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Physico-chemical characteristics of groundwater in some areas of Villupuram district, Tamil Nadu, India

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Abstract
The groundwater is one of the most important sources for drinking water now a day. However due to the dumping of municipal wastes and agricultural wastes into the ground and industrial waste water into the river leads to the contamination of groundwater. Thus the analysis of the groundwater quality is very important to protect the human health. So the present study deals with the physico-chemical characteristics of ground water quality in Villupuram, Vikravandi and Tindivanam towns in Villupuram district. Water samples were collected from different identified bore wells for the purpose of studying the quality of groundwater during JAN 2016. The bore wells from which the samples were collected are extensively used for drinking purpose. It has been proved from the present investigations that value of few parameters TDS, Total Hardness, Calcium, Sulphate, Chloride, Nitrate, Alkalinity, Magnesium, Ammonia and Electrical conductivity are fall out of the permissible range with reference to WHO guideline levels for drinking water. The most serious pollution threat to groundwater is from TDS, Total Hardness, Alkalinity, Calcium, Chloride, Nitrate, Sulphate and Calcium, which are associated with sewage and pollution of industrial waste. Hence, suggested to take proper care to avoid contamination of groundwater pollution through periodic monitoring of the water quality.

Keywords: Groundwater, physico – chemical parameter, Villupuram district

1. Introduction

The chemical constituents in groundwater is one of the major factors which decides the water for suitability for various purposes such as domestic, industrial and agricultural. Groundwater is getting polluted due to urbanization and industrialization in the recent times. Though this water contributes about 0.6% of the total water resources on earth, it accounts for rural domestic water needs (80%) and urban water needs (50%) in developing countries [1].

Generally, both groundwater and surface water can provide safe drinking water, as long as the sources are not polluted and the water is sufficiently treated. Groundwater is preferable over surface water for a number of reasons. First of all, groundwater is reliable during droughts, while surface water can quickly deplete. Groundwater is, in general, easier and cheaper to treat than surface water, because it tends to be less polluted. Groundwater can become contaminated, by many of the same pollutants that contaminate surface water. Pollution of groundwater occurs when contaminants are discharged to, deposited on, or leached from the land surface above the groundwater. Even if there are no industrial and domestic pollution sources in the area, it is important to realize that the water may not be free from contaminants, and should be tested before human consumption. Groundwater quality has become an important water resource issue due to rapid increase of population, urbanization, lowland, & too much use of fertilizers, pesticides in agriculture [2].

Only 12% of people get good drinking water. Inadequate management of water resources directly or indirectly has resulted in the degradation of hydrological environment [3].

Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal. The addition of various kinds of pollutants through the agency sewage, industrial effluents, agricultural runoff etc. into the water bodies brings about a series of changes in the physicochemical and characteristics of water. The well known industrialization and urbanization leads to contaminations of water. For agricultural purposes groundwater is explored in rural especially in those areas where other source of surface water is not considered.

During last decades, this is observed that groundwater get polluted drastically because of increased human activities. In India, industry and agriculture coexists in the same area and share the same water resources. Industries withdraw large quantities of water for their needs and discharge into the river sources. Disposal of untreated industrial effluent creates environmental pollution [4].

The main objective of this work is to analyze various physico-chemical parameters of the ground water at Villupuram, Vikravandi and Tindivanam and its surrounding areas of about 20 square kilometer in Villupuram district, Tamil Nadu.

2. Description of the study area

2.1 Study Area

The study area lies between Latitude N 11^{0}56' and Longitude E 79°29' and is located in Northeast of Tamil Nadu in India, which is in the far southeast part of India, situated 160 km south of Chennai 160 km north of Trichy,177 km east of Salem, 40 km west of Pondicherry it shares the seashore of the Bay of Bengal covering about 7217 Km^2 area (Fig.1). The area includes Villupuram, Vikravandi, Tindivanam.

ZONE-3

S16-Jakkampettai,
S17-Tindivanam police station,
S18-Gandhi nagar,
S19-Eswaran kovil,
S20- Tindivanam Govt Eng College.

