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Original Research Paper

Assessment of Physico-Chemical Characteristics of Groundwater in Chennai

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ABSTRACT

The present work is aimed to analyse physico-chemical characteristics of groundwater in a part area of Chennai, where agriculture is the main livelihood of rural and urban people and the groundwater is the main source for irrigation and drinking. It is noted that in Tamil Nadu, there is evidently much dependence on groundwater due to scarce surface water. Overexploitation of groundwater might lead to complex environmental situation. Hence, a thorough investigation of quality parameters is necessary to ensure the potability of water. The area taken for study purpose is Karayanchavadi which is a part of Chennai in the vicinity of Bay of Bengal. Groundwater samples were collected from 30 wells in the study area and analysed for pH, EC, TDS, TA, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{-2}, NO_3^{-} and F^{-}. A comparison of the groundwater quality in relation to drinking water quality was made. It was found that pH of all the samples was neutral to slightly alkaline. Fluorides, iron and calcium of 90% samples were within the permissible limits. Total dissolved solids, total hardness, sulphate and magnesium of all the samples were within the permissible limits.

INTRODUCTION

Groundwater is one of the Nation's most important natural resources. Groundwater is used for domestic, industrial and irrigation purposes all over the world. In the last few decades, there has been a tremendous increase in the demand for freshwater due to rapid growth of population and the accelerated pace of industrialization. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions.

Exploitation of groundwater has increased greatly, particularly for agricultural purpose, because large parts of the country receive little rainfall due to frequent failures of monsoon and variable flow of surface water sources like rivers, lakes and artificial basins. Groundwater irrigation started with only 6.5 million hectares in 1950-1951 (CGWB 1992), which was later increased to 46.5 million hectares in 2000-2001 (Sivanappan 2002), meeting about 70% of the irrigation water requirements of the country. This clearly indicates the growing pressure on groundwater resources.

The groundwater quality is equally important as that of its quantity. Poor quality of water badly affects the plant growth and human health (WHO 1992, Karanath 1997, Subba Rao 2005). Adverse conditions increase investment in irrigation and health, and decrease agricultural production, which, in turn, reduces the economy of the producer and retards improvement in the living conditions of rural people.

Further, groundwater quality studies with respect to drinking and irrigation purposes have been carried out in different parts of this country (Majumdar & Gupta 2000, Khurshid 2002, Subba Rao & John Devadas 2005), but little work has been carried out in the suburbs of Chennai. Groundwater samples collected every month from the study area during the year 2010 were analysed for various quality parameters.

STUDY AREA

The bearing of the study area is 13°03'00" N and 80°05'59" E, and it covers an area of about 80 sq. km. It is located downstream of the Chembarambakkam lake, which is a major source for agricultural and domestic water supply for Chennai and hence, there is a relative growth in every section of this area. The location map of study area is shown in Fig. 1.

Chennai district enjoys a tropical climate with mean annual temperature of 24.3 to 32.9°C. The temperature is usually in the range of 13.9 to 45° C, and humidity in the range of 65 to 84%. The northeast monsoon during the month of October, November and December chiefly contributes the rainfall for the district. Most of the precipitation occurs in the form of one or two cyclones caused due to depressions in the Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible. The average annual rainfall in chennai is 1200 mm (1978-2008) (Balakrishnan 2008).

Geologically, the district is underlain by formations ranging in age from Archaean to recent. Crystalline rocks

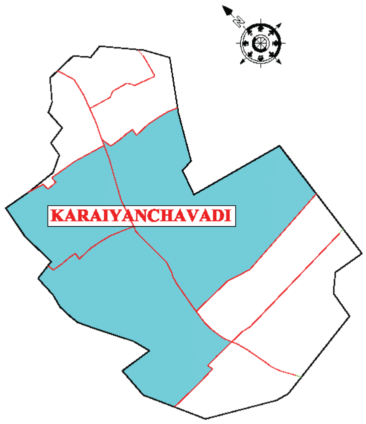

Fig. 1: Location map of study area.

