HEALTH HAZARDOUS: NITRATE-N IN GROUNDWATER AND SOIL IN INTENSIFIED AGRICULTURAL AREAS

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Abstract: The study was focused on estimation of nitrate-N in groundwater and soil in intensive agricultural areas mainly on Valikamam East, Jaffna, Sri Lanka. Groundwater samples from sixty eight wells were collected from the intensive agricultural areas and an analysis was done periodically from July 2007 to February 2008 throughout dry and wet season for nitrate-N concentration. Out of sampled area, some of the areas were selected for soil sampling to see the nitrate level in the soil. Nitrate-N in the groundwater and soil was determined by brucine method. The nitrate- N vary in all the months in sixty eight wells and values were ranged from 0.1mg/l to 17.83 mg/l. Out of sixty eight tested wells, 80% of the wells were not recommended for drinking water in intensified agricultural areas and all the wells were accepted for irrigation requirement. High concentration of nitrate-N was observed till 0- 40 cm of soil profile and the concentration was low below the top layer. There was a good correlation between soil nitrate-N to groundwater nitrate-N.

Keywords: *Soil Nitrate- N, groundwater Nitrate-N, Intensive Agriculture, Limestone*

1. Introduction

Groundwater plays major role in fresh water consumption of human in several countries, including Sri Lanka. Groundwater contamination is a major problem where the places mainly depend on groundwater sources for drinking purposes. The contamination occurs in several ways. Among them inorganic nitrate pollution in groundwater is one of the most common pollution scenario. Groundwater is the major natural water resource in the Jaffna Peninsula, Sri Lanka and it is used for domestic, agricultural and industrial purpose. The population of Jaffna Peninsula is entirely dependent on the groundwater resources for all the purposes with seasonal rainfall. The limestone aquifer has several isolated caves and caverns capable of storing groundwater without evaporation losses. The availability of fresh water is limited and the entire groundwater is generated from percolated rainfall and it forms a fresh water lens above the sea water. After the rainfall, 10-15% of rain water runs off and about 40-48% is lost by evaporation, only 30-32% of rainfall is left over for groundwater recharge [1]. Among the available water in the Peninsula, requirement of 80% is being extracted from the limestone aquifer through open shallow dug wells and deep tube wells [2].

Increasing of the population, the demand of water is also relatively increasing and various human activities have been causing several serious problems, such as nitrate pollution, saline intrusion and bacterial multiplication[3]. In 1983, Gunasegaram [2] studied extensively groundwater contamination in the Jaffna Peninsula and found that the nitrate levels exceeded WHO limits, which is due to the mixing up of abundant nitrogenous waste matter and synthetic and animal fertilizers reaching the shallow groundwater table. This was supported by Mageswaran and Mahalingam in 1984 [4] that high nitrate-N content was in the well water and soil. In 1985, Dissanayake and Weerasooriya [5] pointed out in hydro geochemical atlas of Sri Lanka that Jaffna Peninsula has the highest nitrate content among the groundwater of Sri Lanka. Studies conducted in Jaffna by Nagarajah *et al*. in 1988[6] also substantiated the high concentration of nitrate in groundwater.

Excess nitrate in drinking water affects especially infants and older children, pregnant and nursing mothers. An increasing level of nitrate in groundwater induces health related problems. Increased nitrogen in the soil also may cause serious health problem because some plants such as carrots could store this excess nitrate then reduce it partly to nitrite within it self. The nitrite could convert haemoglobin to methaemoglobin or produce nitrosamines and thus the carrots containing excess nitrite is health hazard [4]. Hence the study was focused with the objective of assessment of nitrate-N in groundwater and soil in the intensive agricultural areas of Jaffna Peninsula.

2. Materials and Methodology

2.1 Selection of the well and collection of water and soil samples

In the intensive agricultural areas, totally sixty eight wells were selected randomly from different cropping discipline mainly in Valikamam East, Jaffna, Sri Lanka . All the selected wells were used not only for irrigation but also for drinking purpose. Groundwater samples were drawn from 15 cm below the surface area of the wells by water sampler for a period of eight consecutive months beginning from July 2007 to February 2008, at monthly interval. Samples bottles were prepared to collect the water samples to meet prerequisites of chemical analysis.

Six locations were selected to collect soil sample to analyze nitrate-N concentration at different land use. The selected locations were near the selected wells and with in the field. Table 1 shows the locations, depths up to which the soil sample was collected and the land use of the field. The maximum depth was tried up to 150 cm in the soil profile. But the collection of soil samples in the paddy field was not possible beyond 25 cm by auger. At the same time, some of the high land crop fields also failed to collect soil samples up to 150 cm due to the interruption of stones.