ZONE-2

S11-Vikiravandi tollgate,
S12-Vikiravandi bus stand,
S13-Kaiyathur Road,
S14-Vikiravandi railway station,
S15-Surya Eng College.

ZONE-1

S1-Janakipuram, S2-Villupuram bus stand,
S3-Villupuram railway station, S4-E.S.Eng College, S5-Papankulam, S6-Nannadu,
S7-Cinthamani, S8-Villupuram medical college, S9-Sugar factory, S10-Panayapuram.

2.2 Rainfall

Villupuram district receives rainfall from both southwest and northeast monsoons. The annual normal rainfall for the district is 1046.8 mm (41.2in). The driest month is march with 6 mm (0.24in) with an average of 222 mm (8.7in) per annum, the most precipitation falls in October.

2.3 Climate

The district enjoys a tropical climate. The highest temperatures are recorded during May and June. The mean daily minimum and maximum temperature are 24.6 to 32.0° C. The average annual temperature 28.4.^{0}C

2.4 Topography

The general geological formation of the district appears to be simple. The greater part of it is covered by the metamorphic rocks belonging to Genesis family. There are also three great groups of sedimentary rocks belonging to different geological periods. The Kalrayan Hills in the north represents a continuous range of hills covered with some thorny forests and vegetation. Among the hills, the most beautiful part of the district lies, round about the Gingee Hills [5].

3. Materials and Methods

3.1 Collection of water samples

Groundwater samples were collected from 20 locations within the study area during month of Jan 2016, Sampling is done at each station in polythene bottles of two-litre capacity. The samples were analyzed for various water quality parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Alkalinity, Total Hardness (TH), Chloride, Sulphate, Nitrate, Iron, Calcium and Magnesium Fluoride and Ammonia were determined using standard methods [6]. The method used for estimation of various Physico-chemical parameters are shown in Table-1. Reagents used for the present investigation were A.R. Grade and double distilled water was used for preparing various solutions. Methods used for estimation of various Physico-chemical parameters are shown in Table-1.

Table 1: Methods used for estimation of Physico - Chemical parameters

S. No	Parameter	Methods
1	P^H	P^H Meter
2	Electrical Conductivity	Conductivity meter
3	Total Hardness	EDTA Titration
4	TDS	Filtration method
5	Alkalinity	Indicator method
6	Chloride	Argentometric method
7	Nitrate	Phenol disulphonic acid method
8	Sulphate	Nephelometry Method
9	Fluoride	SPADN spectrophotometric method
10	Calcium	EDTA titration
11	Magnesium	EDTA Titration
12	Iron	PHENANTHROLINE Spectrometry
13	Ammonia	Calorimetric method

4. Results and Discussion

Results are presented in Table-2, and Table-3 compared with the permissible drinking water standards specified by WHO Standard Specification as per 2011, [7] and the number of samples exceeding the limits parameter wise and their values are given.

Table 2: Physico-chemical parameter of ground water during month of Jan 2016

Sample No	P^H	EC	TH	TDS	ALKALINITY	Cl	NO_3	SO_4	F	Ca	Mg	Fe	NH_3
S1	7.1	2450	510	1682	472	370	25	210	0.2	111	58	0	0.72
S2	7.2	2480	500	1710	480	372	30	212	0.2	118	62	0	0.74
S3	7,2	2470	490	1690	478	360	32	211	0.2	120	64	0	0.76
S4	7.2	2610	460	1646	453	365	22	220	0.6	110	56	0	0.61
S5	7.2	2640	450	1651	462	372	20	220	0.6	116	60	0	0.64
S6	7.0	2640	470	1650	423	355	19	215	0.6	112	75	0	0.5
S7	7.1	1590	280	1054	310	180	32	120	0.4	69	55	0	0.3
S8	7.1	1310	280	1100	328	200	35	123	0.4	72	43	0	0.4
S9	6.5	1140	270	1206	413	220	30	110	0.1	70	42	0	0.4
S10	6.6	980	250	1250	403	218	33	111	0.1	71	45	0	0.4
S11	6.9	4110	1050	2813	585	605	80	244	0.2	234	112	0.4	1.93
S12	7.1	3990	940	2790	570	621	78	223	0.2	232	111	0.3	1.81
S13	7.1	4120	970	2789	587	598	75	221	0.2	231	105	0.3	1.85
S14	7.3	3800	950	2739	530	372	70	236	0.6	232	110	0	0
S15	7.2	4000	960	2742	532	366	67	234	0.6	230	95	0	0
S16	7.2	3850	930	2754	515	370	66	222	0.6	215	108	0	0
S17	7.2	2720	710	1910	580	493	115	221	0.2	156	84	0	0.4
S18	7.2	2740	680	1922	565	480	112	223	0.2	150	85	0	0.41
S19	7.3	2780	820	1960	512	558	105	235	0.1	160	90	0	0.44
S20	7.2	2770	770	1942	498	552	110	220	0.1	145	81	0	0.42

