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Quantitative analysis of Fat, oil and grease in Groundwater of Valikamam area, Sri Lanka

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ABSTARCT

The Jaffna Peninsula is underlain by Miocene limestone that is considered to have appropriate aquifer properties for groundwater storage and discharge. The absence of perennial rivers or major water supply schemes to the Peninsula highlights the importance of groundwater as the predominant water resource for domestic, industrial and agricultural use. The Jaffna Peninsula has four main aquifer systems, namely Chunnakam (Valikamam area), Thenmaratchi, Vadamaratchi and Kayts, of which the Valikamam area is intensively cultivated in the Jaffna Peninsula. Groundwater can become contaminated, by many of the same pollutants that contaminate surface water. Pollution of groundwater occurs when contaminants are discharged or, deposited on, or leached from the land surface above the groundwater. Environmental contamination by petroleum hydrocarbons is the most common site contamination issue encountered by environmental professionals. Contamination of ground water can result in poor drinking water quality, loss of water supply, degraded surface water systems, high cleanup costs, and high costs for alternative water supplies, and/or potential health problems. Used oil and waste fuel have historically been released to the environment through burning, land filling and indiscriminant dumping, accidental spills and through use as a dust control agent on roads. Heavy metals such as chromium, copper, lead, manganese, nickel and zinc are commonly found in used lubricating oil from friction wear on engine parts and can influence the effect the waste has on human health. Sampling was done along the eight directions at the intersections of five concentric rings of 200 meter distance between with the center being close to the Chunnakam power plants. Hexane gravimetric method used to determine the Fat Oil and Grease (FOG) in this study. FOG was recorded in 40 wells. In each well water sample collected in the top as well in the bottom layer. From the results it was identified that only thirty two samples shows FOG is greater than 2 mg/L and forty eight samples shows FOG less than 2 mg/L. Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long-term use. It is, therefore, essential to establish baseline information on water quality and availability to assist in long-term planning whilst ensuring the integrity of supply for the Jaffna Peninsula.

INTRODUCTION

Water is the most vital element among the natural resources, and is crucial for the survival of all living organisms. The environment, economic growth and development of Sri Lanka are all highly influenced by water. Spatial and seasonal availability of surface and groundwater is highly responsive to the monsoon climate and physiography of the country. Availability also depends on upstream withdrawal for consumptive and non-consumptive uses. In terms of quality, the surface water of the country is unprotected from untreated industrial effluents and municipal wastewater, runoff pollution from chemical fertilizers and pesticides, and oil and lube spillage in the coastal area from the operation of sea and river ports.[1] Water quality also depends on effluent types and discharge quantity from different type of industries, types of agrochemicals used in agriculture, and seasonal water flow and dilution capability by the river system.

Water quality criteria are developed by scientists and provide basic scientific information about the effects of water pollutants on a specific water use. They also describe water quality requirements for protecting and maintaining an individual use. Water quality criteria are based on variables that characterise the quality of water and/or the quality of the suspended particulate matter, the bottom sediment and the biota. Many water quality criteria set a maximum level for the concentration of a substance in a particular medium (i.e. water, sediment or biota) which will not be harmful when the specific medium is used continuously for a single, specific purpose. For some other water quality variables, such as dissolved oxygen, water quality criteria are set at the minimum acceptable concentration to ensure the maintenance of biological functions.

Pollution results when a change in the environment harmfully affects the quality of human life including effects on animals, microorganisms, and plants. Pollution has been defined as the presence in significance amounts of an extraneous material which may be solid, liquid or gas in a particular location. Both human activities and natural activities can change the physical, chemical, and biological characteristics of water, and will have specific ramifications for human and ecosystem health. Water quality is affected by changes in nutrients, sedimentation, temperature, pH, heavy metals, non-metallic toxins, persistent organics and pesticides, and biological factors, among many other factors. Many contaminants combine synergistically to cause worse, or different, impacts than the cumulative effects of a single pollutant. Continued inputs of contaminants will ultimately exceed an ecosystem's resilience, leading to dramatic, non-linear changes that may be impossible to reverse.

