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The Drinking Water Response to the Indian Ocean Tsunami Including the Role of Household Water Treatment

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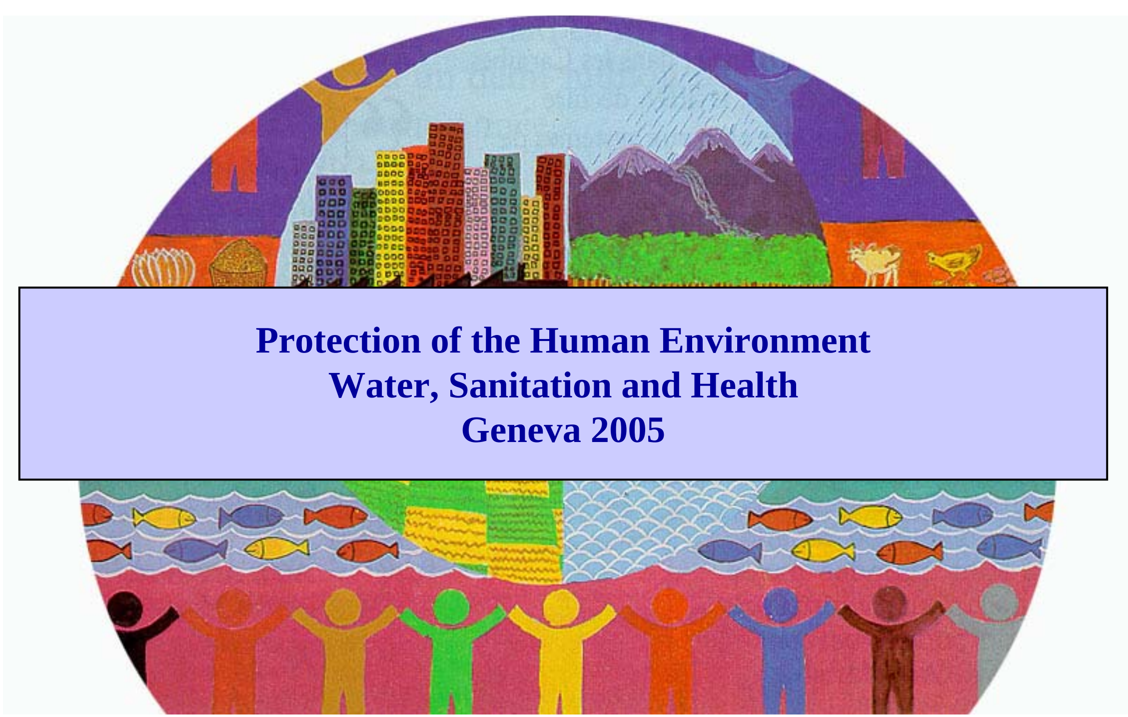

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Water, Sanitation and Health
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Summary

On 26 December 2004, an earthquake off the Indonesian island of Sumatra triggered a massive tsunami that devastated costal areas of eleven countries around the Indian Ocean. More than 280 000 were killed and at least one million were displaced by the disaster. An unprecedented emergency response ensued, with priority focused on the health and well-being of survivors. Citing the threat of outbreaks from waterborne diseases such as diarrhoea, cholera, typhoid and hepatitis, governments, UN agencies and non-governmental organizations (NGOs) urgently appealed for assistance to provide safe drinking water to affected populations. This study was undertaken to document the drinking water response, including the role played by household water treatment.

The destruction wrought by the tsunami on piped-in water supplies and groundwater pumps, and the saline water intrusion of shallow wells and surface sources, rendered much of the pre-tsunami supplies throughout the affected area completely unusable. The combined efforts of governmental bodies, UN agencies, NGOs, defence forces, commercial companies, other organizations and committed individuals, however, mobilized a drinking water response that was timely, comprehensive and effective. While specific actions varied somewhat from country to country, they followed a similar pattern that corresponded with the phase of the emergency. Following the first 48 hours, when survivors relied mainly on unaffected sources and some bottled water, responders began to reach areas in which the affected populations were assembling. They distributed large tanks and mobilized tanker trucks to fill them. As emergency efforts turned to stabilization and resettlement, responders used mobile treatment plants and emergency storage and distribution systems to increase the quantity of water supplied. Distribution systems were repaired or rebuilt. Restoration of many groundwater sources, however, continues to be challenged by saline water intrusion.

Despite evidence in development settings and certain emergencies that household water treatment, including chlorination, filtration, solar disinfection and combined flocculation/disinfection, are effective in improving the microbiological quality of drinking water and thus preventing the risk of waterborne disease, household-based approaches did not play a significant role in the initial phases of the tsunami response with the possible exception of boiling. This was not due to their lack of availability; millions of units of these products where shipped to the region. Rather, responders often found that household water treatment was not suitable during the immediate aftermath of the disaster due to (i) the need to emphasize water quantity over water quality, (ii) the unique conditions imposed by the tsunami that continued to necessitate the supply of bulk treated water, (iii) the unavailability of human and other resources for the programmatic support to launch household water treatment, (iv) concerns that the introduction of new methods of water treatment would send mixed messages about other practices, and (v) concerns about the sustainability of such methods. Boiling did play a role, though there was evidence to suggest that as it was practiced in tsunami affected populations, boiling was not providing adequate protection against faecal contaminants. Some organizations expressed the view that household water treatment would be introduced during the resettlement phase of the disaster response.

Much of the drinking water response to the Indian Ocean tsunami focused on providing a sufficient quantity of water, with perhaps less focus on quality. While this is consistent with recently developed norms, such a compromise may not have been necessary in this situation, where water was largely supplied in bulk and could have been adequately chlorinated at the source, in the truck or other supply line, or in the tanks at the camps. Surveillance of water quality was occasionally hampered by confusion over responsibility as well as a lack of equipment and trained personnel. There is evidence in certain areas that water quality, both at the source and especially at the household level, was compromised by high levels of faecal pathogens.

A comprehensive system of disease surveillance was undertaken in the affected areas in most countries. This yielded little evidence of epidemic levels of any infectious disease, including diseases that are frequently waterborne. This lack of outbreaks, however, is actually consistent with the experience following most natural disasters. The evidence clearly shows that the inevitability of an outbreak following a natural disaster is a myth. An exaggerated risk of waterborne diseases could divert attention from other priorities. At the same time, it is possible that the lack of outbreaks is attributable in part to the massive response that frequently accompanies a natural disaster. In any case, it is important not to become complacent, particularly since living in crowed camps is known to increase risk and the normal season of waterborne diseases increases with the onset of the monsoons.

We conclude with several recommendations: (i) continue to take steps to minimize the risks of waterborne diseases following natural disasters, (ii) develop and disseminate practical solutions for the special circumstances associated with tsunamis, including saline water intrusion, (iii) clarify the conditions under which proven approaches to household water treatment may be useful in emergencies and assess their role in the medium- and long-term response, (iv) improve water quality and surveillance without compromising emphasis on water quantity, (v) take advantage of the enormous resources committed to the tsunami response to make effective and sustainable improvements in water, sanitation and hygiene in the affected areas, and (vi) document experiences from the tsunami response, distil the lessons learned, disseminate the results and develop guidelines to inform future actions.

