PRELIMINARY POST-TSUNAMI WATER QUALITY SURVEY IN PHANG-NGA PROVINCE, SOUTHERN THAILAND

Prapin Tharnpoophasiam[1], Usanee Suthisarnsuntorn[2], Suwalee Worakhunpiset[1], Prasasana Charoenjai[1], Witawat Tunyong[2], Suvannee Phrom-in[2] and Siriporn Chattanadee[2]

[1]Department of Social and Environmental Medicine, [2]Department of Microbiology and Immunology, Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand

Abstract. This preliminary water quality survey was performed eight weeks after the tsunami hit Phang-Nga Province on 26 December 2004. Water samples collected from the affected area, 10 km parallel to the seaside, were compared with water samples from the control area approximately 4 km from the seaside, which the tsunami waves could not reach. These samples included 18 surface-water samples, 37 well-water samples, and 8 drinking-water samples, which were examined for microbiology and physical-chemical properties. The microbiological examinations focused on enteric bacteria, which were isolated by culture method, while physical-chemical properties comprised on-site testing for pH, salinity, dissolved oxygen (DO), conductivity and total dissolved solids (TDS) by portable electrochemical meter (Sens Ion 156). The results of the microbiological examinations showed that water samples in the affected areas were more contaminated with enteric bacteria than the control area: 45.4% of surface-water samples in the affected area, and 40.0% in the control; 19.0% of well-water samples in the affected area, and 7.7% in the control. All eight drinking-water samples were clear of enteric bacteria. Tests for physical-chemical properties showed that the salinity, pH, conductivity, and TDS of surface-water samples from the affected area were significantly higher than the control. The salinity, conductivity, and TDS of the well-water samples from the affected areas were also significantly greater than those from the control area. The surface and well water in the tsunami-affected area have been changed greatly and need improvement.

INTRODUCTION

Tsunamigenic earthquakes, rated at 9.0 on the Richter Scale, off the coast of northern Sumatra on 26 December 2004, triggered one of the worst human disasters in recent history. It has been calculated that a total of 41,509 km^2 of land were destroyed in seven affected countries (JRCEC, 2006), with more than 184,168 deaths, 125,000 injuries, and 45,752 people missing (Wikipedia, 2006). In Thailand, six provinces were impacted, causing 5,354 deaths and 8,457 injuries. Only Phang-Nga Province suffered major damage to its infrastructure, land and human lives, with 4,202 people killed, 5,597 injured, and 1,792 missing (WHO/SEARO, 2005). The number of displaced people as a result of the tsunami, over 25,000, was massive; and many more people had to relocate because of the disaster. A significant number (3,263 cases) of communicable diseases, such as diarrhea, respiratory, dengue, and melioidosis was reported post-tsunami (WHO/SEARO, 2005). The Ministry of Public Health Thailand reported a significant increase in the number of psychological problems, with people suffering anxiety and stress. The tsunami brought a range of problems, including high salinity levels in surface- and well-water (Columbia University, 2005).

The availability of water is a critical environmental issue in the affected areas of the six provinces. The principal water resources in the south are shallow wells and man-made ponds after ore mining. Water demands can be categorized into four major types: household consumption, tourism, agriculture, and industry.

The tsunami created a surge of ocean water able to engulf large geographic areas. As the ocean water came ashore, drinking water wells were submerged and potentially contaminated with microorganisms (bacteria, viruses, parasites) and chemicals that could adversely affect human health. The sea salts associated with saltwater flooding of coastal drinking water supplies were an immediate health threat.

