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A Case Study on Chemical Properties of Ground Water in Madurai District, Tamil Nadu, India

R. Padmanaban, M. Dharmendira Kumar, P.B. Sakthivel, N.S. Elangovan

Abstract*—A case study has been conducted by the present authors to analyze the chemical parameters of ground water in Madurai district, Tamil Nadu, India. The data on ground water has been collected for this study purposes from the Government Department of Tamil Nadu for all the seven Taluks of the Madurai district during the period of 2001-2011 and compared with B.I. Standards 10500-1991. Most of the parameters found in the water samples like Total Hardness (TH), Ca^{2+}, Mg^{2}+, Na+ and F are within the allowable limits. But the abnormal levels of chemicals like Potassium found in ground water is hazardous to human health and will also bring an adverse effect on agricultural products. Remedial measures have been brought out in this paper.

***Index Terms*— Ground water, Chemical properties, Hazard, Human Health, Agriculture**

I. INTRODUCTION

In India, there is a rapid population growth and therefore huge developments in industrial and agricultural sectors are seen, which are main causes for depletion of ground water sources. Also since the ground water is a major drinking water source, the quality of water available to the public should be free from physiochemical and biological contamination and should have a high degree of purity for drinking as well as domestic purposes. Especially in a district like Madurai in Tamil Nadu, India, the availability of groundwater is limited restricting water renewal due to its geological hard rock strata with major confinement of fractured and weathered zones and minor alluvial formation. Also, there are many reports stating that in Madurai, the industrial wastes are discharged into fresh water sources, and there are chances that the polluted water would have infiltrated into the ground and affected the sub-surface water. Hence a study is needed to check whether the chemical parameters of ground water in Madurai district is within the allowable limits, and suggest suitable measures for improvement.

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***** Correspondence Author (s)
R. Padmanaban*, M.E. (Construction Engineering & Management) Student, Department of Civil Engineering, Jerusalem College of Engineering, Chennai, India.
Dr. M. Dharmendirakumar, Department of Applied Science & Technology, Alagappa College of Technology, Anna University, Chennai, India.
Dr. P.B. Sakthivel, Department of Civil Engineering**,** Jerusalem College of Engineering, Chennai, India.
Mr. N.S. Elangovan, Department of Civil Engineering, Jerusalem College of Engineering, Chennai, India.

II. LITERATURE REVIEW

Dar et al. (2010a) [1] carried out studies on Nitrate contamination in groundwater of Sopore town, Kashmir, India. The study indicates that the concentration of nitrate is higher than permissible limit (50 mg/l) in most of groundwater samples collected from bore wells.

The chief sources of nitrate pollution in the study area are agricultural activities, septic tanks, and human and animal wastes. Another study of Dar et al. (2010b) [2] assessed nitrate contamination of Lidder catchment Kashmir, India and find out that hydrochemistry and total mineralization of water in the study area indicates that the carbonate and the silicates play a dominant role in the evolution of water. The dissolution of calcite, dolomite, and intermediate basalts were found largely to determine the major elemental composition of water in the Lidder catchment.

Laluraj et al. (2005) [3] have studied ground water chemistry of shallow aquifers in the coastal zones of Cochin and concluded that groundwater present in the shallow aquifers of some of the stations were poor in quality and beyond potable limit as per the standard set by WHO and ISI. Dar et al. (2010c) [4] evaluated environmental chemistry of groundwater in Thiruporur block, Kancheepuram District, Tamil Nadu, and found that the major contributors of nitrate in groundwater are decaying organic matter, sewage, burning yard wastes, and nitrate fertilizers. In a study of Dar et al., (2010d)[5] who carried out investigation of groundwater quality of Dindigul, Tamil Nadu, they have brought out that the groundwater is hard to very hard, fresh to brackish, and alkaline in nature. The most series pollution threat to groundwater is from nitrate ion. Twelve percent nitrate ion concentration of the study area is beyond the maximum allowable limit for drinking purpose.

Manikandan et al. (2012) [6] carried out investigation of groundwater quality of Krishnagiri district, Tamil Nadu, and the study reveals that higher concentration of fluoride was noted in hard rock terrain of this district . It is found that nearly 58 % of the samples have more fluoride corresponding to magnesium water types. This is due to the release of fluoride from the magnesium-bearing minerals like biotite, hornblende or reasons of weathering of apatite/hydroxyapatites that is observed in charnockites.

