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***Research Paper***

# Hydrochemical Analysis and Evaluation of Groundwater Quality in and around Hosur, Krishnagiri District, Tamil Nadu, India

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***Abstract:*** *The quality of groundwater of any area is of great importance for human being and irrigation. In order to evaluate the problems of pollution hazards of groundwater and to ascertain its suitability for drinking and irrigation purposes in Hosur region, Tamil Nadu. The study area is approximately 153 km$^2$ and underlain by the Granite Gneiss formation. Thirty five groundwater samples have been collected from Hosur region in October 2010 (pre-monsoon) and in January 2011(post-monsoon) and anlysed for physio-chemical parameters (pH, EC, TH, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, $HCO_3^-$, $Cl^-$, $SO_4^{2-}$, $NO_3^-$, $F^-$, $Fe^-$, $Pb^-$, $Cr^-$) in order to understand the hydrogeochemistry of the water. The groundwater is alkaline in nature and total hardness is observed in all samples fall under hard to very hard category. The fluoride concentration in the south region exceeds the permissible limit. The concentration of Iron, lead, chromium is below the detectable limit in most of well samples except in the wells in industrial area (SIPCOT) has exceeds the safe limit. Major hydro chemical facies were identified using piper trilinear diagram. The concentration of physiochemical constituents in the water samples were compared with the Bureau of Indian Standards (BIS) to know the suitability of water for drinking. Based on the analysis, most of the area falls in fresh water to slightly saline except at many locations in industrial area moderately saline in nature leading the water unsuitable for drinking. Various determinations such as Sodium Adsorption Ratio (SAR), Percent Sodium (Na%) and Residual Sodium Carbonate (RSC) revealed that most of the samples are suitable for irrigation. It was observed that the quality of groundwater was not suitable for drinking purpose in industrial area and irrigation few sampling sites are unsuitable by the influences of urban and industrial waste discharge, aquifer material mineralogy, other anthropogenic activities and increased human interventions in the groundwater quality of the study area.*

**Keywords:** Physio-chemical parameters, Drinking water, Irrigation purpose, Hosur Region.

## 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. The safe portable water is absolutely essential for healthy living. Groundwater is ultimate and most essential suitable fresh water resources for human consumption in both urban as well as rural areas. The importance of groundwater for existence of human society cannot be overemphasized. There are several states in India where more than 90% population are dependent on groundwater for drinking and other purposes [1]. Groundwater is a source used for agricultural and industrial sector now a day. In recent years, an increasing threat to groundwater quality due to human activities has become of great importance. The adverse effects on groundwater quality are the over burden of the population pressure, unplanned urbanization, unrestricted exploration, unintentionally by domestic, agriculture and industrial effluents and dumping of the polluted water at inappropriate place enhance the infiltration of harmful compounds to the groundwater[2]. There are several ways as groundwater is contaminated in urban and rural areas such as municipal sewage disposal to nearby water bodies, disposal or seepage of effluent from industries and use of inorganic fertilizers in agricultural farming. Most of the industries discharge the effluent without proper treatment into nearby open land or pass them through unlined channels, resulting in a deterioration of the groundwater resources. The groundwater pollution is highest in urban areas than rural areas where large volumes of waste concentrated and discharged near to the urban lakes. The increasing demand of water from fast growth of industries has put pressure on limited water resources. Variation of groundwater quality in an area is a function of physicochemical parameters that are greatly influenced by geological formations and anthropogenic activities. Groundwater pollution has become a major subject of public concern the world over. Despite the large volume of water that covers the surface of the earth, only 1% is inland fresh and easily available for human use. The qualities groundwater resources vary naturally and widely depending on climate, season, geology of bedrock as well as anthropogenic activities. While most people in urban cities of developing countries have to access to piped water, several others still use borehole for domestic and irrigation. Water quality analysis is one of the most important aspects in groundwater studies. The objective of the present work is to discuss the physicochemical parameters of groundwater that is suitable for drinking and agricultural in and around Hosur town of Krishnagiri district, Tamil Nadu.

## Study area

The present study was carried out in and around Hosur area, located 325 km far from west of Chennai city and about 40 Km from south-east of Bengaluru city. It is well connected by the Golden Quadrilateral Expressway to Bengaluru on the one side and Chennai and Salem on the other side. Hosur is also known as little England and is surrounded by small scale, medium scale and large scale industries. The study area covers an area of 153 Sq.km and lies within the longitudes of 77°47' to 77° 52' and latitudes of 12°42 'to 12°45' and being developed in the adjacent villages. The area form a part of the Survey of India toposheet nos (57 H/13 and 57 H/14). The topography of the area has 950 meters above mean seal level and is undulating terrain. The average temperature in this region varies between 25ºC to 37ºC in summer and between 15ºC to 30ºC during winter, respectively. The area enjoys a more moderate climate throughout the year, with occasional heat waves. The annual rainfall in this area ranges from 700 to 900 mm. Generally the entire area is traversed by the hard rock of granite gneiss formation. Groundwater occurs under phreatic conditions in the weathered mantle and semi confined to confined conditions in the fractured and fissured zones of the rocks. The main source of groundwater recharge is Ramanaickan lake spread out over an expanse of 20 hectares is situated in the heart of the town. Similar the other lakes like Dharga and Therpettai situated at the entrance of the town. It is also turned out to be a collection pond for sewage from industrial area and other housing colonies situated across the lake. The lake is now on the verge of complete decay and also dumping garbage's by residential colonies. Kelevaripalli dam (KP dam) is located about 15 km from the town. Almost 90% of the residents are depending on their own tube wells. The groundwater level in the industrial area has depleted below 1000 feet. The most important economic activity of this area is large numbers of industries have come up in the town. The area is surrounded by State Industries Promotion Corporation of Tamil Nadu Limited (SIPCOT)-I in NW, SIPCOT-II in NE and Southern part by agricultural area. The land is very fertile and the crops grown are tomato, cabbage, onion, mango, carrot, beans etc. Hosur exports most of roses from India to various European countries. The groundwater quality of the study area is adversely affected by the industrialization and urbanization of the town. Increased Population and improper drainage system have potential to influence the groundwater quality. Geographical location of the study area is shown in the Figure 1.

