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Hydrochemical Characteristics of Groundwater in Mayiladuthurai Block of Nagapattinam District, Tamil Nadu

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Abstract : Hydrochemical study was carried out in Mayiladuthurai block of Nagapattinam district in Tamil Nadu with the objective of understanding the suitability of groundwater quality for domestic and irrigation purposes. Groundwater samples are collected from 25 locations during Pre-monsoon (August 2013) and Post-monsoon (January 2014) seasons and analyzed for various physico-chemical parameters. The study reveals that groundwater samples are more or less within prescribed limits as per standards for irrigation and drinking purposes. The spatial variation of groundwater quality parameters was plotted using 3D fieldpro software. To know suitability of water for domestic, the parameters are within the permissible limit at many locations, few placed exceed the limit. High TH and EC in a few places identify the unsuitability of groundwater for drinking and irrigation. The groundwater is mainly $Ca^{2+}HCO_3^-$ type, mixed $Ca^{2+}Na^+HCO_3^-$ type and $Na^+HCO_3^-$ type. Gibb's diagram reveals that most of the groundwater samples fall in the rock dominance field. Wilcox diagram indicate that majority of samples falls in excellent to good and permissible to doubtful. The samples plotted on U.S. salinity diagram indicate that groundwater of the region is medium to high saline and low alkaline in nature. Most of the groundwater samples were suitable for irrigation, except in a few locations. Overall the groundwater quality was suitable for irrigation activities and permissible for domestic purposes.
Keywords: Physicochemical, drinking water, irrigation water, Mayiladuthurai block.

Introduction

Groundwater is a precious source of fresh water, being the most distributed form on the earth, excluding the polar icecaps and glaciers. India accounts for 2.2% of the global land and 4% of the world water resources and 16% of the world population. Two-thirds of the earth surface is covered by water. It is estimated that approximately one third of the world's population use groundwater for drinking purposes. Water is very important to life without water our life cannot move. Water shortages have become an increasingly serious problem in India, especially in arid and semi-arid regions of the country due to scarcity of surface water and vagaries of monsoon. In India groundwater constitutes about 53% of the total irrigation potential and about 50% of the total irrigated area is dependent on groundwater irrigation[1]. Intensive agricultural activities have increased the demand on groundwater resources in India. Among the various reasons the non-availability of potable surface water and a general belief that groundwater is purer and safer than surface water. The problems of groundwater quality are more acute in areas that are densely populated and thickly industrialized and have shallow dug wells. In the last two decades the rapid growth industrialization and urbanization has created negative impact on the environment[2]. Due to industrial, municipal and agricultural waste containing pesticides insecticides, a fertilizer residue with water groundwater has been polluted by leaching process. Water in the natural environment contains many dissolved substances and non-dissolved particulate matter. Generally high concentrations of dissolved constituents are found in groundwater than surface water because of its greater exposure to soluble minerals of the geological formations[3]. The suitability of irrigation water depends upon many factors including the quality of water, soil type, salt tolerance characteristics of the plants, climate, drainage characteristics of soil, geology degree of chemical weathering of prevailing lithology. Groundwater always contains small amount of soluble salts dissolved in it. The kind and quality of these salts depend upon the sources for recharge of the groundwater and the strata through which it flow. The excess quantity of soluble salts may be harmful for many crops. Hence a better understanding of the chemistry of groundwater is very essential to properly evaluate groundwater quality for domestic and irrigation purposes. Groundwater studies are gaining more importance in the present day as it is used for almost all purposes such as domestic and agriculture activities in most parts of the world.

