ANN IST SUPER SANITÀ 2010 | VOL. 46, NO. 3: 236-241
DOI: 10.4415/ANN_10_03_03

A case study of sanitary survey on community drinking water supplies after a severe (post-Tsunami) flooding event

Emanuele Ferretti, Lucia Bonadonna, Luca Lucentini, Simonetta Della Libera, Maurizio Semproni and Massimo Ottaviani
Dipartimento di Ambiente e Connessa Prevenzione Primaria, Istituto Superiore di Sanità, Rome, Italy

Summary. This report presents a case study of a comprehensive sanitary survey on ca. 160 community drinking water supplies after a severe (post-Tsunami) flooding event in Sri Lanka. Sanitary inspection and microbiological and chemical water quality analyses were performed according to specifically-designed procedures established on the World Health Organization (WHO) guidelines. Significant hazards and critical points were identified in almost all the investigated water supplies. The overall results showed a significant level of microbiological and chemical risk associated with drinking water consumption within the investigated areas. The criteria and methods practised in this study are proposed as a model to assure an effective and reliable monitoring in post-emergencies involving possible deterioration of water quality and to identify health priorities related to water consumption.

Key words: water supply, water microbiology, public health, emergencies, Tsunami.

Riassunto *(Caso studio di sorveglianza sanitaria in una comunità per l'approvvigionamento di acque potabili dopo un maremoto post-Tsunami)*. Viene riportato un caso studio relativo alla sorveglianza sanitaria di circa 160 fonti di approvvigionamento di acqua potabile dopo il maremoto che ha interessato lo Sri Lanka. In accordo con una specifica procedura elaborata sulla base delle linee guida dell'Organizzazione Mondiale della Sanità (OMS), sono state effettuate ispezioni sanitarie e analisi sulla qualità microbiologica e chimica dell'acqua. In quasi tutti gli approvvigionamenti idrici controllati sono stati identificati pericoli significativi e punti critici. I risultati mostrano un significativo livello di rischio microbiologico e chimico associato all'uso di acqua potabile nelle aree investigate. I criteri e i metodi utilizzati in questo studio sono proposti come modello per ottenere un pratico ed efficace monitoraggio in condizioni di post-emergenza che possono portare al deterioramento della qualità delle acque ed identificare priorità sanitarie correlate al consumo di acqua potabile.

Parole chiave: fornitura dell'acqua, microbiologia dell'acqua, salute pubblica, emergenze, Tsunami.

INTRODUCTION

The safety of drinking water is one of the most important public health concerns in emergency and post-emergency situations. In fact, these events can reduce the availability of safe and wholesome water.

The flood caused by the Tsunami that seriously affected the population of South-East Asia in 2004 rendered much of the pre-Tsunami supplies throughout the affected areas completely unusable or at risk.

The World Health Organization (WHO) estimated that in areas where the impact of breaking waves was hardest, many of the supply and distribution systems were completely destroyed or otherwise rendered inoperable [1]. Furthermore, wells and other sources of supply that did survive the flood were often used at rates beyond safe recharge.

During the immediate emergency phase, the drinking water response was timely and effective and main efforts were addressed on providing access and a sufficient quantity of water to population. Only once the immediate emergency was over, a greater care was focused on water quality.

There was evidence in certain areas that water quality, both at the source and especially at the household level, was compromised by high levels of microbial and chemical contamination that could pose adverse human health effects. Nevertheless little data on drinking water control were available before the Tsunami. After the disaster less information were traceable on the contribution of drinking water to the transmission of diseases and to the overall exposure to hazardous chemicals in flooded areas. As a result of the limited surveillance, there was little data on the safety of the water provided to and consumed by the affected population. Information on the health risks that may arise during delivery and use of water could

Address for correspondence: Emanuele Ferretti, Dipartimento di Ambiente e Connessa Prevenzione Primaria, Istituto Superiore di Sanità, Viale Regina Elena 299, 00161 Rome, Italy. E-mail: emanuele.ferretti@iss.it.

instead represent the essential knowledge to support strategic actions addressed to improve water quality and health conditions in areas affected by the disaster.

On the basis of these assumptions, the Istituto Superiore di Sanità (ISS), as a national public health institute, was involved by the Italian Civil Protection Department (DPC) in a study with the aim to contribute to the reduction of health and social burden of waterborne disease also through a specific strengthening of the Sri Lanka water surveillance resources and structures.

The Sri Lanka public authority in charge of water supply services and sewerage and sanitation facilities is the National Water Supply & Drainage Board (NWS&DB) [2]. The central laboratory is located in Colombo and other 30 Regional laboratories, with additional laboratories in construction, are distributed on the territory.