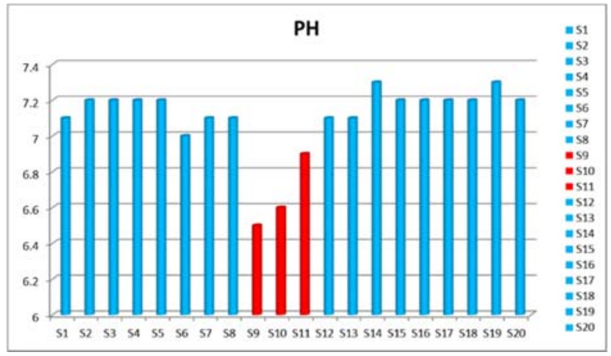
Table 3: Results of water analyzed in comparison with WHO standards

	Permissible limit as per,	Concentration	Observed	No of samples exceeding	Percentage
Parameters	WHO 2011	Minimum	Maximum	permissible limit	%
P^H	7.0-8.5	6.5	7.3	3	15
EC	1000	980	4120	19	95
Total Hardness	300	250	1050	16	80
TDS	1000	1054	2813	20	100
Alkalinity	200	310	585	20	100
Chloride	250	180	621	16	80
Nitrate	45	19	115	10	50
Sulphate	200	110	244	16	80
Fluoride	1.5	0.1	0.6	Nil	Nil
Calcium	75	69	234	16	80
Magnesium	50	42	112	17	85
Iron	0.3	0	0.4	1	5
Ammonia	0.5	0	1.93	8	40

All parameters are expressed in mg/l except pH and EC. EC in µS/cm

4.1 PH

Natural and human processes determine the pH of water. pH is a measure of acidic/basic nature of water. The range varies from 0 - 14, with 7 being neutral. pH less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base [8]. pH is a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. The pH of water determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. High pH causes a bitter taste; water pipes and water using appliances become encrusted with deposits, and depress quantity of chlorine in water. Thus, it causes need for additional chlorine when pH is high. According to WHO desirable limit of pH is 7-8.5. In Villupuram district pH values varies from 6.5 to 7.3. Area comprising of pH less than permissible limit is only 15% (S9, S10, S11) of entire study area. These samples are acidic in nature the remaining 85% samples are within permissible limit, If the pH value lies beyond the limit it affects the mucous membrane of the cells [9].

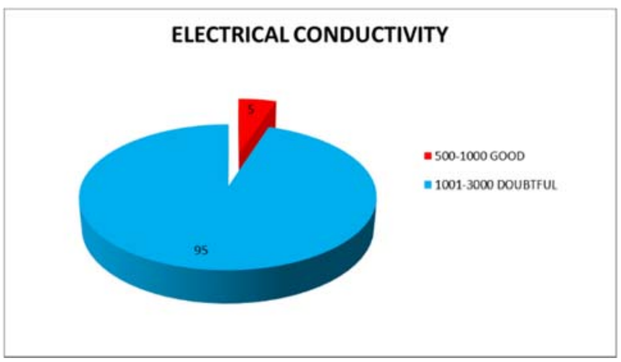


4.2 Electrical Conductivity (EC)

The electrical conductance value of all the samples varies in the (Table.4) range of 980 to 4120 µS/cm. The maximum electrical conductivity value of 4120 µS/cm was found in the sample - S13 and the minimum value of 980 µS/cm was found in the sample S10.The electrical conductance is a good indication of total dissolved solids which is a measure of salinity that affects the taste of portable water. The electrical conductivity is also influenced by ionic mobility, ionic valence and temperature [10].

