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Deciphering groundwater quality for drinking and irrigation in rural areas of Paramakudi block, Tamil Nadu

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Abstract: *The groundwater quality of Paramakudi block in Tamil Nadu, was assessed for drinking and irrigation water use. Totally, 17 groundwater samples were collected randomly from bore wells and hand pumps. The physical parameters pH, EC have been determined in the field itself and major ions were analyzed in laboratory. There are various water quality parameters such as TH, scholler diagram, piper diagram, index of base exchange, Gibb's diagram, chloro-alkaline indices, corrosivity ratio USSL diagram, ilcox diagram, RSC, permeability index, , to know the suitability of groundwater for irrigation purposes. Based on the analytical results, groundwater in the area is generally moderately hard to very hard, brackish, high to very high saline and alkaline in nature. The erratic behaviors of groundwater geochemical elements were spatially given through GIS study. Sodium ion is the most dominant cations and chloride ion as the dominant anions. Assessment of water samples from various methods indicated that groundwater is chemically unsuitable for drinking and irrigation uses in few areas. In general, groundwater in the study area is influenced by both natural and anthropogenic activities.*

Keywords – *Groundwater, spatial variation, domestic, irrigation, ramnad .*

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I. Introduction

Water is essential to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of human body. Water is an essential natural resource and an absolute necessity for sustenance of life. Water is not only the most important essential constituent of all human being, animals, plants and other organisms, but it is also pivotal for the survivability of the mankind in the biosphere. Most of the surface waters in India, including both rivers and lakes are getting increasingly polluted due to onslaught of human activities of diverse nature. The demand for water has increased over the years and this has led to water scarcity in many parts of the world. India is heading towards a freshwater crisis mainly due to improper management of water resources and environmental crisis is already evident in many parts of India. Water supply and scarcity has received increasing attention primarily driven by alarming World Health Organization report that 1.1 billion people lack access to safe and affordable water for their domestic use. The growing scales of cultural and technological development pose new threats to water quality. The predicted water demand for future is alarming. Groundwater based irrigated agriculture and drinking water supply has increased many folds during the last few decades and sustainable development of groundwater resources has become the most important in groundwater management. Groundwater is the primary source of water for human consumption as well as for agricultural and industrial uses in many regions all over the world. Due to inadequate availability of surface water, groundwater remains the requirement for human activities. Groundwater remains the only option to supplement the ever increasing demand of water. It is estimated that approximately one-third of the world's population use groundwater for drinking [1]. It accounts for nearly 80% of the rural domestic water needs and 50% of the urban water needs in the developing countries in India. The quality of the water resources is being increasingly degraded as consequence of its intensified anthropogenic exploitation. In developing countries like India, around 80% diseases are directly related to poor drinking water quality and unhygienic conditions [2]. Groundwater contamination by different pollutants, natural geological formations and due to the intensive agricultural and urban development has placed the whole environment at greater risk. Poor quality of water adversely affects the human health and plant growth. Numerous works have reported in both developed and developing nations that urban development, industrial and agricultural activities directly or indirectly affect groundwater quality [3]. It has been estimated that once pollution enters the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of groundwater aquifer and rendering groundwater supplies unsuitable for consumption and other uses. Water quality analysis is one of the most important aspects in groundwater studies. The hydrochemical study reveals quality of water that is suitable for drinking, agriculture and industrial purposes. Groundwater quality monitoring is a tool which provides important information of water management. In this regard, the present work is to discuss the major ion chemistry of groundwater of Paramakudi taluk of Ramnad district and its suitability for drinking and irrigation purposes.

II. Study Area

The Paramakudi area is located between 9° 27’ 39” N and 9° 37’ 26” N latitude and 78° 21’50” E and 78° 37’ 55” E longitude (Figure 1). Paramkudui is the southern part of Tamil Nadu state on East Coast of India. Another name of Paramakudi is also called as Parambai. Parambai that means the Vaigai river cross the town, that means face of the vaigai so called the name. The river vaigai flows through the Paramakudi on its way to the Bay of Bengal. It is located in Ramnad district of Tamil Nadu, India. Paramakudi is the gateway for entrants to Madurai, Sivagangai and Ramnad districts from north and west. The area has a hot tropical climate, the temperature ranges from 22.3ºC to 37.8ºC and the relative humidity is high at 79% on an average and it ranges from 80% to 90% in coastal areas. The northeast monsoon chiefly contributes to the rainfall. Most of the precipitation in the form of cyclonic storms caused due to the depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible. Agriculture is the main source of livelihood. The main cultivation crops in this area are paddy, millets, chillies, groundnut, gingelly, cotton, pulses, vegetables etc. The soil of the area is covered by deep red, black clayey soil and moderately deep black soil type. Black soil is rich source of calcium, potassium and magnesium, but has poor nitrogen content. The soils are mostly black or black to brownish colour. Alluvial soils occur along the river courses of vaigai. Calcium carbonate concentrations of various sizes and shapes are present in majority of the black soil area and this affects the fertility of the soils. The potash content of soil is high in the area. Groundwater occurs in phreatic aquifer, in generally colourless, odourless and slightly alkaline in nature. Brackish nature of groundwater restricts the use of groundwater for irrigation.

Fig.1 Sampling location map in the study area

III. Methodology

A total of 17 groundwater samples were collected from the study area during January 2016 after a detailed well inventory survey. The location of the samples were marked using a handheld global positioning system (GPS). The selected wells are used for domestic and agricultural purposes. The physical parameters pH and Electrical Conductivity (EC) have been determined in the field itself. Cleaned polythene bottles with 1 liter capacity were used as sample containers. After collection, the bottles were sealed, neatly labeled and carried to the laboratory. The chemical analyses were carried out for the major ion concentrations of the groundwater samples collected from different locations using the standard procedures as per standard methods [4]. Chemical constituents such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), bicarbonate (HCO_3^{-}), sulphate (SO_4^{2-}), nitrate (NO_3^{-}), fluoride (F^{-}) were determined for the groundwater samples.

IV. Results and Discussions

Groundwater chemistry changes as the water flows along in the underground environment, increasing in dissolved solids and major ions. Generally the groundwater in the study area is colourless, odourless and slightly alkaline nature. To understand the groundwater quality in and around the study area 17 groundwater samples were considered.

4.1 Spatial Variation of General Parameters

4.1.1 Hydrogen ion concentration (pH)

The pH of water changes with the production of hydrogen or hydroxyl ion during different chemical reactions. Normally, water pH ranges from 6 to 8.5. It is noticed that water with low pH is tend to be toxic and with high degree of pH it is turned into bitter taste. The pH values of the groundwater samples ranged from 7.6 to 8.6 neutral to alkaline nature. The pH variations (Figure 2) in the study area reflect that groundwater is not highly impacted by any of the microbial or other processes. All the water samples fall in the safe limit of pH standard (6-8.5) for irrigation purpose [5]. Most of the locations in the study show alkaline nature of groundwater may be due to the presence of fine aquifer sediments mixed with clay and mud, which are unable to flush off the salts during the monsoon rain and hence maintained longer no other season [6].