Similarly to other developing countries, the most common source of drinking water in Sri Lanka largely relies upon household (HH) non-piped water systems using shallow (usually < 10 metres deep) and unprotected wells, some fitted with hand pumps. Water quality is not routinely assessed by local authorities, although some tests can be occasionally done by PHIs (public health inspectorates), under the Ministry of Health, when outbreaks of diseases occur. As a result of the partial analytical controls, there is little data on the safety of the drinking water provided to the population.

The general objective of this study was to support the identification of health priorities related to drinking water quality in three districts of Sri Lanka in order to provide information on health and social conditions of Tsunami affected populations and to improve microbiological and chemical water safety and surveillance measures in the flooded areas. In particular, the following specific objectives were achieved during this study: i) assessment of causes of contamination of water systems; ii) identification of priority risks related to water used for drinking, cooking, personnel and domestic hygiene; iii) assessment of the quality of water for human consumption in Tsunami affected areas.

MATERIALS AND METHODS

Study area

The water safety issue was closely related to the survey activities on health and socio-economics conditions of the area. In particular, investigations on water quality were carried out on the same study area and on georeferenced sampling units (households) selected for the health and social condition survey activities. The area involved in the study covered three coastal districts, Kalutara, Galle and Matara, and specifically their affected divisions *(Figure 1)*.

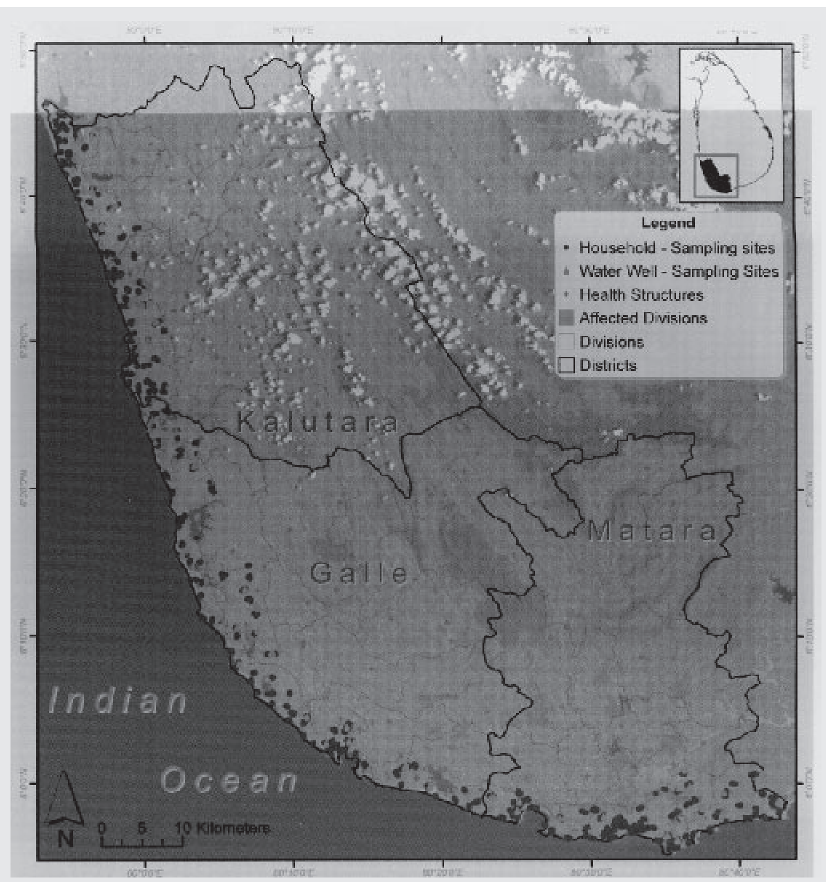

Fig. 1 | *Map of sampling sites investigated in the Divisions of Kalutara, Galle and Matara, Sri Lanka.*

Sampling frame

The choice of sampling sites within the selected districts was based on the response of the health and social condition survey study [3] with the aim to represent different water systems/uses (*e.g.* catchments from surface and shallow wells, treated or non treated water). Although the sampling usually refers to water catchments sites, additional samples were collected within the same HH, depending on local situations, (*e.g.* sample at water collection points and sample at home).

Closely related to sampling and analytical activities, surveillance based information was gathered through direct examination of water supply sites (*e.g.* well depth, general hygienic conditions, observable contamination sources etc.), water treatment practices, water collection, storage and uses within the household.

