Salinity and microbial contamination and natural remediation of Tsunami affected groundwater wellsat two locations in Weligama, Sri Lanka

K.D.N. Weerasinghe [1*], Ranjana.U.K. Piyadasa [1], I.S.Kariyawasam [1], L.M.J.R Wijayawardhana [1], D.S.E .Kumara [1], S.B.Vithana [2], M.Gruber [3], M.Maier [3], D.Maier [4]
[1] Dept. of Agric. Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, [2] Dept. of Agric. Chemistry, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya ,[3] Stadtwerke, Karlsruhe, Daxlander strasse 72, 76185 Karlsruhe, Germany , [4] University of Karlsruhe, Faculty of Chemical Engineering, Germany

Abstract
The current research assesses the contamination of drinking water due to the Asian Tsunami of 26th December, 2004 in Pelena and Kumbalgama, situated in Weligama bay strip in Southern Sri Lanka both within the seawater-invaded zone and unaffected areas within 100 m of the South-Western coastal belt. Electrical Conductivity (EC) increase in affected wells over that of unaffected wells was significant after the impact of the tsunami and the rise of EC was greater at Kumbalgama. A tendency of pH increase in affected water was noted. At both locations, Total Dissolved Solids (TDS) in as much as 75 % of affected wells were above 1999 mg/l. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentrations have also risen significantly at Kumbalgama. Sulphate (SO_4^{-2}) concentration and the salinity of affected water were significantly high at both locations. However, Ca^{2+}, Mg^{2+} and SO_4^{-2} concentrations of affected wells have not exceeded SLS standards.E. coli count was greater and the total coliform count was maximum in affected wells. By the end of November, 2005 EC, salinity and TDS levels of wells in Pelena have shown a tendency to decrease, which suggests a tendency of natural remediation of the pollutants. The study is being continued to monitor the conditions of well waters in Pelena and Kumbalgama in the same manner.

Introduction

The massive crustal plate movement in the ocean bed close to Indonesia and Andaman islands on the 26th December 2004, caused a gigantic tsunami that spread across the Indian Ocean, killing at least 40,000 people in Sri Lanka and badly affecting the livelihood of many that resided close to the sea, while destroying innumerable amount of property. The invasion of sea water into the mainland resulted in contaminating the ground water wells in the affected regions with salt and the debris it carried, thereby making these water sources unsuitable for drinking and consumption. Shallow groundwater wells have been the age-old source of domestic water source in the coastal areas. The disruption from the tsunami estimated that between 12,000 and 100,000 wells in the whole country were damaged, many left unfit for human consumption and even for bathing and washing purposes immediately after the tsunami (ADB *et al.*, 2005; UNEP, 2005).

The area of research belongs to the Wet Zone Low country (WL_4) agro-ecological zone, where climate is tropical monsoonal with a distinct bimodal rainfall pattern. The mean annual rainfall is about 2500 mm, which mainly comes from the South-West monsoon during May to September. During April - May, the mean temperature exceeds 27.5 ^{0}C; average temperature lies between 25 ^{0}C to 27.5 ^{0}C during the rest of the year. The relative humidity is about 70 % during the day and 90 % at night. The mean elevation is less than 30 m from the mean sea level.

Basement Precrembrian metamorphic hard rock in this area is covered by quaternary sedimentary deposits. Topsoil of the area mainly consists of sandy clay. The top unconfined alluvium aquifer of the area is distributed in the river basin area and through the coastal line. Water bearing sand in the top of the section is more often fine and the lower section is usually coarse sand with small portion of gravel. The aquifer mainly consists of calcified sandstone. Recharge of the aquifer takes place mainly from precipitation that falls on the northern catchment. There are about 932 dug wells in the area, which are the primary drinking water sources. In addition, two tube wells and more than 1000 tap water lines are also available for the inhabitants.

Therefore, the objective of this research was to determine the level of contamination of drinking water with respect to number of water quality indices in several randomly selected wells in *Weligama* area and continued observation of natural amelioration of the pollutant levels in the well water.

Materials & Methods

The study was conducted in Weligama bay area selecting two locations in *Pelena* and *Kumbalgama* where a large number of drinking water wells was situated (Figure.1). Due to the tsunami tidal wave, some of these wells were inundated by the sea water while some remained unaffected.