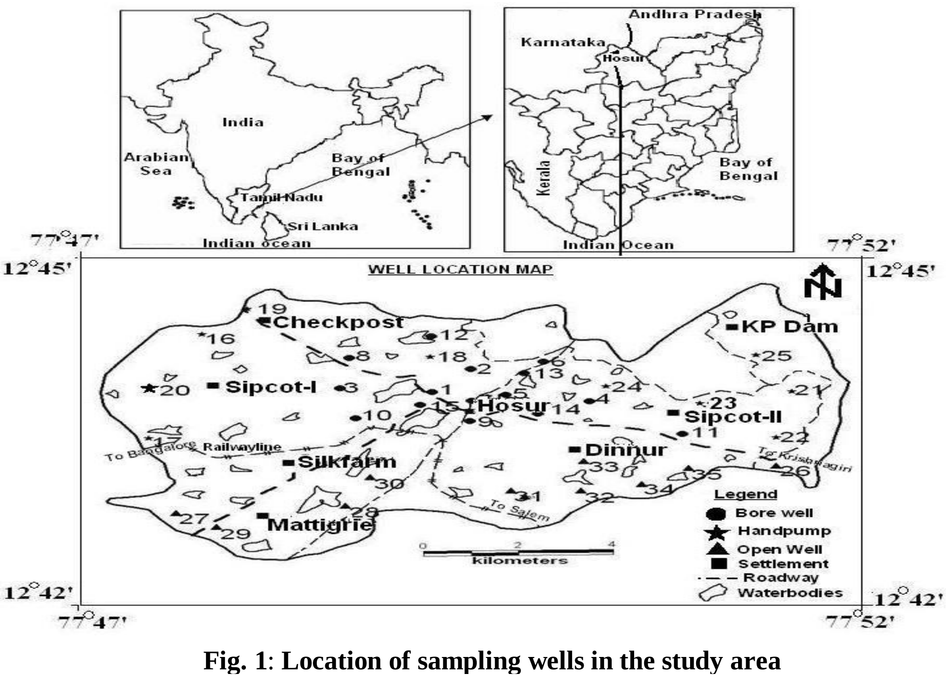


**Fig. 1**: **Location of sampling wells in the study area**

**Table 1**
**Sample collection locations**

| Sample ID | Location | Sample ID | Location |
|---|---|---|---|
| 1 | Teacher Colony | 19 | Timber Industries Road |
| 2 | Lakshmi Naryana Nagar | 20 | Pharmaceutical Road |
| 3 | Indira Nagar | 21 | Textile Industries Road |
| 4 | Venkatesh Nagar | 22 | Granite Industries Road |
| 5 | Kamaajar Colony | 23 | Paint Industries Road |
| 6 | Anna Colony | 24 | Chemical Industries Road |
| 7 | Ram Nagar | 25 | Leather Company Road |
| 8 | Bharthidasan Nagar | 26 | Perranadapalli |
| 9 | Nethaji Street | 27 | Mavakanapalli |
| 10 | Housing Board | 28 | Mattigire |
| 11 | Adhiyamaam Engg College | 29 | Hosur Cattle Farm |
| 12 | Christ Matriculation School | 30 | Dinnur(Silk farm) |
| 13 | Bazaar Street (Rayakottai road) | 31 | Agraharam |
| 14 | Bangalore Bye pass Road | 32 | Karapalli |
| 15 | Old Bangalore Road | 33 | Somanathapuram |
| 16 | Ashokleyland-phase 1 Road | 34 | Channatur |
| 17 | Hindustan Motors Road | 35 | Kasurupetta |
| 18 | Woods Industries Road | | |

## Material and Methods

Groundwater samples were collected from 35 locations in and around Hosur region during pre-monsoon period (October 2010) and Postmonsoon period (January 2011). The parameters like EC, pH were measured on the spot at the time of sample collection using potable kit. The collected groundwater samples were transferred into plastic container for analysis of chemical characters. Sample collection locations are listed in Table 1 shown below. Chemical analyses were carried out for the major ions, minor ions, and trace ions concentrations using the standard procedures recommended by American Public Health Association. The analytical data can be used for the classification of water for utilitarian purposes and for ascertaining various factors on which the chemical characteristics of water depend.

