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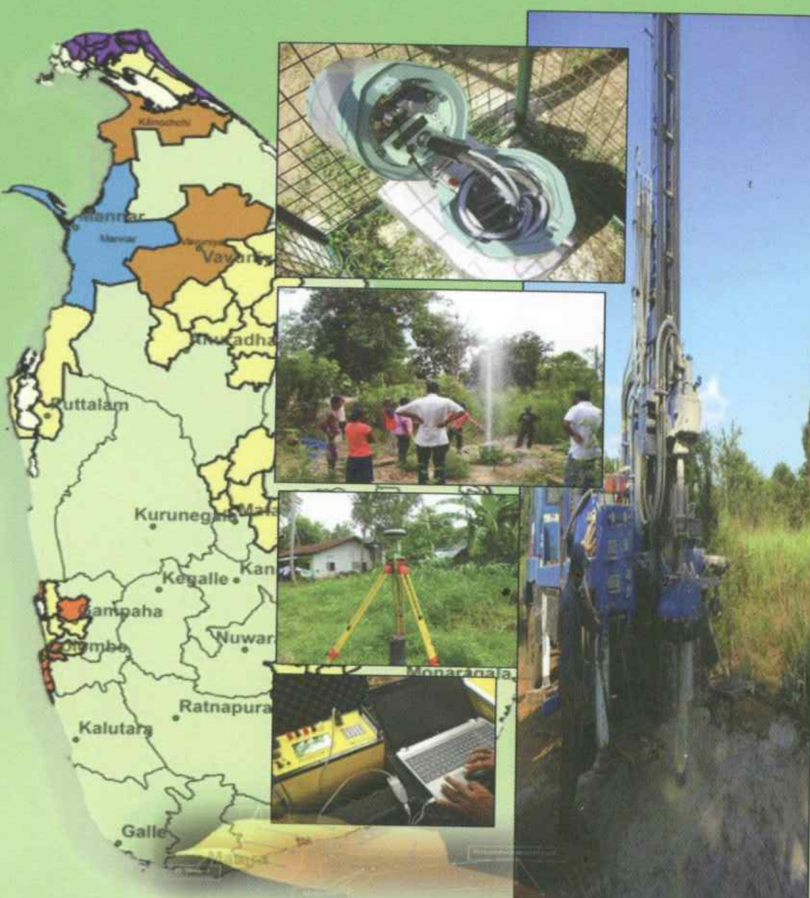

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Sustaining a limestone aquifer: Case of Jaffna Peninsula in Sri Lanka

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Abstract

The population of the Jaffna Peninsula, in Northern Sri Lanka depends entirely on groundwater resources to meet all their water requirements. The four, main fresh water aquifers in the Jaffna Peninsula are saddled within a Karstic limestone, floating on seawater. This limited resource is endangered in terms of quantity and quality, which has deteriorated over time. A major water quality problem identified in the 1960s is seawater intrusion into the wells in limestone area. Nitrate contamination of groundwater has been receiving attention in the Peninsula since the early 1980s. Over extraction of groundwater, uncontrolled use of fertilizer and other agrochemicals and unsafe sewerage disposal (soakage pits) are the main culprits for this situation. Improved groundwater recharge, regulated use of agrochemicals and the introduction of piped sewerage collection and disposal and appropriate solid waste management systems are a must for the sustainability of Jaffna's groundwater system. Training and awareness programs are required to strengthen the public participation. This paper gives an overview of the major issues on groundwater quality and quantity, and justifies the above recommendations.

Key words: Groundwater, Jaffna, Pollution, Sustainability

Introduction

Agriculture is the main source of livelihood for 65% of the population living in the Jaffna Peninsula. About 34 % of the land is cultivated with high-value cash crops for the markets (Thadchayini and Thiruchelvam, 2005). Groundwater is the source for irrigation for these crops. Since the cessation of the civil war in 2009, the interest on quality and quantity of groundwater in the area has increased. It is speculated that after the lifting of fuel and fertilizer restrictions, the issues of groundwater quality and availability will emerge as a significant constraint for the development of the region. Therefore, it is essential to establish a baseline on water quality and availability, to inform future water-related developments and other activities in the Peninsula. This is the main reason used for justifying continued monitoring and investigation of water quality and availability.