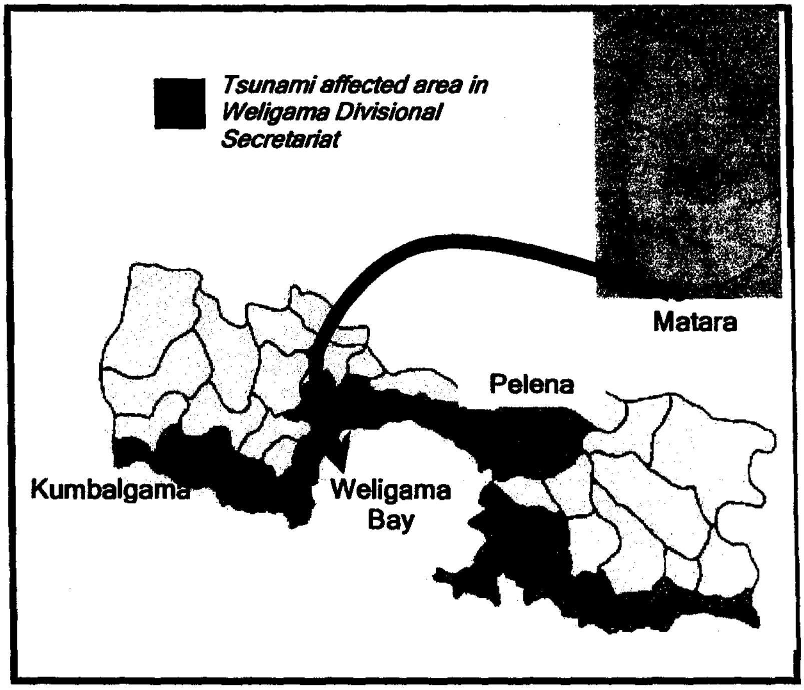


Figure. 1Map of *Weligama* Divisional Secretariat

From each locality, 36 wells were selected to represent both tsunami-affected and non-affected wells. From each well, three samples were taken at two week intervals. The research was initiated in February, 2005 and sampling is still being continued. Parameters such as pH, turbidity, electrical conductivity, total dissolved solids, salinity, concentration of SO_4^{2-} , Mg^{2+}, Ca^{2+} ions were measured using pH meter, turbidimeter, EC meter, digital photometer and Electro-chemical test kits for SO_4^{2-} , Mg^{2+}, Ca^{2+} ions. For microbial counts, quantitray kits developed by IDEXX were used.

Results & Discussion

Chemical, physiochemical and bacteriological parameters of the sampled wells in *Pelena* and *kumbalgama* compared to the sea water are given in Tables 1 and 2.

Table 1. Average values for water quality parameters in wells in *Pelena* (From January to March, 2005)

Parameter	Affected wells	Unaffected wells	% rise over unaffected wells	Seawater	SLS standards	WHO Standards
EC (μs cm^{-1})	3634.5^{a}	679^{b}	435.2	52400	3500	Ns
pH	7.49^{a}	7.10^{b}	5.49	8.0	6.5-9.0	6.5-8.5
Turbidity (NTU)	2.678^{a}	2.641^{a}	1.4	4.9	8	5
Salinity (ppm)	3.6375^{a}	0.1125^{b}	3133.3	34.8	Ns	Ns
Mg^{+2} (ppm)	16.03^{a}	12.11^{a}	32.4	1350	150	Ns
Ca^{+2} (ppm)	55.18^{a}	46.24^{a}	19.33	420	240	Ns
$SO4^{-2}$ (ppm)	194.01^{a}	81.26^{b}	138.75	523.7	400	400
E. coli #	>2419.6 (25%)	2.825	-	>2419.6	0	0
Tot. coliforms #	>2419.6	1618.9	-	214	10	0

Values with different letters are significantly different
* maximum permissible limit
# (MPN/100 ml)
Ns-Not specified

Table 2. Average values for water quality parameters in wells in *Kumbalgama* (From January to March, 2005)

Parameter	Affected wells	Unaffected wells	% rise over Unaffected	Seawater	SLS standards*	WHO Standards
EC (μs cm^{-1})	4489.4[a]	623.8[b]	619.7	52400	3500	Ns
pH	6.5[a]	7.3[b]	12.3	8.0	6.5-9.0	6.5-8.5
Turbidity (NTU)	2.297[a]	1.802[a]	27.46	4.9	8	5
Salinity (ppm)	4.938[a]	0.088[b]	5511.36	34.8	Ns	Ns
Mg^{+2} (ppm)	5.57[a]	3.51[b]	58.7	1350	150	Ns
Ca^{+2} (ppm)	73.3[a]	17.49[b]	319.1	420	240	Ns
$SO4^{-2}$ (ppm)	175.18[a]	79.86[b]	119.36	523.7	400	400
E. coli #	>2419.6 (25%)	90.625	-	>2419.6	0	0
Tot. coliforms #	>2419.6	>2419.6	-	214	10	0

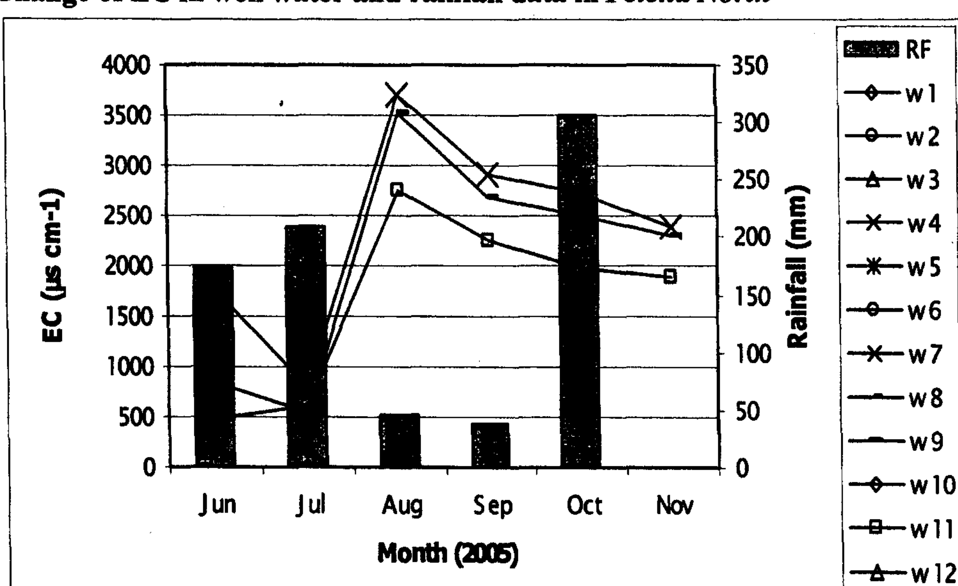
Values with different letters are significantly different
* maximum permissible limit
# (MPN/100 ml)
Ns-Not specified