Groundwater provides valuable provisioning and regulating ecosystem services. Some 30 percent of the world's freshwater stocks are found underground, supplying drinking water for an estimated two billion people and irrigation for an estimated 40 percent of the world's food. Many groundwater systems act to filter and attenuate pollutants, especially microbial contaminants. By virtue of its location, groundwater typically enjoys greater protection from pollutants than do surface waters, though several contaminants degrade groundwater and diminish its utility. Because of the slow movement of contaminants and subsurface water, it may take years for a contaminant plume to pollute a groundwater source. This slow movement and the fact that groundwater and subsurface contaminants are not readily detected also challenge efforts to determine and control pollution sources.

Once contaminated, groundwater is difficult and expensive to remediate. Global data on groundwater quality are very limited, due to the cost of monitoring and analysis. Salinization has become an important threat to groundwater quality, especially in coastal areas where groundwater extraction at unsustainable rates has led to seawater intrusion. Sea-level rise due to climate change is also expected to impact coastal aquifer quality by increasing sea-water intrusion. Certain irrigation practices can also increase groundwater salinity and can increase nitrate and pesticide leaching, increasing costs for drinking water suppliers and for irrigators.

Clean water and healthy freshwater ecosystems provide the basic goods and services upon which many livelihoods depend, including irrigation water, fertile floodplains for agriculture and grazing, and habitat for fish and shrimp that may be eaten or sold. The need for adequate quality of water to support livelihoods has been emphasized less than the need for adequate quantity of water. In reality, both are necessary and polluted water can reduce or eliminate the viability of many livelihoods.

The Jaffna Peninsula has four main aquifer systems, namely Chunnakam (Valikamam area), Thenmaratchi, Vadamaratchi and Kayts, of which the Valikamam area is intensively cultivated in the Jaffna Peninsula. The water available within these limestone aquifers is predominantly used for domestic and irrigation purposes. Intensive irrigation, higher inorganic fertilizer usage along with increases in population growth associated with resettlement has the potential over time for over-extraction of groundwater resources and deterioration in water quality. There is currently a deficit in long-term monitoring of the quantity of water stored and extracted from these aquifers along with changes in the water quality.[2]

An assessment of the vulnerability of groundwater for irrigation and drinking purposes has become a necessary and important task for the management of present and future groundwater quality in the Chunnakam aquifer. The suitability of water for any use is determined not only by the total amount of salt present in the water but also by the type of salt that is present. Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long-term use. It is, therefore, essential to establish baseline information on water quality and availability to assist in long-term planning whilst ensuring the integrity of supply for the Jaffna Peninsula. Though several studies have been undertaken on groundwater quality in the Peninsula, no systematic studies have been carried out to characterize the chemical quality and recharge potentials of aquifers in the Jaffna Peninsula.

Spatial variation of net groundwater recharge ranged between 12 to 69% of total rainfall, with an average of 37% at a specific yield of 0.21 during the short rainy season (i.e., October, November and December). This would suggest that approximately 33% of the rainfall is lost as runoff during the rainy season. The spatial variability observed in computed values could not be entirely attributed to the local geohydrology of the area since there isn't enough rain gauges to capture the rainfall variability.[3]

GROUND WATER CONTAMINATION

Pollution can come from two types of sources; point and non-point. Point sources are identifiable and localized sources of pollution. Point sources that can contaminate groundwater include landfills, buried gasoline or oil storage tanks, septic systems, industrial sources and accidental spills. Non-point sources tend to be in the form of pesticides and nutrients that enter the soil as a result of intense agricultural operations or the widespread use of road salts and chemicals.

Depending on its physical, chemical, and biological properties, a contaminant that has been released into the environment may move within an aquifer in the same manner that ground water moves. (Some contaminants, because of their physical or chemical properties, do not always follow ground water flow.) It is possible to predict, to some degree, the transport within an aquifer of those substances that move along with ground water flow. For example, both water and certain contaminants flow in the direction of the topography from recharge areas to discharge areas. Soils that are porous and permeable tend to transmit water and certain types of contaminants with relative ease to an aquifer below. Just as ground water generally moves slowly, so do contaminants in ground water.[4]

Because of this slow movement, contaminants tend to remain concentrated in the form of a plume that flows along the same path as the ground water. The size and speed of the plume depend on the amount and type of contaminant, its solubility and density, and the velocity of the surrounding ground water.