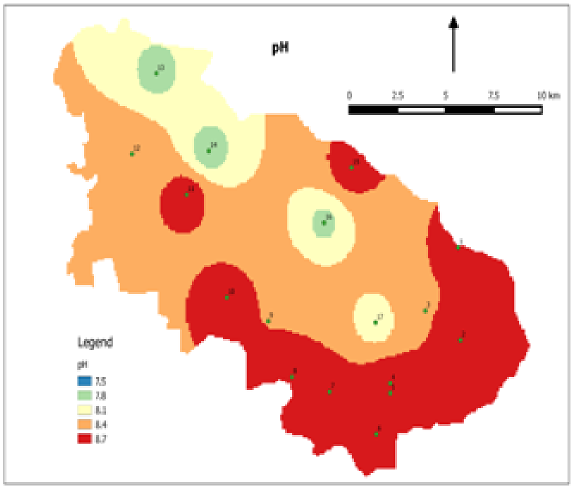

Fig.2 Spatial distribution of pH

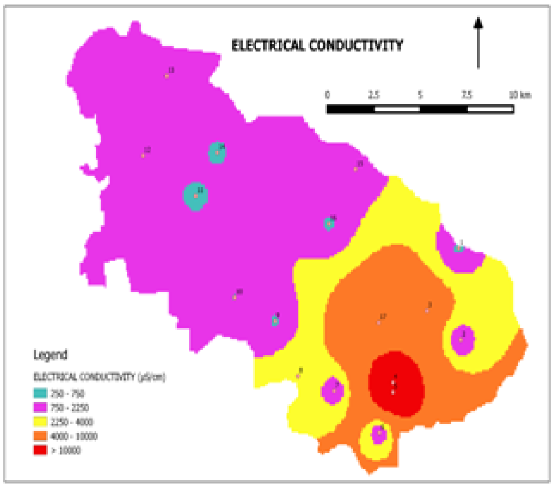

Fig.3 Spatial distribution of EC

4.1.2 Electrical Conductivity (EC)

Electrical conductivity (EC) is a measure of water capacity to convey electric current and importance to salinity; which greatly affects the taste. Chemically pure water has a low electrical conductivity, indicating that it is a good insulator. A small amount of dissolved mineral matter will increase the conductance of the water [7]. EC and ionic concentrations in the groundwater may be attributed to geochemical processes and anthropogenic activities [8]. It directly related to concentration of ionized substances in water and may also be related to problems in excessive hardness. It signifies the amount of total dissolved salts. EC also affects the salt intake capacity of the plants through the roots. The EC values ranged from variation in 610µS/cm to 16180 µS/cm, it can be concluded from the spatial distribution map (Figure 3) that the type of groundwater in the studied area is excessively mineralized water due to the salinity. The higher EC may cause a gastrointestinal irritation in human beings. The results clearly indicate that water in study area was considerably ionized and has the higher level of ionic concentration activity due to excessive dissolved solids High values of EC may be due to long residence time and existing lithology of the region [9]. 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.

4.1.3 Calcium

Calcium content is very common in groundwater, because they are available in most of the rocks, abundantly and also due to its higher solubility, it is abundant almost in all soils [9]. Calcium is the most abundant element of the alkaline-earth metals and is an essential element for plant and animal. It is produced as a result of dissolution processes of sedimentary rocks (calcite, aragonite, limestone, dolomite and gypsum) and from weathering of igneous rocks like (pyroxene, amphibole and plagioclase feldspar). Calcium also occurs in silicate minerals that are produced in metamorphism [10]. But Calcium is an essential nutritional element for human being and maintaining the structure of plant cells and soils [11]. About 95% calcium in human body stored in bones and teeth. The spatial variation map (Figure.4) ranges from 14 mg/l to 300 mg/l. Dissolve Ca and Mg in water are the two most common minerals that make water hard. Insufficiency of Ca causes severe rickets; excess causes concentrations in the body such as kidney or bladder stones and irritation in urinary passages in humans [12]. If the presence of calcium is more in drinking water, it will cause formation of renal calculi (kidney stones). Acceptable limits of calcium in drinking water are 75 mg/l (200 mg/l in case of no other alternative source) [13]. In some of the area it falls above the standards of 75 mg/l. The higher value is mainly attributed due to the abundant availability of lime stone in the area.

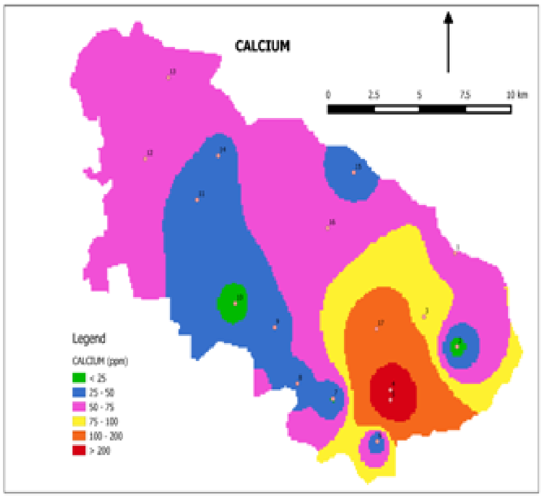

Fig.4 Spatial distribution of Calcium

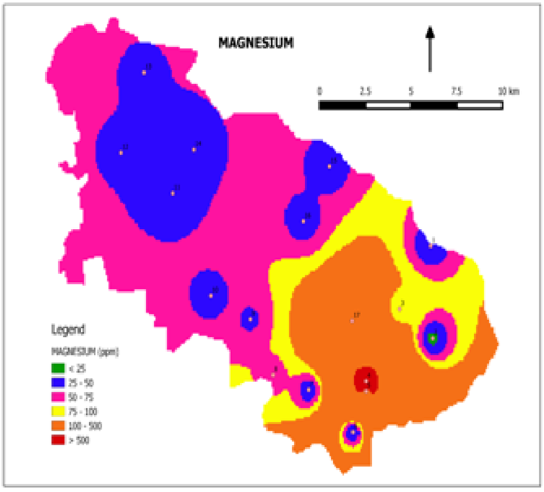

Fig.5 Spatial distribution of Magnesium

4.1.4 Magnesium

Mg usually occurs in lesser concentration than calcium due to the fact that the dissolution of magnesium rich minerals is slow process and calcium is more abundant in earth crust [14]. Magnesium ions are smaller than sodium and calcium ions and it is one of the necessary elements for plants and animals [10]. Dolomite, limestone and clay minerals are considered as essential sources for magnesium ion. Magnesium is also found in igneous rocks and minerals such as (olivine, pyroxene and amphiboles) and metamorphic rocks such as (serpentine and talc) [15]. It is an essential for proper functioning of living organisms and found in minerals like dolomite, magmagnesite etc. Human body contains about 25 g of magnesium (60% in bones and 40% in muscles and tissues). Spatial variation map (Figure 5) of magnesium ranges from 19 to 657 mg/l. Acceptable limit of magnesium in drinking water is 30 mg/l (100 mg/l in case of no other alternative source) [13]. The geochemistry of the rock types may have an influence in the concentration of Mg in groundwater. High concentration of Mg may cause laxative effect [12] and low concentration somewhat effects health of residents as it is essential for human body.

4.1.5 Alkalinity

Alkalinity is due to the presence of one or more ions in water including carbonate or hydroxides and bicarbonate. It can be defined as the capacity to neutralize acid. Moderate concentration of alkalinity is desirable in most water supplies to stable the corrosive effects of acidity. The spatial variation (Figure 6) of alkalinity in the study area has found to be 130 to 1000 mg/l. The weathering of rocks is the potential sources of alkalinity. Bicarbonate is the major anion in the study area. The standard desirable limit of alkalinity in potable water is 200 mg/l as per Indian standards. However, the alkalinity of all samples was above the maximum permissible limit of 600 mg/l [13]. Similar to pH, alkalinity usually has no direct impact on human health.