Table 4: Classification of ground water based on Electrical conductivity

Electrical conductivity µS/cm	No. of. samples	Percentage %	Description
<500	Nil	--	Excellent
500-1000	1	5%	Good
1000-3000	19	95%	Doubtful



4.3 Total Hardness (TH)

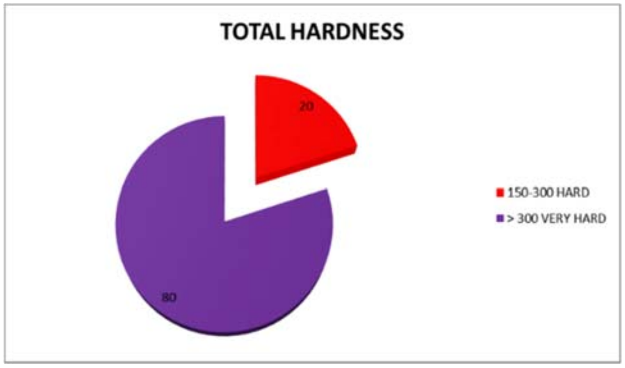
Total Hardness (TH) or Hardness of water is commonly understood as a property, which prevents the lather formation with soap [11]. It is primarily caused by calcium and magnesium, but any alkaline earth metal such as iron, manganese, carbonates, bicarbonates, sulphates, nitrates and silicates may contribute to hardness [12]. In this study area, the Total Hardness in water from all the groundwater resources ranges from 380 and 1050mg/l. In all these samples higher values of Total Hardness was observed, may be due to the presence of high amount of calcium and magnesium metals in the water. The maximum total hardness value of 1050 mg/L was found in the sample S11 and the minimum value of 250mg/L was found in the sample S10.

The classification of groundwater (Table.5) based on total hardness (TH) shows that the majority of samples fall in the hard water category [13] & very hard water category. Hard and very hard water might lead to pre-natal mortality, cardio-vascular diseases etc [14] and is unsatisfactory for domestic purpose and hence water softening processes for removal of hardness are needed [15]. TH of the ground water was calculated using the formula given below [16].

TH (as $CaCO_3$) mg/l = (Ca^{2+} +Mg^{2+}) mg/l x 50.

Table 5: Classification of ground water based on Hardness range.

Total Hardness mg/L	No. of. Samples	Percentage %	Description
0-75	Nil	--	Soft
75-150	Nil	--	Moderately hard
150-300	4	20	Hard
>300	16	80%	Very hard



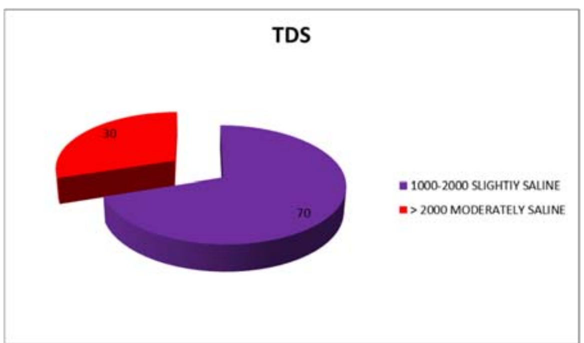
4.4 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) are various kinds of mineral substances present in the water. Some dissolved organic matter may also contribute to Total Dissolved Solids. The concentration of dissolved solids in water gives an idea about suitability of this water for various uses including that of drinking purpose. It also indicates the salinity of water. Dissolved solids tend to increase with increasing pollution of water [17]. Water containing 1000 mg/l of TDS is Permissible limit as per WHO. In the present investigation, the TDS values have varied from 1054 to 2813 mg/l in the study area. These values are more than the WHO standards.