It is evident that 75% of affected wells have TDS of over 1999 mg l^{-1}, equivalent to that of seawater. According to the SLS standards, the maximum allowable limit for TDS in drinking water is 2000 mg l^{-1}. Similarly The EC of affected water at both locations have increased beyond the SLS drinking water standard, which is 3500 μs cm^{-1}.

The *E. coli* count in unaffected wells in *Pelena* was lower than at *Kumbalgama.* However, at both locations, *E. coli* count was greater and the total coliform count was maximum (>2419.6 MPN/100 ml) in affected wells. According to the WHO standards for drinking water, *E. coli* and total coliform count should be zero, whereas it is permissible by the SLS standards to have a coliform count up to 10 cells per 100 ml of water.

Fig. 2 shows the variation of EC during the latter 5 months of the study in *Pelena North.* Wells located in *Pelena North* have shown a marked increase of EC in August following the high rainfall in July. This could be expected due to the leaching of soluble ions accumulated in surface soils consequent to rainfall. On the contrary, EC levels have started to decrease after August in the majority of wells.

Fig. 2 Change of EC in well water and rainfall data in *Pelena North*



This may be due to the gradual transportation of salt ions through the unsaturated zone down to the groundwater table. After August, EC in well water has not shown a drastic surge following the high rainfall in October. In November, salinity level was comparatively low in the majority of wells in *Pelena North.* The graph indicates a downward shift of EC towards November. However, the monitoring should be continued to arrive at a conclusion as to whether the salt ion contamination of well water is gradually remedied or otherwise.

TDS values of majority of the wells just after the tsunami had been over the maximum measurable limit (1999 ppm) of the TDS meter. Nevertheless, the current TDS values showed a steady decline in well water. In general calculations, EC (µS/cm) can be converted to TDS (ppm) by multiplying EC with a common factor, which can be 0.4-0.9 depending on the types of salts creating the EC (IWMI 2005) in water. The EC and TDS values recorded in this study comply with this when the factor 0.4 was used.

Conclusion

Electrical conductivity and the totoal dissolved solids (TDS) of the tsunami affected wells have increased by about 435 and 620 times in the wells of *Pelena* and *Kumbalgama* area in the coastal strip of the *Weligama* bay area.

Despite the seawater intrusion into the groundwater wells, the pH, turbidity, Ca^{2+}, Mg^{2+} and SO_4^{-2} ion concentrations in the affected waters have not increased beyond the SLS standards for drinking water. Due to the tsunami wave the counts of *E. coli* and *coli forms* in affected water have increased considerably over that of unaffected water. However bacteriological contamination exceeded specified SLS and WHO standards even in unaffected wells as well. As such, the water in the area may have other sources of contamination even prior to the tsunami.

Dynamism of the total dissolved solids and EC of the well water had an increasing trend in the locality following the heavy rainfall in August, which is associated with the leaching of the already accumulated salts in the soil by rainwater. However, a decreasing trend of salt accumulation in water is now established in the wells. Further research and continuous monitoring are required before sound conclusions can be made about the remediation of Salinity and EC levels of well water in the study area.

References

ADB, Japan Bank for International Cooperation & WB, 2005. Sri Lanka 2005 Post-Tsunami Recovery Program. Preliminary Damage & Needs Assessment. Colombo, Sri Lanka. Jan. 10-28, 2005. http://www.adb.org/Tsunami/sri-lankaassessment.asp

Gupta, P.K. 2000. Soil, plant, water and fertilizer analysis. Pp. 293-309

Schulz, C.R. and Okun, D.A. 1992. Surface water treatment for communities in developing countries. Pp. 11-15

Tsunami Impacts on Shallow Groundwater and Associated Water Supply on the East Coast of Sri Lanka, A post-tsunami well recovery support initiative & an assessment of groundwater salinity in three areas of Batticaloa & Ampara District in Eastern Sri Lanka: International Water Management Institute (http://www.iwmi.org.) Pp 23

UNEP, 2005. After the Tsunami - Rapid Environmental Assessment. http://www.unep.org/tsunami/tsunami_rpt.asp

WHO, 2004. Guidelines for Drinking Water Quality - Third Edition. World Health Organization, Geneva.