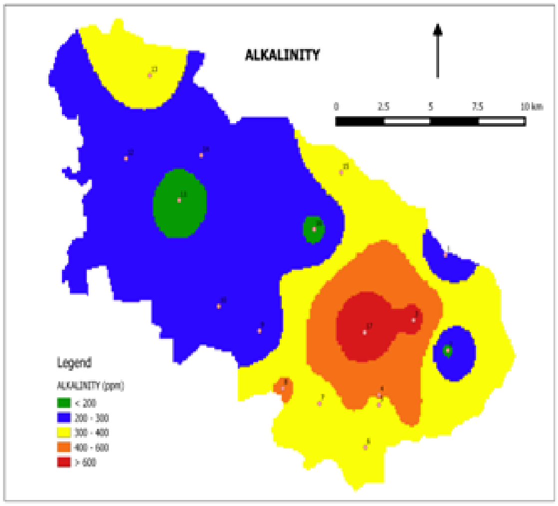

Fig.6 Spatial distribution of Alkalinity

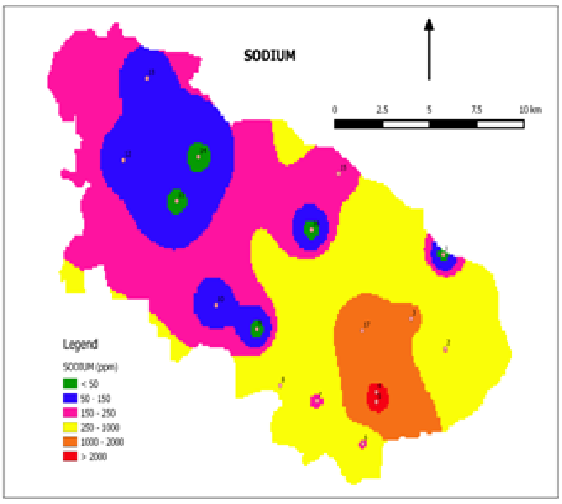

Fig.7: Spatial distribution of Sodium

4.1.6 Sodium

Sodium is a metallic element and found in less quantity in water. The source of sodium in groundwater and comes from erosion of alkalinity feldspar and evaporation rocks and from ionic exchange of clay minerals [16]. Most of salts and sodium ions have high solubility in water; the most soluble salt among them is sodium chloride (NaCl) while the least is sodium bicarbonate ($NaHCO3$) their solubility increases normally at high temperature [10]. Human activities can have significant influences on the concentration of sodium in ground and surface water. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc. No standard limits have been provided by the Bureau of Indian Standards for level of sodium and potassium in drinking water. Concentration higher than limit causes a salty taste for drinking water. Sodium is an abundant ion in most of the hard rocks, due to rock geogenic and anthropogenic source. The spatial variation map (Figure 7) was in the range of 19 to 2238 mg/l. Sodium imbalance in drinking water has been reported to cause a large number of lives threatening diseases. Hence, the excess consumption of sodium has been recognized as risk factor in hypertension as per WHO and high sodium ion in irrigation water may cause salinity problems.

4.1.7 Potassium

Potassium is silver white alkali which is highly reactive with water. Potassium is slightly less common tna sodium in igneous rocks but more abundant in all sedimentary rocks. The main source of potassium is the products formed by weathering of igneous minerals like (orthoclase, biotite and feldspathoid leucit) and sedimentary rocks. Potassium is commonly present in clays like illite and evaporate rocks include sylvite and other potassium salts and organic remains of plants [10]. Potassium is an important fertilizer, strongly held by clay particles in soil and it leaches through the soil to reach the groundwater. Potassium is an essential element for plants and animals; however, high concentration may be harmful to human nervous and digestive systems due to its laxative effects. Potassium deficient in rare but may led to depression, muscle weakness, heart rhythm disorder etc. Agricultural activates also contribute to higher potassium levels in groundwater. The elements present in plants material and are lost from agricultural soil by crop harvesting and removal as well as leaching and runoff on organic residues [17]. Potassium in sample ranges from 4 to 20 mg/l (Figure 8). Potassium contamination in groundwater is due to the application of inorganic fertilizers at greater than agronomic rates. Loss of nutrients, including potassium, from agricultural land have been identified as one of the main causative factors in reducing water quality in many parts of arid and semi-arid regions[18].

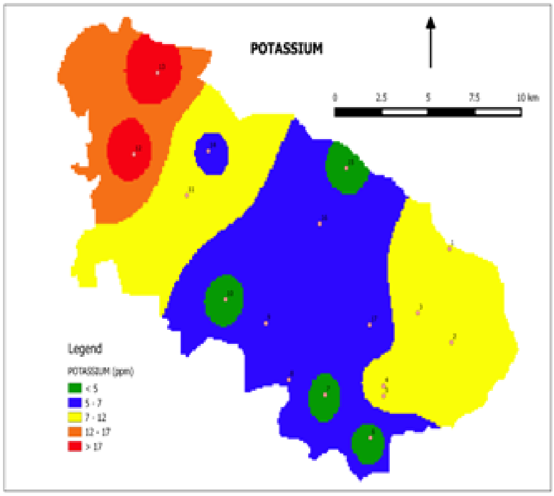

Fig.8 Spatial distribution of Potassium

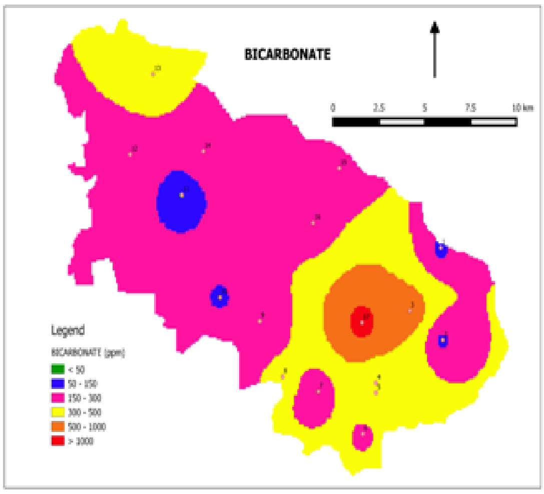

Fig.9 Spatial distribution of Bicarbonate

4.1.8 Bicarbonate

Bicarbonate ions are considered the source of water alkalinity. Alkalinity is the ability of water for interaction with ion of hydrogen (Faure, 1998). CO2 gas in the atmosphere or in the soil dissolved in water is the principle source of bicarbonate, in addition to solution of carbonate rocks and oxidation of organic matter [10]. When pH<8.2 the hydrogen ion is added to the carbonate and become dissolved bicarbonate, but when the pH>8.2 the process of bicarbonate depletion to carbonate in solution becomes high [19]. It is the standard alkaline constitute found almost all surface and groundwater bodies and therefore affects alkalinity and hardness of water. Mostly bicarbonates are soluble in water i.e., bicarbonate of magnesium and calcium etc is the main causes of hardness of water. The hard water is not suitable for drinking purpose and causes the gastro diseases. Bicarbonate (Figure 9) was observed from 49 to 1220 mg/l due the action of CO_3 upon the basic material of soil and rocks. The elevated vales suggest that the groundwater system is open to soil CO_3, resulting from the decay of organic matter and root respiration, which in turn combines with rainwater to form bicarbonates. The pH of water less than 4 indicates the presence of carbon content, while between 4.5 to 8.5 shows the bicarbonate solution and more than 8.5 pH notices the carbonate availability. Bicarbonate is a major element in human body, which is necessary for digestion. Bicarbonate has no known adverse effects on human health, if it exceeds 300 mg/l in the drinking water, as it may leads to kidney stones in the presence of high concentration of Ca, especially in dry climatic conditions. No standard limits have been provided by the Bureau of Indian Standards for level of carbonate and bicarbonate in drinking water.