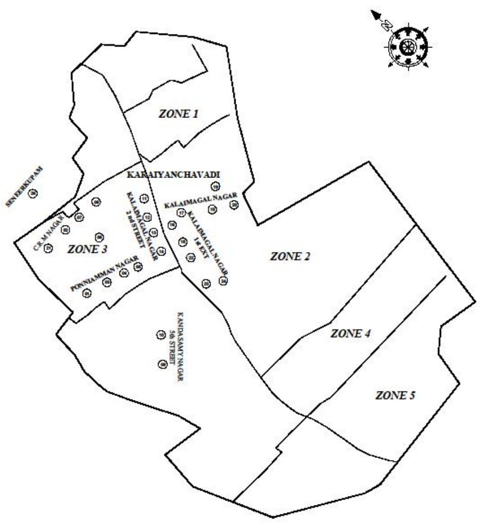

Fig. 2: Location map of open wells.

comprising charnockites, gneisses and associated rocks are restricted to the western part of the district. The central and eastern parts are underlain by a thick pile of Gondwana shales, clays and sandstones below the recent alluvial deposits. Geophysical investigations, carried out in the district, have established the presence of multi-layered substratum, indicating fracture zones in the crystalline formations and multiple granular zones in porous formations (CGWB 2008). The important aquifer systems in the district are constituted by (i) unconsolidated and semi-consolidated formations, and (ii) weathered and fractured crystalline rocks. Groundwater occurs under phreatic conditions in the shallow zones in recent alluvial deposits, Gondwana sediments and weathered residuum in crystalline formations. It is under semi-confined to confined conditions in deeper sedimentary aquifers and fracture zones in hard rocks.

MATERIALS AND METHODS

Groundwater samples were collected from 30 wells during the year 2010 covering both pre-monsoon and post-monsoon periods and analysed for physico-chemical characteristics. The wells have been chosen such that they cover every direction of the study area as shown in the Fig. 2. Depending on the well location, they are set into 5 groups. The samples have been collected in closed white can and numbered accordingly depending on the well location. Special treatments were given for preservation, fixation and handling of water samples before analysis in order to prevent the change in parameters of the sample. The chemical analysis and testing of the samples was carried out immediately by transporting them to laboratory in a controlled environment.

The samples were analysed immediately following the standards methods (APHA 1992). pH was determined by pH meter and electrical conductivity by EC meter. The ion-balance-error computation was made taking the relationship between the total cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and the total anions (CO_3^{-2}, HCO_3^{-} , Cl^{-} , SO_4^{-2}, NO_3^{-} and F^{-}). Each set of complete analyses of water sample was observed to be within the range of acceptability (±5%) used in most laboratories (Domenico & Schwartz 1990).

RESULTS AND DISCUSSION

The analysis of groundwater samples for pre-monsoon and post-monsoon seasons is given in Tables 1 and 2, and presented pictorially in Figs. 3 and 4.

pH: The values of pH range from 6.6 to 7.8 and are within the permissible limit for most of the samples in both the seasons. The average value for pH works out to be 7.2, which in 84% of the limiting value of 8.5. Further, it has been seen that the pH values are slowly and steadily increasing,

Table 1: Pre-monsoon chemical composition of groundwater samples collected from the study area in 2010.

Parameter	Range (mg/L)	Mean	σ	CV
Calcium	24-64	41.58	16.18	38.904
Magnesium	12-70	35.67	17.75	49.773
Total hardness	110-450	238.9	96.97	40.589
Alkalinity	160-270	207.7	35.38	17.039
Chlorides	50-180	111.3	38.36	34.46
Sulphates	55-195	106.3	47.03	44.266
Nitric nitrogen	1.80-5.2	3.793	0.89	23.684
Ammoniacal nitrogen	0.02-1.15	0.378	0.51	135.09
Albuminold nitrogen	0.02-0.64	0.193	0.24	124.65
Iron	0.01-0.7	0.335	0.22	64.746
E.C. (μmho/cm)	630-1270	984.1	218.7	22.227
pH (units)	6.6-7.8	7.157	0.46	6.45
TDS	335-765	580.7	179.2	30.865

Table 2: Post-monsoon chemical composition of groundwater samples collected from the study area in 2010.

Parameter	Range (mg/L)	Mean	σ	CV
Calcium	15-65	43.67	17.09	55.40
Magnesium	7-79	29.33	26.52	27.64
Total hardness	114-488	241.5	133.79	48.80
Alkalinity	147-298	190	52.53	68.12
Chlorides	50-192	99.58	48.60	42.48
Sulphates	38-199	83.67	56.99	157.99
Nitric nitrogen	1.14-4.20	2.733	1.16	98.25
Ammoniacal nitrogen	0.02-1.15	0.313	0.49	124.37
Albuminold nitrogen	0.018-0.68	0.3	0.29	48.02
Iron	0.01-4	1.082	1.34	3.33
E.C. (µmho/cm)	532-1962	854	410.11	34.93
pH (units)	7.1-7.8	7.375	0.24	55.40
TDS	322-864	515.5	180.1	27.64

Table 3: Suitability of water for irrigation.

