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Contamination of Shallow Dug Wells in Highly Populated Coastal Sand Aquifer: A Case Study in Sainthamarudhu, Sri Lanka

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ABSTRACT. *Access to clean water and adequate sanitation facilities is a great challenge in highly populated areas. Sainthamarudhu, a town in the Eastern province with a population density of 24 069/km^2, uses groundwater as the source for drinking water. Public water supply has not been successful since every family has their own well with adequate water. Septic tanks are located regardless of the well distance. In order to assess the groundwater contamination, 26 wells were selected and Escherichia coli (E. coli) level, nitrate concentration, and electrical conductivity (EC) were measured using water samples collected in two week intervals along with the water table depth for a one year period. Groundwater fluctuates within the depth of 3.4 m and -2.1 m from the mean sea level (m. s. l.) and flows from land to sea in the southeast direction. Almost all the wells are contaminated with E. coli in this area and not safe for drinking according to the WHO standards for drinking water. E. coli levels increased in the wet season up to 700 colonies per 100 ml water sample compared to the dry season due to possible contamination of well water with septic effluents. The wells located in the southeastern area beyond the sewage drain are more prone to E. coli contamination. Higher nitrate levels, around 80.8 mg/l, were found in wells in the northwest regions and therefore, along the northwest-southeast diagonal between the main road and sewage canal, is a potential area for nitrate contamination. Levels of nitrate concentration and EC increased in the dry season when compared to the wet season, possibly due to the dilution effect. The wells closer to the sea have higher EC values, as high as 5,550 µs/cm, probably due to sea water intrusion. Contamination of E. coli, nitrate and dissolved solids is less in the wells closer to the main road. The high population density with lack of proper drainage systems and improper excreta disposal methods in the sandy regosols are the main reasons for the contamination.*

INTRODUCTION

Access to clean water and adequate sanitation facilities is a great challenge in the world particularly in highly populated areas. It has been estimated globally that 3 to 4 million people, mostly children, die annually from water related diseases (Olshansky *et al.*, 1997). These deaths are preventable to a greater extent if basic water supply, sanitation and hygiene are ensured. Sri Lanka is also not an exception where diseases resulting from unsafe water supply and inadequate sanitation and hygiene rank among the leading causes of

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hospitalization and ill-health (Shanmugarajah, 2002). This problem becomes more serious with increasing population density in urban cities of Sri Lanka.

Sainthamarudhu is located in the Kalmunai municipal limit in the coastal belt of the eastern province. It is bounded by the sea on the eastern flank and by paddy fields and a river on its western flank as shown in Figure 1. This area is densely populated with 6,266 families and the total population of 24,069 heads (DS Sainthamarudhu, 2003) of which all of them are confined to (approximately) one square km. In general, highly populated areas in Sri Lanka are provided with pipe borne water which is treated and guaranteed by the National Water Supply and Drainage Board (NWSDB) for domestic consumption. However, this facility is neither adequately provided nor attracted by the general public in Sainthamarudhu. This is mainly due to the availability and accessibility of groundwater as an alternative cheap source of water. This tendency implies that the public is not fully aware of the consequences of continuously increasing high population density on the sustainability of safe groundwater.

Groundwater is the only water source available for drinking purposes in the coastal belt of the entire eastern province. Aquifer of this area belongs to the type of 'shallow aquifers on raised beaches' (Panabokke and Sakthivadivel, 2002). A recent attempt to provide potable water to this area by NWSDB succeeded only to a lower percent (≈ 20 %) of residents so far due to various reasons such as availability of water source, financial constraints, personal preferences, *etc.* The number of pipe borne water supply connections provided was 857 out of the total of 6,266 families while a total of 4,428 private or common wells have been used for drinking and/or other purposes (DS Sainthamarudhu, 2003). Therefore, the tendency to use well water continues in this area in spite of the introduction of pipe borne water supply.