BACKGROUND AND INTRODUCTION

On 26 December 2004, an earthquake off the Indonesian island of Sumatra measuring 9.0 on the Richter scale triggered a number of massive tsunamis. The leading wave raced through the deep water at a speed of more than 800 km per hour. As it neared land, its enormous energy unleashed at least three waves of up to 25 m, killing and devastating coastal regions of eleven countries around the Indian Ocean. At least five million people were affected in Indonesia, Sri Lanka, India, Thailand, Malaysia, the Maldives, the Seychelles, Myanmar and Somalia. The death toll exceeded 280 000 people, and more than one million persons were displaced as a result of the destruction.

Citing the threat of outbreaks from waterborne diseases such as diarrhoea, cholera, typhoid and hepatitis, governments, UN agencies and non-governmental organizations (NGOs) urgently appealed for assistance to provide safe drinking water to affected populations. A World Health Organization (WHO) release two days after the event was typical: "Poor quality and quantity of water and insufficient sanitation, overcrowding and poor hygiene in temporary camps will bring forward the risk for outbreaks of different diarrhoeal diseases. Thorough and sustained water purification is an absolute priority." (WHO, 2005) Rapid assessments and statements stressed the urgency of the drinking water response: "Access to potable water is essential to avoid the propagation of waterborne disease. " (IFRC, 29 December 2004). Calls for the provision of safe water—a need with which all humans can readily identify—became a central theme in the campaigns of many organizations as they themselves became inundated with unprecedented levels of contributions from around the world. Many organizations even accepted in-kind donations of filters, chlorine and other water treatment products. Regular situation reports from the field monitored the drinking water response throughout the affected region.

While its magnitude, forcefulness and breadth, along with its seawater medium, present particular challenges in the provision of drinking water, in most respects the profile of a tsunami resembles that of a flood caused by a hurricane or cyclone. The drinking water response corresponds roughly with the phases of the emergency described by Davis and Lambert (2002). During the immediate emergency phase, people flee to high ground or other protected locations. Survivors are dependent on local resources for food and water while outside help begins to mobilize. A stabilization phase ranging from a few days to a few weeks then ensues when survivors begin to gather into makeshift camps. During this period, governmental authorities and relief agencies begin to provide a survival ration of water, gradually increasing to address personal hygiene and other needs. Once the immediate emergency is over, the recovery phase begins with the construction of more durable shelters and support systems, including emergency water treatment and distribution. Camp- and community-scale systems such as those developed by Oxfam and Médecins Sans Frontières (MSF) and many other NGOs come on line. Finally, a prolonged resettlement phase then begins during which destroyed and contaminated water systems, wells and boreholes are restored, rebuilt or replaced.

Household water treatment and storage may play a role at each of these stages. In an emergency context, when normal supplies of drinking water are interrupted or compromised, affected populations have long been encouraged to boil or chlorinate their drinking water in order to ensure its microbiological integrity (CDC, 1993). More recently, the treatment of water at the household level has been shown to be more effective in preventing even endemic diarrhoea than traditional methods of improving or protecting the microbial quality of water at the source or to the point of distribution (Clasen, 2005; Fewtrell, 2005).

With the assistance of the WHO, and funding from Hindustan Lever Ltd., we undertook this study to investigate and document the drinking water response in the immediate aftermath of the tsunami, including the role of household-based water treatment and safe storage. This paper presents and discusses the main results of that investigation. It also makes recommendations for the future based on our findings.

METHODS

Shortly after the tsunami, we began monitoring broadcast, web and print media to obtain information relevant to the drinking water response and to identify organizations that were involved therein. Commencing four weeks after the event, we started contacting the identified organizations, including governmental ministries and authorities, UN agencies, NGOs and private-sector companies. We explained that we were working with the WHO to investigate and document the drinking water response, including the role of household-based water treatment interventions. We encouraged them to provide any relevant information, including copies of any reports or accounts that addressed drinking water issues, and to supply us with the names and contact details of their representatives in the field. We contacted these representatives by phone and email and asked them to provide any further relevant information and reports.

Commencing approximately eight weeks following the event, we began two-week field assessments in India, Sri Lanka and Indonesia. These countries were selected because they collectively represent a significant majority of the human casualties (known dead or missing) and perhaps a similar portion of internally displaced persons (IDP) living in camps or temporary shelters. We interviewed national, regional and local representatives of organizations involved in addressing drinking water issues, obtained copies of reports, and accompanied them on visits to affected areas. During our field work, we interviewed on-site relief personnel working on water, sanitation and hygiene projects, including local personnel involved in providing water. We also met with health workers, mainly in temporary clinics. Finally, we interviewed victims of the disaster and solicited their input on the drinking water response from the immediate aftermath through the first four months. A list the organizations that provided information for this study appears in Annex 1.

Although we took steps to collect as much relevant information as possible, circumstances limited our investigation. First, while we intentionally delayed our investigation so as to minimize interference with the response itself, the continued priorities of attending to the emergency at times limited our access to key personnel. Second, logistical issues and costs permitted us to conduct field assessments in only selected countries and locations. Third, in soliciting information for this study, we agreed to respect the confidentiality of our sources, where necessary, in order to encourage candid disclosure, respect privacy and protect proprietary information. While we acknowledge that these factors may bias our results, they are the limitations that typically attend emergencies of this kind and thus may be necessary to some extent in order to obtain potentially useful lessons.

RESULTS AND DISCUSSION

1. Pre-Existing Water Supplies and Impact of Tsunami.

With the notable exception of Aceh, the areas most affected by the tsunami consisted of a relatively narrow strip of land (a few metres to up to 5 km) along the sea coast. Depending on the location, this area varied in population density from isolated rural areas where no one resided to medium-sized cities. As a result, the water supplies serving the affected area came from a wide range of sources, including surface water (ponds, rivers and streams), hand-dug wells, springs, boreholes, piped-in water systems and tanker-supplied water. Shallow wells (usually <10 metres deep), unprotected wells, some fitted with hand pumps, represented the most common source of drinking water, though these frequently produce water with a high level of saline and faecal contamination and often produce no water whatsoever during the long dry seasons between monsoons that extend to most of the region. Rainwater harvesting is practiced in some areas, but does not play a major role due to limited and seasonal rainfall. Although portions of the affected population had household connections to conventional treatment and distribution systems, most drew water from household or communal sources that were untreated and unprotected. Regardless of the source, many stored water in the home due to inadequate and unpredictable supplies.

The tsunami affected existing water supplies in at least five ways. In those areas hit hardest by the impact of breaking waves, many of the supply and distribution systems, regardless of their type, were completely destroyed or otherwise rendered inoperable. In other areas, where the impact was less forceful, rising waters inundated surface sources and unprotected wells with seawater, sand, debris and, in many cases, faecal matter from coastal areas where open defecation was common and sanitation facilities were largely unimproved. Third, even protected sources such as shallow wells, many of which had high levels of salinity before the tsunami, underwent subsurface saline water intrusion, raising the saline level to a point that rendered them unfit for human consumption. Fourth, wells and other sources of supply that did survive the tsunami itself were often used at rates beyond safe recharge. In some cases, excess use may have increased saline water intrusion, resulting in water that was no longer potable. Finally, in some regions, there were dramatic shifts in the coast line, thus completely eliminating former home sites and complete communities. As a result of all of these factors, many sources of drinking water in the affected areas were unavailable or unusable following the tsunami. Groundwater experts have also expressed concerns that the inundation introduced chemical and microbiological contaminants as well as increased salinity into the aquifers that may affect water quality for years to come (IGRAC, 2005).