To ascertain the suitability of groundwater for any purposes, it is essential to classify the ground water depending upon their hydro chemical properties based on their TDS values [18] which are presented in (Table.6).

Table 6: Classification of ground water based on TDS values.

TDS mg/L	No. of. samples	Percentage %	Description	
<500	Nil	--	Non-saline	Excellent
500-1000	Nil	_	Non-saline	Good
1000-2000	14	70	Slightly saline	Fair
>2000	6	30	Moderately saline	Poor

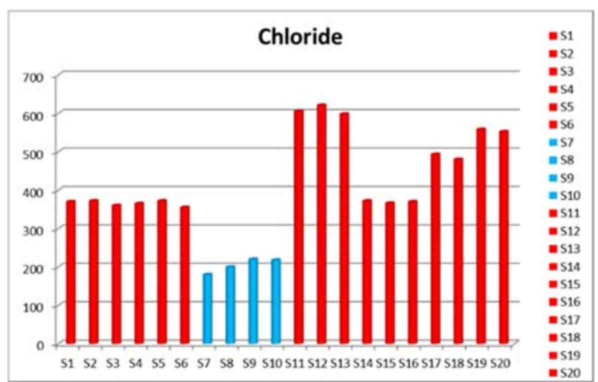


4.5 Alkalinity

The total alkalinity of the contaminated water was noted. The values of all the sample varies in the range of 310 mg/l to 585 mg/l. Very high value is obtained for the sample S11 and very low value is obtained for the sample S7. Alkalinity for a standard drinking water is 200mg/l. But in the area the alkalinity is 587 mg/l. It indicates the presence of bicarbonates, carbonates and hydroxides Above the normal value the water taste becomes unpleasant High alkalinity should be corrected for both economic and health concerns. Measure of alkalinity is useful in water treatment, softening and control of corrosion [19].

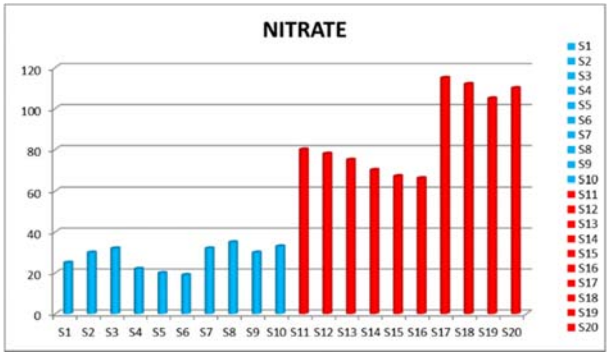
4.6 Chloride (Cl)

Chloride imparts an undesirable taste to water and to beverages prepared from water. In addition, it can cause corrosion in water distribution systems. In the samples selected the value of chloride varies from 180 mg/l to 621 mg/l. Desirable limit is 250 mg/l and thus content of chloride has to be maintained. Only 20% of area is having chloride content less than the desirable limit. Chloride in human blood is an important electrolyte and works to ensure that body's metabolism is working correctly. When there is a disturbance in blood chloride levels, it often leads to kidney damage. Chloride helps the acid and base balance in the body [20].



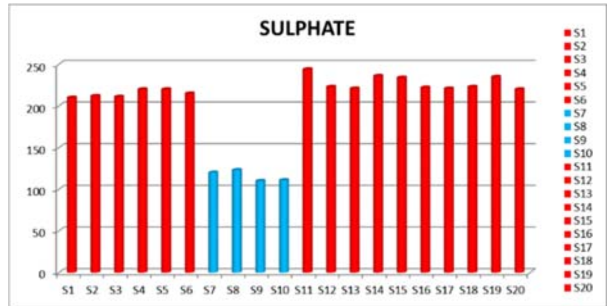
4.7 Nitrate (NO_3)

High concentrations of nitrate suggest pollution. Some animals such as ruminants (cud chewers) can be poisoned by nitrate if the concentration is high. High level of Nitrate encourages growth of algae and other organisms. Nitrates are one of the major inorganic salts regulating the productivity of phytoplankton. The tolerance limit for the nitrate is 45mg/l and beyond this causes methemoglobinemia. Infants below the age of six months who drink water containing nitrate in excess could become seriously ill and if untreated may die. Symptoms include shortness of breath and blue-baby syndrome [21]. The nitrate value of all the test samples varies in the range of 19 mg/l to 115 mg/l. The maximum value 115mg/l of the nitrate is obtained for the sample S17. The minimum value 19mg/l of the nitrate is obtained for the sample S6.



