Tsunami impacts on groundwater and water supply in eastern Sri Lanka

Karen G. Villholth

Most households in the districts of Sri Lanka affected by the *tsunami* possessed drinking water wells, and these wells were contaminated by debris, sludge and saltwater. Once the wells were cleaned, only time and the onset of monsoon rains could reduce the levels of salinity – but local people continued to need information and reassurance about the quality of their water supplies.

The *tsunami* disaster of 26 December 2004 caused wide spread physical devastation and human tragedy throughout many coastal regions of Asia. Sri Lanka was no exception, though it is approximately 1500 km from the epicentre off North Sumatra of the sub-oceanic earthquake which caused the *tsunami* in the Indian Ocean. Much concern was raised soon after the event regarding the provision of safe water for the affected population due to the massive influx of saltwater from the *tsunami* waves and associated contamination of shallow groundwater, which was the main source of domestic water supply in many coastal regions. Physical destruction of the private, shallow drinking-water wells, the backbone of local water supply, and water-quality impairment were immediate problems to solve.[1]

Emergency relief in terms of food supply, medical assistance and support to water supply from a wide range of international and national non-governmental organizations (NGOs) was initiated promptly and effectively in Sri Lanka, and as a consequence neither starvation nor outbreaks of epidemics nor water-related diseases occurred in the affected areas. Water-supply relief measures included the delivery of water disinfection chemicals and bottled water, the rinsing out of flooded and contaminated wells, drilling new supply wells and the trucking in of freshwater from unaffected wells.

Groundwater and water supply

In Figure 1, the major potential physical impacts of the *tsunami* on the local shallow unconfined freshwater aquifers are illustrated. The numbers refer to the various effects:

1. A 'blanket' type infiltration of saltwater through the ground surface during the inundation
2. Entry into open dug wells.
3. Percolation from depressions and ponds
4. Disturbance of the saltwater-freshwater interface underground

As well as houses, a great number of wells and pit latrines were damaged by the *tsunami*. In certain areas the well density was high, around one per household, and the distances between wells and pit latrines were extremely small, with potential for cross-contamination of faecal matter, even in the absence of the *tsunami*.

IWMI's efforts

IWMI, the International Water Management Institute with headquarters in Sri Lanka, in collaboration with local partners, rapidly initiated various on-

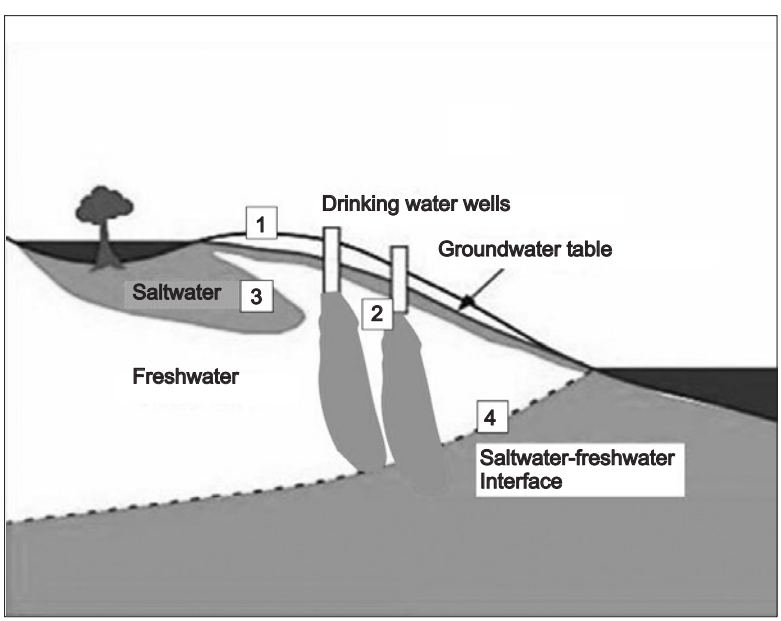

Figure 1. Various impacts on groundwater of saltwater flooding during the *tsunami*. The numbers are referred to in the text.

the-ground activities to support already on-going emergency and rehabilitation efforts, especially in the area south of Batticaloa town on the east coast of Sri Lanka, in the Batticaloa and Ampara Districts. The project area covered a 75 km^2 land strip parallel to the coastline of 2–4 km width where approximately half of the area was inundated by the *tsunami* waves. It was estimated that in this area 18,000 wells were destroyed or contaminated and that about 80,000 people living in settlements close to the coastline were without secure drinking water just after the *tsunami*. In Batticaloa District, approximately 11 per cent of the population was displaced temporarily or permanently as a consequence of the *tsunami*. Most of the affected people returned to their previous houses after rehabilitation and reconstruction.