A specific sanitary improved inspection procedure was developed according to the WHO guidelines for surveillance and control of community supplies [4]; it was shared with local authorities, mainly belonging to the NWS&DB, and designed in order to reach the following objectives: i) efficient assessment of the sanitary situation, through the assessment of specific risk factors, based on local context; ii) simplified sanitary inspection form, suitable for rapid on-site information gathering and data-base structuring; iii) revision of the WHO sanitary inspection form, which currently attributes the same value to each risk factor (usually 1/10), based on a statistical correlation between the importance of microbiological/chemical contamination, as determined by laboratory analyses, and the different diagnostic info identified through the sanitary inspection (*e.g.* construction and surrounding elements of the well, specific contamination factors).

A water sampling plan for the districts of Kalutara, Galle and Matara was estimated in the course of the study on the base of the European standards on frequency of sampling and analyses for water intended for human consumption [5] and on the quantity of water collected and used by households provided by WHO guidelines [6].

In the three districts, a total of 158 of 2561 households wells were inspected and sampled in the period December 2005 – March 2006, being selected among all the households having a well utilised for drinking purposes in the Divisions of Kalutara (448 644 inhabitants), Galle (444 215 inhabitants) and Matara (270 073).

After collection, samples were transported refrigerated (4 °C) to the central NWS&DB laboratory.

Microbiological and chemical analyses

In developing countries the principal risks to human health associated with the consumption of polluted water are microbiological in nature, although the importance of chemical contamination should not be underestimated [7]. The microbiological examination of drinking-water emphasizes assessment of the hygienic quality of the supply. This requires isolation and enumeration of organisms that should be able to indicate the presence of faecal contamination.

In well water microbiological analyses were performed through conventional routine methods according to international and EC standards on the following microbiological parameters: Enterococci, *Escherichia coli*, Heterotrophic Plate count at 37 °C and Coliform bacteria at 37 °C. Besides the analyses of the more traditional microbial parameters, also the cyanobacterial cell count was performed in most of the water samples. Furthermore, the risk directly linked to the presence of pathogens in water used as a drinking water was performed. Thus, in the course of the study, also the presence of Salmonella spp., a common pathogen present in water was determined. For this purpose, water from 121 wells was analyzed. Wells belonged to the following 3 districts: 40 at Kalutara, 37 at Galle and 44 at Matara.

A significant number of serious problems may also occur as a result of chemical contamination from a variety of natural and man-made sources [4]. Determination of a wide range of analytes on a regular basis would be extremely expensive particularly in the investigated areas where the supplies serve small numbers of people. Fortunately, chemical parameters tend to be less variable in source waters than faecal contamination, so that only some chemicals of health significance were considered to be monitored and the results examined in the light of the WHO guideline values [6] and the 98/83/EC Drinking Water Directive [5].

Chemical analyses were performed through rapid validated methods using a multi-parameter probe (Hydrolab DataSonde 5, Corr-Tek Idrometria Srl, Verona, Italy) *in situ* monitoring instrumental systems, reagent kits and *in situ* assays based on photometric response.

The following routine *in situ* analysis on indicator parameters, disinfection parameters and chemical contaminants was immediately performed: temperature, pH, electrical conductivity, dissolved oxygen, RedOx potential, chlorophyll, residual chlorine, total chlorine.

Laboratory analyses performed within the NWS&DB laboratory of Colombo included: turbidity, total phosphorus, ammonium, nitrate, nitrite, fluoride and total organic carbon.

During the analytical activities a quality control data was performed.

Data recording

Raw data related to sampling and analyses were validated, stored and available for an adequate time following the end of the project.

A specific shared database with a controlled internet access within the ISS web site (www.iss.it/site/waterlanka/) was developed in order to collect the analytical results of this study and the information gathered from samplers concerning the household.

The collected data have been archived and elaborated by the on purpose developed software.

RESULTS AND DISCUSSION

The investigation was finalised to identify health priorities related to drinking water quality in order to support a study on health and social conditions of Tsunami affected populations for improving the microbial and chemical water safety and surveillance measures in the flooded areas, also by strengthening the scientific-technical resources of the beneficiary country.

In order to achieve this objective, the first steps were: i) the recognition of the technical competent counterpart (*i.e.* NWS&DB) and the identification of the technical-scientific resources available within the local structures; ii) the sharing with the Sri Lankan experts of the specific resources needed for the project activities and for the water surveillance activities of the structure; iii) the purchasing in Italy of instruments and equipments which were delivered in Sri Lanka; iv), the installation of chemical and microbiological equipments (*i.e.* setting operational conditions for microbiological and chemical routine water analysis laboratory) to strengthen the microbiological and chemical section of the NWS&DB laboratory of Colombo.