Now, water in the affected areas is not appropriate for consumption or supply. The Faculty of Tropical Medicine, Mahidol University performed a preliminary survey of water sampled from the reservoirs and shallow wells in Takua Pa District, Phang-Nga Province, which were analyzed for physical properties, including pH, conductivity, salinity, total dissolved solids, and dissolved oxygen. The preliminary results showed that the conductivity and salinity of water contaminated with seawater had increased greatly

Correspondence: Prapin Tharnpoophasiam, Department of Social and Environmental Medicine, Faculty of Tropical Medicine, Mahidol University, 420/6 Ratchawithi Road, Bangkok 10400, Thailand.
Tel: +66(0)2354-9100 ext 1562-3; Fax: +66(0)2354-9167

(data not shown). Water in shallow wells had turned brackish and the quality had degraded, they found the malaria vector, *Anopheles sandaicus* to be widespread (Apiwathnasorn *et al*, 2005). So, monitoring is necessary for planning to improve water quality. In addition, chemical contaminants found in floodwaters had contaminated wells easily, including fuel products from overturned fuel tanks and pesticides stored in the flooded areas (CDC, 2006).

Because of the unpleasant taste of saltwater, most people will not ingest (swallow) enough to cause immediate health problems. However, disease-causing microorganisms spread by the flood do not normally produce a strong taste, but if such water is ingested, even in small amounts, it may cause immediate, life-threatening health problems, such as acute diarrhea, cholera, and serious infections. Using contaminated water to clean small cuts and open wounds also poses danger of serious infection.

After the tsunami, people in Takua Pa District should have listened for public announcements on the safety of the water supply. Flooded private and public wells needed to be tested and disinfected after the flood waters receded. The purposes of this study were to perform chemical and biological analyses of drinking and usable water from the affected areas. The potabilization method was under preparation by installation of a reverse osmosis machine in Baan Nam Khem, Takua Pa District.

MATERIALS AND METHODS

Study area

The site of water sample collection was Takua Pa District, Phang-Nga Province, located on the west side of southern Thailand. Phang-Nga Province is on the Andaman coast and is one of the six provinces affected by the tsunami on December 26, 2004; Takua Pa District in Phang-Nga Province was one of the areas most affected by the tsunami. Water samples were collected in 4 villages; Baan Nam Khem, Baan Bang Khaya, Baan Khuek Khak, and Baan Bang Niang.

Water sample collection and handling

In this study survey, water samples included surface water, well water, and drinking water.

Each water sample was collected in a 125-ml sterile-glass bottle for microbiological analysis, and a separate 100 ml clean plastic bottle for analysis of physical-chemical properties. For microbiological examination, water samples were collected manually following the standard method (APHA, 1998) and kept in an icebox during transport to the laboratory in Bangkok. After arrival, they were refrigerated overnight and analyzed the next day until all of the samples had been completely tested. The physical-chemical property analyses of the water samples were conducted on-site.

Water quality analysis

Surface water, well water and drinking water were examined for microbiological agents. Only surface water and well water were analyzed for physical-chemical properties.

Microbiological examination. Microbiological examinations were conducted according to the standard methods (APHA, 1998), membrane-filter or spread-plate methods if dilution was needed and then after the incubation period, bacterial colonies were identified.

Physical-chemical properties analysis. The pH, salinity, dissolved oxygen, conductivity and total dissolved solids of water were analyzed by portable electrochemical meter (Sens Ion 156: Hach, USA). Calibrations of parameters were performed before working in the fields, except for pH which was calibrated every time before sample analysis.

Statistical analysis

SPSS version 10.0 for Windows was used to test differences among the medians of water quality, particularly the Mann-Whitney *U* test.

RESULTS

Water samples were collected from two zones; the affected area and the non-affected or control area. The affected area was where pools of seawater and puddles were created by the penetration of the giant tsunami waves. Land, surface water, and houses were flooded with seawater and puddles. Most of the shallow wells in this area had been cleaned and chlorinated once or twice within the first month post-tsunami. The water supply and drinking water were provided by the municipality for people in the shelters for use and consumption.

Water samples were collected on the eighth week post-tsunami, comprising 18 surface water samples from canals and man-made ponds after ore mining; 37 well-water samples from shallow wells, and 8 samples were commercial bottled-drinking water or drinking water provided by the municipality, carried by trucks.