Ground water and contaminants can move rapidly through fractures in rocks. Fractured rock presents a unique problem in locating and controlling contaminants because the fractures are generally randomly spaced and do not follow the contours of the land surface or the hydraulic gradient. Contaminants can also move into the ground water system through macropores—root systems, animal burrows, abandoned wells, and other systems of holes and cracks that supply pathways for contaminants.

In areas surrounding pumping wells, the potential for contamination increases because water from the zone of contribution, a land area larger than the original recharge area, is drawn into the well and the surrounding aquifer. Some drinking water wells actually draw water from nearby streams, lakes, or rivers. Contaminants present in these surface waters can contribute contamination to the ground water system. Some wells rely on artificial recharge to increase the amount of water infiltrating an aquifer, often using water from storm runoff, irrigation, industrial processes, or treated sewage. In several cases, this practice has resulted in increased concentrations of nitrates, metals, microbes, or synthetic chemicals in the water.[5]

Under certain conditions, pumping can also cause the ground water (and associated contaminants) from another aquifer to enter the one being pumped. This phenomenon is called inter aquifer leakage. Thus, properly identifying and protecting the areas affected by well pumping is important to maintain ground water quality. Generally, the greater the distance between a source of contamination and a ground water source, the more likely that natural processes will reduce the impacts of contamination. Processes such as oxidation, biological degradation (which sometimes renders contaminants less toxic), [6] and adsorption (binding of materials to soil particles) may take place in the soil layers of the unsaturated zone and reduce the concentration of a contaminant before it reaches ground water. Even contaminants that reach ground water directly, without passing through the unsaturated zone, can become less concentrated by dilution (mixing) with the ground water.[7,8] However, because ground water usually moves slowly, contaminants generally undergo less dilution than when in surface water.[9]

MATERIALS AND METHODS

Sampling plan

Water samples were collected from wells around Chunnakam power plant area according to a systematic sampling plan. Wells for sampling were selected along eight directions namely North, Northeast, East, South east, South, South west, West, and North West. Along each direction, wells were selected on or near the grid points of 200 meter interval up to 1 km. Hence 40 wells were selected (Figure 1). In addition 8 samples were collected as random samples.

Collection of water samples

Grab sampling method was used to collect the water samples. Approximately 1500 ml water samples was collected into glass bottles and each sample was preserved with 5 ml of 1: 1 HCl. Water samples were collected from the surface and bottom of the dug wells. In the case of tube well only one sample is collected. Ruttner water sampler was used for the water sample collection in our analysis. Samples were collected by direct pumping in tube wells.