Study Area

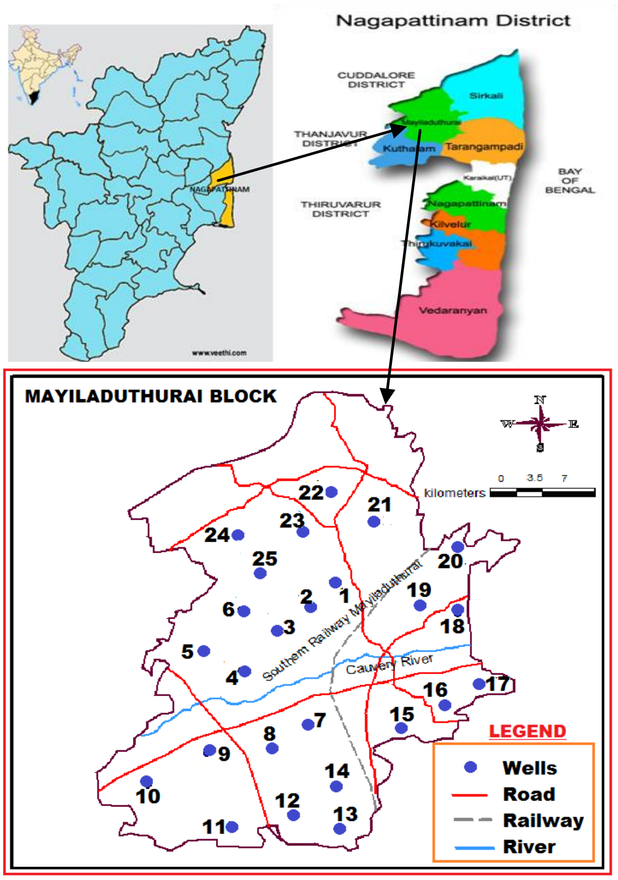

Fig.1: Location of the study area with sampling

Mayiladuthurai is a selection grade municipal town and is situated in Nagapattinam district in Tamil Nadu which is surrounded with the agricultural lands. Mayiladuthurai is located at a distance of 281 Kms from Chennai and 130 Kms from Tiruchirappalli and is well connected to all major towns by road and rails (Fig.1). It covers an area of 251.41 Km^2. The region is a tropical monsoon climate, with mean temperature ranging from 25ºC to 35ºC. The average annual rainfall is about 1125 mm, which is mainly received with high intensity of rainfall during northeast (October-December) monsoon and moderate in southwest (July-September) monsoon. Being coastal region it is prone to frequent cyclones and floods. Flood basins comprising black clay brown clay loam and fine sandy soil occupy the large part of the delta region. The entire block comes under sedimentary terrain and the formation consists of river Alluvial (sand) formations, sandy clay etc. Groundwater occurs both under semi-confined and water table conditions in these formation. Generally shallow to medium tube wells are drilled in these regions. The area forms part of Cauvery delta with gentle slope towards Bay of Bengal. The area mainly depends on surface and groundwater for domestic and irrigation purposes. The Cauvery river water is also used for cultivation in some places but this is not possible throughout the year because it flows only for a few months in a year. Major crops cultivated are Paddy, pulses (Black gram and Green gram), groundnut, sugar cane, cotton etc.

Materials and Methods

25 groundwater samples have been collected during premonsoon and post-monsoon during the August 2013 and January 2014.The samples have been collected from the tube wells and dug wells. Electrical conductivity (EC) and pH have been measured using digital meters immediately after sampling. Water samples

have been analyzed for chemical constituents such as major ions in the laboratory using the standard methods as suggested by the American Public Health Association[4]. The groundwater quality is assessed with respect to standards[5, 6].

Results and Discussion

Spatial representation of groundwater:

Groundwater quality assessment was carried to determine its suitability in terms of domestic and irrigation purposes. The simplest way of representing groundwater quality information on a spatial variation map is to contour the concentration of particular parameters. The chemical composition of groundwater results from the geochemical processes occurring as water reacts with the geologic materials which it flows[7]. The groundwater samples were collected in and around the Mayiladuthurai area. 3D FIELD PRO software is used to understand the spatial distribution and variation of the ions with respect to the location.

Hydrogen ion concentration (pH):

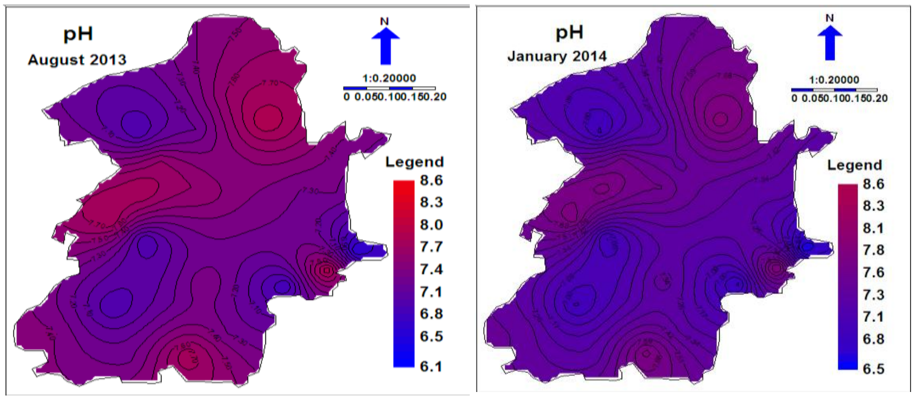

Fig.2: Spatial distribution of pH of groundwater during both the seasons

pH is one of the most important parameters that shows acid-base neutralization and water softening. The pH values for groundwater samples ranges from 6.1-8.6 and 6.5-8.6 during pre and post monsoon respectively (Fig.2). The permissible[6] range of pH for drinking or for domestic uses is from 6.5-8.5. Most of the water samples are slightly basic in both seasons due to presence of carbonates and bicarbonates[8.] If the pH is found beyond the permissible limit, it affects the mucous membrane of cells[9].