Microbiological examination

The total 58 water samples were collected for

microbiological examination; surface water--16 samples, well water--34 samples and drinking water--8 samples.

For surface water in the control area, coliform bacteria (*Enterobacter cloacae*) were found in one sample and other bacteria (*Aeromonas hydrophila* and *Plesiomonas* spp) that cause diarrhea were found. In the affected area, coliform bacteria were found in three samples (two samples of *E. cloacae* and one sample of *E. agglomerans*), and a bacterium causing diarrhea (*A. sobria*) was found in three samples. For well water, coliform bacteria (*E. cloacae*) were found in one sample from the control area. In the affected area, coliform bacteria (*E. cloacae* and *Klebsiella pneumoniae*) were found in two samples, a bacterium causing diarrhea (*A. hydrophila*) was found in two samples, and a bacterium causing food poisoning and dermatitis (*Staphylococcus* coagulase-positive) was found in one sample. No enteric bacteria were recovered from drinking water from the affected or control areas (Table 1).

Physical-chemical properties

The physical-chemical property results of the water quality survey are shown in Table 2. From the statistical analysis, the medians of salinity, pH, conductivity, and total dissolved solids in the surface water samples from the affected area were significantly different from the control, at $p < 0.01$. In well water, the medians for salinity, conductivity, and total dissolved solids from the affected area were significantly greater than the control area, at $p < 0.01$.

DISCUSSION

The extent of environmental disturbance caused by the tsunami's deep penetration into the coastline is evident from the post-tsunami reports (Ramanamurthy *et al*, 2005). Pools of seawater and puddles due to the tsunami increased the brackish level of the surface water and the water supply in shallow wells. The results of microbiological examinations showed that samples from surface and well water in the affected area were contaminated with coliform bacteria, which indicated that the water was more contaminated with feces and potential enteric pathogens that can cause diarrhea than the control area, while drinking water samples collected from the control area were safe.

The results of the water quality survey for physical-chemical properties indicated that surface and well waters in the affected area were contaminated with seawater and puddles because of increased salinity, conductivity, and total dissolved solids, although the survey was performed in the eighth week post-tsunami. The results of this survey revealed that the concentration of total dissolved solids of 7 from 22

Table 1
Microbiological examination of water samples.

Type of water sample	No. of samples examined	Samples found with enteric bacteria (%)	Type of pathogenic bacteria (no. of samples)
Surface water			
Affected area	11	5 (45.4)	*Aeromonas sobria* (3) *Enterobacter agglomerans* (1) *Enterobacter cloacae* (1)
Control area	5	2 (40.0)	*Plesiomonas* spp and *Aeromonas sobria* (1) *Enterobacter cloacae* (1)
Well water			
Affected area	21[a]	4 (19.0)	*Aeromonas hydrophila* (2) *Enterobacter cloacae* (1) *Klebsiella pneumoniae* (1)
Control area	13	1 (7.7)	*Enterobacter cloacae* (1)
Drinking water			
Affected area	2	0 (0)	-
Control area	6	0 (0)	-

[a] One water-supply sample was *Staphylococcus* coagulase-positive.

Table 2
Physical-chemical properties of water samples (median and range).

Water quality parameters	Surface water (n = 18)		Well water (n = 37)	
	Affected area (n = 12)	Control area (n = 6)	Affected area (n = 22)	Control area (n = 15)
Salinity (ppt)				
Median	6.45 [a]	0.00	0.15 [a]	0.00
Range	(0.00-30.20)	(0.00-0.04)	(0.00-4.50)	(0.00-0.00)
pH				
Median	7.61 [a]	6.56	6.01	5.43
Range	(6.40-8.80)	(4.80-6.70)	(4.30-7.40)	(4.70-6.40)
Conductivity (μS/cm)				
Median	11435.00 [a]	45.97	450.00 [a]	84.10
Range	(92.20-46,600.00)	(40.20-326.00)	(98.20-8,220.00)	(41.50-237.00)
TDS (mg/l)				
Median	5715.00 [a]	23.00	225.00 [a]	42.00
Range	(46.10-23,300.00)	(20.10-162.90)	(48.40-4,110.00)	(20.70-118.60)
DO (mg/l)				
Median	6.36	6.61	4.83	5.76
Range	(1.37-9.59)	(3.78-6.82)	(1.20-10.69)	(2.40-10.25)

