The effect of land use on quality of groundwater: A case study from Jaffna peninsula

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Abstract

The study was focused on quality of groundwater in different land use. Sixty eight wells were selected randomly from different land use such as high land crops, mixed crops, banana field and paddy field. Groundwater samples were collected from wells and an analysed periodically from July to December 2007 for nitrate-N, electrical conductivity (EC), total dissolve solid, pH and chloride. The nitrate-N content was determined colorimetrically using the brucine method. The pH and EC were measured by using pH meter and conductivity meter, respectively. Mohr's titration was used for determine of the concentration of chloride. Results revealed that there was a significant correlation between land use and nitrate-N concentration in groundwater. High nitrate-N concentration of groundwater was observed at highland crops land use followed by mixed crops and there was no significant difference between high land and mixed crops. However, there was no significant difference between highland and mixed crops. Similarly, there was no significant different between paddy and banana. 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 were no correlation between land use and electrical conductivity, total dissolve solid, pH and chloride in groundwater.

Introduction

Groundwater is an extremely valuable resource particularly where it is the only source for water supply and pollution of groundwater resources is a matter of serious concern. Among the major threats to groundwater source, leachates from human and animal waste and chemical used in agriculture are very serious. Agricultural leachates often contribute significantly to groundwater pollution. Among the chemical species that pollute groundwater supplies, nitrate is not common. This originates from human and animal excreta as well as from nitrogenous fertilizers that are often used in large quantities in agriculture.

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 (Mageswaran and Mahalingam, 1984, and Nagarajah *et al*., 1988). Farmers apply very large amount of animal wastes, green manures and crop residues in addition to heavy application of inorganic fertilizers. In addition, irrigation is practised at a higher rate and often 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

latosols, rapid movement of any nitrate which is not utilized by crops can reach the aquifers resulting in high nitrate levels (Nagarajah *et al*., 1988).

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. 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. The objective of this study is to asses the ground water quality under highland, banana and mixed crops.

Materials and methods

Selection of the well

Sixty eight wells were selected randomly In the intensive agricultural areas from different cropping patterns high land crops (chilli, onion, brinjal, tobacco), mixed crops (high land crops with 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 using water sampler for a period of six consecutive months beginning from July to December in 2007, 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 (Taras, 1958).The pH and EC of the water samples were measured by using pH meter and conductivity meter, respectively. Mohr's titration (0.01 AgNo3) was used for determination of the chloride content.

Rainfall data was obtained from meteorological department, Jaffna during the study period as secondary data to analyse the correlation between rainfall and quality of water. Measured all chemical parameters were compared with the Sri Lankan drinking water standard and recommended irrigation water quality standards. All the measured data were analysed statistically for the significant different between land use classes and measured parameters.

Results and discussion

pH

pH levels in the sixty eight wells water were varied during the period of study. The values ranged 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 land use and pH. The result of the study was supported by Puvaneshwaran (1986) and Nagarajah *et al*. (1988). According to Ayers and Westcot (1985) normal pH range for irrigation water is from 6.5 to 8.4. All the tested wells were within the range irrigation water and there were no influence of land use on pH.

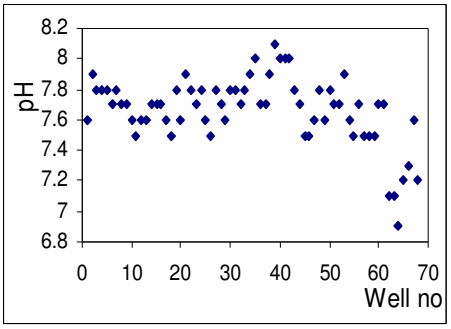

Figure 1: Average pH in groundwater.

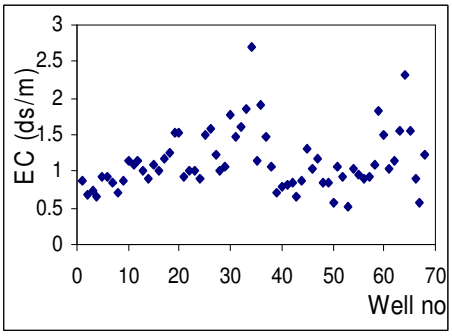

Figure 2: Average EC in groundwater.

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. The EC is widely used to classify the water as low, medium and high saline water. The EC levels varied during the study and ranged 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 permissible level of 3.5 ds/m, all the wells are suitable for drinking. Nine percentages of the wells had EC values below 0.7 ds/m and 91% 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. Panabokke *et al*. (2002) reported that significant rise in EC values of water following the Maha rains in November, due to the fact that a large part of the leaching or washing out of the solutes in the soil. In some of the wells EC values were increased during November due to leaching of the salt from soil. There were no correlation between land use and EC of groundwater.

Chloride

Sources of chloride in groundwater include seawater, fertilizers, sewage water industrial pollutants, and saline residues from soil and minerals such as biotite. Figure 3 shows the average concentration of chloride of all measured wells. The chloride concentration was ranging from 28 to734 mg/l. All the wells were suited for drinking. 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 of Bauder *et al*. (2003) 12% of the wells had the chloride value below 70ppm (safe for all plants) and 33.82% of the wells had chloride values between 70 -140 ppm (sensitive plants show injury), 47.06% of the wells had the chloride values between 141-350 ppm (moderately tolerant plants show injury) and 7.35% of the wells had chloride values above 350 ppm which causes severe problems

De Silva and Ayomi (2004) stated that chloride concentration in excess of about 250 mg/l can give rise to detectable taste in water. There were no correlation between land use and chloride in groundwater even in high land and mixed crop high withdrawal rate. Concentration of chloride in Paddy land was very high because, during the rainy season the runoff water enters into the well with salt.

