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The Effect of Agriculture on Quality of Groundwater: A Case Study

T. Jeyaruba and M. Thushyanthy

Department of Agric. Engineering, Faculty of Agriculture,
University of Jaffna, Jaffna, Sri Lanka

Abstract: The study was focused on quality of groundwater in different cropping system. Groundwater samples were collected from different cropping systems and an analysis was done periodically from July 2007 to February 2008 for important chemical parameters; nitrate-N, electrical conductivity, pH and chloride. Totally sixty eight wells were selected randomly from different cropping systems such as high land crops, mixed crops, banana and paddy field. The nitrate-N content was determined colorimetrically using the brucine method. The pH and EC of the collected water samples were digitally measured by using pH meter and conductivity meter respectively. Mohr's titration was used for determination of the concentration of chloride. Results reveled that 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 followed by mixed crops and there was no significant difference between high land and mixed crops. Concentration of nitrate-N in paddy and banana land use was less than the recommended level of 10 mg/L. There was significant different between high land and mixed crops to banana and paddy land use. But there was no significant difference between paddy and banana. There was no correlation between land use and electrical conductivity, pH and chloride in groundwater. It is worthy to note that the level of nitrate-N concentration of water was influenced by cropping system.

Key wards: Cropping pattern · Groundwater · Quality · Nitrate-N · Jaffna peninsula

INTRODUCTION

Groundwater is an extremely valuable resource and pollution of groundwater resources is a matter of serious concern. Among the major threats to groundwater from which drinking water supplies are obtained are leachates from human and animal waste matter, along with other chemical pollutants. Agricultural leachates often contribute significantly to groundwater pollution. Among the chemical species that pollute groundwater supplies are nitrate. These originate mainly from human and animal wastes as well as from nitrogenous fertilizers that are often used in large quantities in agriculture [1].

The high nitrate levels recorded in well waters of the Peninsula's agricultural areas is very likely related to the intensive cultivation practiced in that region [2]. Farmers are applied very large amount of animal wastes, green manures and crop residues in addition to heavy application of inorganic fertilizers. Additionally, irrigation from well is also provided at a higher rate and water is applied to crops through flood irrigation. In view of the fact, the limestone aquifers are covered by thin mantle of highly permeable *calcic latasol* soil type, rapid movement of any nitrate which is not utilized by crops can reach the aquifers resulting in high nitrate levels [3].

The farmers cultivate the crops in different ways in Jaffna peninsula. The crops are cultivated as high land crops or highland with banana or banana alone in these lands. Paddy is cultivated during *Maha* season in separate land. Depending upon the cultivable lands the amount of fertilizer, fertilizer application interval, amount of irrigation, irrigation interval differs. Since these factors are influencing the ground water quality, the estimation of ground water quality in different agricultural systems was selected as the objective.

MATERIALS AND METHODS

Selection of the Well: In the intensive agricultural areas totally sixty eight wells were selected randomly from different cropping discipline high land crops (chilli, onion, brinjal, tobacco), mixed crops (high land crops with

Corresponding Author: Mrs. T. Mikunthan, Department of Agric. Engineering,
Faculty of Agriculture, University of Jaffna, Sri Lanka

Table 1: Rainfall amount during the study period

Month	Rainfall (mm)
July 2007	31.5
August 2007	92.5
September 2007	95.6
November 2007	398.2
December 2007	383.7
January 2008	22.1
February 2008	35.1

Table 2: Statistical analysis of groundwater nitrate-N in different cropping systems

Land use	Mean nitrate-N
High land crops	11.6303[a]
Mixed crops	10.7369[a]
Banana	5.4148[b]
Paddy	5.3593[b]

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

banana), banana field and paddy field. Since the well in the paddy field is not much existing in the Peninsula, the number of well selected for sampling was seven. At the same time, forty one wells were selected for analysis under high land crops because large extent of land is under high land crops. Thirteen and seven wells were selected from mixed crop and banana respectively. All the selected wells were used not only for irrigation but also for drinking purpose.