## Results and Discussion

**Physicochemical parameters of groundwater:** The Seasonal wise concentration of ions in groundwater samples area are given in Table 2. The pH indicates the acidic or alkaline material present in the water. The pH of groundwater samples in this area ranges from 7.0 - 9 .0 and 7.9 - 9.0 during pre and post-monsoon respectively. The groundwater of this area is generally alkaline (Figure 2) in nature due to presence of carbonates and bicarbonates ions. The pH value in eastern part was found to be 9.0 which are beyond the permissible limit as per Bureau of Indian Standards, due to the seepage of effluent and domestic sewage. If pH is not within the permissible limit, it damages mucous membrane present in nose, mouth, eye, abdomen, anus in human beings. The Total dissolved solids (TDS) observed from this area is between 407-3382 mg/l and 448-3555 mg/l in pre and post-monsoon, and is found that 20 samples are below 1000 mg/l and 10 samples has moderate quality around 1000 - 2000 mg/l and the 5 samples which is having poor quality with TDS exceeds 2000 mg/l. Generally, the higher TDS causes gastro-intestinal irritation to the human beings, but the prolonged intake of water with the higher TDS can cause kidney stones and heart diseases [3]. High TDS of this area may be influence of anthropogenic sources such as domestic sewage, industrial waste, septic tanks, agricultural activities and influence of rock-water interaction.

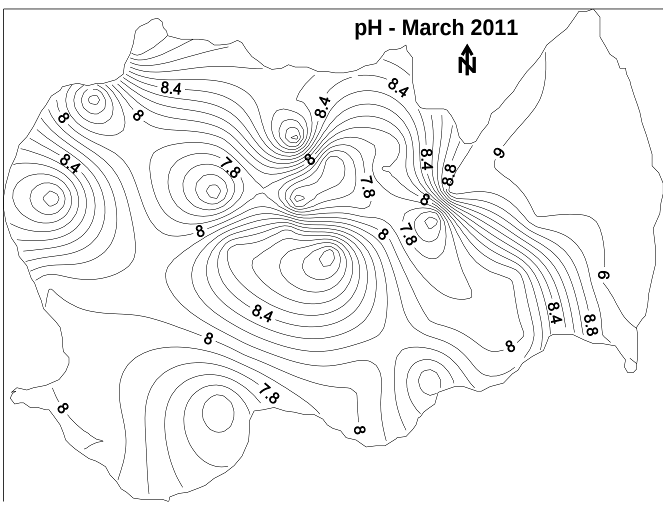


**Fig. 2**: **Spatial variation of pH**

Total hardness (TH) 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 effects; however, some evidence indicates its role in heart diseases [4] and hardness of 150-300 mg/l and above may cause kidney problems and kidney stone formation [5], as it causes unpleasant taste and reduce ability of soap to produce lather. Hard water is unsuitable for domestic use. In this region, the total hardness varies between 29-925 mg/l and 100-950 mg/l during pre and postmonsoon. The maximum allowable limit of TH for drinking purpose is 500 mg/l and the most desirable limit is 100 mg/l as per [6], standards. The total hardness is relatively high in all samples due to the presence of calcium, magnesium, chloride and sulphate ion. Values are very slightly higher in postmonsoon than premonsoon season. The spatial distribution of TH in groundwater of the study area is illustrated in Figure 3. Groundwater in the area exceeding the limit of 300 mg/l as $CaCO_3$ is considered to be hard [7], this may be due to industrial discharge, sewage effluent and geology of the rocks.

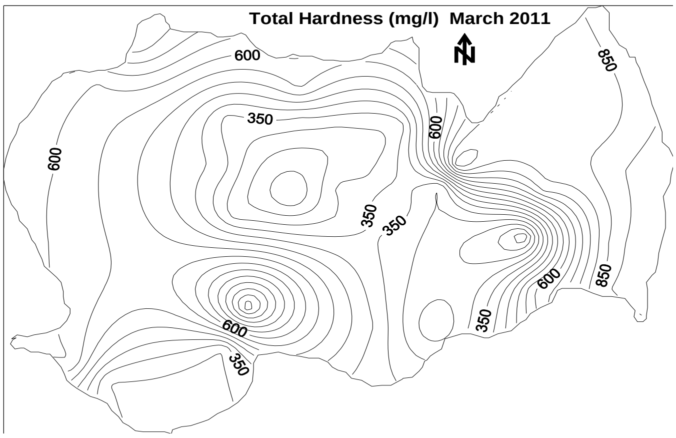


**Fig. 3: Spatial variation of Total Hardness**

Calcium, magnesium and total hardness in the groundwater are inter-related. Calcium ($Ca^{2+}$) is an important element to develop proper bone growth. It is found in alkaline in nature. The presence of calcium in the groundwater is from silicate mineral group, such as pyroxene and amphibole in the igneous rocks. In addition, the shales, sandstone also contain calcium in the form of carbonate. Calcium content is very common in groundwater, because they are available in most of the rocks, abundantly and also due to its higher solubility. However, the range of its availability depends on the solubility of calcium carbonate and sulphate. The permissible limit of calcium in drinking water is 75 mg/l. The calcium concentration in water samples collected from the study area ranged from 9 - 540 mg/l and 10 - 554 mg/l in pre and postmonsoon seasons. So, all the samples exceed the permissible limit. The rapid industrialization and urbanization in the area contribute to the high concentration of calcium in the groundwater of the region.

