Impact of Modernisation of Agricultural Practices on the mineral wealth of Ground Water at Orathanadu Taluk of Tamil Nadu, India

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Abstract— **Modernisation of the agricultural practices has affected the quality of ground water and the extent to which it is affected depends on the location of the water table and the quantity of fertilizer utilised. The present study has been undertaken to verify the extent to which the usage of fertilizers has polluted and influenced the ground water table in a selected area. The water samples have been taken from 20 different locations (a random selection of 68 wells) belonging to different land types such as *nanjai* (highly fertile), *punjai* (fertile), different cropping systems such as high land crops and mixed crops and fields such as banana and paddy fields, were analysed for their quality and effectiveness. The analyses were done periodically for eight months from July 2012 to February 2013, testing for important Physico-chemical parameters like pH, Electrical Conductivity, presence of minerals such as Cl, Na, K, Ca, Mg, Fe, and Cu etc. The analysed results revealed that there was a significant correlation between the cropping system and nitrate-N concentration in groundwater. Even though there was no significant difference between their observed values, a high nitrate-N concentration of groundwater was observed for *nanjai* land followed by *punjai* land. From the testing and analysis it could thus be concluded that the overall quality of groundwater of the selected area is safe for drinking and domestic purposes as well is suitable for irrigation purposes.**

Keywords- ***Cropping pattern, Groundwater Quality, modern agriculture, Fertilizer***

I. INTRODUCTION

Agriculture is an art, science and industry of managing the growth of plants and animals for human use. Modernisation of agriculture makes use of hybrid seeds of single crop varieties, high-tech equipments, fertilizers, pesticides and water. The increased concentrations of nitrogen, phosphorus and potassium contained in most of the fertilizers that are used in modern agriculture pollute the ground water quality thereby affecting the well being of human and animal population through the way of bio-magnification [1-4].

Water, a fortunate and valuable gift of nature to humans acts as a medium for most of the chemical and biochemical reactions and is highly essential for all types of activities. Its impact on environment is critical and is a key factor in the socio-economic development of a country. Groundwater in general, is clean, fresh, pollution free with a high mineral content, and is a part of the hydrological cycle needing proper attention for its evaluation and management. Due to the modern agricultural practices, the pollution of ground water has become a cause for concern.

Farmers persist with very large amounts of animal wastes, green manures and crop residues along with excessive inorganic fertilizers. Limestone aquifers, normally covered only by a thin mantle of highly permeable calcic latasol soil type are affected the most, as any nitrate that is not utilized by the crops reaches the aquifers resulting in high levels of nitrate in them. The extent of ground water pollution depends on various factors such as the rainfall pattern, depth of water level, distance from the source of contamination, and soil permeability [5]. Further it also depends on chemical, physical and bacterial constituents of the pollutants [6].

Human health is also threatened by the excessive application of chemical fertilizers. Once, if the groundwater is contaminated with harmful pollutants, its quality cannot be redeemed. Therefore it becomes imperative to regularly monitor the quality of groundwater and to device ways and means to protect it. Water quality index is one of the most effective tools for ensuring the quality of drinking water [7].

The crops cultivated from the nanjai lands are usually used for cultivating the high land crops or highland with banana or banana alone while paddy is cultivated during the post monsoon season separately. Depending upon the type and area of land under cultivation, the amount of fertilizer, application interval, amount of irrigation and irrigation interval differs. Since any or all these factors influence the quality of ground water, the quality analyses have been done in different agricultural systems and seasons.

Orathanadu taluk, one of the agrarian areas of Tamilnadu, lies in the Cauvery river deltaic region extending from 10o67' N to 10o41' N latitude and from 78o65' to 78o20' longitude at a height of 172 metres (564 feet) above mean sea level. Due to modernisation of cultivation practices, the groundwater quality of this area has been severely affected. Besides Cauvery river of this area receives a heavy volume of sewage, weeds, pesticides, fertilizers, manure and heap which deteriorates the situation further. Information and data relating to the level and type of pollution in the aquifer is thus essential for effective management and to ensure water quality assurance in future. With this knowledge, the present study attempts to evaluate and improve the quality of groundwater in the selected study area and thereby to analyse the various related aspects needed to preserve the quality of ground water in the region.