Electrical Conductivity (EC):

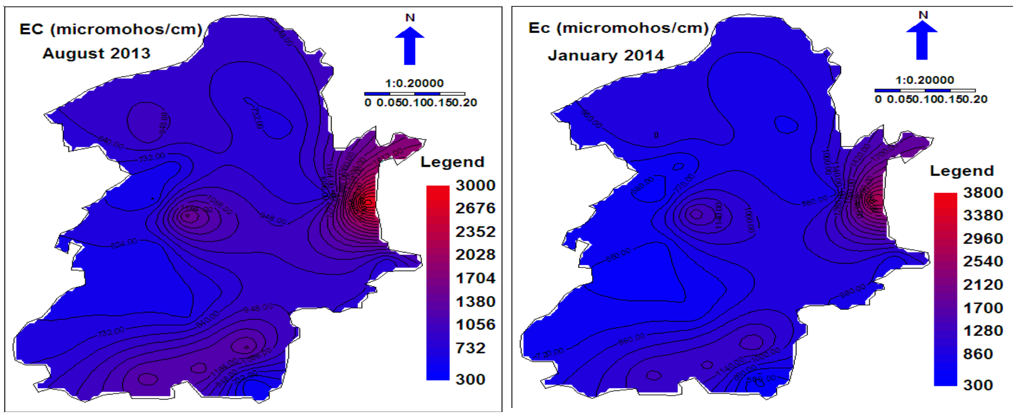

Fig.3: Spatial distribution of EC of groundwater during both the seasons

Electrical Conductivity (EC) or salinity is the most important parameter of water to indicate total dissolved solids and its suitability for domestic and irrigation purposes. As such EC measurement makes it possible to obtain information about the extent of mineralization in the groundwater. EC value varies from 399 to 2906 μScm^{-1} and 290 to 3700 μScm^{-1} during pre and postmonsoon respectively. The spatial distribution of

EC (µscm^{-1}) of groundwater samples during pre and post monsoon seasons as shown (Fig.3). Above high concentration (1500 µscm^{-1}) of EC represent the connate nature of groundwater. The spatial distribution of electrical conductivity in wells reveals that groundwater salinity increases toward the eastern part of the study area. However, some heterogeneity in salinity distribution is observed. Because extraction of groundwater and the concentration is slightly decreased due to dilution process taken place in pre monsoon. EC of water is a direct function of its total dissolved solids[10].

Total Hardness (TH):

Probably the most common problem identified with groundwater is that of hardness. Hardness is caused primarily by the presence of cations such as calcium and magnesium and anions such as carbonate, bicarbonate, chloride and sulphate in water. Water hardness has no known adverse effect; however, some evidence indicates its role in heart disease[11]. The term hard and soft as applied to water date from Hippocrates (460-354 B.C) the father of medicine, in his treatise on public hygiene. Hard water is unsuitable for domestic use. The hardness in water is derived from solution of CO_2, release by bacteria in the soil in percolating rainwater. In this region, the total hardness varies between 93-848 mg/l and 40-560 mg/l during pre and post monsoon. It is inferred that both seasons recorded high TH and is not suitable for drinking and other domestic purposes. Sawyer and McCarty classified groundwater based on TH as a groundwater with TH <75, 75-150, 150-300 & >300 designated as soft moderately hard, hard & very hard respectively[13]. Desirable and maximum permissible limit of hardness in dinking water is 300 mg/l and 600 mg/l respectively[6]. The maximum hardness is found in eastern side of the region. Hardness of water is an important measure of pollution[14]. A thematic map of this study area (Fig 4) has been prepared which shows the distribution of TH in groundwater.

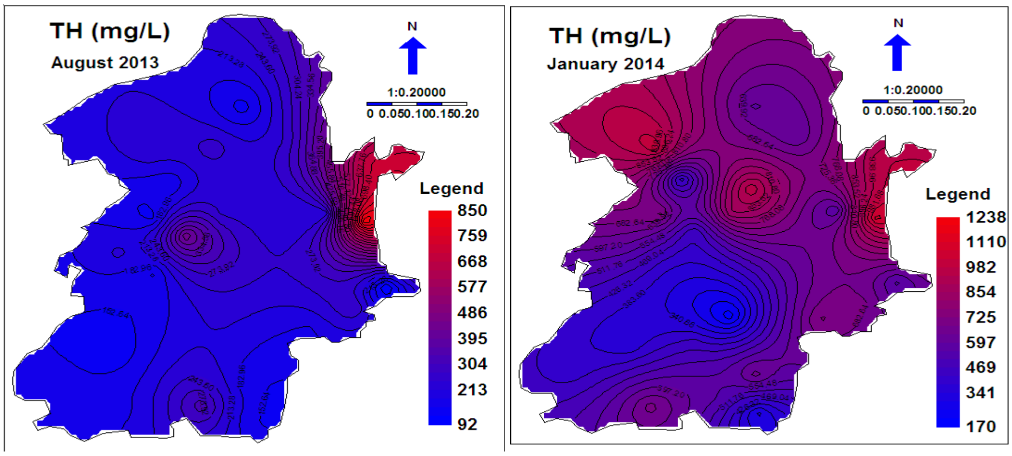

Fig.4: Spatial distribution of TH of groundwater during both the seasons

Calcium (Ca^{2+}):