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 2007 to February 2008, at monthly interval. Samples bottles were prepared to collect the water samples to meet prerequisites of chemical analysis. Each sample was poured into sample bottles after rinsing it twice or thrice with the same water and covered with lid. Samples were then taken to the laboratory for chemical analysis.

Chemical Analysis of Water Samples: The nitrate-N content was determined colorimetrically using the Brucine method [4]. The pH of the collected water samples were digitally measured by using pH meter. 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, Jaffna during the study period as secondary data to see the correlation between rainfall and quality of water and shown in Table 2. Finally measured all chemical parameters were compared with the Sri Lankan drinking water standard and recommended irrigation water quality standards. All the measured data were analysised statistically for the significant different between land use classes and measured parameters.

RESULTS AND DISCUSSION

pH: pH levels vary in all the months in the sixty eight wells water. The values were a range from 6.9 to 8.1 and all the wells were suitable for drinking purpose. Figure 1 shows the average pH value of all selected wells. There were no correlation between different cropping system and pH. The result of the study was supported by [3-5]. The normal recommended pH range for irrigation water is from 6.5 to 8.4 [6]. All the tested wells were within the range irrigation water and there were no influence of cropping system on pH.

Electrical Conductivity (EC): A high value of EC generally means high degree of salinity. Therefore, EC is considered as an important water quality parameter in assessing drinking water as well as irrigation water. EC is a widely used as indicator for salinity and this has also been used to classify the water under medium saline, low and high saline water. EC levels vary in all the months and range from 0. 43 dS/m to 2.99 dS/m. Figure 2 shows the average EC value of all sampled wells. Since measured values were less than Sri Lankan permissible level of 3.5 dS/m, all the wells were suited for drinking. All the

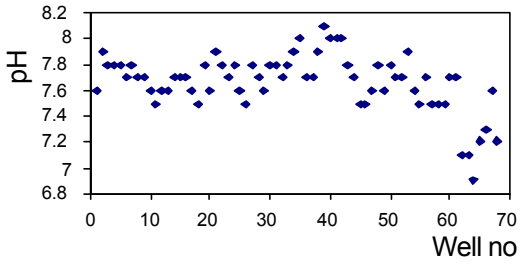

Fig. 1: Average pH in groundwater.