II. MATERIALS AND METHODS

In the present investigation ground water samples were collected using plastic containers with necessary precautions [18-20] from 20 different locations (sixty eight wells) in Orathanadu Taluk of Tiruchirappalli District. The chemicals used for the analysis were of AR grade (99.99% pure). Double distilled water was used for the preparation of the reagents and solutions.

A. Selection of the Well

Intensive agricultural areas following several modern agricultural practices were selected to carry out this research and a total of sixty eight wells (twenty locations) were chosen randomly from different land types [varying from *nanjai* to *punjai*] and cropping discipline; high land crops (chilly, onion, brinjal and tobacco), mixed crops (high land crops with banana), banana field and paddy field.

As the area under study is deltaic, wells are not part of most of the paddy fields, and therefore are not common. Hence, the number of wells selected for sampling in this area was limited to seven only. At the same time, forty one wells were selected for analysis under high land crops because large extent of land is under high land crop cultivation. Similarly, thirteen wells and seven wells were selected from mixed crop and banana respectively. All the wells that are selected for the study were used not only for irrigation but for drinking purposes also.

B. Collection of Water Samples

Samples were drawn from the surface area of the wells by use of water sampler for a period of six consecutive months beginning from July 2012 to February 2013, at regular monthly intervals. Sample containers were prepared to collect the water samples to meet the prerequisites of chemical analysis. Each container was rinsed twice with the sample water before collecting the samples in the bottles and was then covered with a lid. The containers were labelled with respect to the collecting points, date and time in order to avoid any error between collection and analysis. The collected samples were stored in an icebox and brought to laboratory for determining both physical and chemical parameters.

C. Chemical Analysis of Water Samples

The pH and Electrical Conductivity were measured by using Elico digital pH meter (model L1-12T) with an accuracy of ± 0.01 and Elico digital Conductivity meter (model CM 180) with an accuracy of ± 0.01 respectively. Total hardness, Calcium, Magnesium were measured by EDTA titration method. Chloride was measured volumetrically by silver nitrate titre metric method using potassium chromate as indicator [8-10].

Sodium and Potassium were measured by Flame photometer (Elico model CL 22 D) and Ca, Mg, Fe, and Cu were analyzed by Atomic Absorption Spectrophotometer (AAS 400 Perkin Elmer). The nitrate-N content was determined colorimetrically using the Brucine method. The EC of the collected water samples were digitally measured by using conductivity meter. Mohr's titration was used for determination of the chloride content.

Rainfall data was obtained from meteorological department, during the period of study as a secondary data to see the correlation between rainfall and quality of water and shown in Table 1. All the measured data were analysed statistically for the correlation of the association between land use classes and measured parameters. Finally the parameters were compared with the National drinking water standard and recommended irrigation water quality standards.

III. RESULTS AND DISCUSSION

In the studied area, water used for drinking purposes as well irrigation are colourless, odourless and free from turbidity and excess salts. The taste of the water is slightly brackish at some of the locations. The temperature of the water is in the range 18° C - 28° C**.** The important physico-chemical characteristics of analyzed water samples and the values are compared with standard like USPH, WHO, ICMR, BIS etc are shown in Table 2.

A. pH Values

The pH value of drinking water is an important index of acidity or alkalinity. A number of inorganic minerals and organic matters of the various fertilizers interacts with each other to give the resultant pH of the sample.