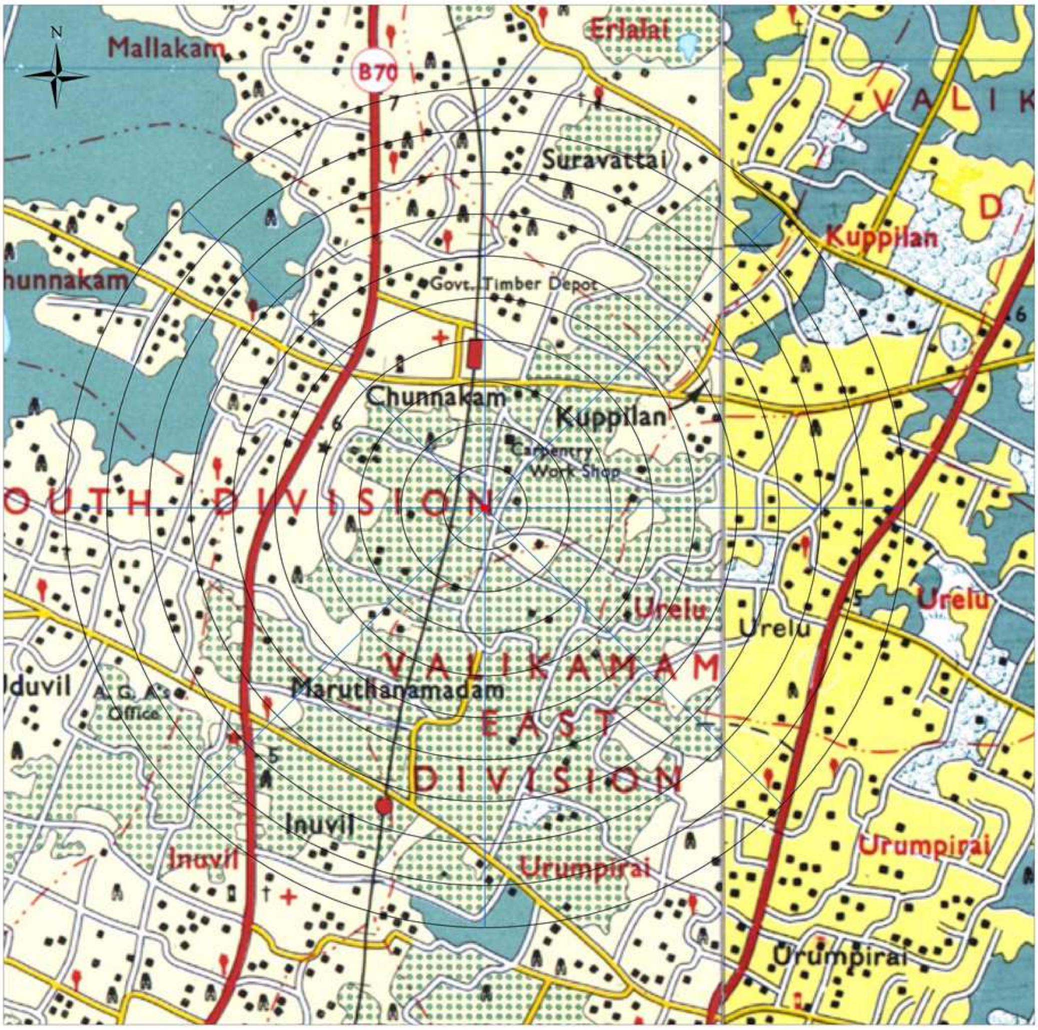

Figure. 1. Sample Collection Location

Analytical methods
Modified APHA 1664 analytical method was in this analysis.[10]

RESULTS

No	IP No.	GPS Location		pH	Depth of water level	Height of water column	Type of well
		Latitude	Longitude				
1	N_w 1	9° 44.539'N	80° 2.064'E	7.5	13 feet	22.2feet	Dug
2	N_w 2	9° 44.728'N	80° 2.027'E	6.8	14feet	*	Dug
3	N_w 3	9° 44.635'N	80° 2.044'E	6.7	13 feet	*	Dug
4	N_w 4	9° 44.992'N	80° 2.042'E	6.8	11 feet	3feet 7 inches	Dug
5	N_w 5	9° 44.840'N	80° 2.076'E	6.8	13 feet	5feet	Dug
6	NE_w 1	9° 44.460'N	80° 2.161'E	6.8	13 feet	5feet	Dug
7	NE_w 2	9° 44.570'N	80° 2.206'E	6.8	13 feet	6 feet	Dug
8	NE_w 3	9° 44.629'N	80° 2.265'E	6.8	14 feet	4 feet 6inches	Dug
9	NE_w 4	9° 44.710'N	80° 2.333'E	6.8	15 feet	7 feet	Dug
10	NE_w 5	9° 44.790'N	80° 2.423'E	6.8	14feet	6feet	Dug
11	E_w 1	9° 44.374'N	80° 2.184'E	6.7	14 feet	*	Dug
12	E_w 2	9° 44.421'N	80° 2.271'E	7.1	14 feet	5 feet 6 inches	Dug
13	E_w 3	9° 44.430'N	80° 2.348'E	7	14 feet 6	1 feet 6 inches	Dug
14	E_w 4	9° 44.396'N	80° 2.484'E	7	14 feet 5 inches	3 feet 11 inches	Dug
15	E_w 5	9° 44.402'N	80° 2.597'E	7.1	14.5 feet	3 feet 11 inches	Dug
16	SE_w 1	*	*	6.9	15 feet	*	Dug
17	SE_w 2	*	*	7.2	15 feet	3.5 feet	Dug
18	SE_w 3	9° 44.402'N	80° 2.240'E	7.4	12 feet 6 inches	3 feet	Tube well
19	SE_w 4	*	*	7.2	11.5 feet	4.7 feet	Dug
20	SE_w 5	*	*	7.1	15 feet	*	Dug
21	S_w 1	9° 44.402'N	80° 2.597'E	7.4	14.2 feet	3 feet	Dug
22	S_w 2	9° 44.402'N	80° 2.597'E	7.2	15.7 feet	6.7 feet	Dug
23	S_w 3	9° 44.402'N	80° 2.597'E	7.1	55 feet	*	Dug
24	S_w 4	9° 44.402'N	80° 2.597'E	6.9	55 feet	*	Dug
25	S_w 5	9° 44.402'N	80° 2.597'E	6.9	6.9 feet	*	Dug