2. The Drinking Water Response

The evidence to date from those countries from which information is available suggests that the drinking water response to the tsunami disaster was timely, effective and comprehensive. Though the area has never experienced a disaster on the scale of the 26 December 2004 tsunami, the countries involved are regularly affected by heavy monsoons and flooding, perhaps explaining why governmental bodies were quick to mobilize. UN agencies and NGOs, some of which already worked in the region with populations affected by conflict, provided invaluable experience and expertise, and were able to assume complete responsibility for specific areas. Defence forces played an important role in the immediate aftermath of the disaster, and continued to help reach remote areas. Commercial companies, organizations and individual volunteers all made important contributions. Their collective efforts with respect to the drinking water can perhaps best be summarized with reference to the phases of the emergency response.

2.1 Immediate Emergency Phase.

During the immediate emergency, when those who survived the impact of the tsunami began assembling onto high ground or other unaffected areas, reliance was chiefly on local water supplies that had not been damaged by the force of the waves or by the rising seawater. Mosques, temples, churches, schools, hospitals and public buildings and grounds offered the first refuge for reuniting families and creating some minimum space for collecting a few possessions. In those areas in which the damage was more sporadic, survivors gathered at the homes of family, friends and neighbours. In the 24-48 hours immediately following the disaster, the affected population relied largely on serviceable groundwater sources in these locations. The quantity of water supplied during this period was extremely limited; many survivors had no vessels in which to store water, and these basic sources were quickly exhausted by the rapidly increasing demand.

2.2 Stabilization Phase.

As the magnitude of the disaster was being realized, governments (including defence forces), UN agencies, NGOs, private-sector companies and committed individuals began to mobilize the relief effort. Rapid needs assessments were undertaken and disease surveillance and control teams were dispatched. A decision was taken not to institute mass immunization campaigns for vaccine-preventable waterborne diseases such as cholera and typhoid, relying instead on environmental interventions and comprehensive disease surveillance. The water response during this period consisted of various initiatives:

- Packaged water (in 200ml polybags and PET bottles) was distributed to some squatter camps, though some organizations expressed concern about the microbial quality of this water. These were also being distributed to thousands of individual volunteers who were conducting search and rescue operations as well as recovery of bodies, road clearing and utility restoration efforts. One clearly visible downside to this response was the high levels of solid waste which persisted around camps due to packaging materials. However, other accounts report that the bottles were often re-used as water collection and storage vessels.

- As roads became serviceable, large plastic 500L to 2500L tanks were set up at the squatter camp sites. These tanks are commonly used by householders for storing larger volumes of water to make up for intermittent supplies from conventional sources. As a result, they were quite readily available in many affected areas. The tanks were typically filled by public and privately operated tanker trucks which are also common in many of the areas. While NGOs frequently hired and paid for the tanker deliveries, water supply was typically provided by the governmental water boards. Because of the focal nature of the damage caused by the tsunami, the tankers were normally able to procure water from unaffected sources within relatively close proximity to the affected areas. While the tankered water was normally believed to be chlorinated at or before the loading point or on the truck, as discussed more fully below, there are questions about such treatment.

- In a limited number of areas, mobile water treatment purification plants (including desalination plants) and portable coagulation/disinfection systems were brought in and began producing large volumes of potable water. In most cases, these were used to fill tanker trucks, though in other cases, they were positioned near camps and supplied them directly, storing water in bulk in corrugated steel "Oxfam" tanks and collapsible bladder and onion tanks, and distributing the water using rigid and layflat (fire) hose to communal tap stands.

- In a few areas, relief organizations began to encourage the affected population to treat their own water, mainly by boiling. In other areas, bleach (sodium hypochlorite), bleaching powder (calcium hypochlorite), chlorine tablets (NaDCC, halazone), PUR sachets (combined flocculant and disinfectant), and alum (flocculant) were distributed with the intent that they be used for treating water at the distribution points or at the household level. These household-based approaches are discussed below. During this period, relief organizations also began distributing vessels and utensils for collecting, storing and consuming water. Nutritional drinks, milk and other available liquids were also distributed as safe though limited means of hydrating survivors.

In most cases, governmental authorities, including state and local water boards took the lead in supplying water. They were also typically responsible for ensuring the microbiological quality of the water they supplied, chiefly by using some form of chlorine alone. In some cases, health authorities monitored water quality, usually only by checking levels of residual chlorine. In those areas where governments could not respond, defence forces and international relief agencies took responsibility for water supplies. Water and sanitation coordination committees, consisting of key actors in this sector, began to form and allocate responsibility, usually by region or camp; these meetings also provided a forum to raise and discuss challenges that were unique to the particular emergency, such as saline water intrusion.

2.3 Recovery Phase.

As more relief supplies were being delivered to the affected areas, especially tents and supplies for establishing more durable shelters, some survivors were moved to semi-permanent 'temporary living centres' with water supply systems and sanitation facilities. Others remained in transitional camps, while relief agencies continued to implement improved water supplies and latrines, cooking facilities, etc. In many cases, however, survivors were already returning to the sites of their former homes, setting up tents or living in makeshift shelters so that they could protect their holdings and begin to rebuild. Some maintained a nominal residence in camps or settlements (thus potentially misleading the official statistics) so as not to jeopardize their eligibility for assistance.

- For the most part, populations continued to rely during this period on tankered water delivered to the large plastic storage tanks, some of which were moved with the population to the temporary settlements. In fact, these two simple and low-technology pieces of equipment probably played the most important role among all hardware involved in the drinking water response. Nevertheless, there were problems with their use. First, despite being deployed in great numbers, the combination of tanks and tankers was often insufficient to meet the demand for water quantity. Water boards often controlled deliveries, making it difficult at times for NGOs to service camps for which they were responsible. Tanks were often empty, a problem that could be aggravated as summer approached and the need for water increases. When the trucks did arrive to fill the tanks, usually no more than once or twice per day, householders rushed out with anything that could hold water and filled them directly from the truck to maximize their water supply, concomitantly increasing the risk of contaminating their stored drinking water prior to use in the home. A lack of coordination, understandable under the circumstances, also meant some locations had more water than they could use. Second, there was often confusion about who was responsible for ensuring that the water was appropriately chlorinated. This lead to a lack of treatment in some cases, and excess levels of chlorine (up to 6 ppm, or 15 times the residual level required) in others. Neither the truck drivers nor, in many cases, anyone in the camps had the tools or know-how to chlorinate or check residual chlorine levels in supplied water. While they were usually filled from deep boreholes, treated municipal systems or NGO water plants, reports also emerged of tanker operators refilling from irrigation points or surface sources to reach their daily target volumes more quickly. Third, while fitted with taps, the tanks had loose fitting, non-secured covers over large diameter openings. As a result, some users found it more expedient to fill their household containers by directly dipping them into the tanks, creating a serious recontamination hazard. Finally, in certain locations, the delivered water had a distinct colour and odour (suggesting the possibility of chemical contaminants) and a floating layer of particulate on the surface in the tank, providing further evidence of refilling from untreated surface sources as well as suggesting insufficient cleaning of tankers.