The final result was the improvement of the analytical performances of NWS&DB laboratories, with the specific aim of: i), provide validated, advanced and standardised technical analytical procedures in microbial and chemical water quality analysis; ii), enhance the surveillance capability with the inclusion of additional important microbial and chemical risk factors; iii), reduce the analysis times and improve the quality of the data produced within the routine analyses.

The dedicated efforts allowed providing the Sri Lanka central water laboratory with a full capability to monitor the quality of water for human consumption according to international standards.

The personnel involved in water quality assessment in Sri Lanka, including sections of National and Regional Laboratory (Galle, Kalutara and Matara) of NWS&DB, was then trained on the activities of the research and water quality assessment. Specific training involved instrumental techniques, calibration, use and maintenance, sanitary inspection procedures, sampling, on-site and laboratory analysis procedures. Training was subsequently implemented by supporting the Sri Lankan experts throughout the different project activities.

According to the elaborated sampling instructions, water sampling were carried out together with the sanitary inspection on wells traditionally used by household as well as on new wells realized by populations post-Tsunami.

Specific data related on samples were collected during the sanitary inspection, regarding source characterization (*e.g.* type of source, well depth, general hygienic conditions, observable contamination sources, distance from sea, and Tsunami effect on the water), water treatment practice, water collection, storage and uses within HH.

The overall results of 158 samples showed a significant level of risk associated with drinking water consumption within the investigated areas, calling for an urgent improvement of water management particularly focused on source protection, disinfection practices (only 7 dug wells adopt disinfection) and contamination sources.

A total of 158 samples of water destined to human consumption was analysed according to EC standard to assess chemical and microbiological quality.

All the data related to (sanitary survey) the 158 wells were elaborate for the identification of potential correlated sanitary risks to the use of the water by using the developed database.

During the investigation, performed in collaboration with personnel of NWS&DB, 158 analyses were carried out on household wells used as drinking water supply.

On the ground of the European Directive 98/83/EC which establishes *E. coli* and Enterococchi in 100 ml to be absent due to their role of indicators of faecal contamination, the water of only 4 wells complied with the parametric values of the directive. In the remaining wells, water samples (97.3%) did not comply for the presence of faecal contamination.

As with sanitary inspection, data on microbiological water quality may usefully be divided into a number of categories; the level of contamination associated with each category should be selected in the light of local circumstances. Examination of the faecal grading together with the sanitary inspection risk scores for a large number of facilities should make it possible to assess relative priorities both for local remedial action and for regional planning purposes.

A typical classification scheme is presented in *Guidelines for drinking-water quality* (WHO) [4], based on increasing orders of magnitude of faecal contamination (*Table 1*).

Table 1 | *Classification scheme based on increasing orders of magnitude of faecal contamination [4]. The classification is based on increasing orders of magnitude of faecal contamination associated to the presence of* Escherichia coli

E. coli/100 mL	Category and colour code	Remarks
0	A (blue)	In conformity with WHO guidelines
1-10	B (green)	Low risk
10-100	C (yellow)	Intermediate risk
100-1000	D (orange)	High risk
> 1000	E (red)	Very high risk

Taking in mind this scheme, and taking into account the recovered concentrations of *E. coli*, results allowed to achieve to the following classification: 18 wells could be included in the A category, because they fulfilled the *WHO Guidelines for drinking-water quality*; 39 wells showed a low risk (B category); 47 wells were included in the C category, intermediate risk; 35 wells showed a high risk (D category) and 10 wells provided water at a very high risk (E category).

Analyses performed for verifying the presence of *Salmonella* in well water confirmed the low hygienic water quality. In fact, among the wells taken into consideration, 59 wells (48.8%) presented a contamination due to the occurrence of *Salmonella*. The *Salmonella*-positive wells were equally distributed in the 3 districts.

Results obtained during the monitoring campaign on well water used as a drinking water showed a wide presence of faecal contamination by which derive a judgement of scarce water quality from the microbiological point of view, with a high risk for population health *(Table 2)*.

Water samples collected by 149 and 158 private wells were analysed to determine chemical sanitary parameters (that is, fluoride, nitrate and nitrate) and chemical indicator parameters (that is, ammonium, colour, electrical conductance, odour, pH and turbidity), respectively, according to the current Drinking Water Directive 98/83/EC [5] *(Table 2)*.

Only 13.3% of the examined sites fully complied with the chemical requirements of the European regulation. Non compliances mainly regard chemical indicator parameters (84.0%) and were often associated with low pH values and/or high water turbidity.