Emmanuel et al. (2009) [7] have studied the geo-chemical characteristics and salinity level of Rio-de- Janeirno in the coastal aquifer in South East Brazil using 30 samples. They used Pipers diagram to study the geo-chemical type. The results revealed that 53 per cent of the water belongs to Na-Ca-HCO_3 type, 20 per cent consists of Na-Ca-Cl-SO_4 type and 27 per cent of the samples are of Na-Mg-Ca-HCO_3-Cl-SO_4 geo-chemical type.

Aravindan et al. (2003) [8] made an attempt to model the principal chemical component of groundwater in the hard rock area of Gadilam River Basin, Tamil Nadu; and the research out brings that during winter, Na+K was closely correlated with Chloride but in summer the concentration of Na+K was not very high.

III. STUDY AREA

Madurai district is situated in the Southern Peninsula of India in the State of Tamil Nadu, with an administrative area of 3742 square kilometers lies in between 09^0 32' 00" to 10^0 18' 00" (N) latitude and 77^0 28' 00" to 78^0 27' 00" (E) longitude. The district is divided into seven Taluks namely Madurai North (M_1), Madurai South (M_2), Melur (M_3), Vadipatti (M_4), Usilampatti (M_5), Peraiyur (M_6) and Tirumangalam (M_7). This study was carried out in this region where the general climate is tropical and it receives rainfall by both North East and South West monsoons. The average annual rainfall of this district is 857.63 mm. The terrain does not contain potential aquifers to store large quantity of water and transmit to other areas due to the heterogeneous nature of hard rock formation.

IV. METHODOLOGY

The ground water samples from 58 control wells and 37 piezometers in seven Taluks in Madurai are collected every year during January-July of every year by the Public works department of Tamil Nadu, and tested for physical, chemical and biological properties. The present authors have collected the data from the respective Government Department and studied the chemical parameters viz., Electrical conductivity (EC), Total Hardness (TH), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Bicarbonate (HCO_3) and Fluoride (F), and this study is only meant for academic purposes.

V. RESULTS AND DISCUSSION

The results observed (mean values) from the ground water samples of Taluks, M_1, M_2, M_3, M_4, M_5, M_6 and M_7 during the period 2001 to 2011 for the various chemical properties are given in Table 1.

Table.1 Mean Values of chemical properties of Ground Water observed during the period 2001 to 2011

Quality parameter	M1	M 2	M 3	M 4	M 5	M 6	M 7	BIS (IS-10500: 1991)
EC (µmhos/cm)	1682	1637	1575	1340	2105	1168	1841	700-3000
TH (mg/l)	477	434	427	468	658	369	568	300-500
Ca2+ (mg/l)	75	78	85	49	101	63	107	75-200
Mg2+ (mg/l)	70	59	52	53	98	51	73	30-100
Na+ (mg/l)	162	197	175	77	186	109	162	200-300
K+ (mg/l)	30	9	39	11	29	11	16	10
HCo3 (mg/l)	334	385	296	322	385	314	309	500
F (mg/l)	0.72	0.85	0.61	0.63	0.91	0.83	0.68	1.0-1.5

Note: M1- Madurai North; M2- Madurai South; M3- Melur; M4-Vadipatti; M5-Usilampatti; M6-Peraiyur; M7- Tirumangalam

Total hardness (TH) - The presence of cations such as Calcium and Magnesium and anions such as Carbonate, Bicarbonate, Chloride and Sulphate in water is the primary cause for the Hardness property of the water. There is no known adverse effect due to Water Hardness; however, some evidence effects indicates its role in heart diseases [2] and hardness of 150-300 mg/l and above may cause kidney problems and formation of kidney stones [4]. Hard waters are undesirable because they cause unpleasant taste and reduce ability of soap to produce lather. Hard water is unsuitable for domestic use. In Madurai district, the range of total hardness varies between 369 to 658 mg/l and it is shown in fig 1. It is observed (from lowest to highest values) that the taluk Peraiyur (M6) has reported the lowest value of 369 mg/l, and other values in the increasing order are 427 mg/litre in Melur taluk (M3), 434 mg/litre in Madurai South (M2) Taluk, 468 mg/litre in Vadipatti (M4) Taluk, 477 mg/litre in Madurai North (M1) Taluk, 568 mg/litre in Tirumangalam (M7) Taluk and the highest of 658 mg/l in Usilampatti (M5) Taluk. All the samples have exceeded the minimum value prescribed by BIS 10500-1991, but within the maximum limit except in Tirumangalam (M7) Taluk and in Usilampatti (M5) Taluk. Groundwater in the area exceeding the limit of 300 mg/l as CaCO3 is considered to be hard [5], this may be due to geology of the rocks and pollution by sewage effluent/ industrial discharge.