4.1.9 Chloride

Chloride is a minor element of the earth's crust, but it is major dissolved constituent of most natural water. The source of chloride in groundwater is from dissolution of sedimentary rocks particularly evaporates like halite and sylvite and ancient sea water entrapped in sediments [19]. Chloride is also abundant in the minerals found in igneous rocks like apatite, feldspathoid and sodalite. Chloride is also obtained from the dissolution of salts of hydrochloric acid as NaCl, $NaCO_2$ and added through industrial and domestic waste water, sewage, sea water etc. Surface water bodies often have low concentration of chloride as compared to groundwater. Excess chloride (>250 mg/l) imparts a salty taste to water. Chloride in drinking water is not generally harmful to human unless present in higher concentration. High chloride concentration affects the aesthetic property of water including taste and renders it unsuitable for drinking purpose [20]. Consumption of high-chloride water leads to health issues related to hypertension, ventricular hypertrophy, osteoporosis, renal stones, kidney disease, heart disease and asthma [21]. Soil permeability and porosity also plays an important role in building up the chloride value. In the present study, chloride content in the groundwater samples (Figure10) ranged from 57 to 4538 mg/l. Acceptable limits of chloride in drinking water is 250 mg/l (1000 mg/l in case of no other alternative source) [13].

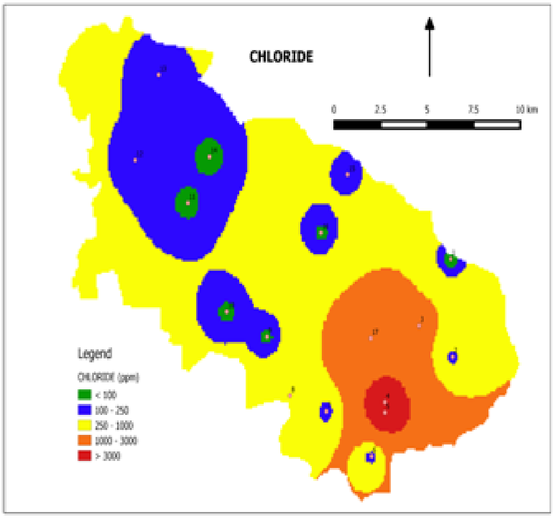

Fig.10 Spatial distribution of Chloride

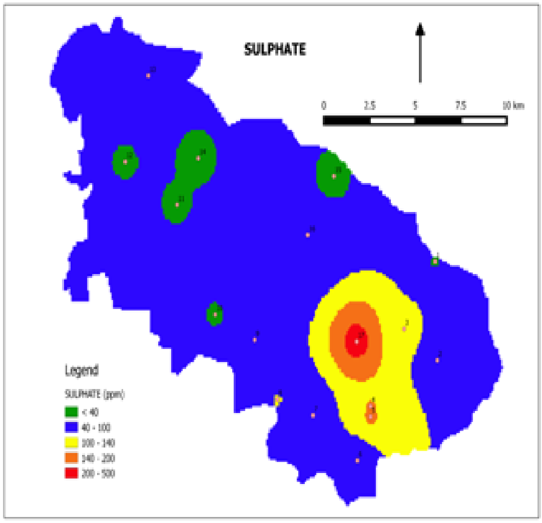

Fig.11 Spatial distribution of Sulphate

4.1.10 Sulphate

The natural source of sulphate ions in groundwater is dissolution of sulphate minerals that are found in sedimentary rocks such as gypsum and anhydrite. Sulphate mainly derived from the dissolution of salts of sulfuric acid and abundantly found in almost all water bodies. Sulphate may come from into groundwater by anthropogenic or industrial addition in the form of sulphate fertilizers [22]. The element is essential in the life processes of plants and animals. High concentration of Na and Mg sulphate exerts a carthartic action in human beings. It is also associated with respiratory illness. Sulphate is generally considered to be non-toxic. However, high amounts of various sulphate salts may give drinking water an offensive taste and can have a laxative effect that may lead to intestinal discomfort, diarrhea and consequently dehydration [23]. The sulphate content of the samples (Figure 11) ranged from 31 to 234 mg/l. Acceptable limits of sulphate in drinking water is 200 mg/l (400 mg/l in case of no other alternative source) [13]. The low levels of sulphate could be as a result of microbial action capable of reducing SO_4^{2-} to S^- leading to depletion of sulphate in the study area. High sulphate concentration in drinking water causes gastrointestinal irritation with Na or Mg can have a cathartic effect on consumers. Samples with higher concentration of sulphate in drinking water are associated with respiratory problems [24]. Concentrations of more than 750 mg/l, along with Mg, may have laxative effect [12].

4.1.11 Nitrate

The main sources of nitrate in water are human and animal waste, use of fertilizers and chemicals, industrial effluent, sewage through drainage system [25]. The chemical fertilizer is the main source of the ion. Nitrate generally occurs in trace quantities in surface water but may attain high level in some groundwater. It is well known that from agricultural areas where there is intensive use of chemicals and organic substances, discharge of domestic wastes and leachates from dump sites are one of the important sources for groundwater nitrate for the past two decades [20]. Higher nitrate concentration (50 mg/l) may result in stomach cancer in humans [26]. Health related issues in humans due to high nitrate concentration in drinking water calls routline monitoring of the water resources. Crops are relatively unaffected until nitrogen exceeds 45 mg/l [27]. The nitrate concentration (Figure12) in groundwater collected from the study area ranged between 7 to 337 mg/l. Hence, as far most of the samples are within the permissible limit and very few samples (3) exceed limit. The origin of nitrate is derived may be from agricultural area due to leaching process from plant nutrients, nitrate fertilizers and poor sanitary condition.

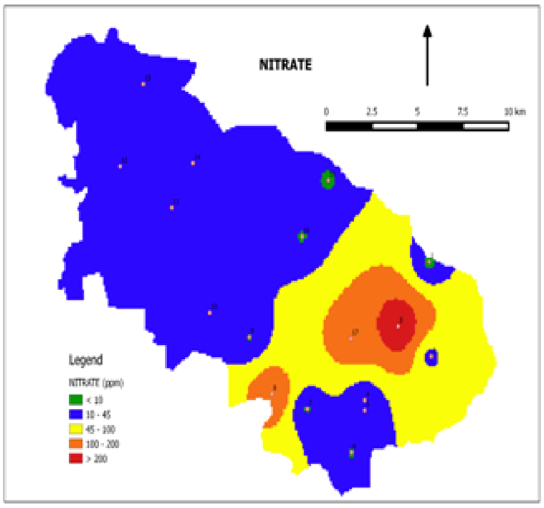

Fig.12 Spatial distribution of Nitrate

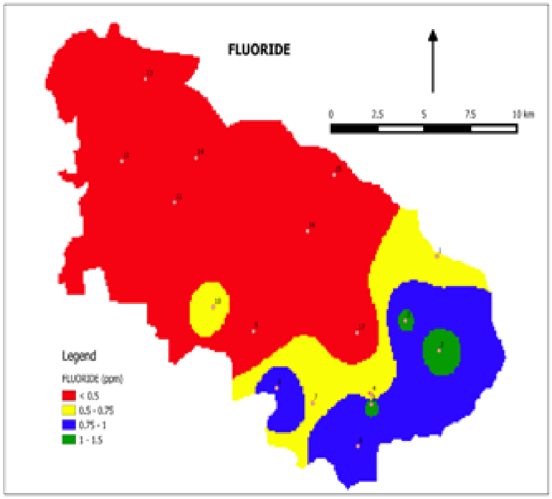

Fig.13 Spatial distribution of Fluoride

4.1.12 Fluoride

Fluoride content is an important factor for the development of normal bones and teeth. Excessive fluoride get deposited on the teeth causes dental fluorosis, deposited on bones cause skeletal fluorosis and cripplinf fluorosis. Bedrock containing fluoride minerals is generally responsible for high concentration of this ion in groundwater. Fluoride normally accumulates in the bones, teeth and other calcified tissues of the human body. Excess of fluoride in water causes serious damages to the teeth and bones of the human body, which shows the symptoms of disintegration and decay, diseases called dental fluorosis (>1.5 mg/l) and skeletal fluorosis (>3 mg/l) [28]. A low concentration (atleast 0.5 mg/l) of fluoride in drinking water is beneficial, since it can help to prevent dental carries. According to UNESCO specifications, water containing more than 1.5 mg/l of fluoride cause mottled tooth enamel in children and are not suitable for drinking purpose. The fluoride concentration (Figure 13) in groundwater of the area varies from 0 to 1.22 mg/l.