Table 1: Soil sampling locations with land use and depth

Place	Crop type	Depths (cm)
Thirunelvely	High land crops	25, 50, 75, 100, 125, 150
Thirunelvely	High land crops	25, 50, 75, 86
Kopay	High land crops	25, 50, 75, 100, 125, 134
Irrupalai	Paddy field	25
Neervely	Banana field	25, 50, 75, 100, 125, 150
Neervely	Perennial crops	25, 50, 75, 100, 125

2.2 Chemical analysis of water and soil samples

Nitrate, ammonium and nitrite were extracted from soil by common reagent 2M KCl [7]. The nitrate-N content of groundwater and soil extract was determined colorimetrically using the Brucine method [8]. Rainfall data was obtained from meteorological department, Jaffna during the study period as secondary data to see the correlation between rainfall and measured nitrate-N in the groundwater. Height of the water surface from the reference point was measured at every sampling time by measuring tape.

2.3 Statistical analysis

All the measured data were statistically analysised by using SAS program version 8.0. The significant different between months and season were observed for nitrate-N.

3. Results and discussion

3.1 Nitrate-N in groundwater in the intensive agricultural areas

Of the sixty eight wells measured, results showed that 20 % of well water was with nitrate-N content of less than 8 mg/l and 12 % were within the critical range of 8 mg/l to 10 mg/l and 68 % were with value of above 10mg/l. The nitrate-N was ranging from 0.1 mg/l to 17.83 mg/l. Figure 1 shows the mean nitrate-N concentration with deviation in all selected wells. The highest value of nitrate-N was observed as 17.83 mg/l at Kondavil. Most of the wells were exceeded the WHO standard [9] of drinking water quality. These wells are mainly used for agriculture. But, when the farmer and family members reside within the farms and labourers who works in their farms uses the well water for drinking. The higher deviation of nitrate-N (Figure 1- Well 36) was due to flowing of runoff water into the well since it has not extended wall above the soil surface. Runoff water collects all fertilizers over the land area, which leads to higher variation of nitrate-N in groundwater. If top of a well is not constructed to divert surface water away from a well, nitrate-N can enter the well from above and increase its concentration in the water. In fact, in many of the farm wells sampled, the tops were either not constructed high enough or were badly damaged so that surface water could easily enter the wells during rainy seasons.

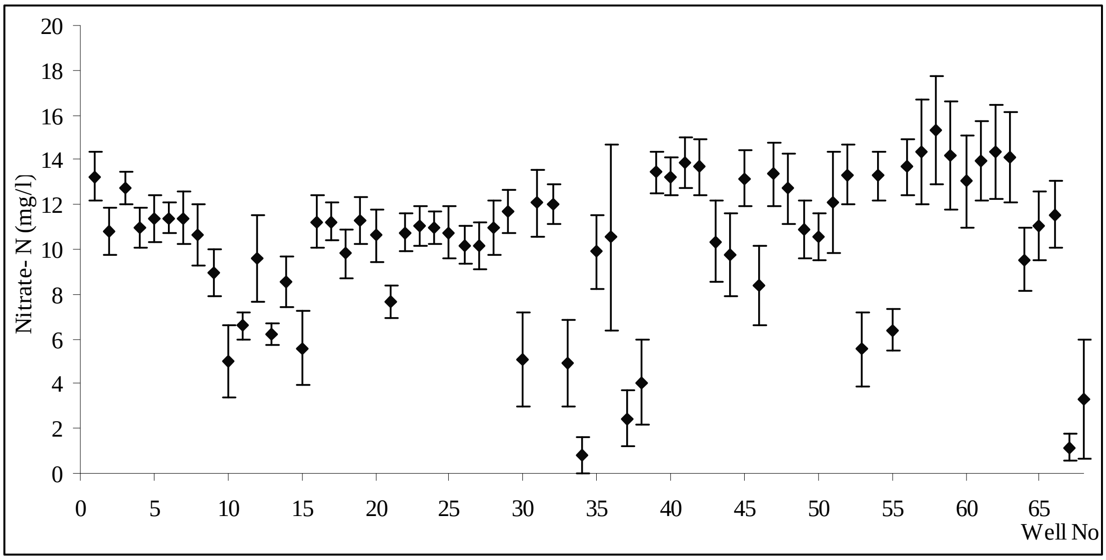

Figure 1: Mean nitrate-N concentration in groundwater in intensive agricultural areas

Nitrates are variously associated with diseases like methaemoglobinemia, gastric cancer, thinning of blood vessels, aggressive behavior and hypertension. Sivarajah [10] mentioned that higher incidence of cancer in Jaffna Peninsula due to higher nitrate level in the groundwater. Panabokke [11], in five year study on the geographical pathology of malignant tumour in Sri Lanka, was presented data on investigation of 24,029 biopsy specimens. According to this study, Northern Province showed the highest incidence (184 per 100,000 populations) of malignant tumours in biopsy material among the nine provinces of Sri Lanka.