TABLE 1 RAINFALL AMOUNT DURING THE STUDY PERIOD

Month wise Rainfall pattern	**(mm)**
July 2012	13.5
August 2012	12.5
September 2012	15.6
October 2012	125
November 2012	110
December 2012	4.8
January 2013	22.1
February 2013	35.1

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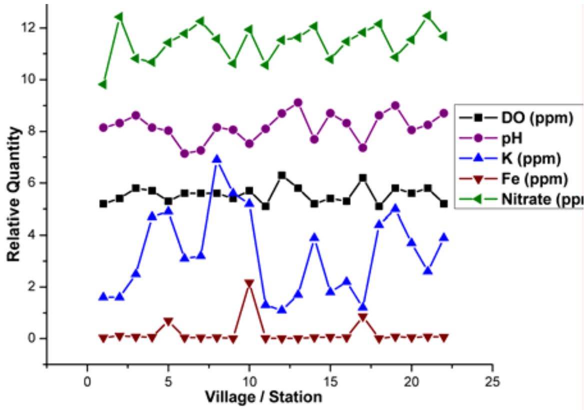

Fig. 1. Graphical representation of DO, pH, K, Fe, Nitrate-N concentration on the ground water of studied area.

In this present samples, the pH ranges from 7.14-9.14 which exhibits slightly alkaline nature and this may be due to existence of hydroxide and carbonate sediments in the ground water [11].

The pH value of 7.0 to 8.0 usually signifies the presence of carbonates of calcium and magnesium, and a pH of 8.5 or above shows appreciable redeemable sodium. The result of the study was supported by the normal recommended pH range for irrigation water is from 7.14 to 8.25. Moreover the location of the study area being an agricultural area, due to the influence of organic fertilizers the pH of the ground may be enhanced to slightly alkaline in nature.

B. Dissolved Oxygen

Dissolved oxygen is the most essential and required criteria for the standard eminence water. Oxygen is a necessary element to all forms of life. DO in water is great importance to all aquatic organisms and is considered to be the factor that reflects the biological activity taking place in a water body which are brought about by the aerobic or anaerobic organisms.

The result of analysis reported that the Dissolved Oxygen in these areas is found to be in the range of 6.8-7.6 mg/L. Drinking water has a Dissolved Oxygen of less than 5 mg/L is considered fairly pure as per BIS [12-15] standard index. As dissolved oxygen level drop below 5.0 mg/L, aquatic life is put under stress.

C. Electrical Conductivity (EC)

The conductivity trend generally reflects the chloride concentration of ground water. The significance of electrical conductivity values, due to the fact that a large part of the leaching or washing out of solutes in the soil. The higher value of electrical conductivity is always predominant with sodium chloride ions.

Conductance is a widely used as indicator of salinity and also this has been used to classify the water as medium saline, low and high saline. EC levels vary in all the months and range from 100-150 µmho cm^{-1}. The Table 3 show the average EC value of all sampled wells. Since measured values were less

TABLE 2 STATUS OF POTABLE WATER WITH REFERENCE TO STANDARD

Parameters	USPH	WHO	ICMR	BIS	Present Report
pH	6.0-8.5	6.5-9.2	6.5-8.5	6.5- 8.5	7.14- 9.11
DO			500	500	5.1 – 6.3
EC	300	300			110-140
Calcium	100	75	75	75	30 - 80
Magnesium	30	50	50	30	31 - 56
Sodium		200			130-220
Potassium		8.0			1.1 – 6.9
Chloride	250	200	250	250	128 - 269
Iron		0.3		0.3	0.01- 2.17
Copper		1.0		0.05	0 – 3.13

USPH - United States Public Drinking water Standard
WHO - World Health Organisation
ICMR - Indian Council of Medical Research
BIS - Bureau of Indian Standards

than National permissible level of 300 µmho cm^{-1}, all the wells were suited for drinking. All the measured wells were under 300 µmho cm^{-1}. Out of measured wells, 8.46% of the wells had EC values below 115 µmho $cm^{-1}$and 91.54% of the wells had the EC values between 115-150 µmho cm^{-1}. Hence, most of the wells are slight to moderate for irrigation purpose. The significant rise in EC values of water is mainly due to the north east monsoon seasonal rains in November, due to the fact that a large part of the leaching or washing out of the solutes in the soil. Some of the wells EC values were increased during November due to leaching of the salt from soil. There was no correlation between cropping system and EC of groundwater.