Sandy regosols are found in the east coast of the Batticaloa District and the west coast consists with reddish brown earth, non-calcic brown soils and low humic gley soils (Jeyakumar *et al.*, 2003). Being the southern border to Batticaloa, Sainthamarudhu has similar features found in Batticaloa. The soils are extremely permeable, prone to leaching of both chemical and biological pollutants and therefore the groundwater is highly vulnerable to nitrate and *Escherichia coli (E. coli)* contamination. It is noted in this area that the most of houses have their own well and a toilet with a septic tank. These wells and septic tanks are located regardless of the proximity to neighbouring wells and/or septic tanks, especially due to the limited land area for each dwelling. Contamination with pathogenic microorganisms is the most critical risk factor in drinking water quality with a great potential for widespread waterborne diseases (Galbraith *et al.*, 1987). Nitrate contamination in dug wells located within the intensively cultivated areas in Kalpitiya, Jaffna and Kilinochci has been reported (Nagarajah *et al.*, 1988; Kuruppuarachchi *et al.*, 1990).

This information is not adequate with respect to the impact of the population density on groundwater quality in Sri Lanka. Therefore, this study aims to asses the contamination of water in shallow dug wells of Sainthamarudhu as a case study in order to get an insight into the degree of contaminants in a highly populated area. In addition, attempts were also made to determine the causes for groundwater pollution and demarcate the areas with higher potential for contamination.

MATERIALS AND METHODS

Study area

Sainthamarudhu D.S. division is located next to Kalmunai town in the eastern coast, dry zone of Sri Lanka. The landscape is almost flat and the highest and the lowest elevations are 3.93 m and 2.39 m, respectively above the mean sea level (m.s.l.). The average annual rainfall recorded at the Malwatta seed production farm is around 1,900 mm and concentrated between the months of October and January.

Wells description

Twenty six open dug wells were selected for monitoring the water quality as shown in Figure 1. .

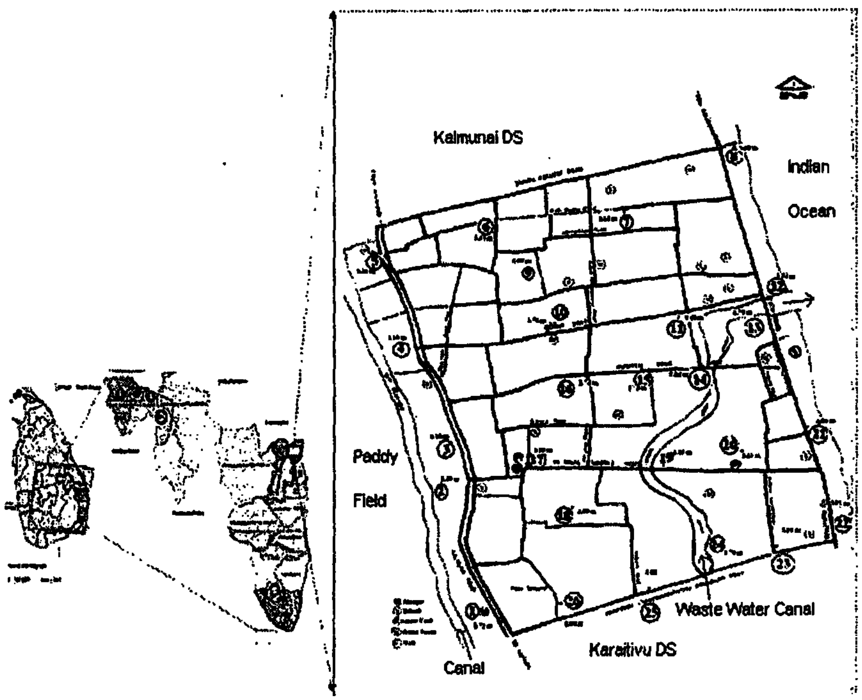


Fig.1. Location of the selected wells and their depths in the study area

The wells were selected randomly to represent the entire residential area. The diameter of wells that were monitored ranged between 89 cm to 102 cm with an average of 92 cm and the depths from the ground surface ranged between 1.70 m to 4.06 m with an average depth of 2.90 m. All the wells are cylindrical and elevated around 1.00 m above the ground level. This eliminates the runoff water entering the well. The bottom part of the wells is made of hume pipes and the above ground part is brick wall plastered with cement.

Water sampling and analysis

The study was conducted for one-year from July 2004 to April 2005 and the data were collected in two weeks frequency. The water table of each selected well was measured as depth to the water surface from the ground level using a wooden stick and a measuring tape. The rainfall data was obtained from the seed production farm at Malwatte which is 7 km away from the study area.