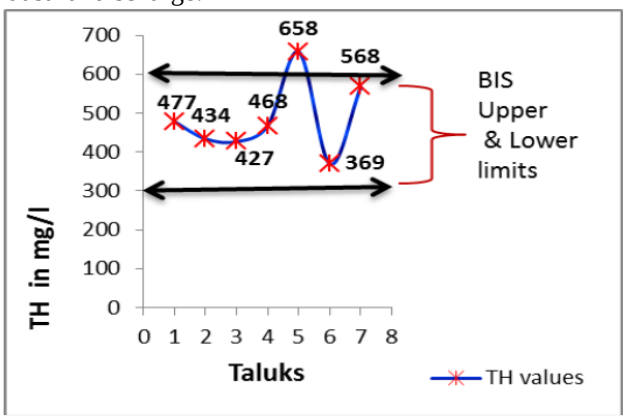

Fig.1 TH of the Ground Water Samples collected in various Taluks of Madurai District

Calcium (Ca2+) content is very common in groundwater, because they are available in most of the rocks, abundantly and also due to its higher solubility. Calcium, in the form of the Ca2+ ion, is one of the major inorganic cations, or positive ions, in saltwater and freshwater. It can originate from the dissociation of salts, such as calcium chloride or calcium sulfate, in water. Groundwater and underground aquifers leach even higher concentrates of calcium ions from rocks and soil due to the presence of Lime stone, Dolomite and Gypsum. The test results shows, the Calcium value in Vadipatti (M4) Taluk of 49mg/l and Peraiyur (M6) taluk of 63mg/l are much below the acceptable limits of 75mg/l, whereas in other taluks, the values are 75mg/l, 78mg/l, 85mg/l, 101mg/l and 107mg/l in taluks Madurai North (M1), Madurai South (M2), Melur (M3), Usilampatti (M5) and Tirumangalam (M7) respectively. Fig.2 shows that the values are within the higher limit of 200mg/l.

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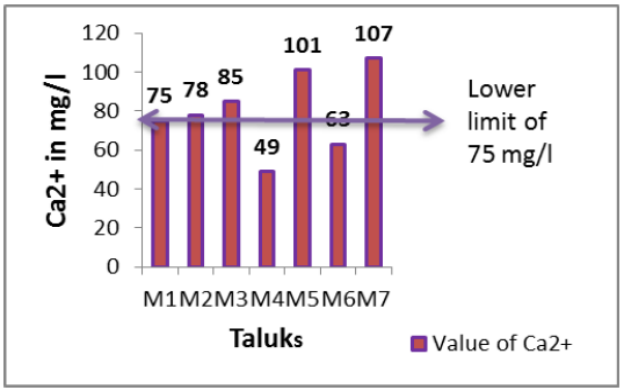

Fig.2 Ca^{2+} of the Ground water samples collected in various Taluks of Madurai District

The Magnesium (Mg2+) 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 [6], while deficiency may cause structural and functional changes in human beings. Magnesium (Mg2+) 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 values are 70mg/l, 59mg/l, 52mg/l, 53mg/l, 98mg/l, 51mg/l and 73mg/l in the Taluks of Madurai North (M_1), Madurai South (M_2), Melur (M_3), Vadipatti (M_4), Usilampatti (M_5), Peraiyur (M_6) and Tirumangalam (M_7) respectively. The values are more than the lower limit of 30mg/l but within the upper limit of the 100mg/l. Generally Calcium, Magnesium and Total Hardness in the groundwater are interrelated.