D. Chloride

Sources of chloride in groundwater are including the rainwater, fertilizers, sewage water, industrial pollutants and saline residues from soil and minerals. The chloride concentration in the studied area displays a more or less uniform. It may be probably due to the percolation of chloride ions into the ground water from the adjacent rivers. Soil porosity and permeability also has a key role in building up the chlorides concentration and generally reflects the electrical conductivity of ground water [16].

The chloride concentration was ranging from 122-219 mg/L. All the wells were suited for drinking. The figure shows the average concentration of chloride of all measured wells. Of the sixty eight wells measured, results showed that 73.53% of well water was chloride content of less than 200 mg/L and 26.47% were within the range less than 300 mg/L. According to the classification, out sixty eight wells, 11.76% of the wells had the chloride value below 70 mg/L (safe for all plants) and 33.82% of the wells had chloride values between 70-140 mg/L (sensitive plants show injury), 47.06% of the wells had the chloride values between 140-250 mg/L (moderately tolerant plants show injury), 7.35% of the wells have chloride values above 200 mg/L which causes severe problems. The chloride concentration in excess of about 250 mg/L can give rise to detectable taste in water. There were no correlation between cropping system and chloride in groundwater even though high withdrawal rate in high land and mixed crop. Concentration of chloride in paddy land use was very high. Because during the rainy season the runoff water enters into the well and it carries lot of salt.

The chloride ion content in Pachur station is high to the tune of 248 mg/L this value is found be higher than the tolerable level for irrigation given by Environmental Geology standard which is 75 – 200 mg/L [17-20]. Hence, the water quality of Pachur station is noticed to be neither useful to drinking but useful to irrigation. High chloride indicates the saline nature of water it may be due to the percolation through this soil bed has enriched saturation of more sodic alkalinity in the water. The WHO emphasized the chloride concentration in excess of about 250 mg/L can give rise to detectable taste in water [21].

E. Sodium

The presence of sodium, a naturally occurring metal in drinking water varies from 130 - 220 mg/L. Minerals of the bed rock are subjected to weathering and subsequently affected by leaching, which contribute sodium salts to groundwater [22-25]. Based on the present survey the sodium concentration in ground water may be considered suitable for domestic.

As per WHO (1999), the permissible sodium content in drinking water is 200 ppm. Very large sodium content is considered to be harmful for people suffering from hypertension. Higher concentration of sodium could be related to cardiovascular diseases as well as toxemia associated with pregnancy [26]. The enrichment of sodium probably accounted by the location of this station close to the Cauvery river flow, it may have led to the increased of sodium content in the ground water.

F. Calcium

Generally Calcium in the ground water is derived from minerals like limestone and dolomite. The total hardness is relatively high in water due to the presence of calcium, magnesium, and chloride and sulphate ion. Hence, the water is not suitable for potable purpose and also leads to heart, kidney related diseases and constipation effects [27-30].

The distribution of calcium in the studied area is found to be highly fluctuating from station to station it may be due to the supply of calcium through sandy materials, mixed up with calcareous constituents without any uniform distribution. The drastic shift in concentration of calcium might be due to the presence of limestone in the aquifers at depth of collection. Most of stations show the Calcium concentration is below the prescribed limits, which is evidenced by the WHO standard.