Water samples were collected every two weeks into 250 ml sterilised glass bottles and transported to the Chemistry laboratory of the Faculty of Applied Sciences, South-Eastern University of Sri Lanka in a Styrofoam box containing ice cubes. Electrical conductivity (EC) of the well water was measured at the site itself using a portable conductivity meter (Cond 315i, VWR). Water samples were collected into clean bottles and the electrical probe was inserted into water and measurement made when stable readings appeared in the meter for recording.

One portion of the water sample was analysed for *E. coli* as indicator bacteria whose presence in water indicates the degree of faecal contamination. Membrane filter technique was used to enumerate the *E. coli* levels. The samples (each 100 ml) were passed through a 0.45 μm membrane filter in a sterile funnel under a vacuum pressure of 10 cm Hg. After filtration, the membrane was placed in a sterile Petri dish containing membrane faecal coliform (m FC) broth. The Petri dishes were incubated for 24 hours in an incubator (Economy size 2 with fan, Gallenkamp) at 44.5 °C. *E. coli* colonies that appeared (in blue colour) were counted and recorded as per volume filtered.

Another portion of the sample was analyzed for nitrate concentration using Spectrophotometer (DR 2010, HACH) by cadmium reduction (powder pillow) method adopted from 'Standard methods for the examination of water and wastewater' (HACH, 2002). HACH program (No. 355) was selected; 25 ml samples were taken in to sample cells. Content of one NitraVer 5 nitrate reagent powder pillow was added to each cell and was shaken well for one minute. It was then allowed for chemical reaction to occur for five minutes. The second sample cell, filled with the same volume of deionised water was used to calibrate the 0.0 mg/L NO_3^- known as blank. Then the prepared sample was measured for its nitrate levels.

Statistical analyses (two-sample t-test and CI) were performed for mean comparison and spatial variability using Minitab.

RESULTS AND DISCUSSION

Seasonal variability of the groundwater

Fluctuation of the water table for a selected well (No. 24) is shown in Figure 2 along with the monthly total rainfall. A similar pattern was observed for all other wells. During the study period, the total rainfall received was 2,169 mm, while the maximum monthly total rainfall of 872 mm was recorded in December 2004 and the minimum monthly total rainfall of 3.2 mm was recorded in August 2004. It is clear that the water level fluctuation in wells follow the rainfall pattern of the area (Figure 2). In the dry zone of Sri

Lanka, recharge of the aquifer mainly takes place only during the wet season (De Silva *et al.*, 1999). The groundwater levels were closer to the ground surface during the period from October to January. The recharge to the aquifer mainly takes place from November to January with the northeast monsoon rains. A lesser recharge is recorded during the April rains (Figure 2).