- In certain areas, such as Tamil Nadu in southeast India, the state water board, municipalities and Gram panchayats restored piped water supplies to many of the affected areas, and established hundreds of new public water points to make up for the loss of wells due mainly to saline water intrusion.

- In some areas, relief organizations were operating desalination plants (reverse osmosis and electro-dialysis). There was concern, however, about the ability to continue using such plants due to their high operating costs (in India, for example, the estimated cost was Rs 0.60 (US$ 0.014) per litre. Some water treatment plants used in the initial phase had already been shut down and were no longer in use. During this period, many of the defence forces, who had brought their own mobile water treatment plants, packed up and moved out, usually taking all their equipment with them. In those instances in which they were operating donated equipment, they coordinated with relief agencies to assume responsibility after their departure.

- By this phase, household water storage vessels were usually in adequate supply. Still, most of these were procured locally and were not fitted with taps or narrow mouths to minimize recontamination. Broken taps were common. In some instances, the hygiene programs that responders began to introduce during this period included instructions on safe water handling and storage.

- Wells that were able to provide drinking water with acceptable levels of salinity were identified as sources of drinking water. In some cases, relief agencies chlorinated and cleaned wells and marked them as safe for drinking. Other wells were used for purposes other than drinking and cooking, though salinity levels were often so high that people did not even use them for personal or household hygiene. In certain areas, people were digging new wells. Here the main concern was locating them too close to latrines or other sources of contamination. There was also a focus on digging both new and existing wells sufficiently deep to accommodate the drop in water table levels that occur during the dry season.

- An additional concern was that when the monsoon season begins, people may begin to use surface water and other untreated sources, thus increasing the risk of waterborne disease.

2.4 Resettlement Phase.

After three months, most new initiatives focused on the resettlement of the affected populations. In some instances, survivors were relocating in new settlements, either because of fear of another tsunami or because of government mandates designed to reduce vulnerability. In such cases, water is supplied centrally, usually via municipal treatment and distribution systems, or settlers rely on household or communal groundwater or surface sources. In most instances, however, displaced populations are returning and rebuilding on their previous home sites. Both scenarios present certain implications:

- Government-drafted recovery plans contemplate the expenditure of significant amounts of tsunami aid to upgrading water and sanitation facilities, particularly in the most populous areas. The unprecedented amount of money raised and committed creates an opportunity to implement suitable, appropriate and sustainable solutions that reflect best practices based on experience in environmental engineering and public health. It also creates the risk that funds will be allocated based on political, commercial and other priorities.

- Restoring wells has presented a particular challenge. While this normally consists of removing silt and debris and chlorinating the well to deal with microbiological contamination, saline water intrusion has rendered many, perhaps even most, wells unusable even after several months. Pumping the wells to encourage freshwater recharge has proved ineffective in many cases. While many of those interviewed expressed optimism that groundwater sources would recharge with freshwater after the commencement of the monsoon, hydrologists have explained that many of the groundwater aquifers servicing such wells have themselves become contaminated, thus raising questions about the near-term restoration of the wells and the futility of digging wells or drilling boreholes that tap the same aquifer.

- In addition to assisting with redevelopment and restoration, relief organizations are involved with other initiatives relating to drinking water. As described below, household-based water treatment, and water handling and management practices generally, are being introduced as part of integrated water-sanitation-hygiene programs. Water quality testing and surveillance can also be implemented on a more systematic basis.

3. Household Water Treatment

While efforts must continue to expand access to safe piped water supplies, treating water at the household level is increasingly recognized as an effective and cost-effective intervention against waterborne disease. In development settings among low-income populations, NGOs have implemented household-based approaches to water treatment, including boiling and pasteurization, chemical disinfection (e.g. the Safe Water System-SWS), solar disinfection (e.g. Sodis), filtration (e.g. ceramic candle filters, biosand filters), combined flocculation/disinfection (e.g. PUR and Watermaker) and improved household water storage vessels. Some of these approaches have also been shown to be effective in preventing waterborne disease in emergencies, including floods and other natural disasters and political conflicts (Roberts, 2001; Doocy, 2005).

In the Indian Ocean tsunami response, boiling was the most common approach to treating water at the household level. This was particularly true in Aceh where UNICEF and the Ministry of Health have promoted boiling for years. Issues arose concerning the introduction of chlorination as an alternative to boiling, particularly when investigators for NGOs found evidence of unsafe water at the household level. In one study, 47.5% of water sampled from 400 households (78% of which reported boiling, the others not treating their water at all) were positive for *E. coli*, and a significant majority found it often (25.7%) or sometimes (42.6%) difficult to practice boiling, mainly due to the unavailability (65.5%) or cost (62.8%) of fuel or lack of a stove (20.8%) (Handzel, 2005). Nevertheless, due to the scale of demand on those involved in the emergency response, most NGOs promoted boiling as the only practical means of treating water at the household level during the initial phases of the emergency. They observed that because boiling was well-known and widely accepted, it did not require programmatic support for its promotion, thus allowing them to focus on providing basic water and sanitation needs. They also reported that they believed boiling was the obvious alternative for those householders who were consuming water from unsafe wells or surface sources because they did not like the taste of chlorinated water being delivered to the camps.

Some relief organizations promoted chlorinating water at the household level, but only to a limited extent. They noted that householders showed greater willingness to chlorinate their water during the initial phases of the disaster, mainly using liquid bleach (sodium hypochlorite), bleaching powder (calcium hypochlorite) or a variety of chlorine tablets that were widely distributed during the first two weeks of the response. Health officials explained that when faced early on with dead bodies and other obvious sources of perceived contagion, survivors seemed more willing to treat their water and accept the uncustomary taste of chlorine. As the recovery effort continued, however, many discontinued this practice, perhaps because their assessment of vulnerability declined, but also because other bulk supplies of water were more readily available. How extensive or important such household chlorination actually was is difficult to assess. What is clear, however, is that in the absence of programmatic support, chlorination in the home was not generally accepted, particularly when the risk of waterborne disease was not readily apparent and alternatives became available.

The limited role of household water treatment was not a result of unavailability of the technology. In fact, the quantity of products sent to the region for the purpose of treating water was remarkable, particularly in view of the quantities that can be shown to have actually been used by the affected population.

- Chlorine and the Safe Water System (SWS). Common sources of chlorine from liquid bleach, bleaching powder, household disinfectants were widely available in most areas, but this was used mainly for cleaning and disinfecting rather than for treating water. An estimated 140,000 bottles of sodium hypochlorite specifically designed for water treatment were shipped to Aceh province from an already established SWS programme in Jakarta for use by an NGO experienced in promoting the SWS. (The SWS combines disinfection with locally produced sodium hypochlorite, safe storage, and community education.) 70,000 bottles were actually reported to have been distributed to affected communities by the end of March. Bottles were initially left with camp coordinators for distribution; however it was soon found that this was not resulting in proper use and distribution was suspended until training could also be provided. A training session of 30-60 minutes significantly increased uptake and the portion of households with sufficient residual chlorine levels.