Water Class	E.C. in µmhos/cm	Alkali Hazard (SAR)
Excellent	< 250	Up to 10
Good	250 - 750	10 - 18
Medium	250 - 2250	18 - 26
Bad	2250 - 4000	> 26
Very Bad	> 4000	-

especially in summer months, implying surface water contamination resulting to infiltration in groundwater.

Specific conductance (E.C.): Specific conductance is a measure of salt content in the form of ions (Karanath 1997). In the present study, the average E.C. value was 220 µmho/cm during pre-monsoon period and 410 µmhos/cm during post- monsoon. As low E.C. values were recorded during the entire period, the water is found to be safe for drinking and domestic purposes.

Total dissolved solids: TDS is an important parameter to ascertain the vulnerability of salt content in dissolved state. Total dissolved solids of water samples range from 322 to 864 mg/L, which shows that most of the samples are within the permissible limit.

Calcium: The mean value of Ca in the groundwater samples was 42 mg/L and 44 mg/L in both seasons as against 200 mg/L which was only 23%. This is not good for the health of people, especially the younger generation and the middle aged people.

Fluorides: Fluoride values ranged from 0.1 to 0.3 mg/L indicating that the values of all the samples are within the permissible limits. Also it shows that the fluoride content is very low in all well waters.

Iron: The concentration of iron in groundwater samples var-

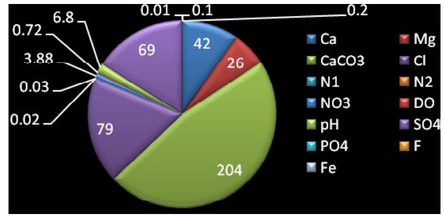

Fig. 3(A)

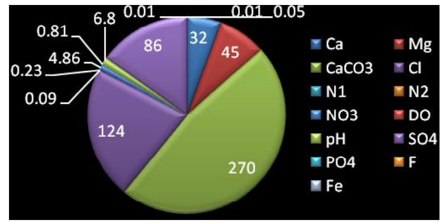

Fig. 3(B)

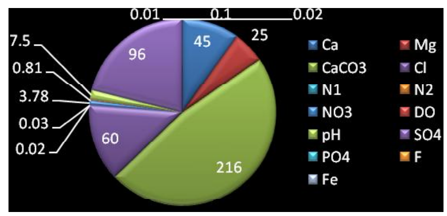

Fig. 3(C)

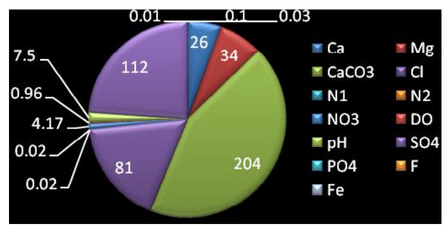

Fig. 3(D)

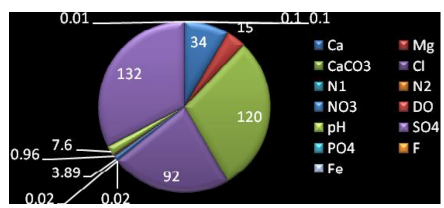

Fig. 3(E)

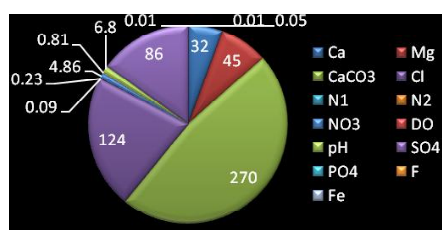

Fig. 3(F)

Fig. 3(A)-3(F): Pie chart showing distribution of chemical parameters in pre-monsoon season.

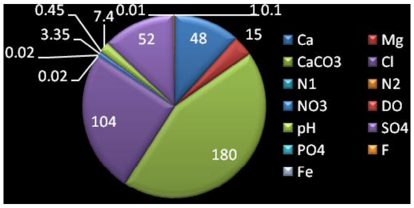

Fig.4(A)

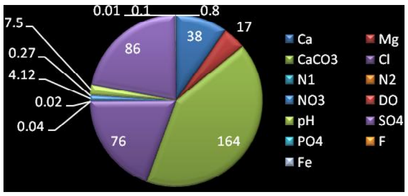

Fig.4(B)

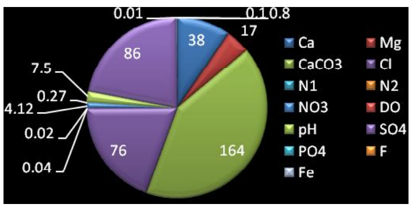

Fig.4(C)

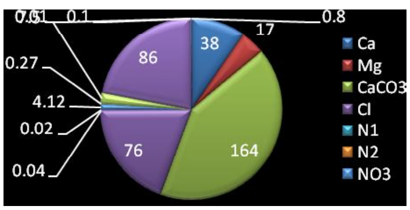

Fig.4(D)