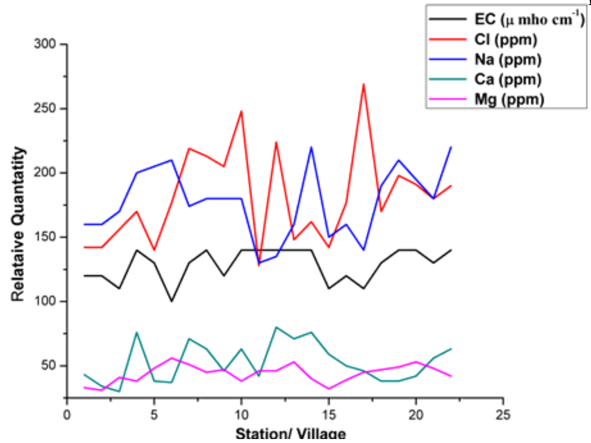

Fig. 2. Graphical representation of EC, Cl, Na, Ca and Mg concentration on the ground water of studied area.

G. Magnesium

The distribution of magnesium in the studied area ranges from 31 to 56 ppm. Magnesium concentration is below or nearest to the prescribed limits for all the stations. The stations 4&5 observed high values of magnesium are probably due to closeness of the stations to nearby Vennar River. This is possible since magnesium would have been supplied in the form of chloride along with sodic salt in the form manure into the water. Moreover Goldschimt (1958) has also indicated the possibility of enrichment of calcium, magnesium & sodium in black sediments [21].

High loading of Mg ions is related to the weathering of ferro magnesium mineral and anthropogenic sources [22]. Too high magnesium causes nausea, muscular weakness and paralysis in human body when it reaches a level of about 400mg/L. Maximum permissible limit of calcium and magnesium in drinking water is 50mg/L as suggested by ICMR, thus the status of ground water is not hazards except very few stations.

H. Potassium

The allocation potassium in the studied area ranges from 1.0-5.6 ppm. The distribution of Potassium establishes higher order of flocculation, it is possible that in the form of chloride, as water moves further down decreasing the chloride concentration. Potassium enters into a drinking water system from natural geological sources, detergents, mining and agricultural wastes.

The increased use or excessive utilisation of fertilizers had frequently been cited as the cause of water quality deterioration [23]. Nitrate leaching can occur in intensively cultivated areas with a shallow water table. Thus, the excess amount of potassium present in the water sample may lead nervous and digestive disorder.

I. Iron

Iron is the most commonly available metal on planet earth. The Iron content in the present study ranges from 0.04 – 1.17 ppm. The maximum iron concentration is found at stations 5, 10 and 17, while other stations display lower iron

TABLE 3 PHYSIOCHEMICAL PARAMETERS (MINERAL WEALTH OF GROUND WATER)

Station Names	DO (ppm)	EC (μmho/cm)	pH	Cl (ppm)	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Cu (ppm)	Nitrate - N (ppm)
1. Ayankudi	5.2	120	8.14	142	160	1.6	43	33	0.04	BDL	9.82
2. Cholapuram	5.4	120	8.32	142	160	1.6	34	31	0.11	BDL	12.43
3. Eachankottai	5.8	110	8.62	156	170	2.5	30	41	0.07	BDL	10.82
4. Illuppaividuthi	5.7	140	8.14	170	200	4.7	76	38	0.06	BDL	10.68
5. Kaavaarappattu	5.3	130	8.03	140	205	4.9	38	48	0.69	BDL	11.43
6. Karukkakottai	5.6	100	7.14	177	210	3.1	37	56	0.04	BDL	11.78
7. Kovilur	5.6	130	7.26	219	174	3.2	71	51	0.04	BDL	12.26
8. Mandalakkottai	5.6	140	8.15	213	180	6.9	63	45	0.05	BDL	11.58
9. Naduvur	5.4	120	8.06	205	180	5.6	46	47	0.01	BDL	10.63
10. Pachur	5.7	140	7.52	248	180	5.2	63	38	2.17	BDL	11.94
11. Palamputhur	5.1	140	8.10	128	130	1.3	42	46	0.02	BDL	10.57
12. Paravathur	6.3	140	8.69	224	135	1.1	80	46	0.01	3.13	11.53
13. Poovathur	5.8	140	9.11	148	160	1.7	71	53	0.01	BDL	11.63
14. Rakavambalpuram	5.2	140	7.69	162	220	3.9	76	40	0.05	BDL	12.06
15. Samipatti	5.4	110	8.7	142	150	1.8	59	32	0.06	BDL	10.79
16. Thekkur	5.3	120	8.32	177	160	2.2	50	39	0.05	BDL	11.48
17. Thirunallur	6.2	110	7.36	269	140	1.2	46	45	0.86	BDL	11.83
18. Unchiyaviduthi	5.1	130	8.62	170	190	4.4	38	47	0.01	BDL	12.15
19. Vadakkukottai	5.8	140	9.01	198	210	5	38	49	0.08	BDL	10.87
20. Vadakkur	5.6	140	8.05	191	195	3.7	42	53	0.05	BDL	11.55
21. Vadaseri	5.8	130	8.25	180	180	2.6	56	48	0.08	BDL	12.47
22. Yokanayakipuram	5.2	140	8.7	190	220	3.9	63	42	0.06	BDL	11.68