- Chlorine Tablets. It is believed that millions of locally-produced chlorine tablets (mainly chloramine/hydroclonazone, halazone and calcium hypochlorite/HTS) were shipped to affected areas. While these were widely available in the early phases of the emergency, we found few of these tablets in the camps after several months, and it was difficult to find shops that stocked them or knew that they could be used for treating water. One foreign manufacture reported shipping a total of 30 million dichloroisocyanurate (NaDCC) tablets to the region in a succession of orders, mainly from NGOs and UN agencies. While chlorine tablets were used to treat water in bulk and in certain settings immediately following the tsunami, only limited use of these tablets at the household level could be confirmed.

- Combined Flocculation/Disinfection. Sachets containing a combination of a flocculant plus a time-released disinfectant have been shown effective in preventing diarrhoea in refugee camps and other emergencies (Doocy, 2004). Within two weeks of the disaster, over 15 million sachets of combined flocculant/disinfectant were shipped to Sri Lanka and Indonesia; a month later, another 1 million sachets went to the Maldives. After four months, however, much of the product had not yet been used. In Aceh, two NGOs suspended distribution after giving out roughly 1.6 million sachets due to questions about its suitability and acceptability, as well as lack of human resources to provide necessary programmatic support. Certain NGOs expressed enthusiasm for the product, noting its potential, especially when turbid surface water (e.g. from the river) is the only available option. In the majority of locations around Aceh, however, water was largely sourced from wells or tanker supplies and was of acceptable clarity. In such cases, recipients reported that the treatment process was too complex and the resultant taste was unpleasant. In Sri Lanka, except for some initial use in limited numbers, NGOs were waiting to use the product at later stages, especially after monsoons commence, when the risk of contaminated (and turbid) water would be greater and the product could be deployed with necessary training and follow-up.

- Ceramic Filters: India and other countries throughout south Asia are among the largest producers and users of ceramic drip water filters. Several brands could be purchased in shops near the areas affected by the tsunami at prices from Rs700-1100 (US$16-25), and local WHO officials reported that some householders were purchasing and using them. Nevertheless, the evidence suggests that filters were used only sporadically in the four months following the disaster. In one camp in Tamil Nadu, RedR India reported that 40% of the population had been given such filters and that the positive results should lead to wider use in villages and urban camps. UNICEF distributed 550 donated filters to families in five locations in Aceh, and though follow-up confirmed the filters were well received and in use, they had no plans to expand the program preferring instead to focus on hygiene messages and promotion of boiling. Oxfam, which has previously used the filters in post-flooding responses and other settings, procured 20,000 filters within two weeks of the tsunami, but decided to deploy them only in the resettlement phase when people began to re-establish their households more permanently.

- Solar Disinfection. Local NGOs (Helvatas and LEAD) introduced the Sodis solar disinfection program in 5 camps in Sri Lanka and 22 villages in Tamil Nadu, India. While local partners are also implementing the Sodis program in other parts of Indonesia, NGOs elected not to implement the intervention in the tsunami-affected areas there due to the availability of treated water under camp- or community-wide systems.

- Biosand Filters. Two NGOs (Dhan Foundation and Samaritan's Purse) with experience in biosand filter programs reported plans to introduce the filters during the resettlement phase of the emergency response. In the earlier phases of the emergency, however, biosand filters did not play a major role.

- Improved Storage. A few NGOs imported and distributed improved water storage devices (with small necks to prevent introduction of hands and taps for safely accessing water). In general, however, householders used locally-produced open-mouth vessels, buckets, pots and tubs to collect and store water and use it in their tents, shelters or homes. Local inhabitants who were not directly affected by the disaster often procured and provided such vessels to survivors, together with food and other utensils. While improved storage vessels may have been readily embraced by the affected population, they simply were not available in large numbers in the immediate aftermath of the disaster, and once conventional water containers were provided, relief organizations did not regard them as a priority.

The main reasons for not using household water treatment fall into five main categories:

- Emphasis on Water Quantity over Quality. As recommended by Sphere and other guidelines, the initial emphasis in the drinking water response was on quantity rather than quality. Physiological needs (hydration) are the first priority, and outweigh microbiological concerns. As discussed more fully below, this will have important implications in the priority attached to household water treatment.

- Unnecessary Given Bulk Supply of Water. Because the population affected by the tsunami was either displaced or had otherwise lost access to their customary sources of fresh water, they were dependent on water supplied in bulk. In fact, it is possible that the saline water intrusion that rendered so many surface and shallow groundwater sources unusable actually helped minimize waterborne disease since affected populations were not even tempted to consume water from such sources that were also likely to be contaminated by microbial pathogens.

- Need for Programmatic Support. All of the common means for treating water and maintaining its microbiological quality at the household level require some level of programmatic support. While some approaches, such as certain gravity filters that are easy to use and make noticeable improvements in water aesthetics, may require less of a behaviour change campaign than chlorination or solar disinfection, all household-based approaches require a commitment of both human and financial resources for their introduction that may be impractical in the early phases of a disaster. Moreover, while emergencies are often viewed as an opportunity to expose and introduce an affected population to new health and other initiatives, this in not typically true until the situation has become stabilized and recovery begins. As noted above with respect to parts of Aceh, the introduction of chlorination as an alternative to boiling was resisted. Among other things, this was due to its awareness, given its own long-standing campaign to promote boiling, of the significant effort required to obtain high levels of adoption of such interventions even without having to deal with a massive disaster.

- Concern about Mixed Messages. In Aceh where the practice of boiling drinking water is widely reported and genuinely appears to be a well-established behaviour, there was concern (particularly from the Ministry of Health and UNICEF) that new messages about alternative water treatment methods may confuse matters and result in a decrease in normal practice, thus leaving individuals exposed to increased risk of waterborne diseases. With so many agencies working on water, sanitation and hygiene promotion issues, the early stand made by UNICEF and the Government of Indonesia on the water boiling issue was an attempt to avoid proliferation of conflicting messages being given to the affected populations which only serves to dilute their effectiveness.

- Concerns about Sustainability. In addition to the previously discussed preference for existing practice, concerns about the sustainability of new household-based water treatment methods also led to resistance to their introduction. For example, the Indonesian Government made it clear that they would not commit to the chlorination of all public water supplies once the relief agencies left and so it was important to maintain the high pre-tsunami levels of boiling. Although the circumstances and raised risk perceptions which result from a natural disaster may be sufficient to trigger initial or short-term behaviour change, as has been discussed, these do not seem to be sustained and people may no longer feel the need to treat their water if there aren't any visual or sensory cues to suggest that it is unsafe or unpalatable. Such short-term behaviour change without sustained promotion could be detrimental to health if it means the abandonment of previous safe drinking water practices. It will also be essential to maintain a supply of the hardware (e.g. sodium hypochlorite or flocculent/disinfectant sachets) which may become difficult in the unstable regions of Sri Lanka and Aceh.

Except for the concerns about sustainability, these reasons mainly argue against the premature introduction of household water treatment, rather than against its use altogether. In fact, many of the relief organizations who had procured products with a view toward introducing household water treatment reported that they still planned to do so but were waiting for more appropriate circumstances. Some organizations expressed the view that point-of-use water treatment at the household level was an ideal solution for certain members of the affected populations once they began to return to their home sites and no longer had access to bulk supplies of treated water. Others also reported that they planned to take advantage of the presence of large numbers of people in the camps and temporary settlements to introduce household water treatment as part of an overall water/sanitation/hygiene program and ensure its proper use before people vacated these settings.