The activities of IWMI included:

- guidance for the well cleaning and rehabilitation efforts;
- salinity monitoring of wells in the project area;
- research into fundamental saltwater intrusion and recovery processes in groundwater;
- household surveys of people's perception and reaction to the disruption and recovery of their water supply.

Though saltwater is not detrimental to human health in the concentrations normally acceptable for drinking, it was the most pressing problem for the water supply because of the objectionable taste. The second major concern with drinking water quality was the microbiological contamination.

Well cleaning

No internationally accepted guidelines or standards for well cleaning after saltwater flooding existed, and hence IWMI contributed to the guidance of

Box 1. Salinity in drinking water

There are no health-based standards for maximum salinity in drinking water. This is because saltwater presents no risk to human health in the concentrations normally acceptable for drinking. Furthermore, salinity is not an unambiguous parameter, but depends on the chemical constituents or ions giving rise to the salinity. Finally, acceptable levels of salinity are a matter of taste and custom. Some people, like the population on the east coast of Sri Lanka, may be used to elevated levels, even before the tsunami, where the salts are concentrated in the shallow groundwater and wells during the dry season. IWMI found that a salinity of 1000 ìS/cm was the average threshold for acceptable drinking water quality among the households. The Sri Lankan official standard is 3,500 ìS/cm, while the NGOs used a criterion of 2000 ìS/cm for the out-phasing of water tankering.

Box 2. Guidelines for well cleaning just after the tsunami

- Pumping of wells to decrease salinity should be done as quickly as possible and within one month after the tsunami
- The well should be emptied and shock-chlorinated *once only* and all sludge at the bottom and floating debris should be removed. The sides of the walls should be rinsed. Water removed from the well should be discharged to the sea.
- Chlorination should be done strictly according to accepted international standards.[2] Make sure no over-pumping or over-dosing of chlorine takes place and that people are aware of precautions.
- Cleaning should only be done by qualified and trained personnel with reporting to the local authorities.
- Cleaning should be done with accompanying monitoring of salinity, before and after.
- Repeated chlorination of wells, with accompanying emptying of wells, is not recommended. The (smaller) portion of extracted water that is used for drinking should be purified separately by other means, e.g. by chlorine tablets, boiling, or by the SODIS (Solar Disinfection) method.
- Wells that are salty or becoming salty should be pumped less or abandoned temporarily, and freshwater should be sought from neighbouring wells that are fresh.
- Intensive pumping for water tankers should not be concentrated in the same wells for extended times. Pumping should be distributed to more, interchangeable wells.
- Intensive pumping should preferably occur from shallow wells away from the coast, and away from other sources of pollution. Similarly, new high-production wells should be shallow and sited away from the coast and other pollution sources.
- Deep wells (> 5m) and wells pumped with motorized pumps should be regularly monitored for salinity as they stand a greater risk of salinization.
- Wells should *not* be deepened in the coastal areas in an attempt to avoid saltwater.
- New deep wells (> 10m) should not be drilled in the coastal aquifers in an attempt to get freshwater.
- An abandoned well should be covered to reduce risk of mosquito breeding, and to indicate that the well is not in use.
- Stagnant water bodies should be cleaned for debris. In case of suspicion of pollution (e.g. visible oil film on the surface), the water should be drained to the sea. Cases should be reported to the authorities who should take action.
- In other cases, stagnant water bodies should not be drained in an attempt to remove saline water. Rather, the deliberate channellng of rainwater to depressions should be performed in order to increase the flushing of the groundwater.

Guidelines for well cleaning one month after the tsunami:

- One month after the disaster, the pumping of wells to decrease salinity should be discontinued.
- If pumping is needed to remove sludge and debris, only slow pumping (preferably with a sludge pump at the bottom) should be done. The drawdown in the well must not exceed 0.5 m for more than 15 minutes. The well must *not* be emptied if more than 0.5 m of standing water is present. Water removed from the well should be discharged to the sea.
- If pumping/cleaning was performed previously on the well and the salinity increased, the well should *not* be cleaned again.