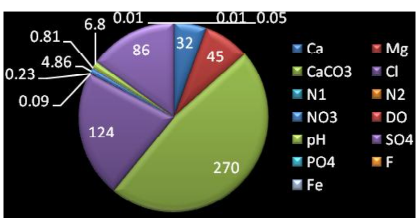

Fig.4(E)

Fig. 4(A)-4(E): Pie chart showing distribution of chemical parameters in post-monsoon season.

ied from 0.01 to 0.7mg/L in pre-monsoon indicating the values of all the samples are within the permissible limit, whereas in post-monsoon season, the concentration varied from 0.01-0.85 mg/L., except in well No. 15, where the iron concentration was found to be 4 mg/L. The removal of excess iron from water is by aeration followed by sedimentation is suggested for water having higher concentration of iron.

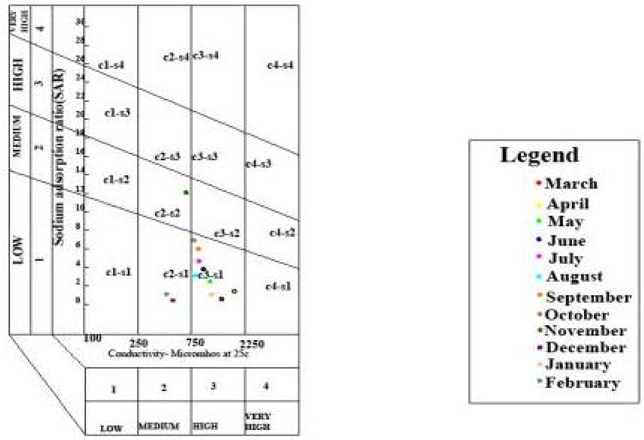

Fig. 5: U.S. Salinity Laboratory's diagram.

Chloride: The upper permissible limit of chloride content as per WHO standards is 1000 mg/L. But in most of the wells the Cl content was far less. On an average the Cl content is as low as 176 mg/L, i.e., 17.6%, whereas the highest is 27.5%. Both the situations are not encouraging, meaning that we need to arrest the toxic effect of other chemical contents so as to improve the Cl effect.

Calcium carbonate: The concentration of $CaCO_3$ varied from 105mg/L to 450mg/L. The average of the least values is 224mg/L. This suggests that as of now the $CaCO_3$ content is 36.5%. This is not an alarming situation. On the other hand the average of the higher values shows that the $CaCO_3$ content is 70%, which is really an alarming one in many of the wells. If unchecked, these wells may become highly polluted by $CaCO_3$ to the determinant of domestic as well as agricultural users**.**

Sulphate: The SO_4 content, compared to the limiting values of 400 mg/L, has the percentage of 33. This is considered a tolerable limit as for other cases too.

Total hardness: Total hardness values vary from 110 mg/L to 450 mg/L in pre-monsoon season and 114 to 488 mg/L in post-monsoon season, which shows that majority of the samples fall under the hard category.

Irrigation water quality: The suitability of groundwater for irrigation purpose is normally assessed by electrical conductivity and SAR. There is a close relationship between SAR values in irrigation water and the extent to which Na^+ is adsorbed by soils. If water used for irrigation is high in Na^+ and low in Ca^{2+}, the ion-exchange complex may become saturated with Na^+, which destroys soil structure, because of dispersion of clay particles. As a result, the soils tend to become deflocculated and relatively impermeable. Such soils can be very difficult to cultivate. The total concentrations of soluble salts in irrigation water can be classified based on electrical conductivity and alkali hazard as given in Table 3.

The sodium adsorption ratio (SAR) value was calculated for all groundwater samples and varies from 2 to 14 in both pre-monsoon and post-monsoon seasons. A graph has been plotted using US salinity Laboratory's diagram (Fig. 5) (US Salinity Laboratory Staff 1954) to check the vulnerability of saline and sodium hazard. For the study area, it has been found that it falls between low to high.

CONCLUSIONS

The groundwater of the study area, in general, is colourless, odourless and slightly alkaline in nature with an average EC of 410 µmhos/cm. Total dissolved solids, total hardness, sulphate, nitrate, and alkalinity in all the groundwater samples in both the seasons are within permissible limit of drinking water standards. However, chlorides and fluorides are found to be very less in certain samples in both the seasons. Hence, groundwater in Karayanchavadi of Chennai region requires precautionary measures for higher chloride and fluoride content to avoid adverse effect on human health. On the basis of US Salinity Diagram the suitability of irrigation water was ascertained.

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