4.2 Suitability of groundwater for domestic and Agriculture purposes

Water for human consumption must be free from organisms and chemical substances in concentration large enough to affect adversely. Groundwater suitability depends on several parameters (major and minor elements, inorganic, organic chemicals and biological constituents). For the purpose of evaluating the suitability of groundwater for human drinking, BIS were used to determine its suitability as drinking water in the study area.

4.2.1 Drinking water quality assessment:

Total hardness (TH) and total dissolved solids (TDS) and are two important parameters in assessing drinking water quality. As per WHO standards a level of TDS lower than 1000 mg/l is acceptable for human consumption. TDS express the degree of salinity of a medium. The TDS values of the groundwater samples in the study area were in the range of 307 to 8037 mg/l. The concentration level of TDS in groundwater can be classified as fresh groundwater (TDS<1000 mg/l), brackish water (1000<TDS>1000 mg/l) and saline water (TDS>10000 mg/l) [29]. Higher concentration of TDS causes gastrointestinal irritation in human and may also leads to laxative effects. Total Hardness (TH) is not a specific constituent of water. It is due primarily to the presence of ions of calcium and magnesium in water. Consumption of water with high TH may raise the risk of calcification of arteries, urinary concretions, diseases of kidney or bladder or stomach disorders. Both these elements are essential for the human body. The TH values of the groundwater samples in the study area were in the range of 120 to 3450 mg/l. The maximum permissible level of hardness in drinking water is 600 mg/l as per Indian standards. The TH in groundwater can be classified as soft water (TH<150mg/l), moderately hard water (150>TH>300mg/l), hard water (300<TH>450mg/l) and very hard water (TH>450mg/l) [30]. The plot (Figure14) of TDS versus TH suggests that the groundwater samples lie in the different quality levels among the samples. 1 samples falls in soft-fresh water 9 samples belonging to moderately hard- fresh water is suitable for human consumption with acceptable degree of hardness, 4 samples falls in very hard –brackish water 2 samples in hard-fresh water and 1 sample in hard-brackish water belongs to hard in nature.

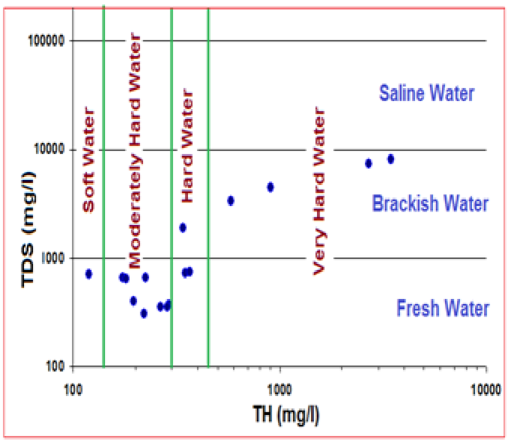

Fig.14 Plot of TDS versus TH

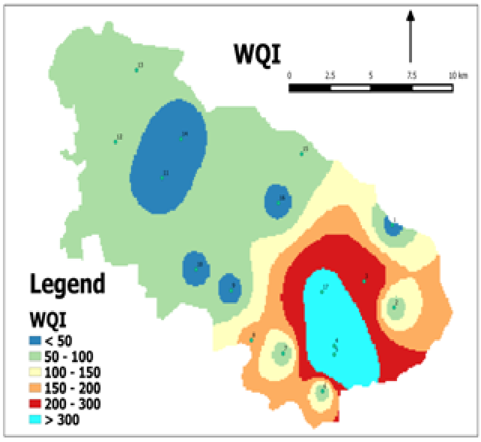

Fig.15 Spatial distribution of Water Quality Index

4.2.2 Water Quality Index (WQI)

Water quality index is a very useful tool for communicating the information on overall quality of water. WQI helps for the better management of water quality issues and improve the effectiveness of protective measures. WQI is a mathematical tool which can transform large amount of water quality data into a single number which represents the water quality level. It is an important parameter to classify water quality for suitability of drinking purposes[31]. In this research work WQI has been applied to evaluate the suitability of groundwater for drinking purpose. The WQI range and type of water can be classified as excellent (<50); good water (50-100); poor water (100-200); water unsuitable for drinking purposes (>300). The calculated WQI (Figure15) value of the study area ranges from 22.27 to 595.36.

4.2.3 Scholler Diagram

The scholler diagram (Figure 16) shows a general increase of mineralization along the flow path. Groundwater ions is discussed by means of combination its major ions and minor ions and the result obtained indicates that Cl is dominant and F as the least. The diagram [32] is used to present average chemical composition of Paramakudi area groundwater. The relative tendency of ions in mg/l shows Na>Mg>Ca>K and Cl>HCO3> CO3>SO4>NO3>F.

4.2.4 Hydrochemical Facies

The hydrochemical evolution of groundwater can be understood by plotting the major cations and anions in the piper trilinear diagram [33]. The diagram reveals similarities and differences among water samples because those with similar qualities will tend to plot together as groups [34]. Hydro-geochemical facies interpretation is a useful tool for determining the flow pattern, origin of chemical histories of groundwater. The Rock Work software was used for plotting this diagram to display the relative concentration of the different ions in water samples in the study area. The piper diagram is useful in bringing out chemical relationships among water in more definite terms [35]. The plot shows (Figure 17) that the groundwater samples fall in $CaHCO_2$ type, NaCl type, Mixed $CaNaHCO_3$ type and mixed CaMgCl type facies.