The unconfined aquifer of limestone present in Jaffna Peninsula is the richest source of groundwater among the different types of aquifers in Sri Lanka (Panabokke and Perera, 2005). The low salinity groundwater lenses that constitute the Jaffna aquifer system (Chunnakam, Thenmaradchi, Vadamaradchi east and Kayts) are also the only sources of drinking water for towns and villages strewn across the Peninsula. Major soils in the Peninsula are *calcic red-yellow latosols*, which are shallow, fine-textured, and well-drained, with a very rapid infiltration rate, and provide no protection against pollutants entering the groundwater aquifers (De Alwis and Panabokke, 1972).

Groundwater monitoring has primarily been carried out by the National Water Supply and Drainage Board and the Water Resource Board in Jaffna Peninsula. Several research studies have been carried out by the University of Jaffna, the Water Resource Board, non-Government Organizations and other institutions. The International Water Management Institute (IWMI) too, has done a study on hydro geochemical characterization of a part of Jaffna's aquifer systems in 2011. This paper as a part of that study, explores the major groundwater quality issues, related reasons for contamination and resulting health issues, based on published research articles. Based on this review, the paper proposes few recommendations to ensure sustainability and safe use of the groundwater resources in Jaffna.

Groundwater availability/ recharge

All four groundwater lenses in Jaffna were formed and continue to recharge by the perennial monsoonal rainfall over the land masses. Groundwater recharge has been viewed as a function of effective rainfall. After losses (surface runoff - about 10-15 %, and evaporation - about 40-48 %), 30-32 % of the rainfall is potentially available for recharging groundwater (Navaratnarajah, 1994). IWMI's study (2011) found that 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 33 % (approximately) of the rainfall is lost as surface runoff during the rainy season. The spatial variability of these values cannot be entirely attributed to the geological conditions of the locality, since there are no rain gauges in the area to capture the rainfall variability. Roberta (2012) stated that natural ponds could be effective in the control of the aquifer recharge and the water storage in the Jaffna Peninsula. According to Balendran et al. (1968), approximately 50 % annual recharge of groundwater, which is between 10 to 20 MCM, eventually drains out to the sea and the remainder is used mostly for agriculture and domestic purposes.

Groundwater quality in Jaffna Peninsula

Salinity development

Salt water intrusion into the groundwater system is a major water quality problem, identified in the 1950s and highlighted in the 1960s (Balendran et al. 1968). IWMI's study (2011) shows that there is high Electrical Conductivity (EC) in groundwater in parts of the Peninsular and EC values decrease further into inland of Chunnakam aquifer (see *Figure 1*). High values for EC generally means a high degree of salinity. The above results are in agreement with the spatial distribution of chloride (Cl^-), sodium (Na^+) and sulfate (SO_4^{2-}). The concentration of Na^+, Cl^- and SO_4^{2-} in seawater is much greater than in fresh water. Based on EC, 18 % of the wells have already become unsuitable for irrigation purposes in Chunnakam aquifer of Jaffna Peninsula (Sutharsiny *et al.,* 2012). It was clear that wells that are located near the coastal area had severe salinity problems compared with other wells located interior and could be related to seawater intrusion.