For these reasons, conclusions about the role that household-based water treatment and safe storage in the tsunami response may be premature. Such interventions have demonstrated their effectiveness in development settings, and it is possible that they will be an important part of the overall drinking water response in the medium- and long-term. We have therefore recommended that this specific issue be revisited 12 to 18 months following the tsunami to better assess the role of household-based water treatment.

4. Water Quantity and Quality.

The common dichotomy between water quantity and water quality was evident in the drinking water response. In part, this was due to the similarly common separation of responsibility: supplying minimum amounts of water was often the responsibility of one branch of government (e.g., Public Works, Water Board, etc.) while ensuring the quality of the water fell to another branch (e.g., Ministry of Health, Health Board, etc.). More likely, however, this reflects the actual differences in the demands of the affected population, the natural response of the first responders, and basic fact that providing water does not require unusual training or technology.

Initially, most responders emphasized water quantity, access and availability. For the most part, the evidence suggests that these efforts were successful. As can be expected in the early phases of a disaster response, there were camps and other settings with inadequate water. This was perhaps particularly true in those locations in which the wells or other sources were completely inoperable or in communities that traditionally had been water stressed. Those populations that could still obtain water from shallow wells, even though too saline to drink, were able to meet certain water needs from these sources. The almost immediate availability of tanks and tanker trucks was a key factor in satisfying water demand. Moreover, the government response in restoring, and in many cases, installing piped water and distribution points, also contributed significantly to the provision of adequate supplies of water.

Efforts to ensure the quality of the delivered water, on the other hand, were less successful. While some international NGOs brought and used portable water testing kits that assessed water for faecal contamination, most governmental and other agencies involved in the provision of drinking water were not regularly testing the microbial quality of the water whatsoever. In some instances, there was no clear allocation of responsibility for chlorinating the water. In most cases, however, it seems that authorities were too overwhelmed with the supply of water to focus much attention on its quality. While the WHO and others provided chloroscopes and pool testers to measure the residual levels of free chlorine in supplied water, those with access to these devices often did not know how or when to use them. Excess levels of chlorine in supplied water encouraged some people to revert to more risky alternative sources due to the unacceptable taste and smell. For the reasons discussed below, the fact that no serious outbreaks of waterborne diseases were reported from the affected areas should not lead to an inference that the drinking water quality was consistently sufficient.

It is possible that organizations emphasized water quantity over water quality. In fact, this is recommended under Sphere standards and other guidelines (Sphere, 2004; Davis & Lambert, 2002). In the present case, however, it is not clear that surveillance of water quality needed to be compromised to concentrate on water quantity. Governments often allocated this responsibility to different branches, and NGOs experienced in water and sanitation are organized to do both. If water quantity and water quality is a zero-sum game in an emergency such as this, however, the need to emphasize quantity may have important implications for household water treatment. First, the evidence supports the perhaps obvious point that in the absence of sufficient quantities of water, interventions to improve water quality are not effective (Clasen, 2005). Second, most approaches to household water treatment require some, and for certain technologies, considerable, programmatic support. This simply may not be practical in the initial phases of a disaster response when other higher priorities out-compete in the demand for time and resources.

5. Surveillance

5.1 Disease Surveillance

Disease surveillance was an important priority immediately following the disaster. In most regions, this was led by national ministries of health, with assistance from the WHO South-East Asia Region and certain relief agencies. Most countries had a reasonably well-established disease surveillance system in place which formed the basis for special measures in response to the tsunami. Medical and public health teams were dispatched to the camps to undertake disease surveillance. As the response developed, outbreak early warning systems were implemented in certain areas, and laboratories were organized and equipped to diagnose epidemic-prone diseases. In India, teams recruited from the hundreds of Ministry of Health and Family Welfare personnel throughout the country were assembled and each assigned to cover six or seven camps (Chatterjee, 2005). In Sri Lanka, disease surveillance was primarily handled by medical personnel working in camps and settlements. In Indonesia, on top of high losses of health staff and facilities the task was made more difficult due to lack of sufficient pre-tsunami capacity; no system for centralised data collection at the district or provincial level was previously in place meaning that there was only limited health statistics available.

While these efforts appeared to be adequate, there are some uncertainties about the adequacy of the disease surveillance and the lack of reported outbreaks. In Thailand, where one of the most well-developed public health infrastructures is in place, officials from the Ministry of Public Health reported significantly higher cases of acute diarrhoeal disease following December 26 in the six provinces affected by the disaster (CDC, 2005). By mid January, the annualized rate was 1.7 times that of the previous year. No similar increase in respiratory or febrile illness or wound infection was observed. A survey of 400 households in IDP settlements in Aceh found 25.3% (54 of 214) children under 5 years of age reported having diarrhoea during the two weeks prior to the interview, with 2.4% reporting an episode of bloody diarrhoea during this period (Handzel, 2005). In some instances, we observed that health workers from outside the area could not say with certainty what number of cases represented normal endemic levels of common diseases such as diarrhoea.

Three months after the disaster, however, status reports and end-of-mission summaries from emergency responders in the region agree that no serious outbreaks of infectious disease ever materialized. While cases of malaria, measles, watery diarrhoea and hepatitis were reported, the WHO and others concluded that there was no evidence that these were above normal background levels in countries in which these diseases are endemic. In respect of waterborne diseases such as cholera, shigellosis and dysentery, no serious outbreaks were reported (WHO, 2005a). In its 90-day report, the WHO observed that “millions of Tsunami (sic.) survivors throughout South Asia and East Africa have escaped the horrors of major epidemics of communicable diseases in the immediate aftermath of the disaster”, and credited this to “the resilience of the public health systems and response capabilities of the affected countries, the hard work by local communities as well as national and international support” (WHO, 2005a).

In fact, the increased occurrence of outbreaks of infectious diseases following natural disasters may be exaggerated. More than twenty years ago, Seaman and colleagues questioned this widespread belief, noting that it probably evolved from the historical association of war, famine and social upheavals with epidemics of smallpox, typhus, plague and dysentery (Seaman, 1984). Drawing on his experience at the US Centers for Diseases Control and Prevention as well as other research, Blake (1989) concluded in 1989 that during the previous 40 years, outbreaks of communicable diseases following natural disaster had been unusual. In a recent update of Blakes' work, a review of 38 natural disasters (including at least 10 floods) around the world between 1970 and 1992, only six were accompanied by outbreaks, and only two of those was a potentially waterborne agent (typhoid fever in Mauritius in 1980 following a cyclone, and diarrhoeal disease in the Sudan in 1988 following a flood) (Toole, 1997). The inevitability of epidemics following natural disasters is a myth.

These reviews notwithstanding, it is nevertheless important to continue efforts to minimise the risk of infectious diseases in the aftermath of a tsunami and to maintain good disease surveillance. First, while perhaps not meeting Blakes' definition of an outbreak, there is evidence of increased transmission of faecal-oral transmission of infectious diseases following a flood (WHO, 1998). Published studies have reported post-flood increases in cholera, cryptosporidiosis, non-specific diarrhoea, poliomyelitis, rotavirus, typhoid and paratyphoid, and a variety of vector-borne diseases (Ahern, 2005). Second, as noted above, there was evidence of increased levels of diarrhoeal disease in certain areas affected by the tsunami even though most reports concluded there was no outbreak. This may, in fact, be attributable to less than optimal surveillance or perhaps to the willingness of local health officials to tolerate some increase in incidence of disease without characterizing it officially as an outbreak. Finally, even if epidemics following floods have been largely averted in the past, it cannot be ruled out that this was the result of active steps in disease prevention such as the provision of safe drinking water.