Magnesium ($Mg^{2+}$) usually occurs in lesser concentration 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's crust. If the concentration of magnesium in drinking water is more than the permissible limit, it causes unpleasant taste to the water. The magnesium derived from dissolution of magnesium calcite, gypsum and dolomite from source rocks. Magnesium is an essential ion for functioning of cells in enzyme activation, but at higher concentration, it is considered as laxative agent [8], while deficiency may cause structural and functional changes in human beings. The acceptable limit is 30 mg/l as per standards. In this present study area the magnesium level in the water samples ranged from 0.45 - 241 mg/l and 0.20 - 170 mg/l in pre and postmonsoon seasons. Most of the locations exceed the permissible limit. Anomalously high concentrations are seen near the industrial area

Sodium ($Na^+$) occurs as a major cation in the water samples. The primary source of sodium in natural water is from the release of the soluble products during the weathering of plagioclase feldspars. The concentration of sodium in the area varies from 5-462 mg/l in premonsoon and in postmonsoon the value from 50-700 mg/l. The spatial distribution of sodium in groundwater of the study area is illustrated in Figure 4. The sodium concentration more than 50 mg/l makes the water unsuitable for domestic use because it causes severe health problems like hypertension [9]. Groundwater most of the area comes under the non-safe zone for drinking with reference to the concentration of sodium, which is more than 250 mg/l. Therefore, sodium restricted diet is suggested to the patients, who suffer from the heart diseases and also from the kidney problems. The higher concentration of sodium may pose a risk to a persons suffering from cardiac, renal and circulatory diseases [10]. Sodium is derived from untreated industrial and domestic waste, weathering of feldspar rocks and also due to over exploitation of groundwater sources in this area.

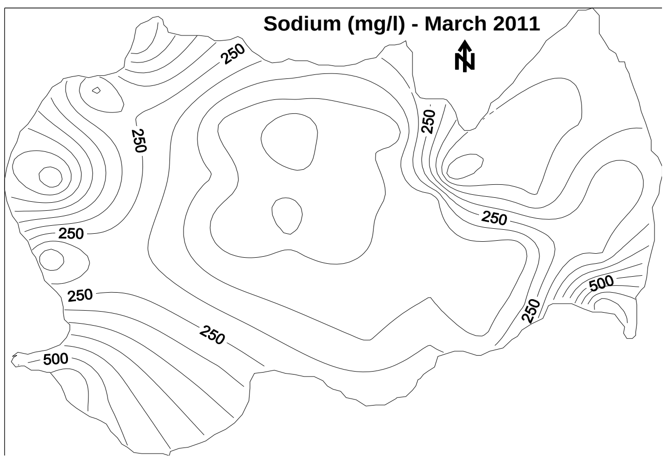


**Fig.4: Spatial variation of Sodium**

Generally the behaviour of potassium ($K^+$) is similar to the sodium content in the water but not found in the concentration as much as the sodium in groundwater. The most common minerals which are the potassium source are the orthoclase, feldspar, microcline, leucite, biotite are present in granites of the area [15]. The concentration of $K^+$ is less than 10 mg/l in the drinking water. It maintains fluids in balance stage in the human body. In present investigation potassium concentration was ranged from 0 - 55 mg/l and 0 - 80 mg/l during pre and postmonsoon. The permissible limit of potassium is 10 mg/l and in study area nearly 50% of the samples exceed the permissible limit. Thus, the excess amount of potassium present in the water sample may lead nervous and digestive disorder [11]. The higher values in this area may be contributed due to the effluent discharged by industries and domestic sewages. However, excessive fertilizer usage may also increase its concentration in groundwater.

Bicarbonate ($HCO_3^-$) was observed higher of 100-800 mg/l during postmonsoon season than premonsoon 100-522 mg/l due to action of $CO_2$ upon the basic material of soil and granitic rocks. 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 [12]. The pH of water less than 4.5 indicates the presence of carbon content, while between 4.5 to 8.5 pH notices to bicarbonate solution and more than 8.5 pH shows the carbonate availability. The higher concentration of bicarbonate in the water infers a dominance of mineral dissolution [13]. Bicarbonate is a major element in human body, which is necessary for digestion. The 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 higher concentration of Ca, especially in dry climatic conditions.

Chloride ($Cl^-$) is a widely distributed element in all types of rocks in one or the other form. Therefore, its concentration is high in groundwater, where the temperature is high and rainfall is less. Mostly, the chlorides are found in the form of sodium chloride in the groundwater. Soil porosity and permeability also has a key role in building up the chloride concentration. Chloride imparts a salty taste and some times higher consumption causes the crucial for the development of essential hypertension, risk for stroke, left ventricular hypertension, osteoporosis, renal stones and asthma in human beings [14]. Although, the chloride plays an important role in balancing level of electrolyte in blood plasma, but higher concentration can produce some physical disorders. The chloride concentration varied from 99 - 560 mg/l and 70 - 987 mg/l during pre and postmonsoon. In this study area few areas has higher concentration, which could be dangerous from health point of view. The high chloride may be attributed to industrial, domestic wastes, leaching from upper soil layers in dry climates and natural geochemical activities in this area.