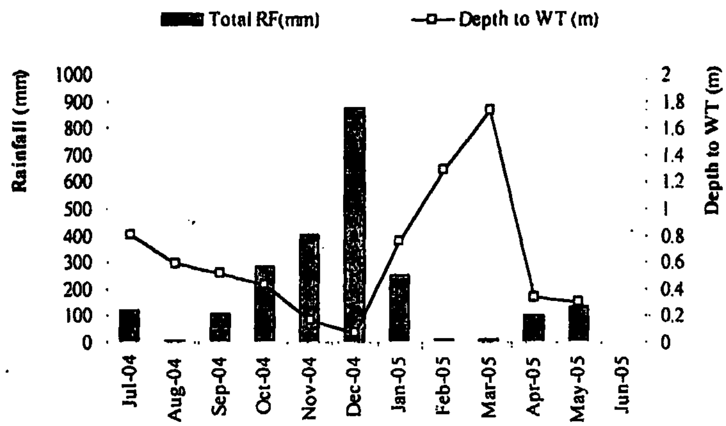


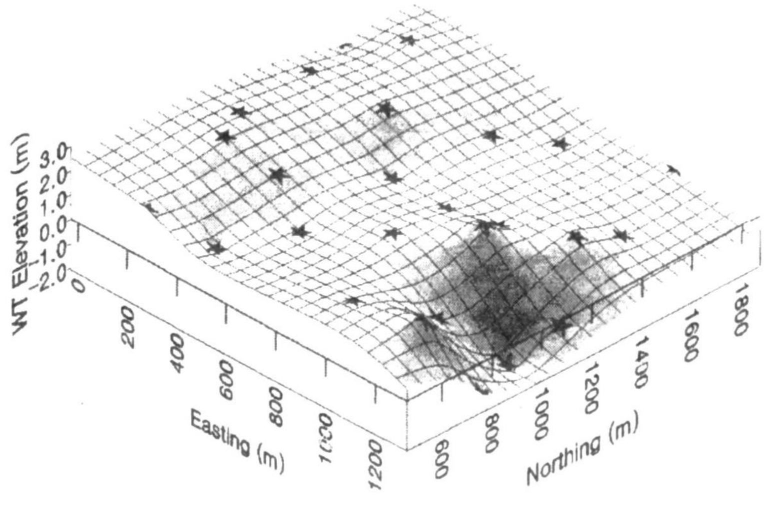
Fig. 2. Temporal variation of rainfall and depth to the water table (WT) for well No. 24

The maximum, minimum and average water table depths of the selected wells are shown in Table 1. The water head in the well No. 2 is higher throughout the year since it is recharged from the adjacent paddy fields. Water levels in most of the wells were closer to the ground surface at the end of the rainy season. The highest depth from the ground surface was 4.03 m, recorded for the well No. 21. It had a water head of 3 cm, at the end of the dry season (on 23rd March 2005). Water levels, lower than the m. s. l. were recorded in the wells (Well No. 21 and 22) closer to the sea (Figure 1).

Figure 3, (A) and (B) show the spatial variability of water table of the study area for dry and wet seasons, respectively. The hydraulic head differences were found to be around 3 m and 2 m in wet and dry seasons, respectively between the highest and lowest water levels from North-West to South-East. The water flows from land area to sea in both seasons.

Table 1. Summary of water table fluctuations (height from the m. s. l.) during two periods

	Maximum (m)	Minimum (m)	Average (m)	SD
Dry Period	2.49 (Well No. 2)	-2.10 (Well No. 21)	0.82	1.18
Wet Period	3.38 (Well No. 2)	-1.11 (Well No. 22)	1.66	1.32



(A)

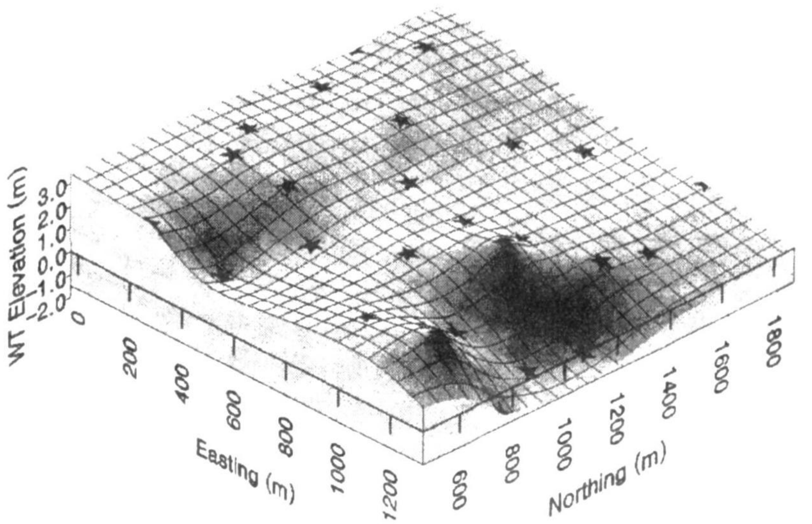


Fig. 3. Spatial variation of the water table within the study area for dry (A) and wet (B) seasons

Faecal coliform contamination

The water quality indicator bacteria, *E. coli*, were found in almost all the wells in both seasons (Figure 4). WHO (2004) guideline reports that all water directly intended for drinking must not be detectable *E. coli* in any 100 ml sample. The most of the area is contaminated with *E. coli* at various levels. The minimum was recorded as 0 colonies per

100 ml water sample in wells, numbered 1, 3, 10, 15, 16 and 25 during the dry season, while the maximum 700 colonies per 100 ml water sample was found in the well No. 18 on 31st January, 2005. The average *E. coli* counts were significantly higher (P = 0.034) during the wet season (October – December 2004) than during the dry season (July - September 2004). The reason could be probably due to the shallow water table during the wet season which intercepts the nearby septic tanks and help *E. coli* to freely move into the aquifer contaminating the well water.