High nitrate levels recorded in well waters of the Jaffna Peninsula's agricultural areas was very likely related to the intensive cultivation practiced in that region. It is a well known fact that farmers in this region apply very large amounts of animal wastes, green manures and crop residues in addition to heavy applications of inorganic fertilizers and agrochemicals. Additionally, irrigation from wells is also provided at a higher rate and frequency. Water is applied to the crops (chilli, onion, tobacco, vegetables etc) through flood irrigation. Also, the limestone aquifers are covered by a thin mantle of highly permeable red yellow latosols, rapid movement of any nitrate-N not utilized by crops can reach the aquifers resulting in high nitrate levels.

The recommendation of WHO [9] for nitrate-N for irrigation purposes is in the range of 5 to 30 mg/l. All the wells concentration was less than the recommended level of WHO. The presence of high nitrate in the irrigation water also effects the concentration of nitrate in the vegetable product.

The above mentioned problem occurs not only in Jaffna Peninsula but also some other parts of the Sri Lanka. Vaheesar [12] showed that the highest nitrate content was observed at Mamunai, Batticaloa district as 96.60 mg/dm^3 and out of tested thirty three wells, 85% of the wells contained nitrate concentration under the safe level and only 15% of the wells had nitrate content of greater than 45 mg/dm^3. Kurupuarachchi and Fernando [13] stated that increase in nitrate concentration is approximately 1 – 2 mg/l per year in Kalpittiya. Finally the study was concluded that 80 % of the well was not recommended for drinking in intensified agricultural areas and all the wells were accepted for irrigation requirement.

3.2 Temporal variation of nitrate- N with rainfall

The variation of water level from the soil surface was from 0.41 m to 3.16 m during July to December. Figure 2 shows fluctuation of groundwater table with rainfall in some selected wells. All the wells show the same pattern of fluctuation.

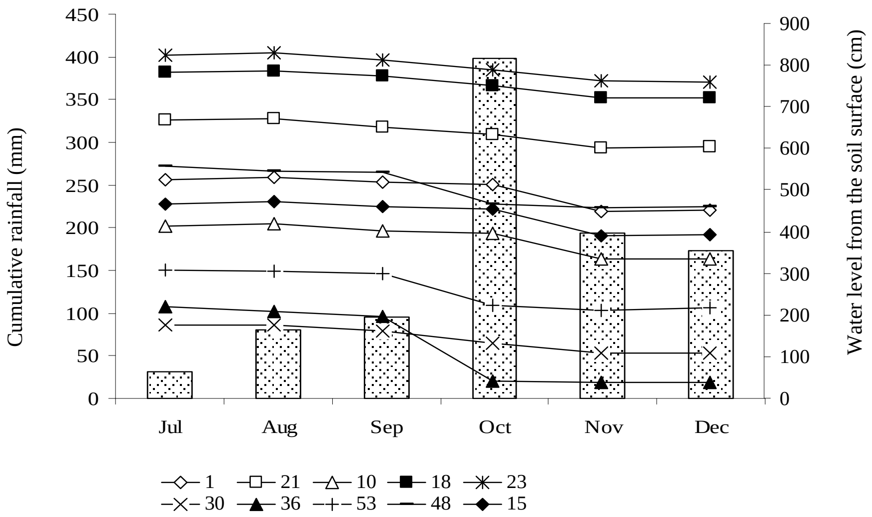

Figure 2: Fluctuation of groundwater table with rainfall in some well

Kuruppuarachi *et al.* [14] showed that nitrate concentration of groundwater in dug wells exceeded the limit in agricultural lands at Kalpitiya in regosols. That groundwater nitrate concentration showed a pronounced seasonal variation with peak values as high after the period of *Maha* rains (October to February) and is associated with a general rise in the water table. A smaller increase in nitrate concentration during April – June may occur as a result of excessive irrigation during the *Yala* season with consequent leaching of the nutrients.

The concentration of nitrate increases is lesser amount of situation during dry season, because of gradual slow leaching of fertilizers. After rainfalls starts in October, the concentration of nitrate was increased in the agro well. Increment in agro well is due to leaching from adjoining cultivated lands with high application rate of fertilizers and also due to more agricultural activities during rainy season. During rainy season, the soil will be wet enough up to the water table for nitrate leaching.