5.2 Water Quality Surveillance

Water quality surveillance did not reach the same level of coverage. As noted elsewhere, government agencies responsible for water supply focused primarily on providing sufficient quantities of water, and only secondarily on water quality. NGOs reported that water quality surveillance was a problem before the tsunami. Ministries of Health in certain countries were able to mobilize surveillance teams to monitor water quality in some cases. Public Health Inspectors (PHIs) were sometimes used for this purpose, as were volunteers, including women's and youth groups. However, even when there were personnel to test water quality, they often depended on WHO or NGOs to provide them with even basic tools to assess residual chlorine levels; few had apparatus or know-how for testing physical parameters to ensure proper disinfection or microbiological and chemical contaminants that could present immediate or longer-term health hazards.

As a result of the limited surveillance, there is little data on the safety of the water provided to and consumed by the affected population. In Aceh, CARE coordinated a pilot survey of 48 households four weeks after the tsunami (Albert, 2005). Of these, 77% were using shallow wells as their primary source of drinking water, the others using tanks (10%), boreholes (8%) and streams (4%). 85% considered their water to be unsafe, and all reported boiling to make it safe for drinking, though not in every instance. Except for 2 of 3 tanks maintained by relief organizations, sources were all positive for *E. coli* , including shallow wells (median 450 CFU/100ml), boreholes (15 CFU/100ml) and streams (>2500 CFU/100ml). More troubling, however, was the finding that 67% of the 43 samples from water stored at the household were positive for *E. coli*, with 15% having counts >101 CFU/100ml (the WHO "high risk" level) and 22% between 11 and 100 ("intermediate risk"). The findings raised questions about the adequacy of the boiling approach being promoted in the region as an alternative to household chlorination, especially since the only samples free of the faecal indicator at source or household were those found to contain residual chlorine.

In February, CARE and the Provincial Health Office conducted a more extensive survey of 400 households from 51 IDP settlements in Aceh (Handzel, 2005). In these camps, most people relied on tankered water (61%), shallow wells (12.1%), boreholes (8.8%) or treatment units directly serving the camps (5.8%). Only 11.9% considered the quantity of water supplied to be inadequate. Water supplies under camp management were generally, though not universally, positive for residual chlorine (11 of 14 tanks, 3/5 piped supplies, 2/2 tanker trucks, 3/3 treatment plants). While only 1 of 11 tankers were positive for *E. coli*, boreholes (7/10) and especially hand dug wells were highly contaminated (10/10, with geometric mean of 216.8 CFU/100ml). The survey found that 97.7% of the householders reported collecting water from the camp-managed tanks and 99% reported using this water for drinking. Interestingly, of those who use the chlorinated water for drinking, 78% said they boil it first, perhaps due to lack of experience and/or trust of chlorinated water which was not the norm pre-tsunami. Despite these generally encouraging findings, however, 47.5% of the 400 water samples taken from water stored in the home for drinking were positive for *E. coli*, with 13.3% at the "high risk" level and 18.0% at "intermediate risk". In other areas, NGOs confirmed cases of significant under-dosing (no detectible residual chlorine) and over-dosing (up to 6 ppm) of chlorine. While inadequate disinfection of supplied water presents an obvious health risk, over-dosing is also problematic since it encourages people to consume water from untreated sources and form strong opinions against chlorinated water which may be difficult to reverse.

Under the co-ordination of UNICEF and with technical support from CDC, plans are under way in Aceh to involve more NGOs in an extension of the CARE surveys. This will involve water quality monitoring (at source and household level) and active diarrhoeal disease surveillance through household surveys in around fifty sentinel camps and temporary living centres (TLCs) around Banda Aceh and Aceh Basar; such a monitoring system is vital to gain a more accurate picture of living conditions and highlight areas for improvement in the response as it moves into the rehabilitation phase.

CONCLUSIONS AND RECOMMENDATIONS

1. Continue to take steps to minimize the risks of waterborne diseases following natural disasters.

Drinking water is cited as a health priority in most emergencies. Texts used to guide emergency response identify water as an immediate need of an affected population (Davis & Lambert, 2002; Médecins Sans Frontières, 1997; Adams, 1999; House & Reed, 2000; Eade & Williams, 1995; Sphere Project, 2004). As has been noted, however, the risk of outbreaks following natural disasters may be exaggerated. Blake noted that following a disaster, there is enormous pressure on political leaders and public health officials to take control, and that disease control interventions such as water received immediate attention because they were relatively easy to organize, highly visible and photogenic, and gave health authorities and the public a sense of accomplishment. Unfounded risk assessment can result in unwarranted allocation of resources and failure to attend to more pressing priorities.

At the same time, it is important not to become complacent from a lack of outbreaks of serious disease. As noted above, studies have shown increased transmission of faecal-oral diseases following floods and there was at least some evidence of increased incidence of diarrhoeal disease in the areas affected by the tsunami. Moreover, the infrequency of epidemics following natural disasters could in fact be attributable to the response that such events tend to mobilize. There are also circumstances that may have minimized the risk here. Those affected by the tsunami initially settled in relatively small camps and with host communities, reducing the overcrowding (and subsequent disease outbreaks) which have occurred in massive conflict-induced refugee camps. Saline water intrusion prevented the affected population in many areas from consuming water that may have been microbiologically unsafe. As the response moves into the rehabilitation and resettlement phases, governments are working to relocate people from tents to semi-permanent structures (in Indonesia, *baraks*) and eventually to rebuild homes. These population movements, as well as the normal increase in diarrhoea that accompanies the monsoons, could cause increased morbidity and mortality (Orellana, 2005).

2. Develop and disseminate practical solutions for the special circumstances associated with tsunamis, including saline water intrusion.

As has been previously discussed, the response to the tsunami raised unique challenges for those involved in the relief effort. This included the forcefulness and breadth of the devastation, the extent of the loss of life and property, and the time that would be necessary to recover. The vulnerability of these populations, their economic dependency on the sea, and the special characteristics of their dwellings, water supplies, sanitation facilities and hygiene practices, all created special circumstances that affect the drinking water response. Nevertheless, most disaster response guides do not address tsunamis at all, or treat them generally as floods (Duffy, 1990; French & Holt, 1989; Johns Hopkins/IFRC, undated). Many relief organizations acknowledged that they lacked experience and know-how in dealing with the hydrological and engineering issues associated with saline water infiltration. Some who had responded to floods in the area in the past admitted that some of their initial preparations were misguided. Rapid assessments did not always identify the special issues presented by the tsunami. Innovative solutions were often necessary to deal with the special circumstances presented.

A coordinated effort by international organizations, governments, donors and responders is necessary to document the emergency response to this tsunami and to distil the lessons learned. This should include the development of practical and scalable approaches to deal with common problems wrought by tsunamis, including the restoration of groundwater and soil affected by saline water intrusion.