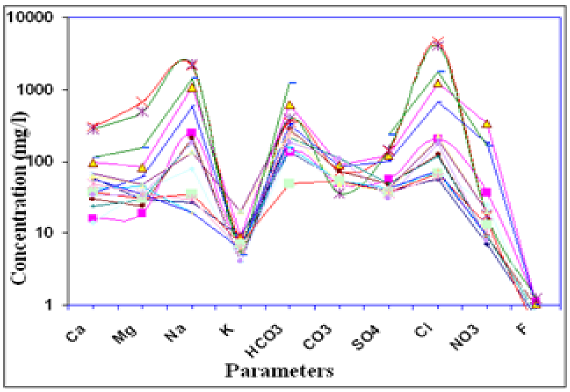

Fig.16 Scholler diagram

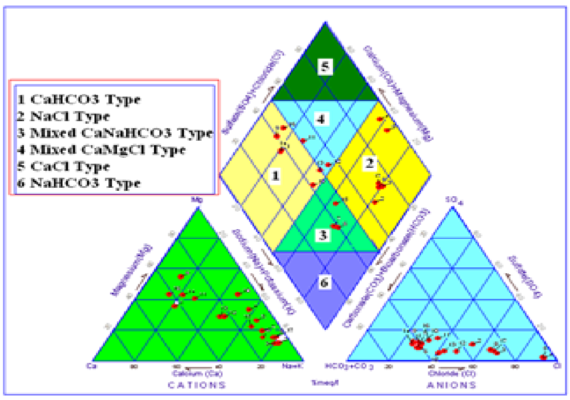

Fig.17 Piper trilinear diagram

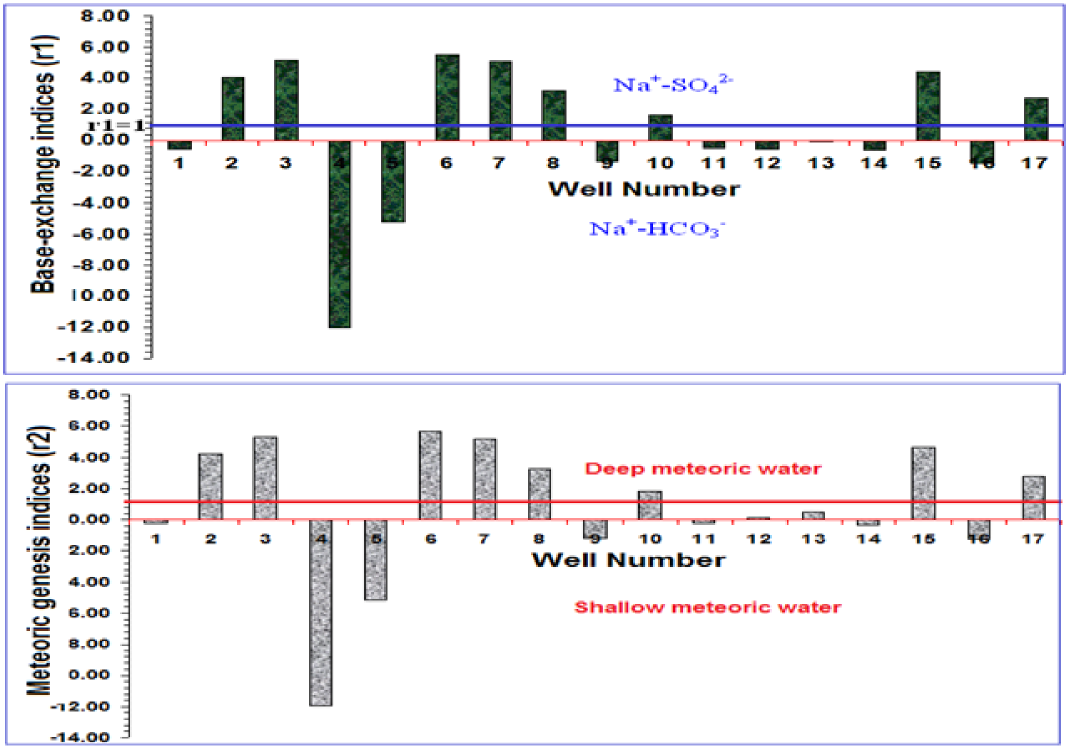

Fig.18 Base Exchange indices and Meteoric exchange Indices

4.2.5 Base exchange indices and Meteoric exchange:

According to [36], base exchange equations are as follows:

Base Exchange= $(Na^+$-$Cl^-)/SO_4^{2-}$ meq/l----------------(1)

Meteoric genesis= $[(K^++Na^+)$-$Cl^-]/SO_4^{2-}$ meq/l-------(2)

Matthess (1982) classified the properties of groundwater based on the predominant of chemical constituent of Na^+-SO_4^{2-} and Na^+-HCO_3^- type. Where r1 is the base-exchange index and Na^+, Cl^- and SO_4^{2-} concentrations are expressed in meq/l. If r1<1, the groundwater sources are Na^+-SO_4^{2-} type, while r1>1 indicates the sources of Na^+-HCO_3^- type. Base exchange indices as indicators of salinzation or freshening of aquifers.

The base-exchange (Figure 18) indices (r1) are shown in diagram about 8 groundwater samples are classified as Na^+-SO_4^{2-} type (r1<1) and 9 groundwater samples are Na^+-HCO_3^- type which can be attributed to the geological formations of this region.

Meteoric genesis indices

The groundwater sources can also be classified based on meteoric genesis index and can be computed using the equation [37].

$R2=(K^++Na^+)$-$Cl^-/\ SO_4^{2-}$

where r2 is the meteoric genesis index and the concentration of K^+, Cl^- and SO_4^{2-} are expressed in meq/l. If r2<1, the groundwater source is of deep meteoric water percolation type while r2>1 indicates that it is of shallow meteoric water percolation type. The values of meteoric genesis indices (r2) are also shown in (Figure 18) based on 8 samples falls under deep meteroric water type and 9 water types are shallow meteroric water types.

4.2.6 Mechanisms Influencing the Groundwater Chemistry

To know the groundwater chemistry and the relationship of the chemical components of water from their respective aquifers such as chemistry of the rock types, chemistry of precipitated water and rate of evaporation, [38] Gibbs has suggested a diagram in which ratio of dominant cations are plotted against the values of total dissolved solids (TDS). Gibbs diagram, representing for cations and anions as a function of TDS is widely employed to assess the functional sources of dissolved chemical constituents, such as evaporation dominance, rock dominance and precipitation dominance. The predominant samples fall in the rock-water interaction dominance and few samples fall in the evaporation dominance field of the Gibbs diagram (Figure 19). This reflects the lithology is the main factor for the chemistry of water in addition to intensive irrigational practices and also the percolated waters under the subsurface in the study area.

4.2.7 Metasomatism of Groundwater

Metasomatism is a process in which underground formations may sometimes absorb and exchange their cations with the anions present in the water. Kaolinite, illite, halite and chlorite are some of the clay minerals in which the ions are held and hence the exchange capacity is lesser. In case of surface water, the number of ions are more and hence exchange capacity is also very high. Schoeller (1965) proposed a measure, called Index of Base Exchange (IBE), to describe this metasomatism taking place in groundwater. Based on the two indices prepared by schoeller, the study area can be divided into positive and negative zones, demarcating the area of recharge and discharge respectively [39]. There are two chloro-alakline indices, CAI1 and CAI2 for the interpretation of ion exchange between groundwater and host environment. The CAI are calculated using the below the formula,

CAI 1= [Cl-(Na+K)]/Cl and

CAI 2=[Cl-(Na+K)]/SO_4+HCO3+CO_3+NO_3

Positive CAI indicates the direct base exchange reaction or chloro-alkaline equilibrium. If the exchange is in the reverse order, then the exchange is indirect and the indices are found to be negative, indicating chloro-alkaline disequilibrium. These reactions are known as cation-anion exchange reactions i.e. ion exchange between the groundwater and its host environment during residence or travel in the subsurface formation. In the study (Figure 20), CAI-1 values ranges from -1.66 to 0.53 while CAI-2 values ranges from -0.90 to 3.10. CAI 1, 1 calculation shows that 41.18% of the groundwater samples are negative and 58.82% positive; two types of water are identified in the study area. Recharge of groundwater is good in the positive areas whereas in the negative area discharge is more.