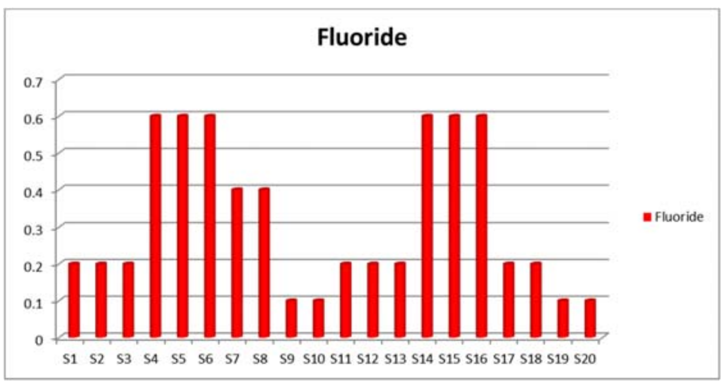
4.8 Sulphates SO4

High concentrations of Sodium and Magnesium sulphate cause cathartic and dehydration in human beings [22, 23]. The recommended concentration of sulphate in drinking water is limited from 100 to 200 mg/l. In the present study, the sulphate concentration in the choose water samples varied from 110 to 244 mg/l. The results indicate that the distribution of sulphate is much above the limit in 16 samples, prescribed by WHO The maximum Sulphate value of 244 mg/L was found in the sample S11 and the minimum value of 110mg/L was found in the sample S9.



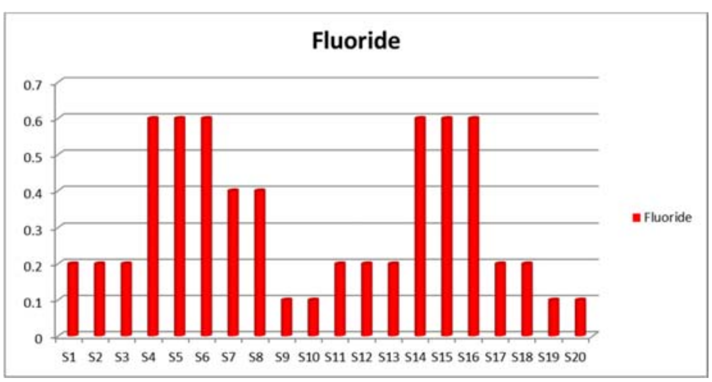
4.9 Fluoride (F)

Fluoride in groundwater has drawn worldwide attention due to its considerable impact on human physiology [24, 25]. In general, incidence of fluoride depends on the geological, chemical and physical characteristic of aquifer, and also on the porosity and acidity of the soil and rocks. Similarly, industries and agricultural activities also act as secondary sources [26]. Though fluoride is considered essential at very lower concentrations for human beings, higher concentration will lead to health defects. The maximum and minimum level of fluoride found in the test samples are 0.6 mg/L and 0.1mg/l respectively. All the values are within in the limit 1.5 mg/L which is recommended by WHO [7].