The sulphate ($SO_4^{2-}$) ion is one of the important anion present in natural water produce catharsis, dehydration and gastrointestinal irritation effect upon human beings when it is present in excess of 150 mg/l. It is mainly derived from gypsum on oxidation of pyrites. The sulphide minerals add the soluble sulphate into the groundwater through oxidation process. In present investigation sulphate concentration was ranged from 0 - 80 mg/l and 0 - 200 mg/l during pre and postmonsoon. In the study area the sulphate level is within the permissible limit of 250 mg/l. The higher sulphate content may be contributed due to bio chemical, anthropogenic sources and industrial process etc.

Nitrate ($NO_3^-$) generally occur in trace quantities in surface water but may attain high levels in some groundwater. It is well known that the nitrogenous fertilizers are one of the important sources for groundwater nitrate for the past two decades. Further, nitrogenous materials are rare in geological system [16]. In excessive limits, it contributes to the illness known as methenglobinemia in infants. The permissible limit of nitrate is 45 mg/l prescribed by [17] standards. The nitrate concentration in groundwater collected from the study area ranged between 0 to 96 mg/l in pre and postmonsoon. Hence, as far as the nitrate is concern few water samples exceed the permissible limit. The origin of nitrate is derived may be from agricultural areas due to leaching process from plant nutrient, nitrate fertilizers and poor sanitary conditions.

One of the main trace elements in groundwater is fluoride ($F^-$) which generally occurs as a natural constituent. Bedrock containing fluoride minerals is generally responsible for high concentration of this ion in groundwater [18]. Fluoride normally accumulates in the bones, teeth and other calcified tissues of the human body. Excess of fluoride in water causes serious damage to the teeth and bones of the human body, which shows the symptoms of disintegration and decay, diseases called dental fluorosis and skeletal fluorosis.

[19] has stated that the higher intake of fluoride may change the metabolic activities of soft tissues (brain, liver, kidney, thyroid and reproductive organs). The permissible limit of fluoride in drinking water is 1.5 mg/l as per [17]. The fluoride concentration in groundwater of the area varies from 0.05 to 4.0 mg/l in premonsoon and 1 to 4.2 mg/l in postmonsoon season. The concentration is higher than 1.5 mg/l in 13 locations. 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. Excess fluoride may also lead to fluorosis that can result in skeletal damage. Clinical report indicate that adequate calcium intake is directly

associated with reduced a risk of dental fluorosis [20]. Vitamin C also safeguards against the risk [21]. The spatial distribution of fluoride ion concentration in groundwater is shown in Figure 5. In this area fluoride is higher due to leaching from fluoride rich rocks, long term irrigation processes, semi-arid climate and long term residence time of groundwater.

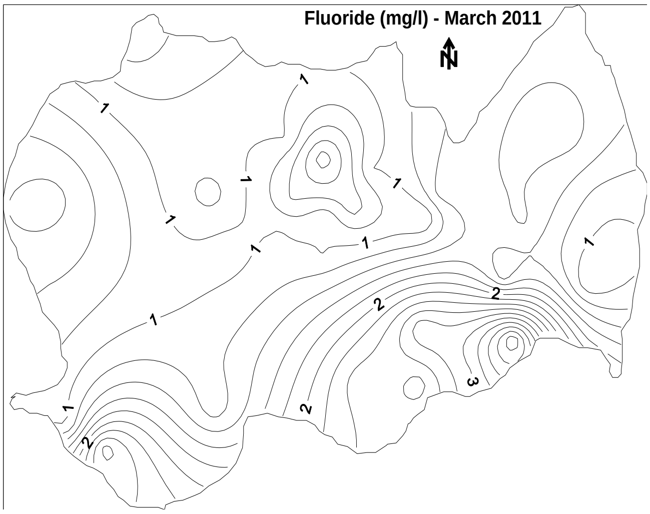


**Fig. 5: Spatial variation of Fluoride**

Iron ($Fe^-$) concentration in natural water is very low. Iron is biologically an important element which is essential to all organisms and present in haemoglobin system. High concentration causes slight toxicity, inky flavour, bitter and astringent taste. Iron contained water makes the teeth and nail black and weak, stickiness of hair and water. The shortage of iron causes a disease called anaemia and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called as haermosiderosis [22]. Iron occurs in groundwater as a soluble (ferrous) form and it becomes as an insoluble (ferric) form when it comes in contact with air. The concentration in the groundwater of the area varies from 0.5 - 1.92 mg/l and 0.06 - 5 mg/l during pre and postmonsoon season, and most of the samples have low iron concentration and very few samples exceeds the permissible limit of 1.0 mg/l of [17] drinking water standards. In present study discharge of waste effluents on land and weathering of rock and are generally considered the main source of iron in groundwater.