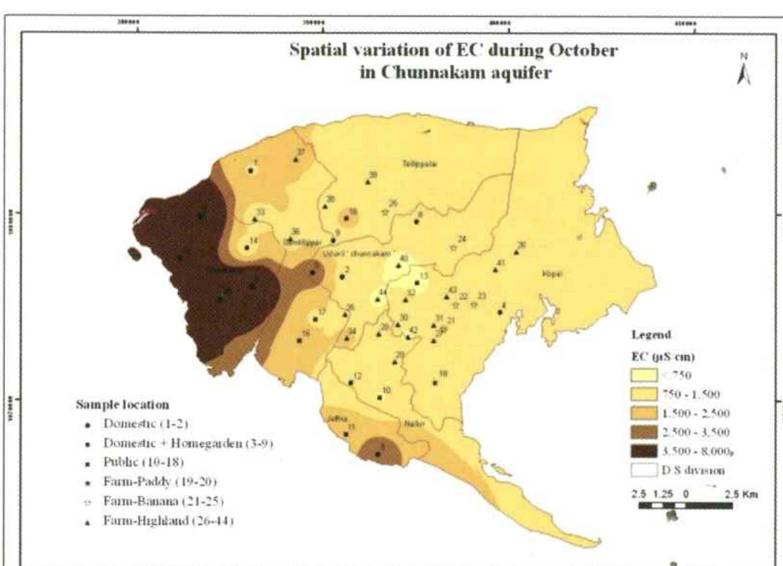

Fig. 1: Spatial variation of EC in Chunnakam aquifer

Freshwater in the form of a lens of varying thickness is floating on saline water in this aquifer. The surrounding water has varying salinity levels depending on the location and distance from the sea. When the fresh water lens contract, saltwater takes its place. Puvaneswaran (1986) reported that the salinity of groundwater in a location at the Valukai aru drainage basin in the Valikamam area and is inversely related to its distance from the sea. Rajasooriyar et al. (2002) mentioned that a high chloride concentration in some selected coastal locations provide evidence for seawater intrusion. Therefore, over-extraction of groundwater leads to an increased seawater inflow, as the aquifer is surrounded by seawater.

During the 1960s, in some parts the Peninsular, the density of wells was reported to be up to 30 agricultural wells per 100 acres. The largest number of domestic wells was found in the Jaffna town as152 per 100 acres (Balendran *et al.,* 1968). GTZ study reported over 100,000 dug wells, of which 17,860 are agricultural wells and the remainder is used to meet the domestic and home garden demands in urban and rural areas (Kraft, 2002). Punthakey and Gamage (2006) for an ADB study reported that there are 10,263 agricultural wells in the Valikamam area of Jaffna Peninsula. In 2011, IWMI counted 19,905 agro wells identifiable through satellite images in the part of Jaffna Peninsula. In some areas the density is high as over 200 wells per sq.km.

Prior to 1960, water was drawn from wells using traditional water-lifting devices (well sweeps). However, now most wells are equipped with inexpensive small electric or fuel used pumps. Consequently, there is a tendency to use more water for crops than required. These changes in technology and excess withdrawal of water are also reported by Navaratnarajah (1994). The recommended groundwater extraction rate from Valikamam is 14,400m^3/day, Vadamaradchi is 6,000m^3/day, and Point Pedro is 4,000m^3/day (Feasibility report, 2006).

Nitrate contamination

There is no purification/ pollutant retention capacity either in thin soil layer or limestone, which is widespread in the Jaffna Peninsula. Pollutants reaching the groundwater are therefore able to spread far and wide. Nitrate-N contamination of groundwater has been receiving attention in the Peninsula since the early 1980s (Mageswaran and Mahalingam 1983; Dissanayake and Weerasooriya 1985; Nagarajah et al. 1988; Rajasooriyar et al. 2002; Mageswaran 2003; Mikunthan and De Silva, 2008). Findings of some of studies are given in *Table 1.*

Table 1: Summary of research findings for nitrate-N contamination in Jaffna Peninsula

Year	Findings	Reference
1983	nitrate-N content in the well water and soils were above the WHO recommended level in Jaffna district	Mageswaran & Mahalingam, 1983
1985	high Nitrate (40 m/l) concentration in Jaffna Peninsula (Geochemical Atlas of Sri Lanka)	Dissanayake, C.B. & Weerasooriya, 1985
1988	Concentration of nitrate in farm and domestic wells were 79 % greater than WHO in Jaffna and Kilinochchi districts	Nagarajah et. al., 1988
1997/1998	Large numbers of wells exceed the WHO standard in Valikamam area of Jaffna Peninsula.	Rajasooriyar et al., 2002
2001/2002	groundwater from most of areas has nitrate value in the range of 10 to 45mg/l in Jaffna district	Mageswaran, 2003
2007/2008	within the intensively cultivated area groundwater had nitrate-N concentration within the range of 10-15mg/l in some part of Valikamam area	Mikunthan & De Silva, 2008
2012	Nitrate-N level is ranging from 0.0 to 15.5 mg/l	Hidayathulla & Karunaratna, 2013

IWMI's study too, noticed that the nitrate-N concentration ranged from an undetectable value to 35 mg/l (Fig. 2). Nitrate-N values from domestic and public wells ranged from below 0.1 to 12.1 mg/l. During the rainy season, 38% of the agro-wells exceeded the limit established by the World Health Organization (WHO) for drinking water (10 mg/l). However by the end of dry season, the number of agro-wells exceeded this nitrate-N limit has dropped to 15%.