Figure 3 shows the fluctuation of nitrate-N concentration in groundwater with rainfall in selected wells. 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. Nandasena *et al.* [15] reported that the rainfall influences the distribution of nitrate-N in the groundwater by raising or lowering of the groundwater table. Rainy season coming just after a well-aerated condition of a soil, easy migration of nitrate-N from topsoil into the relatively shallow water table could occur which results in high concentrations of nitrate-N in groundwater.

Table 2 shows the statistical analysis of variation among monthly data. Significance different between monthly mean nitrate-N value of October significantly differed from July, August, November and December. Monthly mean nitrate values was not significantly differed between September and October while monthly mean nitrate value of the September was not significantly differed from July, August, November and December. Significant effect of October may be due to the effect of the heavy rainfall which influences the recharge. It was supported by high water level in the well (Figure 2). Monthly mean nitrate values of the water samples not significantly differed among the seasons while there was significant interaction found between the season and months.

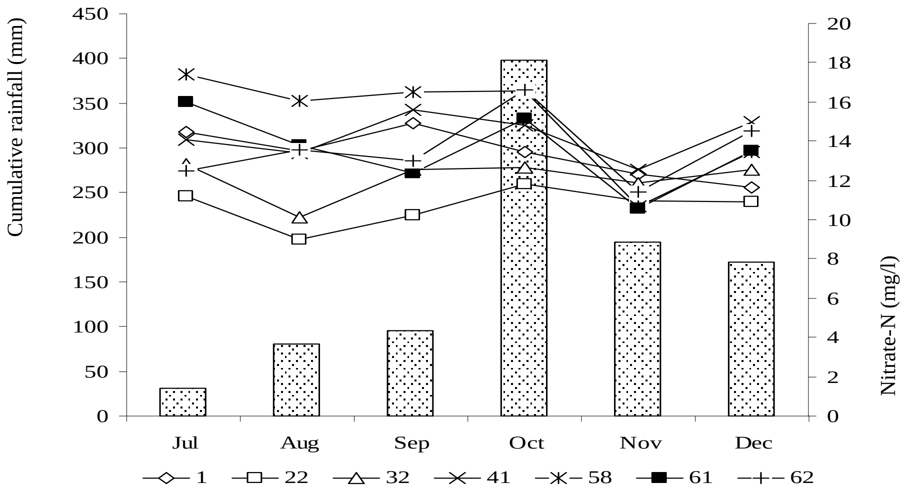

Figure 3: Fluctuation of nitrate-N concentration in groundwater with rainfall

Table 2: Statistical analysis of groundwater nitrate-N among monthly data ($p < 0.05$)

Months	Mean nitrate-N
July	9.68 [b]
August	9.65 [b]
September	10.79 [ab]
October	11.37 [a]
November	9.50 [b]
December	10.03 [b]

Means with same letter aren't significantly different in Duncan's grouping.

3.3 Nitrate-N in soil

Figure 4 shows the presence of nitrate-N in the soil in different cultivated area. High concentration of nitrate nitrogen was observed up to 40 cm of soil profile and the concentration was low below the top layer. Because normally the organic and inorganic fertilizers were incorporated within the top soil surface which results in high concentration in top soil for all type of land use. The concentration was very high within the profile 0 – 25 cm in paddy soil. Premanandarajah *et al.*, [16] reported that 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 N will remain in the soil for next crop.