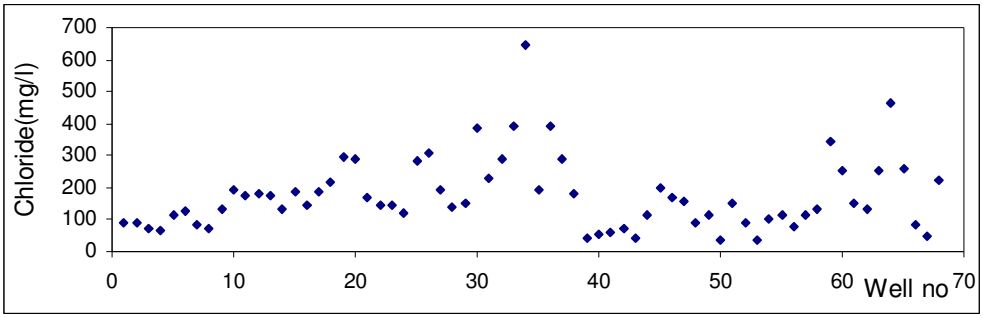

Figure 3: Average chloride in groundwater.

Nitrate-N

The nitrate- N varied 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 wells founding intensified agricultural areas was not recommended for drinking but were accepted for irrigation requirement. The farmers have the practice of applying excess amount of inorganic fertilizers. The excess fertilizers leached out to the shallow groundwater. Dissanayake and Weerasooriya (1985) pointed out in 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. Gunasekeram

(1983) studied extensively on groundwater contamination in the Jaffna Peninsula and found that the nitrate levels exceeded the WHO limits due to mixing up of abundant nitrogenous waste matter and synthetic and animal fertilizers with shallow groundwater.

The above mentioned problem occurs not only in Jaffna Peninsula but also some other parts of the Sri Lanka. Vaheesar (2001) showed that the highest nitrate content was observed at Mamunai, Batticaloa district as 96.60 mg/dm^3. Kurupuarachchi and Fernando, 1999 stated that increase in nitrate concentration is approximately 1 – 2 mg/l per year.

Presence of nitrate-N in different land use

Figure 4 shows nitrate-N in the groundwater in the different land use 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.

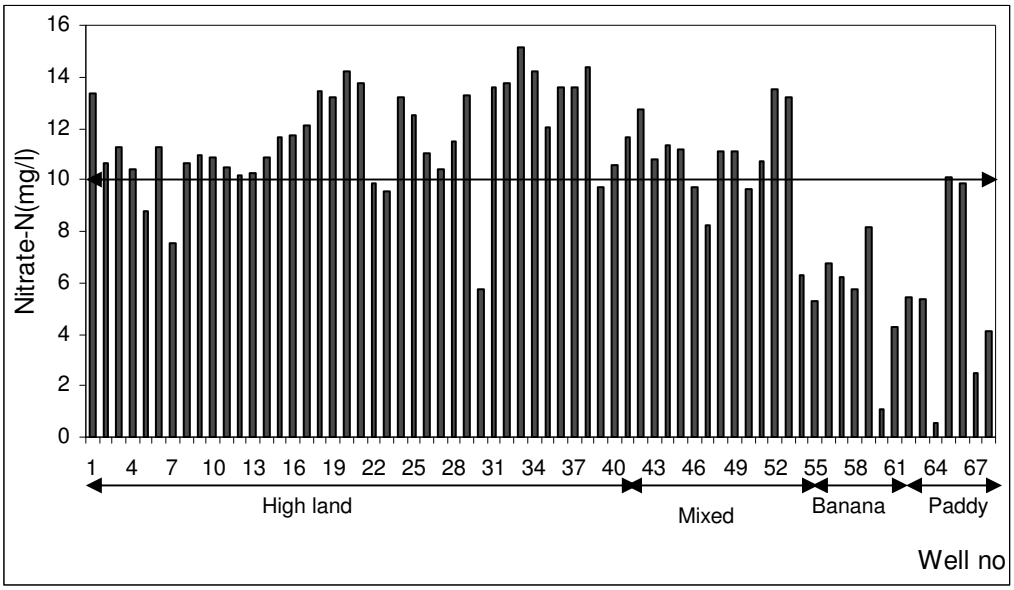

Figure 4: Average nitrate-N in the groundwater in the different land use classes.

In intensified agricultural areas, farmers used to practice year round cultivation without fellow period. In addition to that they are practicing high intensity cropping (planting three crops at a time in the same field; for example amaranthus (15-20 days), radish (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. Mean nitrate-N concentration in groundwater of high land and mixed crops significantly ($p < 0.05$) differed from banana and paddy fields. This 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.

Table 2: Statistical analysis of groundwater nitrate-N in different land use.

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).

The result of this study also was supported by the study of Kuruppuarachchi *et al*., 1990. 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 green manures into the pits. They keep the plants in the field nearly for five years. Most of the farmers are not using any inorganic fertilizers for cultivation. Premanandarajah *et al*., 2003 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. 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 and then 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.

Lawrence *et al*., 1988 reported that the limestone aquifer of the Peninsula is not only highly vulnerable to pollution but also subject to land use activities likely to generate pollutants.

Conclusion and suggestions

All the wells are acceptable for irrigation based on pH and nitrate. On the basis of chloride and EC the wells could be classified as slightly moderate. All the wells are acceptable for drinking based on pH, EC and chloride. But 81% of the wells are not suitable for drinking due to high nitrate -N concentrations. There was a good correlation between land use 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. 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. But, no significant different between paddy and banana cultivation was observed. It is note worthy that the level of nitrate concentrations of water show significant influence by land use.

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.
- 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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