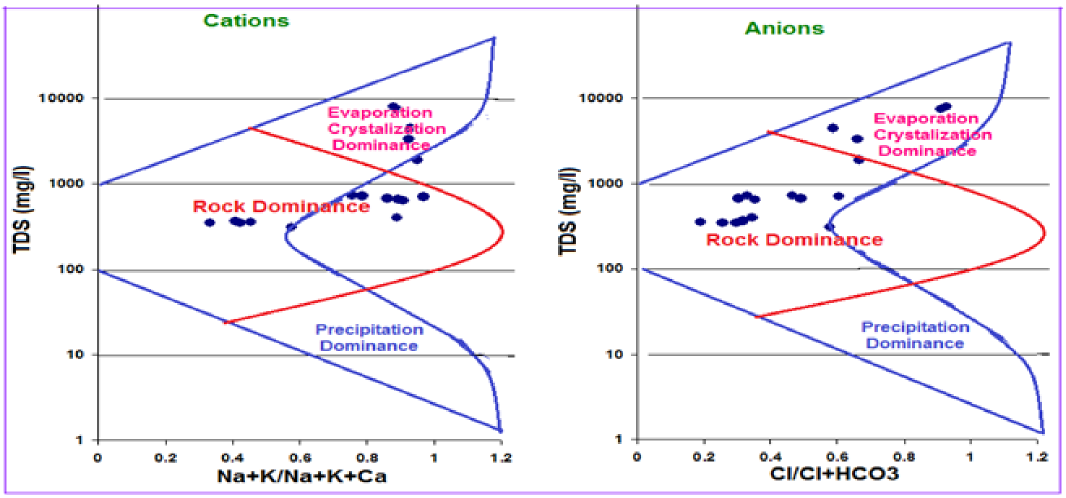

Fig.19 Gibb's diagram

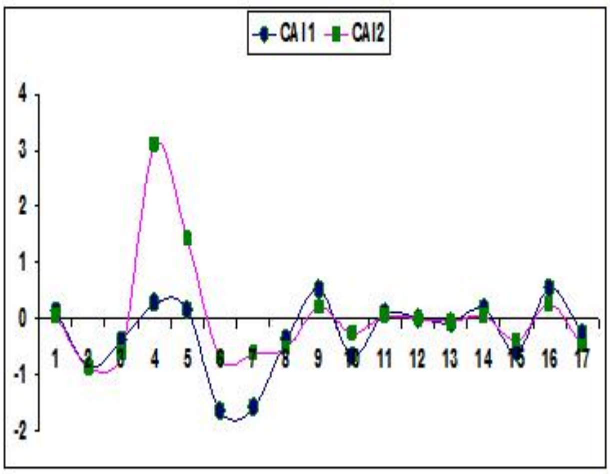

Fig.20 Metasomatism of Groundwater

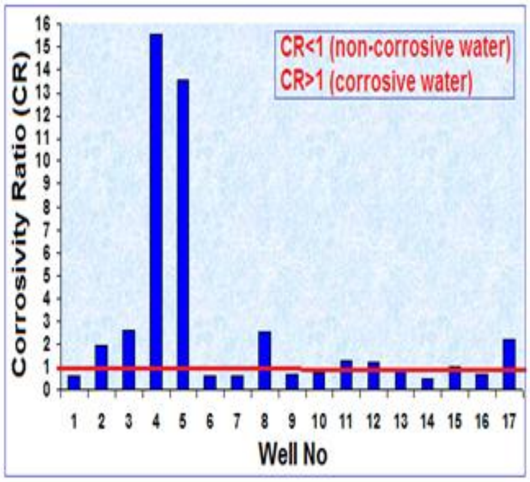

Fig.21 Corrosivity Ratio Method

4.2.8 Corrosivity Ratio Method (CR)

Ryzner (1994) proposed a ratio to evaluate the corrosive tendency of groundwater on metallic pipes. The effects of corrosion are loss in hydraulic capacity of pipes [40]. The increased conductivity is due to dissolved solids in water samples. The groundwater with corrosivity ratio<1 is considered to be safe for transport of water in any type of pipes, whereas >1 indicates corrosive nature and hence not to be transported through metal pipes [40]. The calculated values of groundwater samples (0.48 to 15.57) as shown in figure 21, which suggests that 9 samples are safe whereas 8 samples are corrosive in nature and need non-corrosive pipes for transporting and lifting of groundwater. In such case, non-corrosive [polyvinyl Chloride (PVC)] pipes can be a better choice for the water transportations.

4.2.9 Groundwater Chemistry and its suitability for Irrigation

The quality of water, type of soil and cropping practices play an important role for a suitable irrigation practices. Presence of excessive amounts of dissolved ions in irrigation water affect plants and agricultural soil physically and chemically, thus reducing productivity. The chemical effect is to disrupt plant mechanism. Good quality of waters for irrigation is characterized is acceptable range. Use of poor quality can create four types of problems, namely toxicity, water infiltration, salinity and miscellaneous. To assess water quality for irrigation, there are four most popular criteria are used.

4.2.10 Integrated effect of EC and SAR

The best measures of a water likely effect on soil permeability, soil structure and create toxic conditions for plant growth is the water SAR considered together with its EC. The US salinity diagram which is based on the integrated effect of EC (salinity hazard) and SAR (alkalinity hazard) has been used to assess the water

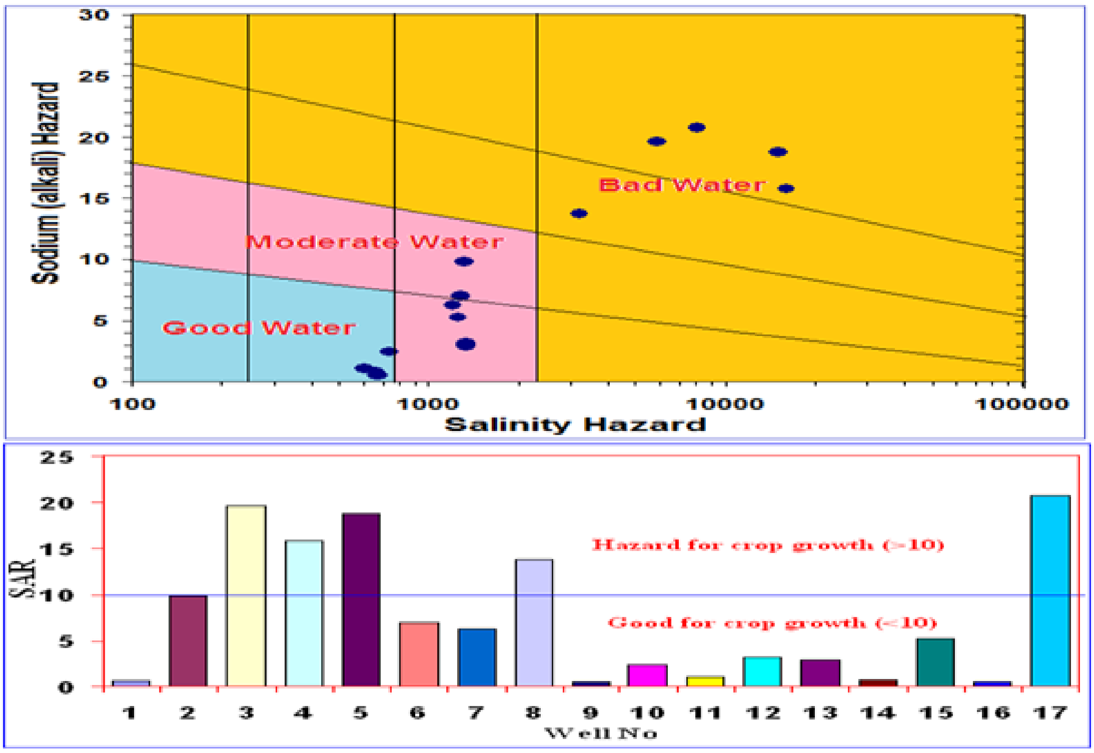

Fig.22 Integrated Effects of EC and SAR

Suitability for irrigation [41]. The plotting of the chemical data in the diagram gives an idea about the suitability of groundwater for irrigation and it would be possible to group the areas with good, moderate and bad waters. In the present study, the classification of groundwater with respect to SAR as per CSSRI as shown in figure.22. High salt (EC) leads to formation of saline soil, high sodium (SAR) leads to development of an alkaline soil. While Na enriched water causes soil aggregates to disperse, reducing its permeability .The results of the study revealed that SAR of the water samples varied from 0.49 to 20.74. Five samples is sodium hazard to crop growth with respect to SAR, while twelve samples shows well for crop growth. This index quantifies the proportion of sodium to calcium and magnesium ions in a water samples. As per Richards's classification, the

SAR values of all samples fall in good water, moderate water and excellent water. The good water can be used for irrigation with little danger of harmful levels of exchangeable sodium. The moderate water can be used to irrigate salt-tolerant and semi-tolerant crops under favorable drainage conditions. The bad water is not suitable for irrigation, should not be used on clayey soils of low permeability and should be used to irrigate plants of high salt tolerance. The plot for SAR vs EC values when lesser than 10 indicates low SAR with medium salinity, high salinity, very high salinity and the values greater than 10 requires careful management by application of gypsum, which makes water feasible and increases soil permeability.