No	IP No.	GPS Location		pH	Depth of water level	Height of water column	Type of well
		Latitude	Longitude				
26	SW_w 1	9° 44.327'N	80° 1.973'E	6.6	3.8 feet	*	Dug
27	SW_w 2	9° 44.259'N	80° 1.891'E	6.5	3 feet	*	Dug
28	SW_w 3	9° 44.163'N	80° 1.823'E	7.1	15.7 feet	5.3	Dug
29	SW_w 4	9° 44.094'N	80° 1.733'E	6.8	45 feet	*	Dug
30	SW_w 5	9° 44.980'N	80° 1.691'E	6.7	4.1 feet	*	Dug
31	W_w 1	9° 44.418'N	80° 1.938'E	7.1	15.9feet	3.7 feet	Dug
32	W_w 2	9° 44.389'N	80° 1.845'E	7.5	14 feet	3.4 feet	Dug
33	W_w 3	9° 44.393'N	80° 1.735'E	7.2	4.8 feet	*	Dug
34	W_w 4	*	*	7.1	*	*	Dug
35	W_w 5	*	*	6.8	*	*	Dug
36	NW_w1	*	*	6.5	*	*	Dug
37	NW_w2	9° 44.584'N	80° 1.914'E	6.4	14 feet	9 feet	Dug
38	NW_w3	9° 44.648'N	80° 1.804'E	6.5	12 feet	5 feet	Dug
39	NW_w4	9° 44.717'N	80° 1.726'E	6.8	11 feet 6	4 feet	Dug
40	NW_w5	9° 44.781'N	80° 1.669'E	6.8	9 feet	3 feet 4	Dug