3. Clarify the conditions under which proven approaches to household water treatment may be useful in emergencies, and assess their role in the medium- and long-term response.

Although the household-based approaches to water treatment have proven to be effective in development programmes and certain refugee settings, their utility in emergencies has not yet been widely demonstrated. Quite to the contrary, the evidence from the first three months following the Indian Ocean tsunami suggests that household water treatment may be inappropriate during the immediate phases of a disaster of this kind. Because of the scale of damage and numbers affected, other priorities such as ensuring access to a sufficient quantity of water, took precedent. Thus, despite large shipments of various household water treatment technologies, the evidence suggests that most have still not yet been distributed. While some relief organizations initially tried introducing such products, most concluded that they would be of more use once the displaced population began to settle permanently, either in their original community locations or the governmental temporary living centres (designed to last between 1-2 years), i.e. when people actually have 'households'.

It is important to note that household water treatment, like all other hardware, also requires appropriate software (i.e. promotion and training support) to be fully effective. Experience has shown that victims of a disaster may not be open to any new intervention offered to them with a promise of health improvement; they will still have preferences as under normal circumstances and if drinking water treatment is to be sustained into the future then methods must appeal to these preferences. If there are insufficient field staff in the initial emergency stages to carry out such training, it is perhaps preferable to delay the introduction of new point-of-use methods until it can be done more thoroughly with plans for sustainability, rather than risk detrimental effects (such as a decrease in established boiling practices).

When conditions and staffing are suitable for a household-based intervention, implementers should consider carefully the context and choose from among proven technologies. Among the factors to be considered include the following: (i) the extent and precise composition of the microbiological threat (e.g., most filters are not effective against viruses, and some encysted protozoa are resistant to chemical disinfection); (ii) physical water parameters (temperature, pH, turbidity, etc., that may affect performance); (iii) anticipated period during which the population will be using the intervention; (iv) extent and nature of the programmatic support necessary to introduce and ensure adoption of the intervention; (v) portability and transferability of the intervention to permanent location; and (vi) mechanisms for sustaining the intervention following the departure of the implementing organization (e.g., local availability of consumables, affordability, acceptability, etc.).

Finally, as noted above, there is evidence to suggest that household-based water treatment and safe storage may play a more important role in the affected area over the medium- and long-term. It is therefore recommended that this issue be revisited, perhaps 12-18 months following the tsunami, to better understand the actual significance of these interventions in the overall response.

4. Improve water quality and surveillance without compromising emphasis on water quantity.

Although quantity should continue to take precedence over quality in disaster response, governments and relief organizations should seek ways maximizing microbial water quality even in the initial stages of a disaster response. Experience from the Indian Ocean tsunami repeatedly showed instances of inadequate or excess chlorination, both of which can lead to health hazards. Drinking water surveillance plans have been developed for low-income settings (Bartram, 1990). Simple procedures and tools for treating water and monitoring its microbial quality must be devised and consistently implemented for emergency settings. For example, tanker operators should be trained in the chlorination process, including correct dosing and the methods for testing residual levels. Samples should be taken from each tanker at regular intervals throughout the day to test residual chlorine levels and water quality (chemical and microbiological) surveillance systems established as early in the response as possible. As is under development in Aceh, this could be incorporated into the regular camp visits of co-operating agencies and organisations with a central system for sample processing and data collection.

5. Take advantage of the enormous resources committed to the tsunami response to make effective and sustainable improvements in water, sanitation and hygiene in the affected areas.

The UN's Office for Coordination of Humanitarian Affairs (OCHA) have reported that committed humanitarian assistance to the Flash Appeal for tsunami-affected countries currently stands at US$2.73 billion with a further US$1.45 billion pledged but not committed (OCHA, 2005); this is in addition to further funds raised by individual organisations or campaigns. The World Bank has already committed loans of several billion dollars to help rebuild housing and infrastructure in countries affected by the disaster. With such widespread public, NGO and donor support, there is an unprecedented opportunity to improve standards of living and public health in the affected areas, rather than a matter of simply returning them to their status quo ante. Oxfam has dubbed the mission 'Reconstruction Plus'.

Many organisations still working in the affected regions are indeed working to take advantage of this opportunity. Governments in the affected nations are crafting master plans to establish and budget for priorities. These should include health-driven initiatives that are evidence-based and cost-effective. In the area of environmental health, these should include ensuring appropriate water and sanitation provision for newly built schools, updating municipal water supply and sewerage systems during their repair and rehabilitation, protecting open water sources (e.g. wells, springs), raising awareness through health promotion campaigns. In certain cases, household water treatment should be a priority given its proven effectiveness and cost effectiveness. The emergency should also be used as an opportunity to introduce integrated health and hygiene programs that can address not only water- and food-borne agents, but also other environmental hazards such as air quality and disease vectors. In each case, the interventions should be implemented in consultation with the communities to ensure that they are appropriate, acceptable and sustainable.

6. Document experiences from the tsunami response, distil the lessons learned, disseminate the results, and develop guidelines to inform future actions.

The forgoing summary may suggest an orderly response based on early, accurate and comprehensive assessments, supported by sufficient supplies of experienced personnel and appropriate equipment, and validated by timely and complete monitoring and evaluation of information that was widely disseminated to all stakeholders. In fact, responders reported that in many areas, the first three months were a nightmare of disorganization, with conflicting opinions, poor cooperation, major territoriality, organizational self-promotion, and irrational use of resources. There was frustration with the lack of early data collection or the failure to act on information that was collected. There was often a lack of consensus about the specific technologies or methods that should be deployed at various stages of the response. Accordingly, shipments of equipment and supplies were did not always correspond with the immediate priorities. While national governments were mainly driving the response, at times there was a lack of central command and control.

Although these shortcomings are common in large disaster responses, it may be possible to mitigate them to some extent by documenting experiences, distilling the lessons learned and disseminating the results. As with the Sphere Project, this could lead to improved guidelines to inform future actions on emergency response.

Finally, while this report focuses on issues relating to emergency response, it should be noted that mechanisms should be created to increase emergency preparedness. Addressing this aspect of the disaster management cycle would minimize substantively the costs of response and many lives would be saved.

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ANNEX 1

Action for Food Production (AFPRO)
AmeriCares
Apollo Hospitals
Aquaya/Brown University
Bless
BushProof
CARE
Catholic Relief Services (CSR)
CAWST
Centers for Disease Control and Prevention
Community and Water Environment Forum
DHAN Foundation
EAWAG
Evangelical Church of India
Helvetas Sri Lanka
Hindustan Lever Ltd.
Indian Ministry of Health and Family Welfare
International Committee for the Red Cross
International Federation of Red Cross & Red Crescent Societies (IFRC)
International Network to Promote Household Water Treatment and Safe Storage
IRC
Johns Hopkins University
LEAD
London School of Hygiene & Tropical Medicine
Lutheran World Service
Katadyn Products AG
Medentech Ltd.
Médicins Sans Frontières
National Water Supply & Drainage Board (Sri Lanka)
Oxfam GB
Procter & Gamble Company
Project Hope
PSI
Red Cross Sri Lanka
RedR
Tamil Nadu Water and Drainage Board (TWAD)
Samaritans Purse
Sri Lanka Ministry of Health
UNICEF
Yayasan Dian Desa
WaterAid
World Health Organization
World Vision