[a] Statistically significant difference at p<0.0; ppt = part per thousand; μS/cm = micro-siemens per centimeter

well water samples in the affected area were > 1,000 mg/l, which is the regulatory level for a water supply (Notification of the Ministry of Industry, 1994). Dissolved oxygen levels in 4 of 12 surface water samples in the affected area were < 6 mg/l, which is recommended for surface water (Notification of the Ministry of Industry, 1994). The values for these parameters were slightly better than those found in a survey in the first month post-tsunami (Aiumsiri, 2005). The physical-chemical parameters of shallow well waters in this study had improved over the former survey; salinity reduced from 5-6 ppt to 0.0-4.5 ppt, conductivity reduced from 7,000-43,000 μS/cm to 98.2-8,220.0 μS/cm, and dissolved oxygen increased from 0.7-1.9 to 1.2-10.69 mg/l.

This preliminary water quality survey, eight weeks post-tsunami in Ta Kua Pa District, Phang-Nga Province, indicated that the surface and well waters in the affected areas were still brackish and contaminated by seawater and puddles. They were not appropriate for consumption and the water quality of these water sources must be improved.

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REFERENCES

Aiumsiri O. Environmental impact assessment of the tsunami in Thailand. Nakhon Pathom: Petchrung Karnpim, 2005.

American Public Health Association (APHA). Standard methods for the examination of water and wastewater. 20th ed. Washington, DC: American Public Health Association, 1998.

Apiwathanasorn C, Samung Y, Prummongkol S, *et al*. Impact of Tsunami on occurrence of mosquito vectors in the affected areas of Phang Nga province [Abstract]. Bangkok: The Joint International Tropical Medicine Meeting, 30 November-2 December 2005.

Centers for Disease Control and Prevention (CDC). Tsunami: Water quality. [Cited 2006 May 8]. Available from: URL:http://www.bt.cdc.gov/disasters/tsunamis/waterquality.asp

European Commission Joint Research Council (JRCEC). South Asia earthquake and potential land affected in tsunami inundation zone. [Cited 2006 May 8]. Available from: URL:http://www.ird-dc.org/assets/applets/Asia#tsunami#07January#landcover.pdf

Columbia University. Indian Ocean tsunami reports from the field -- Part 4. [Cited 2006 May 8]. Available from: URL: http://www.earthinstitute.columbia.edu/news/2005/report3_fellowstsunami05.html

Notification of the Ministry of Industry, Thailand. No. 8, B.E. 2537 (1994), issued under the Ground Water Act B.E. 2535 (1992). *Roy Govern* 1994 Feb 94; 111 (Part 16).

Ramanamurthy MV, Sundaramoorthy S, Pari Y, *et al*. Inundation of sea water in Andaman and Nicobar Islands and part of Tamil Nadu coast during 2004 Sumatra tsunami. *Curr Sci* 2005;88:1736-40.

Wikipedia. 2004 Indian Ocean earthquake. [Cited 2006 Aug 23]. Available from: URL:http://en.wikipedia.org/wiki/2004_indian_Ocean_earthquake

World Health Organization Regional Office for South-East Asia (WHO/SEARO). Emergency preparedness and response: South-East Asia earthquake and tsunami: Thailand tsunami situation report. [Cited 2005 Jan 25]. Available from: URL: http://w3.whosea.org/EN/Section23/Section1108/Section1835/Section1851/Section1870_8589.htm