*Note: * - Data not available/not measured*

Table 1. Detailed location of water sample collection wells

No	Sample Number	Final results of Oil and Grease in mg/L
1	N_w 1(T)	Not detected (LOD 1mg/L)
2	N_w 1(B)	3.63
3	N_w 2(T)	7.26
4	N_w 2(B)	6
5	N_w 3(T)	4.62
6	N_w 3(B)	4.95
7	N_w 4(T)	Not detected (LOD 1mg/L)
8	N_w 4(B)	Not detected (LOD 1mg/L)
9	N_w 5(T)	Not detected (LOD 1mg/L)
10	N_w 5(B)	Not detected (LOD 1mg/L)
11	NE_w 1(T)	10.56
12	NE_w 1(B)	10.89
13	NE_w 2(T)	Not detected (LOD 1mg/L)
14	NE_w 2(B)	Not detected (LOD 1mg/L)
15	NE_w 3(T)	12.54
16	NE_w 3(B)	6.27
17	NE_w 4(T)	1.65
18	NE_w 4(B)	1.65
19	NE_w 5(T)	Not detected (LOD 1mg/L)
20	NE_w 5(B)	Not detected (LOD 1mg/L)
21	E_w 1(T)	Not detected (LOD 1mg/L)
22	E_w 1(B)	7.59
23	E_w 2(T)	5.28
24	E_w 2(B)	5.61
25	E_w 3(T)	10.56
26	E_w 3(B)	5.28
27	E_w 4(T)	Not detected (LOD 1mg/L)
28	E_w 4(B)	Not detected (LOD 1mg/L)
29	E_w 5(T)	Not detected (LOD 1mg/L)
30	E_w 5(B)	Not detected (LOD 1mg/L)
31	SE_w 1(T)	Not detected (LOD 1mg/L)
32	SE_w 1(B)	1.65
33	SE_w 2(T)	9.99
34	SE_w 2(B)	10.56
35	SE_w 3(T)	Not detected (LOD 1mg/L)
36	SE_w 3(B)	Not detected (LOD 1mg/L)
37	SE_w 4(T)	Not detected (LOD 1mg/L)
38	SE_w 4(B)	Not detected (LOD 1mg/L)
39	SE_w 5(T)	Not detected (LOD 1mg/L)
40	SE_w 5(B)	Not detected (LOD 1mg/L)
41	S_w 1(T)	Not detected (LOD 1mg/L)
42	S_w 1(B)	Not detected (LOD 1mg/L)
43	S_w 2(T)	4.95
44	S_w 2(B)	5.94
45	S_w 3(T)	8.58
46	S_w 3(B)	6.27
47	S_w 4(Tube well)	Not detected (LOD 1mg/L)
48	S_w 5(T)	Not detected (LOD 1mg/L)
49	S_w 5(B)	Not detected (LOD 1mg/L)
50	SW_w 1(T)	3.96
51	SW_w 1(B)	3.96
52	SW_w 2(T)	3.96
53	SW_w 2(B)	13.86
54	SW_w 3(T)	Not detected (LOD 1mg/L)
55	SW_w 3(B)	Not detected (LOD 1mg/L)
56	SW_w 4(Tube well)	Not detected (LOD 1mg/L)
58	SW_w 5(T)	Not detected (LOD 1mg/L)
59	SW_w 5(B)	Not detected (LOD 1mg/L)
60	W_w 1(T)	3.33

Table. 2:Final FOG results in mg/L

No	Sample Number	Final results of Oil and Grease in mg/L
61	W_w 1(B)	Not detected (LOD 1mg/L)
62	W_w 2(T)	13.53
63	W_w 2(B)	Not detected (LOD 1mg/L)
64	W_w 3(T)	Not detected (LOD 1mg/L)
65	W_w 3(B)	Not detected (LOD 1mg/L)
66	W_w 4(T)	Not detected (LOD 1mg/L)
67	W_w 4(B)	Not detected (LOD 1mg/L)
68	W_w 5(T)	Not detected (LOD 1mg/L)
69	W_w 5(B)	Not detected (LOD 1mg/L)
70	NW_w 1(T)	9.24
71	NW_w 1(B)	3.33
72	NW_w 2(T)	8.25
73	NW_w 2(B)	3.33
74	NW_w 3(T)	1.65
75	NW_w 3(B)	Not detected (LOD 1mg/L)
76	NW_w 4(T)	Not detected (LOD 1mg/L)
77	NW_w 4(B)	Not detected (LOD 1mg/L)
78	NW_w 5(T)	Not detected (LOD 1mg/L)
79	NW_w 5(B)	Not detected (LOD 1mg/L)

Table . 3 Final FOG results of the control samples

No	Sample Number	Final results of Oil and Grease in mg/L
1	R1(T) Chunnakam Police Station	Not detected (LOD 1mg/L)
2	R1 (B)	Not detected (LOD 1mg/L)
3	R2(T) Mr.Murlaitharan, sabapathypillaiveethy, UduvilEast	Not detected (LOD 1mg/L)
4	R2(B)	Not detected (LOD 1mg/L)
5	R3(T) Dr.Ms.Ambhaipakan, Mallakam	Not detected (LOD 1mg/L)
6	R3 (B)	Not detected (LOD 1mg/L)
7	R4(T) Mr.Inparaj, Tellipalli	Not detected (LOD 1mg/L)
8	R4(B)	Not detected (LOD 1mg/L)
9	R5(T) Mrs.Selvendran, Kantharodai,	10.56
10	R5 (B)	Not detected (LOD 1mg/L)
11	R6(T) Prof.Ms.Kuganathan, Champion lane, Kokuvil	Not detected (LOD 1mg/L)
12	R6(B)	Not detected (LOD 1mg/L)
13	R7(T) Farm school, Thirunelveli	Not detected (LOD 1mg/L)
14	R7(B)	Not detected (LOD 1mg/L)
15	R8(T) Thanagavilpillayarkovil, Thirunelveli	Not detected (LOD 1mg/L)
16	R8(B)	Not detected (LOD 1mg/L)