Lead ($Pb^-$) is an undesirable trace metal less abundantly found in earth crust. Lead is used principally in the production of lead-acid batteries, solders and alloys. Lead is also found in soil, vegetation, animals and food. It is a serious cumulative body poison. Lead inhibits several key enzymes involved in the overall process of haemosynthesis, whereby metabolic intermediate accumulates [23]. Lead in the environment may derive from either natural or anthropogenic sources. Generally the natural content of lead in this area ranges from 0.01 to 4 mg/l in premonsoon and in postmonsoon it is 0.05 to 3 mg/l. The concentration of lead is below detectable limit in most of the well samples except in the wells in industrial area has exceeds the safe limit of 0.05 mg/l.

Chromium ($Cr^-$) is an essential micronutrient for animals and plants. Chromium is considered as a relative biological and pollution significance element. Chromium is an essential nutrient in man because it helps the body in the use of sugar, protein and fats but at low concentration.

**Table 2**
**Seasonal wise concentrations of ions in groundwater samples**

| S. No. | Constituents | Bureau of Indian Standard (IS-10500:1991) | Pre-monsoon (Aug 2011) | Post-monsoon (Mar 2011) |
|---|---|---|---|---|
| | | | Range | Range |
| 1 | pH | 6.5 – 8.5 | 7- 9.02 | 7.9 – 9 |
| 2 | EC(μmhos/cm) | 700-3000 | 637 – 5284 | 700 – 5555 |
| 3 | TDS (mg/l) | 500-2000 | 407-3382 | 448-3555 |
| 4 | TH(mg/l) | 300-500 | 29 – 925 | 100 – 950 |
| 5 | $Ca^{2+}$ (mg/l) | 75-200 | 9-540 | 10-554 |
| 6 | $Mg^{2+}$ (mg/l) | 30-100 | 0.45-195 | 0.68-170 |
| 7 | $Na^+$ (mg/l) | 200-300 | 5-462 | 50 – 700 |
| 8 | $K^+$ (mg/l) | 10 | 0-55 | 0 – 80 |
| 10 | $HCO_3^-$(mg/l) | 500 | 100 – 522 | 100 – 800 |
| 11 | $Cl^-$(mg/l) | 250-1000 | 99 – 560 | 70 – 987 |
| 12 | $SO_4^{2-}$ (mg/l) | 150-400 | 0-80 | 0-200 |
| 13 | $NO_3^-$(mg/l) | 45 | 0 – 96 | 1 – 96 |
| 14 | $F^-$(mg/l) | 1.5 | 0.05 – 4 | 1 – 4.2 |
| 15 | $Fe^-$(mg/l) | 1.0 | 0.5 – 1.92 | 0.06 – 5 |
| 16 | $Pb^-$(mg/l) | 0.05 | 0.01-4 | 0.05-3 |
| 17 | $Cr^-$(mg/l) | 0.05 | 0.001- 2 | 0.03 – 5 |

However, intake excess causes various health effects such as skin rashes, stomach upset, ulcer, respiratory problems, alteration of genetic materials, weakness of immune system, kidney and liver damage, and can even lead to death [24]. Generally the chromium concentration in the area water varies from 0.01 to 2 mg/l and 0.03 to 5 mg/l in pre and postmonsoon. In the present investigation, the chromium concentration exceeds detectable level 0.05 mg/l as per [17] standards in most of the well samples in industrial area.

**Hydrogeochemical facies:** The hydrochemical evolution of groundwater can be understood by plotting the major cations and anions in the piper trilinear diagram [25]. The diagram reveals similarities and differences among water samples because those with similar qualities will tend to plot together as groups [26]. Hydro geochemical facies interpretation is a useful tool for determining the flow pattern, origin of chemical histories of groundwater. The piper diagram is useful in bringing out chemical relationships among water in more definite terms [27].

The plot shows in Figure 6 that the majority of groundwater samples fall in $CaHCO_3$ type, mixed CaMgCl type and NaCl type facies with minor representation in CaCl and mixed $CaNaHCO_3$ type facies. Results obtained from the chemical analysis indicate that the overall chemical composition of the groundwater is characterized by high chloride concentration and high variations in cation concentrations notably $Ca^{2+}$ and $Na^{+}$. This might be due to the cation exchange reaction between aquifer minerals [28].

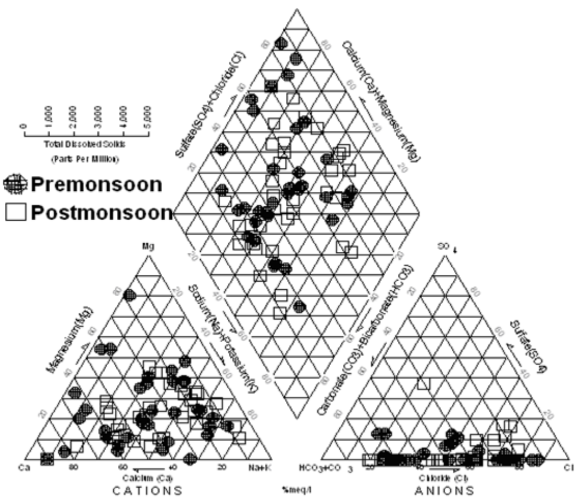


**Figure 6: Piper diagram**

**Groundwater for Irrigation Purpose:** The water quality used for irrigation is essential for the crop yield and quantity, maintenance of soil productivity and protection of the environment. The quality of irrigation water is very much influenced by the land constituents of the water source. The important parameters affecting the suitability of groundwater for irrigation purposes are: Electrical Conductivity (EC), Sodium adsorption ratio (SAR), Sodium percentage (Na %) and Residual sodium carbonate (RSC).