Emergency supply of drinking water to *tsunami* victims

the well cleaning and rehabilitation efforts that went on extensively in the affected areas. The purpose of the well rehabilitation was to quickly restore the wells (which were commonly 3–4 m deep) to pre-*tsunami* conditions and to ameliorate the contamination impacts, from saltwater ingress, cross-contamination from pit-latrines and other wastewater sources, and from simple entry of debris of natural and human sources. A wealth of pumping and disinfection programmes by NGOs was initiated and many wells were pumped and chlorinated several times. But it soon became apparent that the activities were not necessarily effective. Salinity levels did not always improve and un-coordinated, excessive and repeated pumping and disinfections often left the well water unusable for drinking, counter to expectations (see Lipscombe's article in this issue). In these circumstances, IWMI developed simple guidelines (Box 2) and awareness sessions, which were given at various levels, from local to national, for the cleaning of wells and the protection of the groundwater.[1] A common mistake was to discharge well water right next to the well, which basically recycled the saltwater and delayed the natural recovery process.

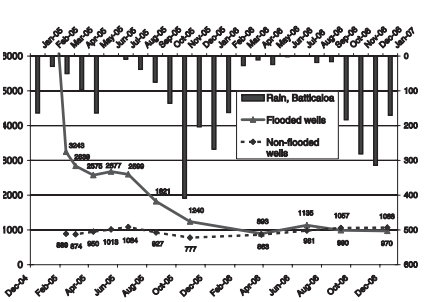

Figure 2. Average well-water salinity and rainfall since the *tsunami*

Salinity monitoring

IWMI began monitoring drinking water wells on the east coast of Sri Lanka shortly after the *tsunami* to assess and document the extent of the salinity problems. The initial monitoring, using very rudimentary equipment but verifying the magnitude of the problem, was subsequently expanded and continued on a regular basis in order to detect the spatial and temporal trends in salinity changes after the *tsunami* and to monitor the persistence of the problems. In Figure 2, it is seen that the salinity of the wells (about 150 wells in three villages) generally reduced as a function of the monsoon rainfall and returned to the background levels (represented by the unflooded wells) after the first two monsoons after the *tsunami*, i.e. by April 2006. Due to the very permeable, rather homogeneous sandy soils and the shallow unconfined aquifers, the groundwater was rapidly affected by the infiltrating saltwater. However, the same properties also ensured that rainfall relatively quickly flushed the system and remedied the situation. In general, these aquifer systems are very vulnerable to any type of contamination from near-surface sources, and pit latrines constantly (in the absence of the *tsunami*) present a major risk to the groundwater quality in these areas, especially when the groundwater level rises towards the soil surface in the wet season.

Investigating the groundwater recovery processes

In order to understand more of the processes of groundwater contamination by saltwater and how best to improve the situation, detailed field investigations and laboratory experiments were conducted in Sri Lanka as well as in the USA.[2] Because saltwater is naturally more dense than freshwater, the plume of saltwater generated in the groundwater from the infiltrating seawater had a tendency to sink faster than would be the case for other dissolved contamination. It is believed that this process improved the *tsunami* impacts considerably. However, the pumping and mixing due to human interference may in fact have hampered

Devastation of wells and pit latrines as a consequence of the *tsunami*. Note that wells and pit latrines were often sited quite close to each other.

and counteracted this natural clean-up process.

Household surveys

In two rounds of surveys with the same 120 households in two villages, questions were raised regarding people's perception of the impact of the *tsunami* on their water supply and water quality and how they had coped with the situation. The first survey was conducted in April–May 2006 and the second in January–February 2007. All householders were dependent on open dug wells for domestic use and were satisfied with the system and the water quality prior to the *tsunami*. People were now concerned about the water quality, in terms of salinity, 'cleanness' and other intangible psychological aspects associated with the calamity. Hence the well cleaning also served an important psychological purpose, besides the practical and physical rinsing. Among the affected households, 72–80 per cent had used the tankered water but had not always found it reliable in terms of supply and quantity. The chlorine taste varied, indicating that the chlorination of tankered water was not always controlled properly.

Some of the coping mechanisms of the local people involved sharing a neighbour's well, water saving, tapping of diverse sources, and better hygiene. Typically, the households used their well water for washing and cleaning purposes while they used the tankered water (or a neighbour's well, if it was fresh) for drinking and cooking. Further, 15 per cent of the households reported problems with skin rashes just after the *tsunami*, which could be attributed to over-chlorination of the wells and a lack

Well cleaning after the *tsunami*, demonstrating what *not* to do, i.e. discharge saline well water next to the well

of proper information on necessary precautions in connection with chlorination.