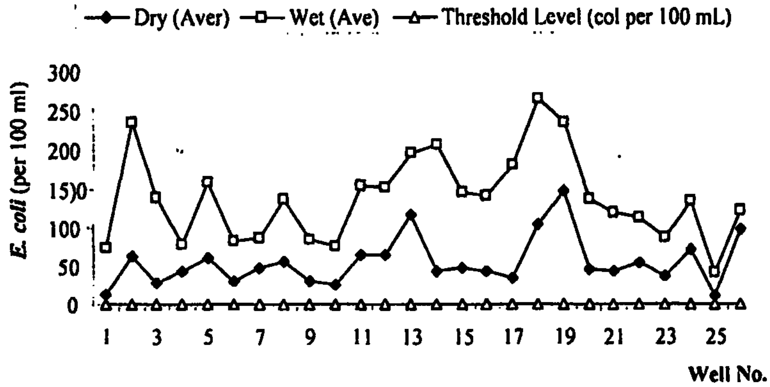
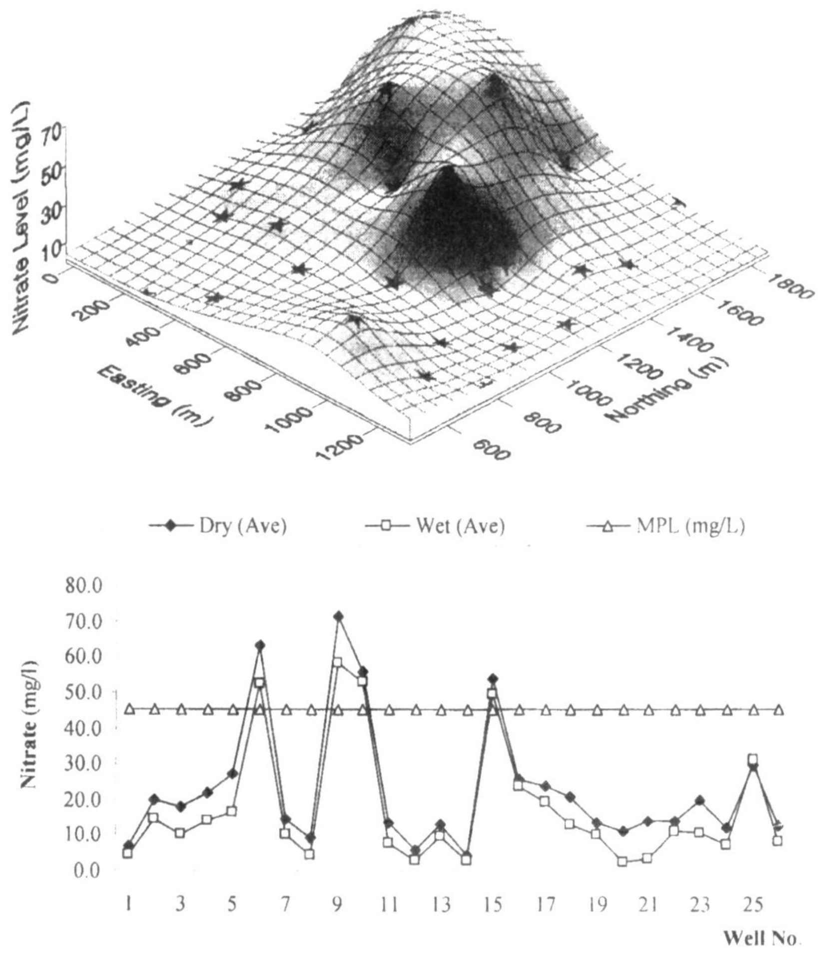


Fig. 4. Spatial distribution of *Escherichia coli* (average counts) during wet and dry seasons

Nitrate concentration in groundwater

Higher concentrations in groundwater and potable water have been reported especially in areas with higher application of fertilizers to agricultural fields (Dissanayake *et al.*, 1984; Nagarajah *et al.*, 1988; Kuruppuarachchi *et al.*, 1990). In Sainthamarudhu, the agricultural activities are restricted to paddy fields, the west boarder of the study area and there is no cultivated area within the land side for possible fertilizer application. The only source of nitrate contamination is septic tanks in this area.