Sodium (Na+) - The release of the soluble products during the weathering of plagioclase feldspars is the primary source for the presence of sodium in the ground water. The sodium concentration more than 50 mg/l makes the water unsuitable for domestic use because it causes severe health problems like hypertension [8]. Here in the entire district, the result shows, the presence of Sodium is well below the minimum acceptance value of 200mg/l. The mean values are 77mg/l in Vadipatti (M_4) Taluk,109mg/l in Peraiyur (M_6) taluk, 162mg/l in both the Taluks of Madurai North (M_1) and Tirumangalam (M_7), 175mg/l in Melur (M_3), 186mg/l in Usilampatti (M_5) and 197mg/l in Madurai south (M_2).

Potassium (K) occurs in various minerals, from which it may be dissolved through weathering processes. The most common minerals which are the potassium source are the orthoclase, feldspar, microcline, leucite, biotite are present in granites of the area. Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy human beings. Adverse effects may occur, when consuming drinking-water with unusually high levels of potassium. Individuals most at risk are primarily those in which excretion of potassium ions might be reduced or compromised, including those with kidney disease or renal insufficiency, older individuals who have reduced physiological reserve in their renal function, as well as individuals with other conditions (heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency and existing hyper kalaemia) and/or individuals who are taking medications that interfere with normal potassium-dependent functions in the body. In addition, infants may also be more vulnerable because of a limited renal reserve and immature kidney function.

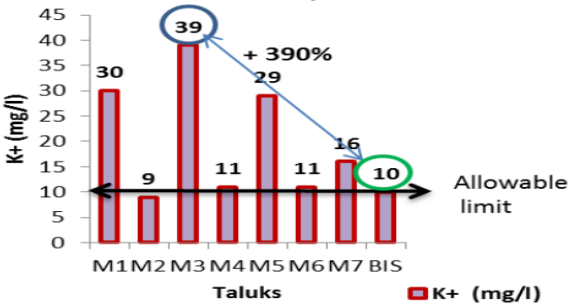

Fig.3 K^+ of the Ground water samples collected in various Taluks of Madurai district

Figure 3 shows, in Madurai district the values of Potassium present in the ground water is much more than the allowable limit of 10mg/l except in Madurai South (M_2) Taluk with 9 mg/l which is also in the border line. In all other areas the value of potassium present is in higher side of 390% (39mg/lit), 300% (30mg/l), 290% (29mg/l), 60% (16mg/l) and 10% (11mg/l) in Melur (M_3), Madurai north (M_1), Usilampatti (M_5), Tirumangalam (M_7) and Peraiyur (M_6), Vadipatti (M4) respectively. The excessive amount of Potassium in ground water in this region may be due to excessive usage of fertilizer on the cultivation lands and also the effect of effluent discharged by domestic sewage and industrial effluents in and around these areas.

The Bicarbonate (HCO3) and Fluoride (F) in the ground water of this region are satisfactory and below the admissible limit of 500mg/l and 1mg/l of BIS 10500-1991. The lowest limit is absorbed at Melur (M_3) taluk with HCO3 as 296mg/l and F as 0.61mg/l. The range varies up to a higher range of HCO3 as 385mg/l and F as 0.91mg/l in Madurai south (M_2) and Usilampatti (M_5).

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 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 loss from transpiration.

The values of electrical conductivity of the ground water of the seven Taluks range from 2105 to 1168 µS /cm. The higher value is obtained in Usilampatti taluk (M_5) 2105 µS /cm and the lower value in Peraiyur taluk (M_6) 1168 µS /cm. The values of other taluks are 1682 µS /cm in Madurai North (M_1), 1637 µS /cm in Madurai South (M_2), 1575 µS /cm in Melur (M_3), 1340 µS /cm in Vadipatti (M_4) and 1841 µS /cm in Tirumangalam (M_7) respectively.

VI. CONCLUSION

From the above studies, it was found that the parameters like total hardness (TH), Ca2+, Mg2+, Na+ and F are well within the allowable limits. The abnormal levels of Potassium content observed in the samples may be due to excess usage of fertilizers on the cultivation lands/ crops and effluent discharged by industries, which would have infiltrated into the ground water. The excess pottasium levels will certainly cause health hazard to human beings and will also have an adverse effect on agriculture.

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It can thus be concluded that the chemical parameters of ground water samples in Madurai district, Tamil Nadu, India is more suitable for domestic and agricultural usages than drinking purposes. It is better to take preventive action by the government by controlling ground water pollution than taking corrective action after the water gets polluted. This study further recommends that if samples are collected at shortened intervals, it will bring more insight on the standards of ground water of Madurai district.

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