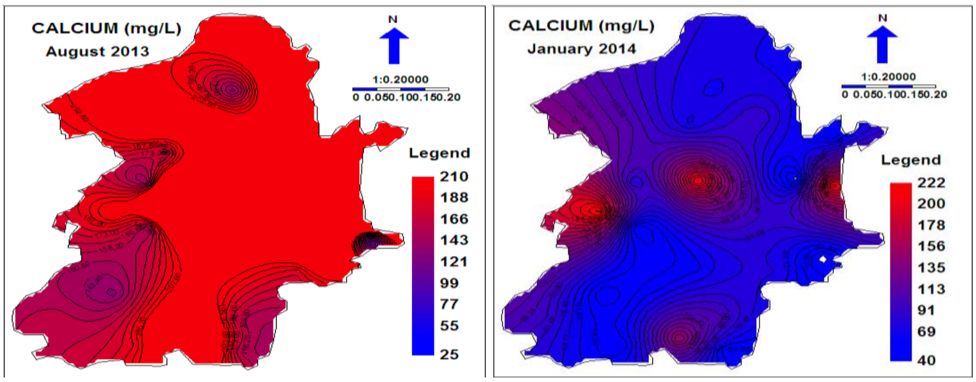

Fig.5: Spatial distribution of Ca of groundwater during both the seasons

Calcium, magnesium and total hardness in the groundwater are inter-related it is found in alkaline nature. Calcium is an important element to develop proper bone growth. It also cause concentration in the body and may cause intestinal disease and stone formation[15]. The presence of calcium in the groundwater is from silicate mineral group. The shale's, sandstone also contain calcium in the form of carbonate. In groundwater the calcium content generally exceeds the magnesium content[16]. Desirable and maximum permissible limit of calcium in drinking water is 75 mg/l and 200 mg/l [5]. The calcium concentration in water samples collected from the study area ranged from 36-208 mg/l and 36-220 mg/l in pre and post monsoon seasons (Fig.5). So, most of the samples are within the permissible limit in both monsoon.

Magnesium (Mg^{2+}):

Magnesium concentration in groundwater is generally lower than calcium due to the fact that the dissolution of magnesium rich minerals is slow process and that of calcium is more abundant in the earth is crust. In low concentration it is non toxic. However it adds to hardness of water. Magnesium is a common constituent of natural water for domestic use and causes nausea and paralysis The magnesium level in the water samples ranged from 07- 79 mg/l and 05- 256 mg/l in pre and post monsoon seasons (Fig.6). Desirable and maximum permissible limit [5] in drinking water is 30 mg/l and 100 mg/l, higher concentration of magnesium can cause hardness of water and exerts a cathartic and diuretic action[4].

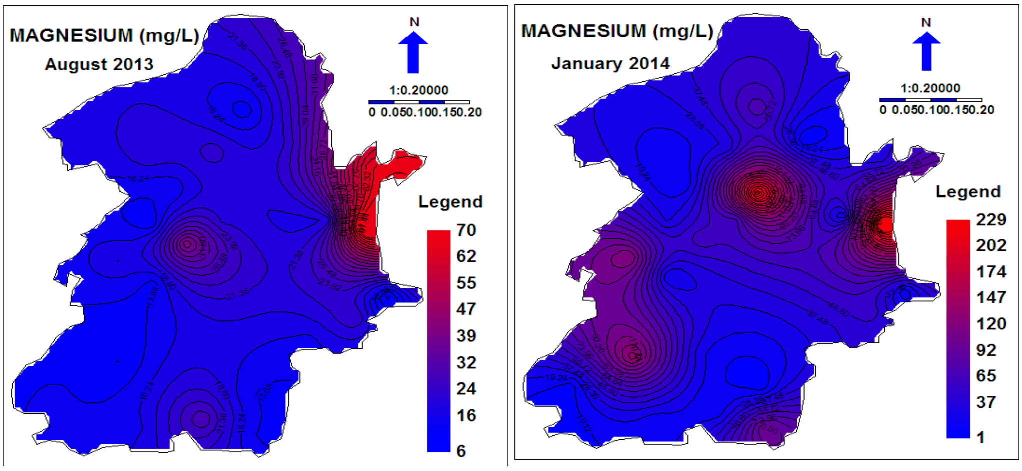

Fig.6: Spatial distribution of Mg of groundwater during both the seasons

Sodium unlike calcium magnesium and silica is not found as an essential constituent of many of the common rock-forming minerals. Sodium toxicity is recorded as a result of high sodium in water as Na% and SAR ratios. Typical toxicity symptoms to plants and trees are burn and dead tissues along the outside edges of leaves[17]. The sodium ranges between 39.3-307.2 mg/ and 9.2-280.6 mg/l during both the seasons (Fig.7). The maximum permissible limit of Na is 200 mg/l[5]. The sodium concentration more than 50 mg/l makes the water unsuitable for domestic use because it causes severe health problems like hypertension. The source of Na^+ into the groundwater is due to the weathering of feldspar untreated domestic waste and due to over exploitation of groundwater[18] and there is dilution in postmonsoon due to recharge. Sodium is found in association with high concentration of chloride resulting in salinity.