CONCLUSIONS

In conclusion, the results of the activities concerning water assessment were substantially in compliance with the planned objectives of the project. They involve a number of important outputs, such as:

- enhance the surveillance water quality authorities through a substantial improvement in instrumental resources and specific knowledge, thus resulting in providing the central laboratory in Colombo with a full capability to monitor the quality of water for human consumption according to international standards;
- detailed water quality survey on HH wells sited in coastal Tsunami affected areas, focused on health sanitary risks related to water consumption (drinking, personnel hygiene, cleaning, cooking) and identification of priority risk factors;

Table 2 | *Values of microbiological (n = 158), chemical (n = 149) and physicochemical (n = 158) parameters in well water (unit as specified)*

Parameter	Unit of measures	Min	Max	Geometric mean	WHO	EC
Coliforms at 37 °C	CFU/100 mL	0	> 200.5	-	0	0
Escherichia coli [/100 ml]	CFU/100 mL	0	> 200.5	-	0	0
Enterococci	CFU/100 mL	0	> 200.5	-	0	0
HPC at 37 °C	CFU/mL	2×10^1	2.4×10^8	-	n.d.	n.d.
Salmonella spp.	P-A/ L	-	-	-	A	A
Temperature	°C	25.29	37.09	28.9	/	/
Hydrogen ion concentration	pH units	1.9	7.9	5.8	6.5 - 8.5	6.5 - 9.5
Electric conductivity (20 °C)	µs/cm	30.6	951	222.3	/	2500
Redox potential	mV	1.46	558	291.1	/	/
Chlorophyll	µg/L	0	26.9	0.78	/	/
Cyanobacterial cells	cells/mL	0	16 850	1231.62	/	/
Dissolved Oxygen	mg/L	0.07	42.7	3.62		/
Chlorine residue	mg/L	0	0.5	0.12	5.0	5.0
Total chlorine	mg/L	0	1.1	0.18		/
Turbidity	NTU	0.17	177	8.79	0.1	Acceptable to consumers and no abnormal change
Total phosphorus	µg/L	0	0.49	0.085	/	/
Ammonium	µg/L	0.01	4	0.24	/	0.50
Nitrate	µg/L	0.01	32	1.36	50	50
Nitrite	µg/L	0.001	2880	0.041	0.20	0.50
Fluoride	µg/L	0.01	2.21	0.33	1.5	1.5
TOC		0	4	1.1	/	No abnormal change

- organization of standardized monitoring net, operating procedures, sanitary inspection, sampling and analytical methods, and quality data entry/elaboration for surveillance of water quality in community water systems in Sri Lanka, potentially applicable in other developing countries.

According to the results of the study, the health risk related to consumption of water from household wells is very high, underlining the need of training on the health risks related to the use of household wells and on the safe well management in the investigated areas and in other Sri Lankan regions.

Efforts should be particularly addressed to simple measures to prevent health hazards related to water supply and uses and to introduce disinfection practices as key for the provision of safe drinking water.

Acknowledgments

We would like to gratefully acknowledge Lucia Falchetti for the assistance in Sri Lanka and the organization of the mission of ISS experts. A special thanks also to Padmasiri and the personnel of NWS&DB laboratory of Colombo for the valuable support and kind hospitality and to Nishanta and Giulia Gagliardini who collaborated in sample collection and *in situ* analyses.

Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

Submitted on invitation.
Accepted on 22 April 2010.

References

1. Clasen T, Smith L. *The drinking water response to the Indian Ocean Tsunami including the role of household water treatment.* Geneva: Water, Sanitation and Health Protection of the Human Environment, World Health Organization; 2005. Available from: www.reliefweb.int/library/documents/2005/who-Tsunami-apr05.pdf.
2. *National Water Supply & Drainage Board (NWS&DB).* Ratmalana, Sri Lanka. Available from: www.waterboard.lk.
3. Protezione Civile Nazionale. *Rapporto intermedio e finale 2006*. Available from: www.iss.it/binary/aqua/cont/Rapporto%20tecnico%20finale%20Sri%20Lanka.1204886059.pdf.
4. World Health Organization. *Guidelines for drinking-water quality, Surveillance and control of community supplies.* Geneva: WHO; 1997, 2.ed. vol.3.
5. Council of the European Union. Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. *Official Journal of the European Community* L 330, 5/12/1998.
6. World Health Organization. *Guidelines for drinking water quality. Incorporating the firstand second appenda.* Geneva: WHO; 2004. 3. ed. Available from: http://www.who.int/water_sanitation_health/dwq/fulltext.pdf
7. Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. *Nature* 2005;438:310-7.