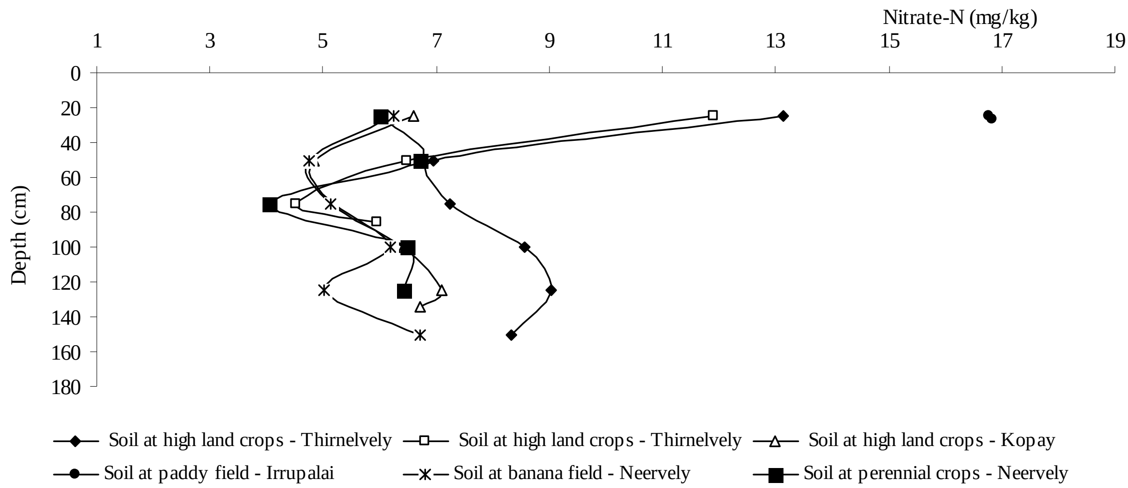

Figure 4: Nitrate-N in soil in different land use classes

3.4 Nitrate-N in groundwater and soil in different land use

Nitrate-N in the groundwater and soil in the different land use classes is shown in Figure 5. There was a good correlation between soil nitrate-N to groundwater nitrate-N except paddy land use. Even though the concentration of nitrate-N was high in the paddy land use there was no leaching to the groundwater because leaching was restricted due to the presence of hardpan. De silva and Ayomi [17] reported that low nitrate content despite of intensive vegetable cultivation in Malsiripura in Kurunegala district due to the characteristics of the soil which consists of high clay and less pores which restricts the free leaching of nutrients to the shallow groundwater. Poorly drained soils can reduce the risk of groundwater contamination even in areas with high nitrogen input.

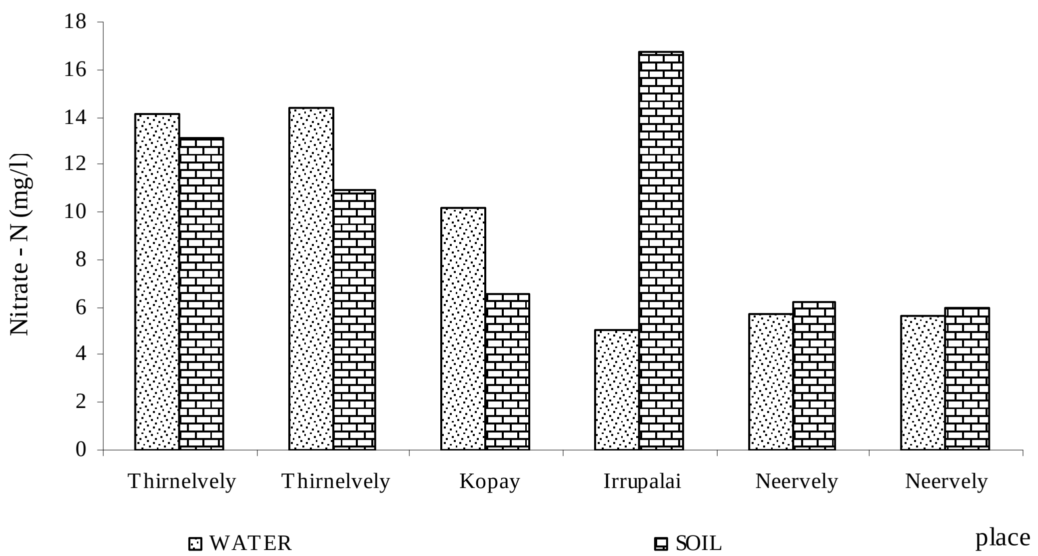

Figure 5: Nitrate-N in soil and water in different places

Wijewardena [18] revealed that the low nitrate – N content in the drinking waters of the up country, Sri Lanka where intensive vegetable cultivation is practiced may attribute to heavy textural fraction in ultisol. Loss of nitrate to groundwater is regulated by the amount of infiltration of the soil and water movement in the soil profile. Accordingly, nitrate mobility is high for moderately well drained soil and low for a poorly drained soil. The study area consists of red yellow latosol with the porosity of 46 % and infiltration rate 430 mm/hr [19], which facilitates free leaching of nutrients to the shallow groundwater.

4. Conclusion

The nitrate- N varies in all the months in sixty eight wells and values were ranged from 0.1 to 17.83 mg/l. The highest value of nitrate-N was observed as 17.83 mg/l at Kondavil. Out of sixty eight wells, 80% of the well was not recommended for drinking in intensified agricultural areas and all the wells were accepted for irrigation requirement. High concentration of nitrate nitrogen was observed up to 40 cm of soil profile and the concentration was low below the top layer. There was a good correlation between soil nitrate-N to groundwater nitrate-N except paddy land.

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