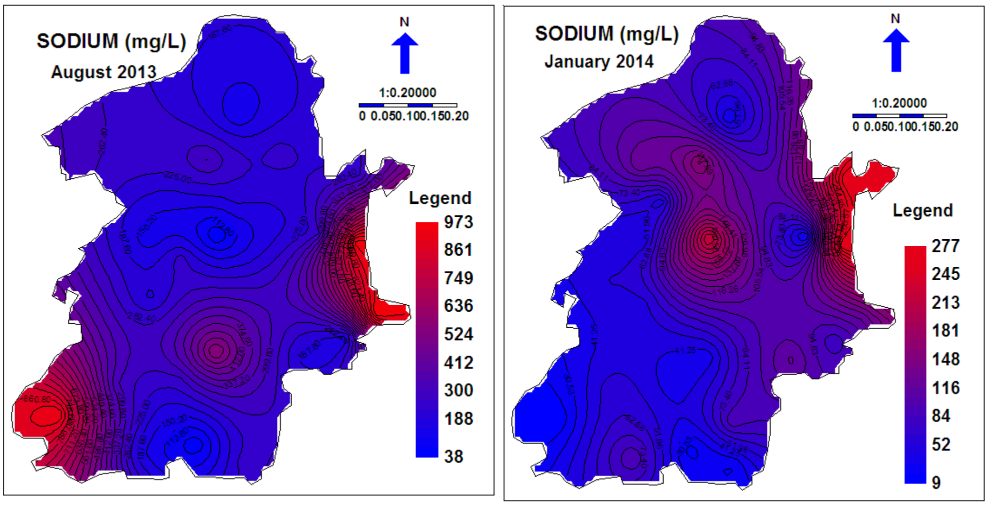

Fig.7: Spatial distribution of Na of groundwater during both the seasons

Chloride (Cl^-):

Chloride is a most common inorganic anion present in water added to it through biogenic sources and indicates the state of contamination[19]. The most common toxicity in water used for irrigation purpose is chloride. Higher chloride concentration intake beyond the tolerance limit in plants develops symptoms like leaf burn and drying of leaf tissues. Excessive dead tissue is often accompanied by early leaf drop[20]. The high chloride content may harm metallic pipes and may harm growing plants[21]. Mostly, the chlorides are found in the form of sodium chloride in the groundwater. Chloride in excess (>250 mg/l) imparts a salty taste and some times higher consumption causes renal stones and asthma in human beings[22]. The chloride concentration varied from 32-590 mg/l and 42.6-262.7 mg/l during pre and post monsoon. 250 mg/l has been established as desirable limit and 1000 mg/l as the maximum limit for chloride in drinking water[5]. Anthropogenic sources are domestic sewage effluents and run off from agricultural field through fertilizers. Higher concentration of chloride in water may be due to the runoff from surrounding catchments areas and discharge from sewage[23]. The spatial concentration of chloride for both monsoons is shown (Fig.8). In this study area few areas has higher concentration in premonsoon and decreased concentration in postmonsoon.

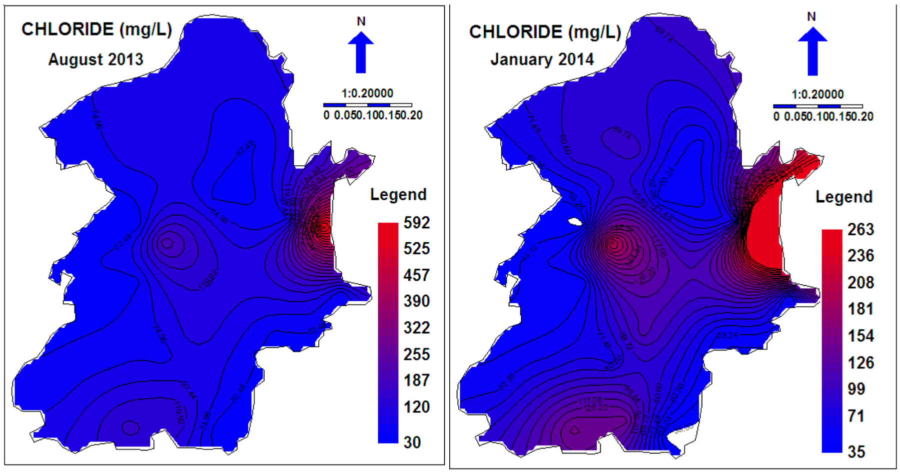

Fig.8: Spatial distribution of Cl of groundwater during both the

Bicarbonate (HCO_3^-):

Bicarbonate was observed 134.2-951.6 mg/l during post-monsoon and pre monsoon 183-1085.8 mg/l due to action of CO_2 upon the basic material of soil and rocks. The relative amount of the anions depends on the pH of the water and other factors. Bicarbonate increase as the pH decreases. Bicarbonates ion served as the main buffer in aqueous freshwater systems and provides CO_2 for photosynthesis. The elevated values suggest that the groundwater system is open to soil CO_2, resulting from the decay of organic matter and root respiration, which in turn ,combines with rainwater to form bicarbonate. Normally in natural water as the pH value ranges from 7.0-8.0 would contain much more bicarbonates than carbonates[24]. Alkalinity of the circulating water is mainly responsible for the increase concentration of fluoride. The spatial variation of both monsoons is shown (Fig.9). The higher concentration of bicarbonate in the water infers a dominance of mineral dissolution and irrigation activities in that area.