The spatial variability of nitrate within the study area is shown in Figure 5. Nitrate concentrations of well water ranges from 0.1 - 80.8 mg/l. It was found that the nitrate concentration was comparatively higher than the threshold level, 45 mg/l, in the North-west region of the study area (Figure 5A). Northeast, East and Southwest regions show relatively lower concentrations below the threshold level. Nitrate content showed a drastic increase in September followed by a decline after January/February. Furthermore, seasonal variations ($P<0.05$) in the groundwater nitrate concentrations were also noted (Figure 5B) with higher values during dry periods. Well numbers 6, 9, 10 and 15 show higher concentrations around 60 – 70 mg/L. Nitrate is an anion and easy to leach in a sandy regosols as reported by Bawatharani *et al.* (2004). Compared with nitrate values reported for the coastal sand aquifer in Kalpitiya, (Kuruppuarachchi, 1995) the present condition in the eastern coast aquifer could be considered to be the initial stage of developing an unhealthy condition. Even though, the nitrate concentration is within the permissible limit, the increasing trend has to be considered as alarming situation.



(B)

Fig 5. Distribution of nitrate levels within the study area; spatial (A) and seasonal (B).

Electrical conductivity (EC)

The EC reflects the dissolved solids concentration in water. As shown in Figure 6, broad variation of EC in the different segments of the aquifer became apparent. Seasonal variation of EC clearly indicates the salinity hazard, especially in the dry season. However, in most of the wells, EC values were below the acceptable limit for drinking water that is 5 –

through the land. All individual wells show variation of EC value for rainfall less than 300 mm, but the value remains fairly constant during high rainfall periods.

The water in wells numbered 8, 13, 14, 20, 21, 22 and 23 are of higher EC due to its proximity to the sea resulting in higher salinity. Also, it was found from the water table variation (Figure 3) that water levels were below the mean sea level within the eastern zone. There is a high hydraulic potential for water to flow from the sea to those wells that are located within the coastal area resulting in high salinity. Comparing the spatial distribution of wells, the water quality is fairly good in the area close to the main road.

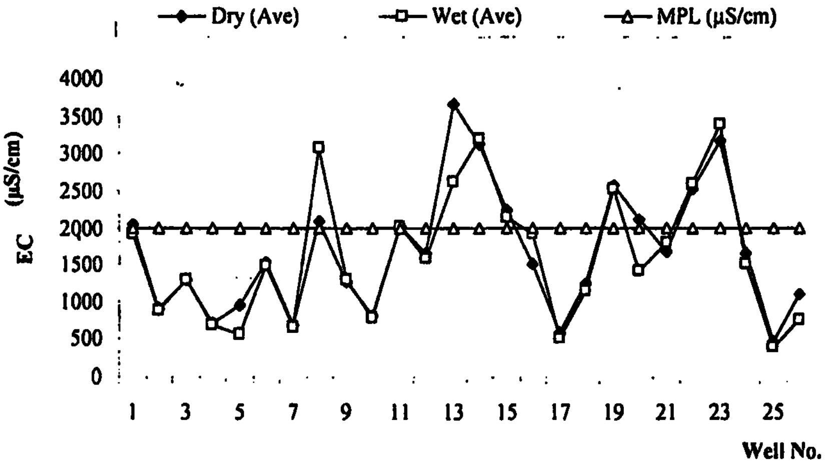


Fig. 6. Spatial distribution of EC during dry and wet seasons

At present, there is no evidence of solute concentration build up in well waters in the land side. It could be reasoned out that the annual rainfall received is adequate to leach out and dilute solutes in this region that have been built up in the soil during the dry season. Seasonal variation of EC clearly indicates the salinity hazard especially during the dry season. However, in most of the wells, EC values were under the desirable limit but unlimited exploration of groundwater from coastal area needs immediate attention.