Generally, people were reluctant to return to their wells after the phasing-out of the tankers. This was attributed to uncertainty regarding the well-water quality and generally a lack of information given to the population regarding the phasing-out, the best alternative to use, and the safety of the water. Many people (50–77 per cent) reported that they thought salinity was detrimental to health and despite the salinity having come down to pre-*tsunami* levels by the time of the second survey, many householders perceived the salinity to be too high and indicated this to be the reason for not returning to their well.

At the last survey, two years after the *tsunami*, all households were back to using wells (their own or a neighbour's) or a public stand-post tap as the primary drinking water source. Concerns persisted regarding salinity and also the quantity and reliability of available water resources. Many people (65–83 per cent) also reported problems with diarrhoea.

Lessons and ongoing work

Two years after the *tsunami*, the majority of the coastal population in the studied areas is back to their previous water supply and the well-water salinity levels are acceptable from an objective point of view, while a minority now receive water from new piped systems. Some of the lessons learned from the present studies include:

- Well cleaning alone did not improve the salinity levels but had a psychological cleansing effect, reassuring the population about returning to use their wells.
- Replenishment of groundwater from rainfall is the primary mechanism of mitigation of the salinity problem.
- Health problems were associated with over-dosing during well chlorination and inadequate information about necessary procedures and precautions.
- Overemphasis on salinity, and a lack of information about the relationship between salinity and health, made people afraid of drinking water with even low levels of salinity.
- A lack of information on phasing-out the tankering and alternative water sources made the people insecure regarding the return to their wells.
- Despite good hygiene campaigns and high levels of adoption people still suffered from stomach infections.
- People were concerned about not having enough water in the future.

Based on these findings, it is clear that less emphasis could have been put into the well-cleaning activities (and the approach could have been improved) and more effort could have gone into giving local people information about the ongoing planning related to the rehabilitation of water supplies and the water quality and health/hygiene issues. With respect to well cleaning, it is clear that accessible guidelines were urgently needed but were not available just after the *tsunami*. IWMI is now further developing the guidelines shown in Box 2, based on field experiences as well as fundamental research on saltwater intrusion processes in groundwater. These guidelines, to be presented to the World Health Organization and/or the Sphere Project,[3] will be applicable to coastal flooding with saltwater and are relevant to *tsunami* disasters as well as other seawater floods.

Long-term concerns about water-quality remain, especially regarding the microbiological contamination associated with poorly planned sanitation facilities. In general, protection from pollution and over-exploitation of the highly vulnerable coastal aquifer systems in the area is a prerequisite if communities are to rely on groundwater for water supply.

Preliminary salinity monitoring just after the *tsunami*

About the author

Karen G. Villholth is a Senior Researcher and Groundwater Expert at IWMI, International Water Management Institute, Sri Lanka.

References

1 Villholth, K.G., P.H. Amerasinghe, P. Jeyakumar, C.R. Panabokke, O. Woolley, M.D. Weerasinghe, N. Amalraj, S. Prathepaan, N. Bürgi, D.M.D.S. Lionelrathne, N. G. Indrajith, S.R.K. Pathirana (2005) *Tsunami impacts on shallow groundwater and associated water supply on the east coast of Sri Lanka*, Colombo, Sri Lanka, International Water Management Institute (IWMI). 68 pp. ISBN 92–9090–622–7. (http://www.iwmi.cgiar.org/TSUNAMI/Index.asp).

Illangasekare, T., S.W. Tyler, T.P. Clement, K.G. Villholth, A.P.G.R.L. Perera, J. Obeysekera, A. Gunatilaka, C.R Panabokke, D.W. Hyndman, K.J. Cunningham, J.J. Kaluarachchi, W. W-G. Yeh, M-R Van Genuchten, and K.H. Jensen (2006) 'Impacts of the 2004 tsunami on groundwater resources in Sri Lanka', *Water Resources Research*, 42, W05201.

2 WHO (2005) *Cleaning and disinfecting wells in emergencies*, WHO Technical Note for Emergencies No. 1. http://www.who.int/water_sanitation_health/hygiene/envsan/tn01/en/index.html

3 Hogan, M.B., R.R. Goswami, K.G. Villholth, T.H. Illangasekare, and T.P. Clement, (2006) 'Understanding the flow and mixing dynamics of saline water discharged into coastal freshwater aquifers', selected peer-reviewed paper presented at the SWIM-SWICA meeting. Cagliari, Chia Laguna, Sardinia, Italy. September 24–29, 2006.

The Sphere Project (2004), www.sphereproject.org