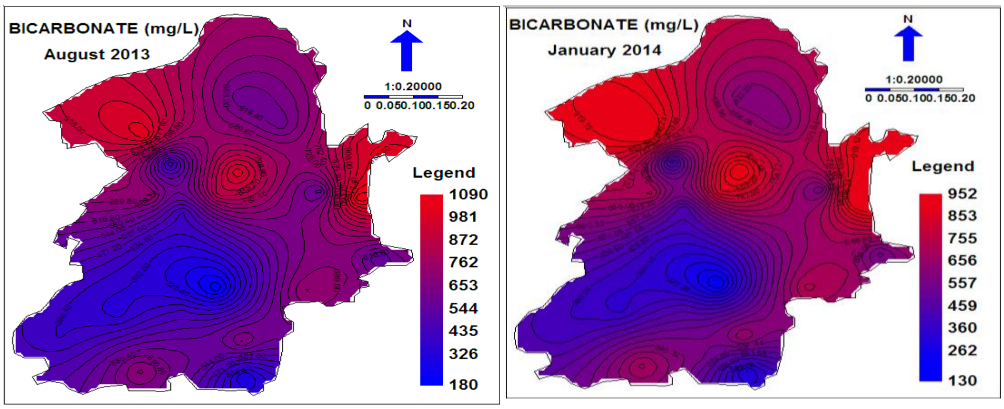

Fig.9: Spatial distribution of HCO3 of groundwater during both the seasons

Hydro geochemical Facies:

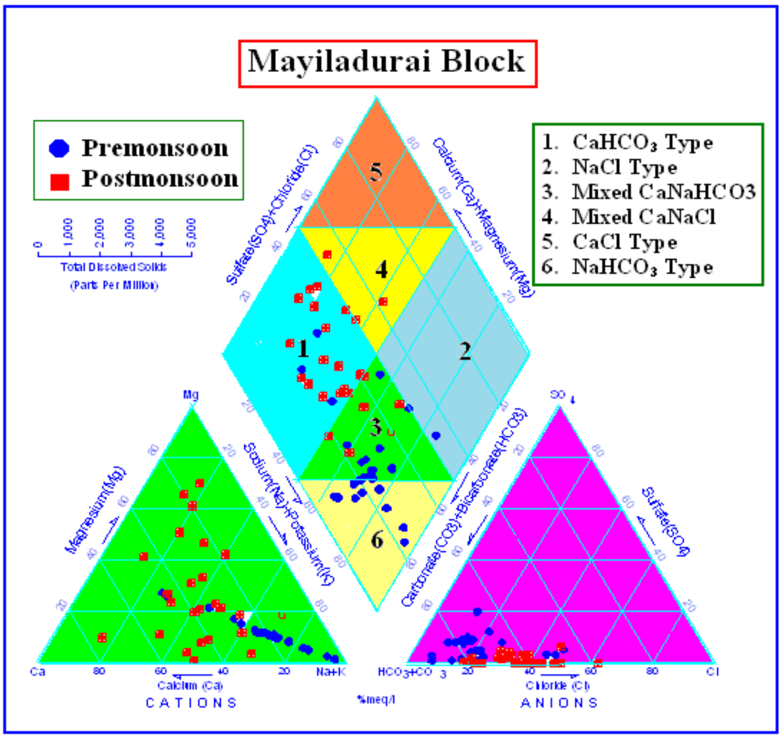

Fig.10: Hydrochemical Facies of groundwater

The geochemical evolution of groundwater can be understood by plotting the concentration of major cations and anions in the trilinear diagram[25] (Fig.10). The concept of hydrochemical facies has been used[26] to denote the diagnostic chemical character of water in hydrologic systems. The faces reflect the effect of chemical processes occurring between the minerals of lithologic formation and groundwater. The plot shows that the groundwater samples fall in the field of Ca^{2+}-HCO_3^-, Ca^{2+}-Na^+-HCO_3^- and Na^+-HCO_3^- due to alkaline earths (Ca^{2+} + Mg^{2+}) exceeds than alkalis (Na^++ K^+) and HCO_3^- exceeds the other ions.

Mechanism Controlling Groundwater Chemistry:

