calcium. Calcium is an essential constituent of many igneous rock minerals, especially the chain silicates pyroxene and

amphibole and the feldspars. Calcium is exceeding the permissible limit in Arasarkulam sample location. In igneous rock, magnesium is typically a major constituent of the dark colored ferromagnesian minerals (Hem 1985). Arasarkulam water sample has exceeding maximum acceptable limit of the study area (Fig. 6 and Fig. 7).



Sodium (Na): Sodium concentration is varied from 16 to 205 mg/L. The possible source of sodium might be located at deeper aquifer which may be percolation from water of top soil layers and due to atmospheric precipitation that has been subjected to concentration effects of Magnesium (Herman Bower, 1978). Most of the samples records higher Na, indicating contribution from weathering process of Na plagioclase feldspar along with dissolution of Kankar (Srinivasamoorthy *et al*. 2008). Human activities can have a significant influence on the concentrations of sodium in groundwater (Hem, 1985). The uses of salt for deicing highways in winter flowing from wells have had direct, noticeable regional effects. Somewhat less directly, the reuse of water for irrigation commonly leaves a residual that is much higher in sodium concentration than was the original water. Sodium is very high in the south parts of the study area mainly Nagaram water sample at the same time the low sodium has been noticed in the northwest part of the study area mainly Arayappatti water sample (Fig. 8).

Potassium (K): The natural water contains sodium, less than one tenth, because of the high degree of stability of potassium bearing alumino silicate minerals (Davis and DeWiest, 1966). Potassium ranges from 3 to 59 mg/L. This may be the result of soil leaching by runoff. The potassium value exceeds in Mangottai, Nagaram and Arasarkulam sample location of the study area (Fig. 9).

Bicarbonate and Carbonate (HCO_3 and CO_3): Bicarbonate and carbonates produce alkalinity in water. Carbonates and bicarbonates are being estimated from the alkalinity values (Hem, 1985).

Bicarbonates vary in the study area from 78.747mg/L at Alangudi to 170.84 mg/L at Mangottai water sample (Fig. 10 and Fig. 11).

Carbonates are varied between from 0.0 mg/L at Nagaram and 200.0 mg/L at Arasarkulam water samples. The high alkalinity increased due to the action of carbonates on the basic materials in the soil which gives an unpleasant taste to water in the study area. HCO_3 concentration is classified based on WHO's (2008) standard < 100 ppm is categorized as poor quality water which is suitable only for industrial activity except in Alangudi have the value of 78.74 mg/L.

Sulphate (SO_4): Sulphate is naturally occurring anion in all kinds of natural waters. Sulphate produces an objectionable taste at 300 – 400 mg/L. As per BIS standard desirable limit for drinking is 200 mg/L. Sulphate concentration is classified based on the above standards as soft water and good water suitable for drinking is fixed as less than 200 ppm. Sulphate is found to be within prescribed limit for drinking water except in Arasarkulam water sample of the study area (Fig. 12).

Chlorine (Cl): Chlorine concentration is classified based on BIS standard, less than 250 ppm as good water suitable for drinking. Chlorine is often an important dissolved constituent