The level of nitrate-N concentration in agro-well water was influenced by the cropping system. A high nitrate-N concentration of groundwater was observed at highland crops followed by mixed crops when compared with banana or paddy. The same result was observed by Jeyaruba and Thushyanthy (2009) that is the level of nitrate-N concentration of water was influenced by cropping systems.

Table 2 shows amounts of nitrogen (as inorganic fertilizer) applied for onion, carrot and beetroot. Inorganic fertilizer application practices were decided by farmers based on their own experiences. In addition to the inorganic fertilizer, farmers use organic materials such as biomass, and cattle and goat dung, which are rich in nitrogen. For irrigation, they apply about 5 – 10 mm/day water (Table 3). This amount is 130 - 230 % in excesses of the net water requirement.

The study area contains red yellow latosol which is highly porous and having an infiltration rate of 430 mm/hr, conducive for the free leaching of nutrients to the shallow groundwater (Joshua, 1973).

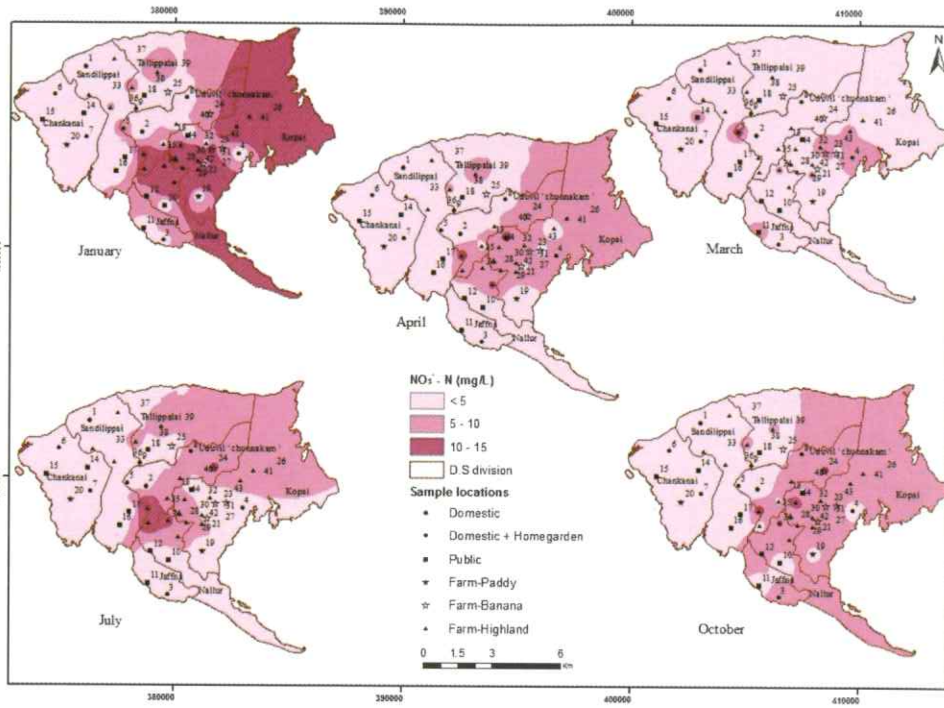

Fig. 2: Spatial variation of nitrate-N in the Chunnakam aquifer

The use of large quantities of inorganic fertilizers and manure together with excessive irrigation were considered to be responsible for the high nitrate content in intensified agricultural area of Peninsula. Leachate of nitrate-N from these sources could have accumulated in these aquifers.