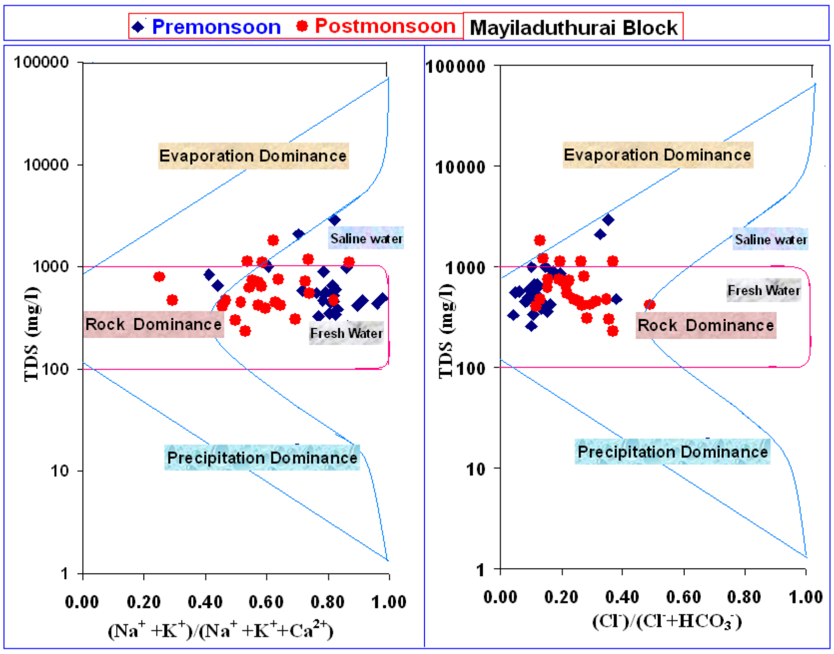

Fig.11: MECHANISM CONTROLLING GROUNDWATER CHEMISTRY

Gibbs diagram (Fig.11) that represent the ratios of (Na^+ +K^+)/ (Na^++ K^++ Ca^{2+}) and Cl^-/ (Cl^-+ HCO_3^-) as a function of TDS are widely employed to understand the functional sources of dissolved chemical constituents such as precipitation dominance, rock dominance and evaporation dominance[27]. The chemical data of groundwater are plotted in the Gibbs diagram. This plot provides very good genetic information about the composition origin and distribution of dissolved constituents in groundwater for better known controlling mechanisms. According to Gibbs classification the majority of groundwater samples are controlled by the rock dominance of major cations and anions. The groundwater samples of the area on the plot TDS versus Cl^-/ (Cl^- +HCO_3^-) show similar variation with that of earlier cation diagram. The rock-water interaction may play major role for the groundwater chemistry of the area[28].

Groundwater Suitability for agricultural purposes:

The suitability of groundwater for irrigation depends upon the mineral constituent present in the water. Water used for irrigation always contains measurable quantities of dissolved substances are called as salts. The salts present in the water besides affecting the growth of the plant directly also affect the soil structure permeability and aeration which indirectly affect the plant growth. Good quality water is essential for achieving maximum crop productivity. Groundwater suitability for irrigation purpose in this study area was assessed using Na% and SAR.

Wilcox Diagram:

Sodium is an important ion used for the classification of irrigation water due to its reaction with soil, reduces its permeability. Irrigation water having high EC content will affect root area and water flow. Increasing of sodium ion ratio in irrigation water will affect the soil where it leads to decrease its porosity and permeability, thus will affect the plant growth or stunted growth (Na%) values was calculated according to the following equation[29] and all concentrations were expressed in meq/l.

$Na^+ \% = (Na^+ + K^+) \times 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$

Sodium percentage values reflected that the water was under the category of good (20-40 Na%), permissible (40-60 Na%) and (60-80 Na%) class[29]. As per Indian Standard[5] a maximum sodium percentage of 60% is recommended for irrigation water. The value of sodium percent are varying from 28% and 97% and 12% to 70% during both the seasons. Based on the above Na% groundwater samples are classified as shown in Wilcox diagram (Fig.12). EC and Na% are plotted in which showed that most of the samples excellent to good, good to permissible doubtful and few samples fall under unsuitable category, indicating the dominance of ion exchange and weathering from litho units of the study area. From the plotted showed that most groundwater samples were good for irrigation.

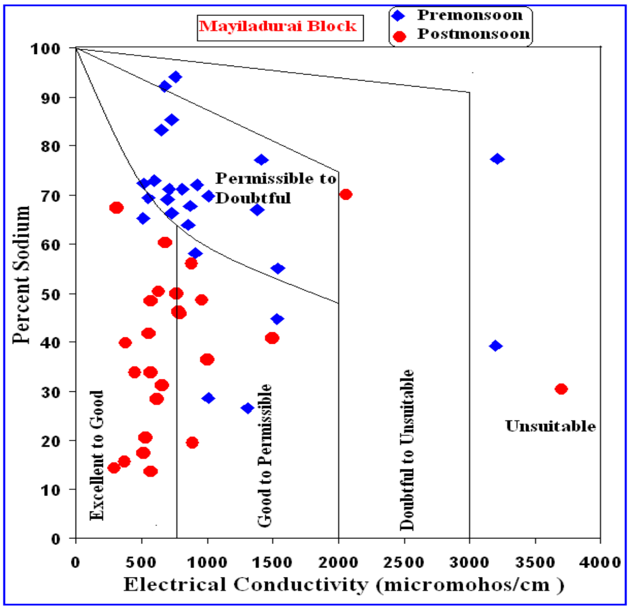

Fig.12: Spatial distribution of EC of groundwater during both the seasons

USSL Diagram:

SAR is another important parameter for determining the suitability of groundwater for irrigation because it is a measure of alkali/sodium hazard to crops. SAR is calculated by the following formula (where the concentration of all ions is in meq/l)[30],

$SAR = Na^{+} / \sqrt{(Ca^{2+} + Mg^{2+}/2)}$

The results of the analyzed samples of the study area for both seasons are plotted on diagram[31]. Water used for irrigation can be classified into four types - C1, C2, C3, C4 based on salinity hazard and S1, S2, S3, and S4 based on sodium hazard. Fig 13 shows the plot of groundwater samples grouped on the above basis. According to the US Salinity Laboratory classification, most of groundwater samples fall under C2S1 and C3S1 which are suitable and which is permissible for irrigation. Thus the groundwater in this area was seen to be suitable for irrigation except very few samples that are poor due to the high salinity based on salinity hazard.