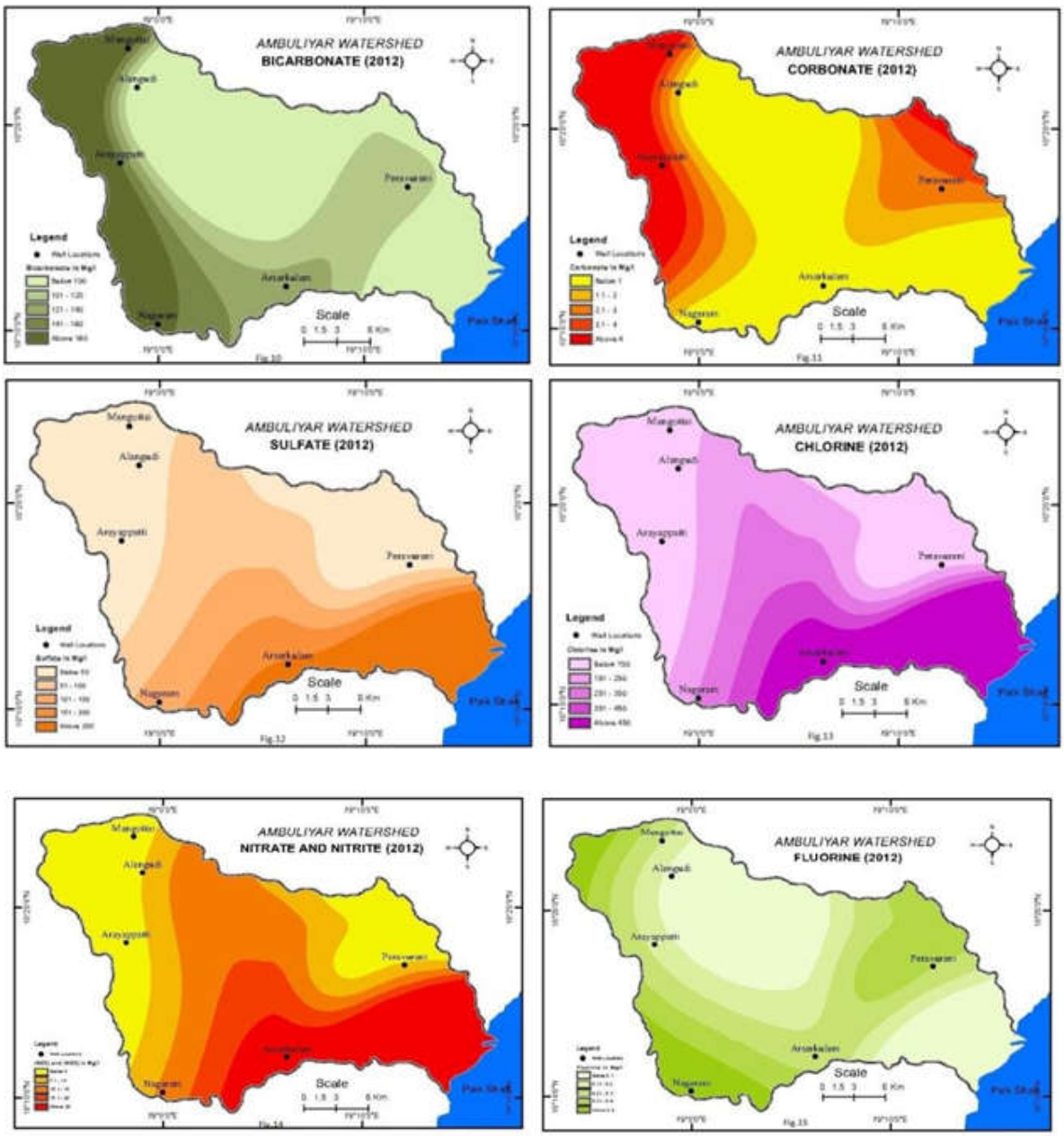


Fig.3 Map for Ca, Mg, Na and K

in groundwater, may originate from various sources including, dissolution of halite and related minerals. The concentration of chlorine is between 46 and 574 mg/L indicating the leaching of chlorine from topsoil / weathered zone and Base Exchange reactions (Bower, 1978). Anthropogenic processes can locally affect chlorine concentrations in groundwater. Some anthropogenic factors commonly influencing chlorine levels in water include road salting during the winter, improper disposal of oil field brines, contamination from sewage and contamination from various types of industrial wastes (Hem, 1993). Only two water samples namely Nagaram and Arasarkulam come under the exceeding maximum permissible limit, the remaining water samples zone is within maximum permissible limit of the study area (Fig. 13).

Nitrate and Nitrite (NO_3 and NO_2): Nitrogen plays a dominant role in the life cycle process of plants and animals. Most investigators have attributed nitrogen in groundwater, derived from organic industrial effluents, fertilizer or nitrogen fixing bacteria, leaching of animal dung, sewage and septic tanks through soil and water matrix to groundwater (Madison and Brunett, 1984). The nitrate ion concentration is varied from 1 to 25 mg/L. The concentration of nitrogen in groundwater is derived from the biosphere. Nitrogen is originally fixed from the atmosphere and then mineralized by soil bacteria into ammonium. The high concentration of nitrate in drinking water is toxic and causes blue baby disease in children and gastric carcinomas. According to the nitrate and nitrite, the study area has within the permissible limit of all water sample locations (Fig. 14).

Fluorine (F): Fluorine is essential for human beings as a trace element and higher concentration of this element causes toxic effects. Concentration of fluorine between 0.6 to 1.0 mg/L in potable water protects tooth decay and enhances bone development (Kundu *et al*., 2001). Bureau of Indian Standards

has suggested permissible limit of fluoride in drinking water at 1.0 mg/L and tolerance range is up to 1.5 mg/L. Ingestion of water with fluorine concentration above 1.5 mg/L results in fluorosis, dental mottling and bone diseases. In the study area, fluorine ranges between 0.2 and 0.26 mg/L falls in desirable limits (Fig. 15).

Conclusion

Geochemical parameters exceeding permissible limit have been identified in most of the locations indicating higher ionic concentration. There are seven geochemical parameters such as TDS, Mg, Na, K, Cl, SO_4 and EC exceed the maximum permissible limit. P, Ca, Total Hardness, CO_3, HCO_3 and F are within the permissible limit. The pH indicates the strength of the water to react with the acidic to alkaline material present in the water. The occurrence of high EC values in the study area reflects the addition of some salts through the prevailing agricultural activities. The suitability of groundwater for any purpose, it is essential to classify based on the TDS concentration spatially in the northeast part of the study area unfit for drinking and irrigation purposes. The present study reveals that the Arasarkulam water sample is exceeding the permissible limit. Various geochemical parameters were mapped in GIS, which is very effective and efficient. These maps will helpful to the planners and policy makers especially of public health and irrigation departments for sustainable water management.

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