DISCUSSION

From the results it was identified that only thirty two sample shows greater than 2 mg/L, and forty eight samples shows less than 2 mg/L. In the controlled samples only one sample collected at Kantharodai shows 10.56 mg/L. Jaffna is predominantly an agricultural area with a large extent of commercial crop cultivation such as red onions, chillies, potatoes, tobacco, vegetables, bananas and grapes. With this there is a huge demand for water and without any rivers and tanks in the plains; ground water is heavily pumped out for agricultural needs. Rapid development of agriculture, economy and increase of population due to resettlement has increased the use of water. Scientists fear that Jaffna's limestone aquifer will become depleted over the years leaving no fresh water on the peninsula.[5,7,8] According to research the Jaffna peninsula has four main aquifer systems, such as the Chunnakam (Valikamam area), Thenmaratchi, Vadamaratchi and Kayts, of which the Valikamam area is intensively cultivated in the Jaffna Peninsula.

Excessive use of chemical fertilizer together with excessive water application is the cause for the presence of excessive nitrate-N concentration in water. There is a need for awareness rising within farming communities highlighting the hazards associated with excessive use of chemical fertilizers. Furthermore, efficient irrigation water management practices should be introduced to prevent leaching of chemicals to the groundwater. Seasonal fluctuations in certain water quality parameters were identified which made the water unsuitable for drinking during certain months of the year. Therefore, it is recommended that awareness is created among people living in the Jaffna District on the potential health hazards that can arise due to the use of contaminated water for drinking purposes.

An assessment of the vulnerability of groundwater for irrigation and drinking purposes has become a necessary and important task for the management of present and future groundwater quality in the Chunnakam aquifer. The suitability of water for any use is determined not only by the total amount of salt present in the water but also by the type of salt that is present.

Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long-term use. It is, therefore, essential to establish baseline information on water quality and availability to assist in long-term planning whilst ensuring the integrity of supply for the Jaffna Peninsula.

As the Peninsula is currently entirely dependent on groundwater as its sole source of water supply for domestic and agricultural use, the management of this resource is critical in order to avoid compromising this resource through saltwater intrusion. Whilst further research and monitoring of groundwater is required to establish safe and sustainable yields from the aquifers that predominate the Jaffna Peninsula the following tentative recommendations are suggested:

- The over use of inorganic fertilizers is assumed to be the source of excessive levels of inorganic nitrate observed in groundwater samples. Change in farmer behavior through extension trainings in the use of fertilizers as well as possibly considering a reduction in subsidies on fertilizers are possible approaches that could be considered.
- Assess the potential for rainwater harvesting at the household levels through the provision of roof top harvesting systems and associated storage tanks.

CONCLUSION

The level of allowable FOG in Sri Lanka is 2 mg per litre, though until recently it was 1 mg per litre. FOG is a significant aspect of water quality especially in the temperate zones where this component could freeze in the pipes and tanks and cause large blocks and thus the check on these are very rigid. These include a range of items which may be including under this viz. soap, mineral oil, chemical sprays, fertilizers, waste oil and grease, petroleum products, Sulphur compounds etc. The presence of FOG does not confirm contamination by petroleum products though it may also be present. These FOG results are based on a gravimetric method which involved weighing of minute amount evaporating and drying these compounds, which has greater chances of inaccuracy which tends to give higher value, if drying has not been adequate and the moisture could give a higher value.

Therefore Gas Chromatography analysis and detail hydrocarbon analysis is essential to confirm the possible presence of any petroleum oil products in the ground water.

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