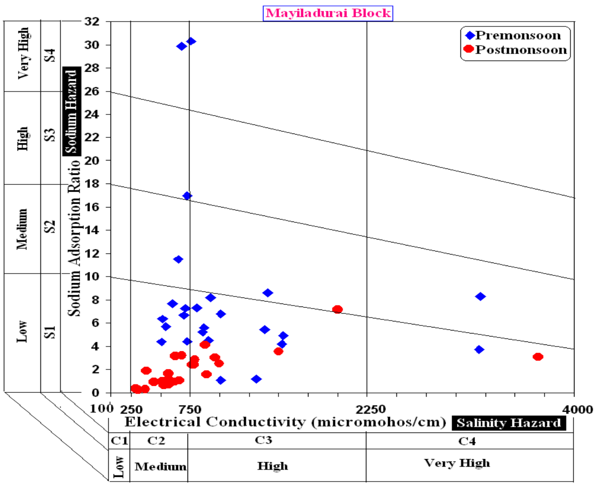

Fig.13: Spatial distribution of EC of groundwater during both the seasons

Permeability index (PI):

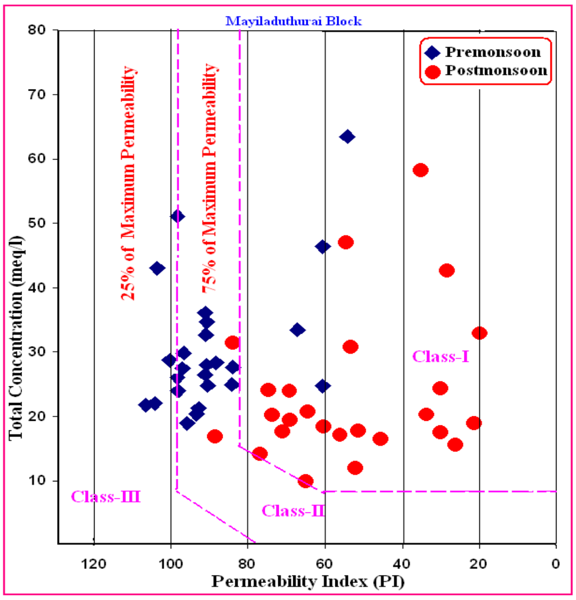

Fig.14: Spatial distribution of EC of groundwater during both the

The permeability index (PI) values also depicts suitability of groundwater for irrigation purposes, since long-term use of irrigation water can affect the soil permeability, influenced by the Na^{+}, Ca^{2+}, and HCO_3^{-} contents of the soil. Doneen [32] have evolved a criterion for assessing the suitability of water for irrigation based on PI. Based on permeability index, (Fig.14) classified the groundwater as class I, class II and class III to find out suitability of groundwater for irrigation purpose. It is calculated by using the formula; where the concentrations are expressed in meq/l

PI- (Na+ + √HCO3-) x 100/ (Ca2+ + Mg2+ +Na+)

As per PI values the groundwater samples fall in class I and class II during both seasons indicate water is good to moderate for irrigation purposes[33].

Conclusions

The groundwater quality in Mayiladuthurai block has been evaluated for their chemical composition and suitability for domestic and irrigation purpose. An investigation was carried out by collecting a total of 50 groundwater samples for two seasons to decipher groundwater quality for determine its suitability for agricultural purposes. The pH of water is slightly acidic to alkaline in nature. High TH and EC in a few places identify the unsuitability of groundwater for drinking and irrigation.. The concentrations of major ions in groundwater are within the permissible limits for drinking except in some places. The piper plot indicates the dominant groundwater was of Ca^{2+}-HCO_3^- type, Ca-Na-HCO3 type and Na-HCO3 type. Gibb's diagram reveals that most of the groundwater samples fall in the rock dominance field. This field indicates the interaction between rock chemistry and the chemistry of the percolation waters under the subsurface. Based on Wilcox classification, most of the samples excellent to good, good to permissible doubtful and very few samples fall under unsuitable category The suitability of groundwater for irrigation was assessed from USSL plot indicates most of the samples fell in C2S1 and C3S1 domain and it is suitable for irrigation purpose. According to permeability index plot samples fell in class I and class II category indicates water is good for irrigation purposes in both seasons. Thus the study suggests appropriate remedial measures to improve the groundwater quality. In general, groundwater in the study area influenced natural and anthropogenic activities.

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