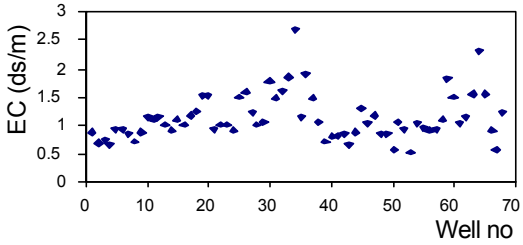

Fig. 2: Average EC in groundwater

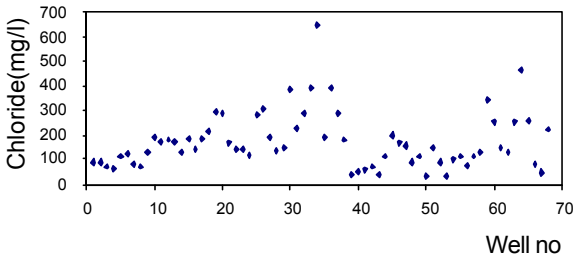

Fig. 3: Average chloride in groundwater

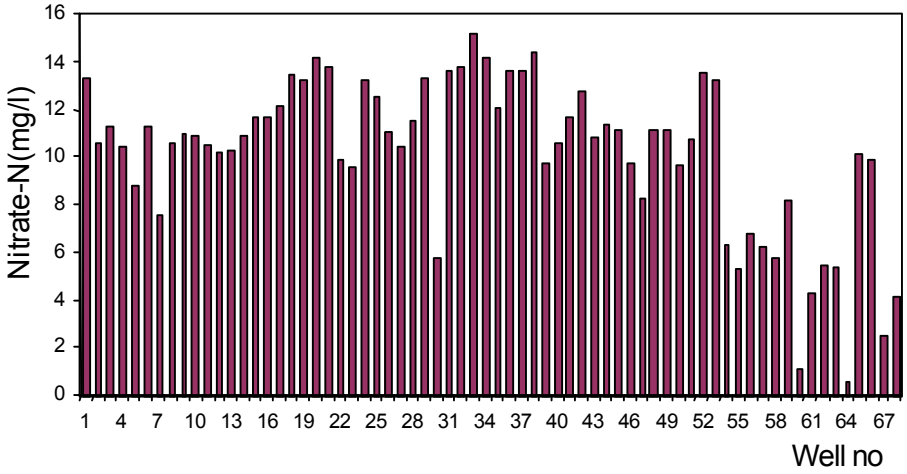

Fig. 4: Average nitrate-N in the groundwater in the different land use classes

measured wells were under 3.0 dS/m. Out of measured wells, 8.82% of the wells had EC values below 0.7 dS/m and 91.18% of the wells had the EC values between 0.7-3 dS/m. Hence, most of the wells are slight to moderate for irrigation purpose. The significant rise in EC values of water following the main *Maha* rains in November, due to the fact that a large part of the leaching or washing out of the solutes in the soil [7]. 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.

Chloride: Sources of chloride in groundwater include rainwater, fertilizers, sewage water industrial pollutants and saline residues from soil and minerals such as biotite. The chloride concentration was ranging from 28 to 734 mg/l. All the wells were suited for drinking. Figure 3 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 with in the range of 200 mg/l to 1200 mg/L. According to the classification [8], 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 141-350 mg/L (moderately tolerant plants show injury), 7.35% of the wells have chloride values above 350 mg/L which causes severe problems.

The chloride concentration in excess of about 250 mg/L can give rise to detectable taste in water [9]. The action level is 250 mg/L [10]. 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.

Nitrate-N: The nitrate-N vary in all the months in sixty eight well and values were ranged from 0.16 mg/L to 17.41 mg/L. The highest value of nitrate-N was observed as 17.41 mg/L at Kondavil. Out of sixty eight wells, 81% of the well was not recommended for drinking in intensified agricultural areas and all the wells were accepted for

irrigation requirement since the concentration was less than 30 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 Jaffna Peninsula but also some other parts of the Sri Lanka. The highest nitrate content was observed at Mamunai, Batticaloa district as96.60 mg/dm^3 [11]. The increase in nitrate concentration is approximately 1-2 mg/L per year [12].

Presence of Nitrate-N in Different Cropping System: Figure 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 land use and followed by mixed crops. Most of the wells were 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 Sri Lanka that Jaffna Peninsula has the highest nitrate content among the groundwater of Sri Lanka due to higher usage of fertilizers [13].

In intensified agricultural areas, farmers used to practice for year round cultivation with out 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 2 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 Jaffna Peninsula 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 N will remain in the soil for next crop [14]. 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.

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.

The limestone aquifer of the Peninsula is not only highly vulnerable to pollution but also subject to land use activities likely to generate pollutants. 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.

CONCLUSION AND SUGGESTIONS

All the wells were accepted for irrigation requirement based on pH and nitrate and based on the chloride and EC wells were recommended as slight to moderate for irrigation. 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.

Suggestions:

- Construction of proper lining of the agro well to prevent the run off water into the well.
- Promote the use of bio fertilizers instead of using chemical fertilizers in agriculture. It is recommended to Shift the cultivation into organic agriculture and use of natural and bio agents for the management of pest and disease and attention to near future.
- Introducing the micro irrigation system to reduce the extraction of aquifer and also to reduce the leaching of ions from the soil profile to ground water aquifer by applying accurate required amount of irrigation water.
- Awareness program to public through the extension officers regarding the dangerous situation of quality of finite natural resource.

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