4.2.11 Water Quality Based on Wilcox's

Sodium considered as the main factor for determine groundwater suitability for agricultural purposes. Irrigation water containing large amounts of sodium is of special concern because it reduces soil permeability and porosity as well as increases the hardness of soil, thus will affect the plant growth or stunted growth [42]. Presence of sodium is usually expressed in terms of Na% and is calculated by the formula. The classification of groundwater for irrigation was grouped based on sodium percentage as Excellent (<20%), Good (20-40%), Permissible (40-60%), Doubtful (60-80%) and Unsuitable (>80%). Based on Na% the value <60% is suitable for irrigation purposes and >60% is unsuitable. The (Fig.24) samples range from 14.47% to 82.10%. Wilcox's proposed (Figure 23) a classification in which Na% is correlated against EC of salts to find the suitability of water for irrigation. According to this classification, in the study area 12 samples are falls in the excellent, good and permissible and 5 samples falls in the field of unsuitable class. The agricultural yields are generally low in lands irrigated with water belonging to doubtful to unsuitable category.

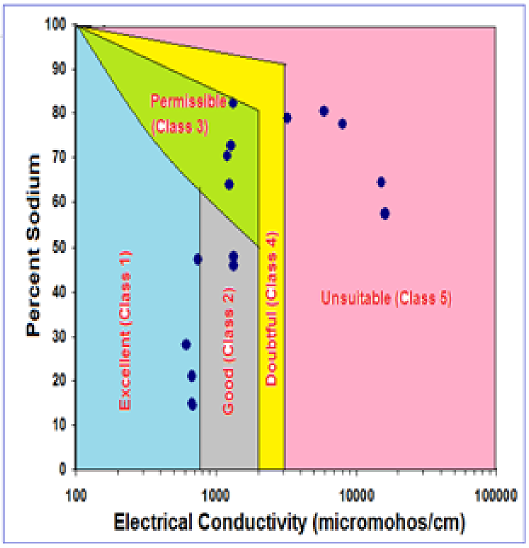

Fig.23 Integrated Effects of EC and Na%

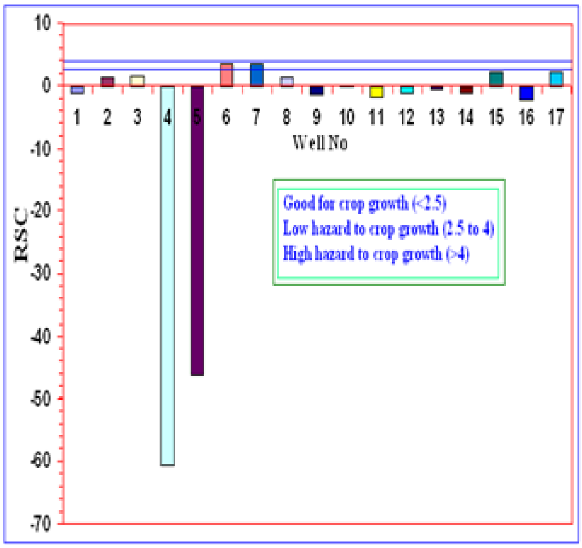

Fig.24 Effects of RSC

4.2.12 Residual Sodium carbonate (RSC)

RSC is considered the most appropriate method for water quality assessment in irrigation aspect. RSC is measured as: RSC= $(HCO_3^- + CO_3^-)-(Ca^{2+}+Mg^{2+})$. Here all the ions species were measured in meq/l. Bicarbonate occurs in low salinity water and its concentration usually decreases with an increase in EC. The proportion of HCO3 ion is higher than Ca ions are considered undesirable, because after evaporation of irrigation water HCO3 ions tend to precipitate Ca ions. The water quality may diminish if the content of the carbonate species (HCO_3^-, CO_3^-) exceed over the content of sum of Ca^{2+}, Mg^{2+}. The RSC value less than 2.5 is safe for irrigation, a value between (2.5 to 4.0) is of margin quality and a value greater than 4.0 is unsuitable for irrigation. Further the value is negative which is generally good for agriculture and water with high RSC has high pH and land irrigated by such water becomes infertile owing to deposition of NaCO3, high RSC affects crop yields are known from the black colour of the soil. The results of the above study (Figure 24) revealed that RSC of the samples varied from -60.75 to 3.54 meq/l. 15 samples shows RSC<2.5 indicating good for crop growth and 2 samples shows low hazard to crop growth with respect to RSC and none of the samples comes under high hazard conditions .

4.2.13 Permeability index (PI)

Permeability index developed by Doneen in 1964 is important parameters that influence the quality of water for irrigation. Soil permeability is affected or reduced by long term use of irrigation water containing high salts (Sing and Sing 2008). A criterion for assessing the suitability of water for irrigation was based on PI water and can be classified as class I and class II and class III orders. Class I and class II water was categorized as good for irrigation purpose with 75% or more maximum permeability. Class III water was unsuitable with 25% of maximum permeability [44]. The PI of the groundwater samples ranges from 36% to 96%. On the basis of PI classification, majority of samples of the study area belongs to class I and II (Figure 25). The increased % of groundwater samples under class II is due to dilution and subsequent lower values of PI.

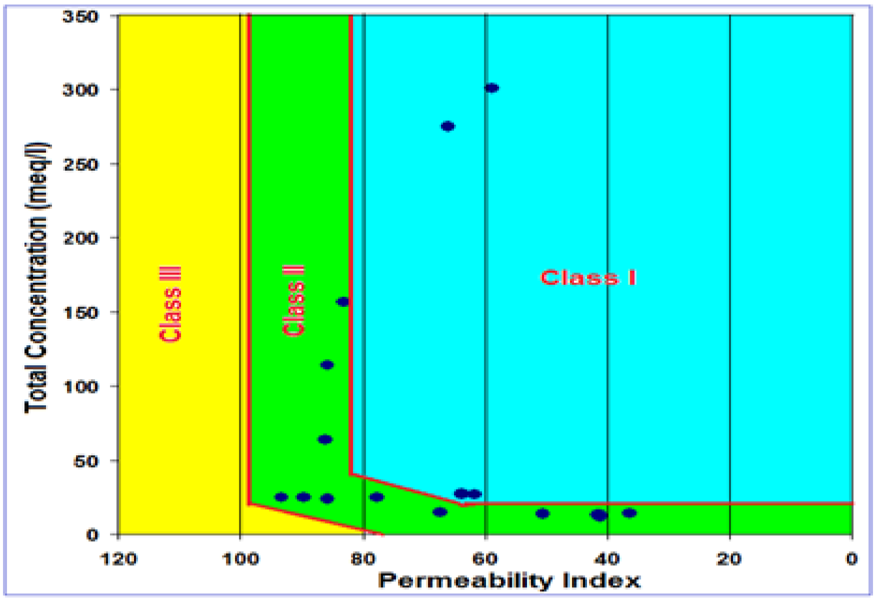

Fig.25: Doneen's Chart

V. Conclusions

The groundwater resources in the Paramakudi region were evaluated for their chemical composition and suitability for drinking and irrigation. The quantitative chemical analysis results reflects that dominant cations are sodium ion and the dominant anions are chloride ion. Hydrochemical facies as well th pH of water, both indicates that groundwater in the area is of alkaline nature. Most of the water samples were found to be moderately hard in nature with exceptions of a few hard to very hard types as well. The water quality index results show that 76% of water samples are fit for human consumptions. According to Gibb's ratio, the majority of groundwater is effectively controlled by rock dominance. The suitability of groundwater for irrigation was evaluated based on quality parameters like SAR, Na%, RSC and PI classification and found to be suitable for irrigation but the rest (30%) of samples are not suitable for irrigation however it may be suitable in well-drained soils. It is recommended that for salinity control and selection of crops with good tolerance is to be adopted.

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