CONCLUSIONS

The mean water table of the studied area was around 2.37 m. The lowest point of 2.82 m from the m. s. l. is nearly equal to the depth of septic tanks. The shallow aquifer is mostly contaminated with *E. coli* in this area and not safe for drinking. *E. coli* counts increased in the wet season compared to the dry season ($P<0.05$) due to possible contamination of well water with the septic effluents. The wells located in the South Eastern area beyond the sewage drain are more prone to *E. coli* contamination and protective measures should be taken. Groundwater flows from land to sea in the southeast direction. Higher nitrate levels found in wells in the northwest regions along the North West-South East diagonal between the main road and sewage canal is a potential area for nitrate contamination. The only source of nitrate contamination is septic tanks in this area. Any influence of the fertilizer application beyond the main road on the western direction should be confirmed by a further study. Levels of nitrate concentration and EC increased in the dry season compared to the wet season possibly due to dilution effect rather than *E. coli* fluctuation. The wells closer to the sea have higher EC values due to sea water intrusion. Hence, unlimited exploration of groundwater closer to the beach needs immediate attention. The wells closer to the main road and paddy field have less contamination of *E. coli*, nitrate and dissolved solids. Anthropogenic activities due to high population density with lack of proper drainage systems and improper excreta disposal methods in Sainthamarudhu are the main reasons for the contamination.

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REFERENCES

Bawatharani, T., Mowjood, M.I.M., Dayawansa, N.D.K., and Kumaragamage, D. (2004). Nitrate leaching as a function of fertilization and irrigation practices in sandy regosols. Tropical Agricultural Research, 16: 172 - 180.

De Silva, C. S., Fernando, N., Sakthivadivel, R. and Merrey, D. (1999). Managing groundwater in hard-rock areas through agro-well design and development. Water Resources Development, 15 (3): 333 - 348.

Dissanayake, C.B. Weerasooriya, S.V.R. and Seneratne, A. (1984). The distribution of nitrates in potable waters of Sri Lanka. Aqua. 1: 43 - 50.

DS Sainthamarudhu (2003). Divisional Secretariat Office report, Sainthamarudhu.

Galbraith, N.S., Barnett, N.J. and Stanwell-Smith, R. (1987). Water and disease after Croydon: A review of waterborne and water associated disease in the United Kingdom (1937-1986), Journal of the Institution of Water and Environmental Management, 1: 7 - 21.

HACH. (2002). Water analysis handbook. (4^{th} Ed), HACH Company, Loveland Coloroda. USA. 573 - 578.

Jeyakumar, P., Premanandarajah, P. and Mahendran, S. (2003). Water quality of agro-wells in the coastal area of the Batticaloa district. In: Pathmarajah, S. (Ed). Use of groundwater for agriculture in Sri Lanka, PGIA, University of Peradeniya. pp. 99 - 107.

Kuruppuarachchi, D.S.P., Fernando, W.A.R.N. and Lawrance, A.R. (1990) Impact of agriculture on groundwater quality in Kalpitiya peninsula in the north western dry zone of Sri Lanka. In: Gunawardena, E.R.N. (Ed). Irrigation and water resources, PGIA, University of Peradeniya. pp. 199 - 213.

Kuruppuarachchi, D.S.P. (1995). Impact of irrigated agriculture on groundwater in Sri Lanka. Proc. Sri Lanka Assoc. Adv. Sci. Pt II, 49 - 66.

Nagarajah, S. Emerson, B.N. Abeykoon, V. and Yogalingam, S. (1988). Water quality of some wells in Jaffna and Kilinochchi with special reference to nitrate pollution. Trop. Agric. 144: 61 - 78.

Olshansky, S., Carnes, B., Rogers, R., and Smith, L. (1997). New and ancient threats to world health. Population Bulletin 52 (2): 2 - 43.

Panabokke, C.R., and Sakthivadivel, R. (2002). Coastal sand aquifers in Sri Lanka, general characteristics, present utilization and gaps in knowledge. In: Unknown (Ed). Critical Issues Facing Groundwater Section in Sri Lanka and south India. Kodaikkanal, Tamil Nadu. pp. 1 - 20.

Shanmugarajah, C. K. (2002). Health, water and sanitation. In: Imbulana, K.A.U.S., Peter Droogers and Ian W. Makin, (Ed). World Water Assessment Programme Sri Lanka. Case Study, Ruhuna Basins. IWMI, Colombo. p. 97.

WHO (2004). Guidelines for drinking water quality. (3rd Ed) Vol.1, World Health Organization, Geneva.