BDL* - *Below Detectable Limit*

concentration. The reason behind considerable iron concentration they are in depth levels is probably due to the same kind of sediment that is common in these stations. The black soil, black clay present in soil, it must have been encouraging the presence of iron [24].

Excess amount of iron (more than 10mg/L) causes rapid increase in respiration pulse-rate and coagulation of blood vessels, hypertension and drowsiness. The shortage of iron causes a disease called “anemia” and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called as haermosiderosis [24].The ground water used for drinking should not exceed the maximum permissible limit of 0.3 ppm. In the present study, except three stations such as 5, 10 and 17 the iron content is not hazardous.

J. Copper

Copper is the principle component in metal alloys, preservatives for food and some fungicides, sewage, fertilizers and pesticide residue [30]. The presence of copper in the studied area is found to be nil except in station 12, it may be due to, such concentration in water is generally, expected to the zone of copper sulphate associated in the sediment. Further Goldschmidt (1958) pointed out the possibility of higher copper in highly oxygenated sandy beds [26]. Incidence of higher copper content may also be a phenomenon of localized nature, probably due to the type of fertilizers impregnated with $CuSO_4$, being used much commonly in the particular field. Excess of copper in human body is toxic and causes hypertension and produces pathological changes in brain tissues. Excessive ingestion of copper is responsible for specific disease of the bone [25].

K. Nitrate-N

The nitrate-N varies in all the stations and values were ranged from 0.16 mg/L to 12.47 mg/L. The highest value of nitrate-N was observed as 12.47 mg/L at Vadaseri. Out of sixty eight wells, 81% of the well was recommended for drinking in intensified agricultural areas and all the wells were accepted for irrigation requirement since the concentration was less than 3 mg/L. The farmers have the practice of applying excess amount of inorganic fertilizers. The excess fertilizers leached out to the shallow groundwater. The above mentioned problem occurs not only in Orathanadu but also some other parts of the India. The nitrate concentration is approximately increased as 1-2 mg/L per year.

TABLE 4 STATISTICAL ANALYSIS OF GROUNDWATER NITRATE-N IN DIFFERENT CROPPING SYSTEMS

Land use	Mean nitrate-N
High land crops	11.63
Mixed crops	10.73
Banana	5.41
Paddy	5.35

L. Presence of Nitrate-N in Different Cropping System

Table 4 shows nitrate-N in the groundwater in the different cropping system classes such as high land crops, mixed crops, banana and paddy. High nitrate-N concentration of groundwater was observed at high land crop use and followed by mixed crops. Most of the wells were not exceeded the recommended level for drink water standard. Concentration of nitrate-N in paddy and banana land use had less than the recommended level of 10 mg/L. The hydro geochemical atlas of orathanadu has the moderate nitrate content due to higher usage of fertilizers.