The salt concentration is generally measured by the determining the electrical conductivity of water. Excess salt increases the osmotic pressure of the soil solutions that can be result in a physiological drought conditions. Even though the field appears to have plenty of moisture, the plants wilt because insufficient water is absorbed by the roots to replace that lost from transpiration. The total soluble salt content of irrigation water generally is measured by determining its electrical conductivity. The electrical conductivity values ranged 637-5284 µmhos/cm in premonsoon and 700-5555 µmhos/cm in postmonsoon all the groundwater samples in both the seasons. The spatial distribution of EC in groundwater of the study area is illustrated in Figure 7.

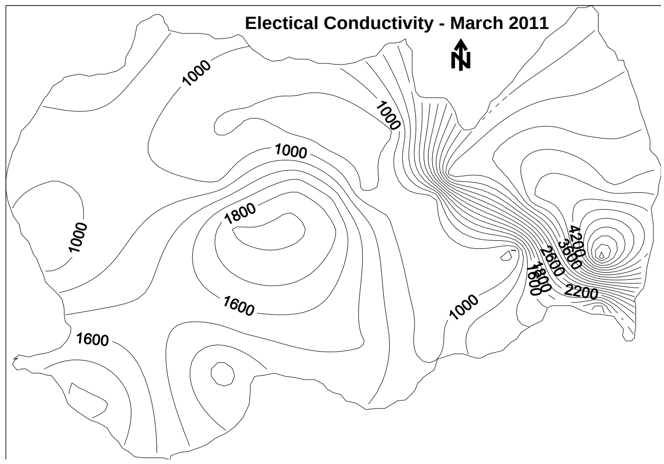


**Figure 7: Spatial variation of Electrical Conductivity**

The large variation in EC is mainly due to lithologic composition and anthropogenic activities prevailing in this region. It is observed that in some samples the EC values increases with the increasing amounts of sulphate, chloride, bicarbonate and hardness as $CaCO_3$. Normally, irrigation water with an EC<700 µmhos/cm causes little or no threat to most crops, while EC>3000 µmhos/cm may limit their growth [29]. As it can seen from the study area having very high salinity and are unsuitable for irrigation. Increasing the soluble minerals along flow path, groundwater movement through salt and evaporation are the major causes of salination in the industrial area. However, irrigation with saline water, dissolution of the chemical fertilizers by the irrigation water, industrial and municipal waste disposal increases the rate of salination in eastern part of SIPCOT-II. Although sodium contributes directly to the total salinity problems with a high sodium concentration affect the physical properties of soil.

This can been seen in the study area water with a 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 [29]. The sodium hazard is typically expressed as sodium adsorption ratio (SAR). This index quantifies the proportion of sodium to calcium and magnesium ions in a water sample. Sodium hazard of irrigation water can be well understood by knowing SAR. The SAR values for each water sample are calculated by using the following equations [30].

SAR= Na/ √Ca+Mg/2 expressed in meq/l.

As per Richards's classification, the SAR values of all samples fall in excellent category. 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 favourable drainage conditions. The bad water is not suitable for irrigation and should be used to irrigate plants of high salt tolerance. The calculated value of SAR in the study area ranges from 0.05 to 6.13 and 0.05 to 9.75 in pre and post monsoon.

The plot for SAR vs EC (Figure 8) values when lesser than 10 indicates low SAR with medium salinity, high salinity, very high salinity and values greater than 10 requires careful management by application of gypsum, which makes water feasible and increases soil permeability [31]. Na is important cations which in excess deteriorates the soil structure and reduces crop yield [32]. When the concentration of Na is high in irrigation water, Na tends to be adsorbed by clay particles displacing Mg and Ca ions. This exchange process of Na in water for Ca and Mg in soil reduces the permeability and results in soil with poor internal drainage. Hence, air and water circulation is restricted during wet conditions and become hard when dry [33]. Na causes an increase in the hardness of soil as well as reduction in its permeability [29]. The sodium in irrigation water is also expressed as percent sodium (%Na) and can be determined using the following equation

$Na\% = (Na^+ + K^+) *100/ (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$ where all ionic concentrations are expressed in meq/l.

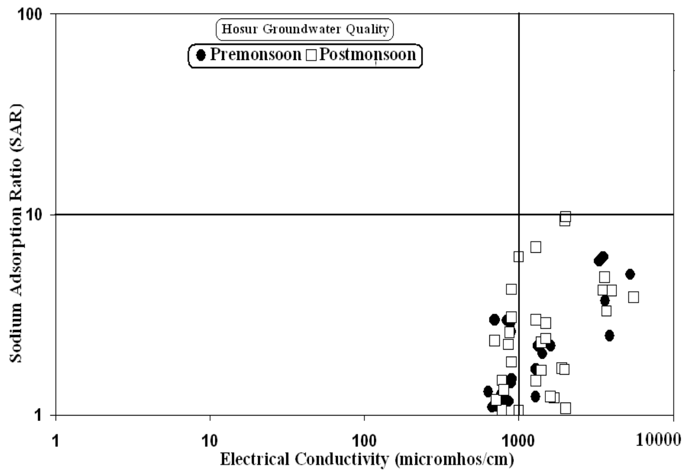


**Fig. 8: USSL classification of Groundwater**

The values from the percent sodium in the study area ranges from 2.16 to 74% in premonsoon and 8.87 to 81.60% in postmonsoon, it is observed that about 8 samples have high sodium percent (above 60%) and is not suitable for irrigation purposes. The figure 9 shows the Wilcox diagram of both pre and postmonsoon seasons. According [34] diagram relating sodium percentage and total concentration indicates that most of samples of the groundwater samples fall in the fields of good to permissible suitable and 5 samples are unsuitable for Irrigation respectively.