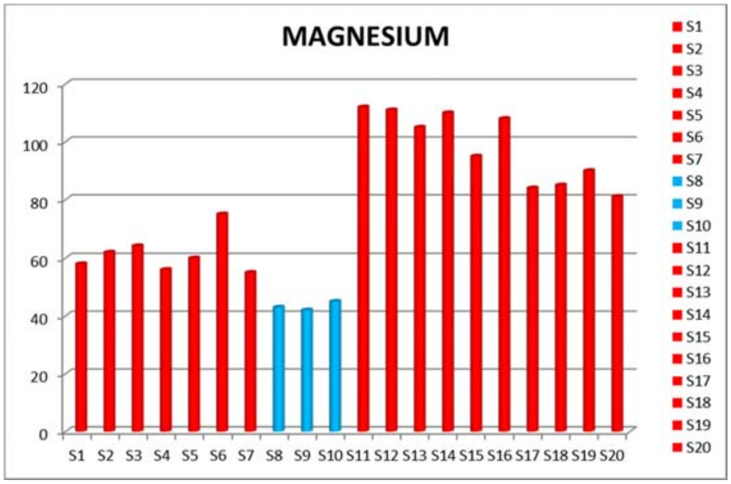
4.10 Calcium (Ca)

Calcium is naturally present in water. Temporary hardness is a type of water hardness caused by the presence of dissolved bicarbonate minerals like calcium bicarbonate and magnesium bi- carbonate. Adequate calcium intake is essential for achieving peak bone mass and subsequent prevention of osteoporosis (WHO, 2011) [27] In study area calcium content varies from 69 to 234 mg/l. The maximum value of the calcium was obtained for the sample S11, and the minimum value of the calcium was obtained for the sample S7. All the test samples have higher calcium value than the permissible value.



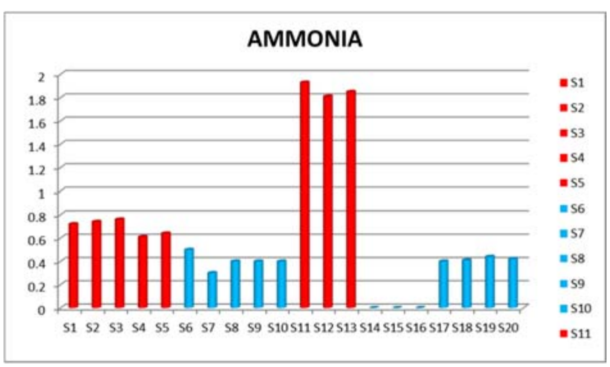
4.11 Magnesium (Mg)

Magnesium is the fourth most abundant cation in the body and the second most abundant cation in intracellular fluid. Magnesium has many different purposes and consequently may end up in water from many anthropogenic sources e.g. chemical industries, fertilizer applications and cattle feed (WHO, 2011). In the test samples Magnesium quantity varies from 42 mg/l to 112 mg/l. Area having less than 30 mg/l is considered as inadequate of magnesium. Low magnesium status has been implicated in hypertension, coronary heart disease, type 2 diabetes mellitus and metabolic syndrome [27]. Moreover, permissible limit of magnesium is 50 mg/l but 85% study areas are exceeding that limit (S1, S2, S3, S4, S5, S6, S7, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20) so some precaution should be taken.



4.12 Iron (Fe)
The iron value of all the test samples varies in the range of 0 to 0.4 mg/l. The maximum value of iron is obtained for the sample S11 and the minimum value of the iron is obtained for the samples S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S14, S15, S16, S17, S18, S1, S20. The permissible limit of the iron value in the groundwater is 0.3 mg/l as per WHO standards. Four samples have higher value than the permissible value.

4.13 Ammonia (NH_3)
Ammonia is freely soluble and diffusible in water. It is an excretory product of all aquatic organisms. Ammonia is generated by heterotrophic microbes as a primary end product of decomposition of organic matter either directly from proteins or from the organic compounds. In the present case the concentration of NH_3 was found to vary between 0 –1.9mg/l [28]. The permissible limit of the ammonia value in the ground water 0.5mg/l as per WHO standards.



5. Conclusion
The underground water in Villupuram district is deteriorating and the maximum sampling stations needs special attention, This study concluded that most of the parameters exceed the permissible limits of WHO standards such as TDS, Total Hardness, Alkalinity, Calcium, Chloride, Nitrate, Sulphate and Calcium. So people should be aware about the quality of water that they are drinking and this problem will be more aggressive when same water sources are used for drinking purpose for a longer period (Chronic) because of the possible clinical problems associated with these chemicals in the drinking water. Hence proper water treatment is required in terms of community health.

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