In intensified agricultural areas, farmers have the practice for year round cultivation without giving off season to the field. In addition to that they are practicing high intensity cropping (planting three crops at a time in the field for example *Amaranthus* (15-20 days), raddish (45 days) and onion (90 days)) to keep the land for maximum utilization. Hence they are using high fertilizers to satisfy all the stages of the crop.

Table 4 shows the statistical analysis of significance among different land use. In statistical analysis of significance, mean nitrate-N concentration in groundwater of high land and mixed crops significantly ($p<0.05$) differed from banana and paddy land use. Significant difference in high land and mixed crops may be due to the effect of the rate of application of fertilizer and soil type. There was no significant different between high land crops and mixed crops and also mean nitrate concentration of paddy field not significantly differed from banana crops.

In Orathanadu the condition of paddy soil (due to hardpan formation) restricts the leaching of nitrogen fertilizers to groundwater. Cultivation of banana is normally under basin irrigation with organic fertilizers. Before planting of banana suckers farmers burry large lot of green manures into the pits and they keep the plants in the field nearly for five years. Most of the farmers are not using any inorganic fertilizers for cultivation. The addition of organic manure increases nitrogen retentions capacity and reduces nitrate loss by leaching in sandy soils, therefore crops can efficiently utilize the applied fertilizer and residual nitrogen will remain in the soil for next crop. Since nitrogen retention increases with organic fertilizers, this may be the reason for low nitrate-N concentration in groundwater in banana land use. Hence one of the ways to reduce nitrate pollution of groundwater is by incorporating organic manures [31,32].

The highest concentration of nitrate nitrogen occurred during the October after that the concentration was reduced during November because of high recharge to the well which dilutes the concentration of nitrate in high land and mixed crop. Again the concentration was increased during December due to the continuous leaching of nitrate -N from the soil. In most of the well in paddy and banana the concentration was high during October and then gradually decreasing because of dilution. Finally conclusion was made that there was a good correlation between cropping system and nitrate nitrogen concentration in groundwater and other parameters pH, EC and chloride. It is worthy of note that the level of nitrate concentration of water show a significant influence by land use.

IV. CONCLUSION

In the present study, reveals that most of the ground water samples at orathanadu taluk were found to be less polluted in physiochemical profile. The ground water samples from orathanadu taluk have been collected from 22 stations, the physiochemical parameters of water like DO, Chloride, pH, EC, Ca, Mg, Na, K, Fe & Cu, using chemical titration, Flame photometer, UV spectrometer and Atomic Absorption Spectrometer has been studied.

All the wells were accepted for drinking based on pH, EC and chloride. But 81% of the wells were not suited for drinking due to the nitrate-N concentration. There was a good correlation between cropping system and nitrate-N concentration in groundwater. High nitrate-N concentration of groundwater was observed at high land crops land use and followed by mixed crops and there was no significant difference between high land and mixed crops. There was significant different between high land and mixed crops to banana and paddy land use but no significant different between paddy and banana. It is worthy of note that the level of nitrate concentration of water show a significant influence by cropping system.

Now, the people of these area are used ground water for their utilization without the treatment in present but in future care must be needed to control the usage of fertilizers for modern agriculture activity and is also essential to understand the ground water pollutant impact on human being. The periodically analysis required for every six months in view of social concerned with human health and wealth cannot be ignored for extensive time.

Suggestions

- Construction of proper lining of the agro well to prevent the runoff water into the well.
- Encourage the use of bio fertilizers instead of chemical fertilizers. It is suggested to Shift into organic agriculture for the management of pest and disease.
- Introducing the micro irrigation system to reduce the leaching of ions to ground water aquifer by applying required amount of water.
- Awareness to Farmers regarding the perilous situation of finite natural resource.

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