The agricultural yields are, generally, very low in the lands irrigated with the water of unsuitable category due to the presence of excess sodium salts. This causes osmotic effects on soil-plant system. In addition to the SAR and Na%, the excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the unsuitability of groundwater for irrigation. This is termed as residual sodium carbonate (RSC) [30]. The RSC is calculated using the formula given below:

$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$ where the concentrations are expressed in meq/l.

If RSC<1.25 meq/l, the water is considered safe. If RSC lies between 1.25-2.5 meq/l, the water is of marginal quality. If RSC>2.5 meq/l, the water is unsuitable for irrigation. In the groundwater, most of the samples fall in good category indication water is fit for irrigation purpose except 3 samples RSC>2.5 meq/l. Thus, based on RSC criteria, the majority of groundwater samples can be considered safe for irrigation purpose as per Figure 10.

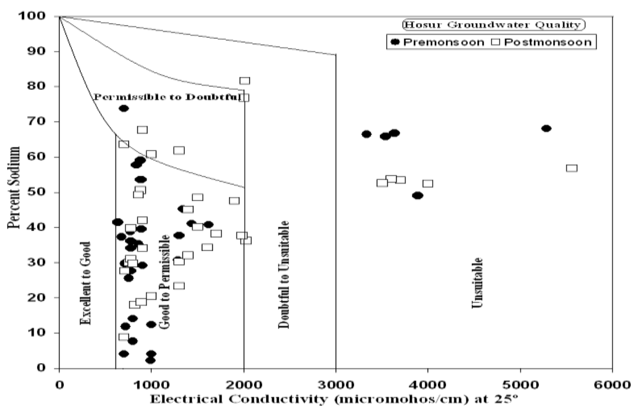


**Fig. 9: Wilcox classification of Groundwater**

## Conclusion

Groundwater quality in and around Hosur area has been analyzed in the present work. The groundwater is alkaline in nature and total hardness is observed in all samples fall under hard to very hard category. The TDS falls under fresh water to saline categories. The fluoride concentration in the south region exceeds the permissible limit.

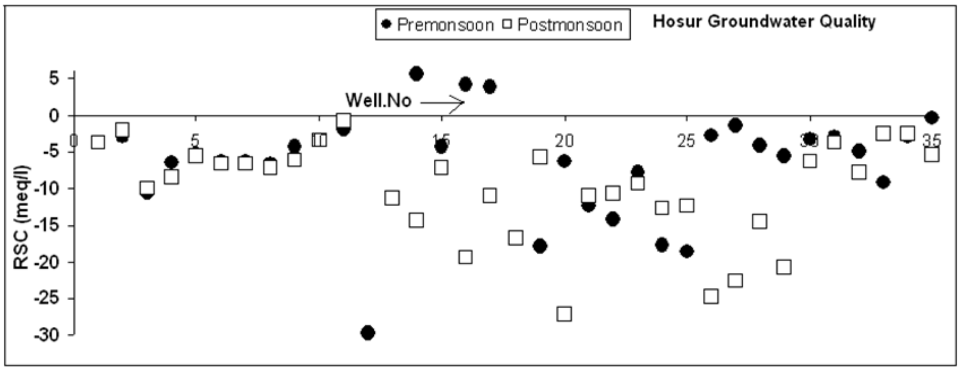


**Figure 10: RSC classification of groundwater**

The concentration of Iron, lead, chromium is below the detectable limit in most of well samples except in the wells in industrial area (SIPCOT) has exceeds the safe limit. Major hydro chemical facies were $CaHCO_3$ type, mixed CaMgCl type and NaCl type facies identified using piper trilinear diagram. The concentration of physiochemical constituents in the water samples were compared with the Bureau of Indian Standards (BIS) to know the suitability of water for drinking. Based on the analysis, most of the area at many locations in industrial area falls in moderately polluted to severely pollute leading the water is unsuitable for drinking purpose. Various determinations such as Sodium Adsorption Ratio (SAR), Percent Sodium (Na %) and Residual Sodium Carbonate (RSC) revealed that most of the samples are suitable for irrigation. According to the quality classification of irrigation water proposed by Wilcox and US salinity classification all the water samples fall in the suitable range for irrigation purpose. It was observed that the quality of groundwater was not suitable for drinking purpose in industrial area and irrigation few sampling sites are unsuitable by the influences of urban and industrial waste discharge, aquifer material mineralogy together with semiarid climate, other anthropogenic activities and increased human interventions in the groundwater quality in the study area.

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