Table 2: Excess amount of nitrogen application for each crop

Crop	Avg. nitrogen applied (kg/ha)	Recommended nitrogen (kg/ ha)	Excess nitrogen (kg/ha)
Onion	178	70	108
Carrot	230	150	80
Cabbage	142	150	-7
Beetroot	246	180	66
Tobacco	262	No recommendation	-

Table 3: Excess irrigation for each crop

Crop	Crop water requirement	Irrigation by farmers (mm/day)	Excess irrigation (mm/day)	(%)
Banana	4.98	11.86	6.88	138
Cabbage	4.76	15.65	10.89	229
Cassava	3.62	9.45	5.82	161
Onion	4.53	11.25	6.72	148
Tobacco	4.08	9.41	5.33	131

Bacteriological contamination

It was mentioned earlier that the water movement through soils of Jaffna is often rapid. Therefore filtration and removal of micro-organisms within the unsaturated zone is not effective, and there is no purification capacity within the limestone as well. In 2002, the tap water at Kayts, Gurunagar and the supply from Kondavil well were found to be contaminated with fecal coliforms on E-Coli bacteria (Kraft, 2002). Mageswaran (2003) reported that normal coliforms were observed in water from Passaiyoor, Kurunagar, Koddady and Navanthurai areas. Most of the dug wells had a high amount of total coliforms and E. coli (Sutharsiny *et al.,* 2009). This is supported by Birunthai *et al.* (2007). The reason could be the rising water table during the wet season, which floods the nearby septic tanks and help move coliform and E. coli to into the aquifer, contaminating well water. Distances between latrine pits and dug wells are not maintained as recommended, particularly in densely populated urban areas (Table 4). The distance chosen between well and the septic tank depends on the site geology and more importantly on the soil type. Due to the relatively short distance between the well and latrines soak pit, a higher coliform contamination was observed in Jaffna.

Table 4: Distance between pit latrines and dug wells in the Jaffna Peninsula (Rajasooriyar *et al.*, 2002)

Jaffna Municipal area (1990)		Valikamam area (1997)	
Distance (m)	% of dug wells	Distance (m)	% of dug wells
< 1.5	5.7	< 10	13.6
1.5 – 3.0	8.0	10 – 20	48.2
3.0 – 4.5	5.7	> 20	38.2
4.5– 6.0	6.8		
> 6.0	73.5		

Health risk

Bacterial contamination leads to an increase in the incidence of water borne diseases such as enteric fever, dysentery, viral hepatitis A, typhoid, cholera and diarrhea in Jaffna Peninsula. Nitrate is potentially hazardous when present at sufficiently high concentration in drinking water. World Health Organization (WHO) reported that the effect of excessive nitrate in drinking water is linked to methemoglobinemia (blue baby syndrome) especially with infants. However no such cases are yet recorded at the Teaching Hospital of Jaffna. Anyway, there is a high risk of nitrate toxicity related blue babies in the Peninsula. The five year study on the geographical pathology of malignant tumors in Sri Lanka from 1973-1977, has confirmed that the incidence of cancer especially oesophagus cancer incidence is relatively higher in Jaffna (Panabokke, 1984). Several studies came up with warnings on the risk of esophagus cancer and stomach cancer in Jaffna due to consumption of well water with higher nitrate - N concentration than the recommended level by WHO (Dissanayake, 1988, Kraft, 2002, Sivarajah, 2003 and Gunalan et al., 2011). Therefore a detailed study of epidemiology for oesophagus and stomach cancer in the areas is important.

Conclusion and recommendations

The Peninsula is entirely dependent on groundwater as its sole source of water supply for domestic and agricultural use. Over 50% of the recharged water is lost to sea while in some parts of the Peninsula; saltwater is getting into fresh water aquifers due to over extraction. Excessive use of fertilizer, agro-chemicals, and improper waste disposal together with excessive irrigation is causing the nitrate-N concentration in groundwater. Hence, the management of all these activities is critical to safeguard human health, livelihoods and environment.

Therefore, it is recommended to create awareness within farming communities and other citizenry highlighting the hazards associated with their bad practices and implement relevant existing regulations to prevent further damage to the aquifers. Furthermore, efficient irrigation technologies need to be introduced to prevent leaching of chemicals to groundwater. Rehabilitation of available recharge ponds and increasing rainwater harvesting are important contributing activates for the sustainability of Jaffna's groundwater system. Improved wastewater, sludge and solid waste management practices are vital for the reduction of groundwater contamination in the Peninsula. Continuous research and monitoring with above activities would help in achieving the water security in Jaffna Peninsula.

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