Water Quality Assessment and Treatment in a Developing Community: Tangkae, East Timor

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Abstract

In conjunction with water supply and sanitation studies, this study entails a detailed assessment of current water sources for the village of Tangkae, Dili District, East Timor. Focusing on water usages and the quality of water sources, cultural perspectives of water are also taken into consideration. With a population of two hundred and sixty four people the water sources used to supply the village with water for drinking, cooking, washing and cleaning are of difficult and distant access. Preliminary investigations and analysis indicate these water sources are microbiologically contaminated and highly turbid. To ensure sustainable solutions are implemented a multiple barrier approach is recommended, consisting of protection of the water source, appropriate level of treatment, safe water storage and sound hygiene and sanitation practices. A principal component of this project is building relations, exchanging information and endeavouring to empower various stakeholder parties to improve the opportunities available to them. The investigations from this study will provide recommendations for the community in question to use as a guide for implementation of improved water supply and treatment systems.

1.0 Introduction

Water is essential to sustain life and to reducing poverty (World Health Organisation, 2004). According to the United Nations, over 1.1 billion people lack access to safe drinking water and 2.4 billion to improved sanitation, of which nearly two thirds live in Asia (World Health Organisation, 2006). As a result of inadequate access to safe drinking water over 10,000 people die each day from avoidable water-related diseases (AusAID, 2003).

East Timor, officially the Democratic Republic of East Timor, became the 191st United Nations member state on 27 September 2002 (Department of Foreign Affairs and Trade, 2005). East Timor is found on the island of Timor, belonging to the driest and least developed parts of the Indonesian archipelago (Hiorth, 1985). The soft, scaly clay overlaid with limestone offers little support for heavy vegetation or the intense monsoonal rains that the country experiences for several months of the year. The lengthy dry season results in the clays drying out, leaving little sustainenance for surviving vegetation and a severe lack in water sources for many communities.

The presence of both the Portuguese and Indonesians has shaped the development situation that it is today. Fragmented political representation, the presence of a spiritual authority and a largely multilingual population suggests that the nation's development requires comprehensive cultural understanding, as well as consideration of the population's diversity and the present situation. Examining the current capacity of the population helps build a basis for the development of this capacity.

With the lowest per capita GDP in Asia (most of the population are living on less than US$2 per day), the National Development Plan of East Timor identifies poverty reduction and governance as pressing priorities. Long-term development plans with the aid of international assistance aim to increase the annual GDP growth rate and reduce the number of people living below the poverty line. The availability of plentiful and safe water for domestic use and adequate sanitation have long been known to be fundamental to the development process (Gadgil, 1998) and promote the reduction of poverty.

Engineers Without Borders (EWB) works in partnership with developing communities to achieve environmentally sustainable, socially responsible and economically viable solutions within the context of their engineering problems. This dissertation contributes to the EWB *Water and Sanitation East Timor Student Program,* in conjunction with *Sanitation and Waste Disposal* by Phoebe Mack and *Community Water Supply* by Vaughn Grey. This project team extended to include six engineering student volunteers from the National University of East Timor or Nacional Universidade de Timor-Leste (UNTL). The investigations of the projects focused on the water and sanitation situation of a small village, Tangkae, in rural East Timor.

1.1 The Effects of Unsafe Water Supply

The lack of access to safe water and adequate sanitation is at the core of the main symptoms and causes of world poverty, reinforcing the cycle of poverty and incapacity that keeps people trapped and slows the development of societies. Inadequate access to safe water can cause people's health to suffer, especially children (Figure 1), ranging from reduced growth and life expectancy to critical bouts of diseases, often leading to death (Mathew, 2005). WHO (2006) estimates that 88% of diarrhoeal disease is attributed to unsafe water supply, inadequate sanitation and poor hygiene, resulting in the deaths of more than 2 million people every year.

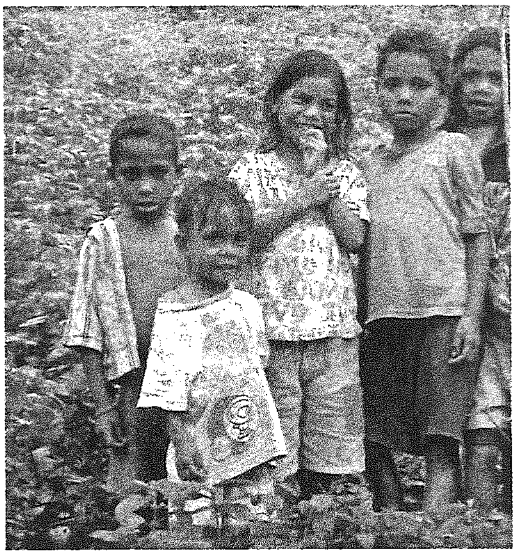

Figure 1. East Timorese children show signs of reduced growth and malnutrition. (Photo by Phoebe Mack).

The time taken to collect water, being sick or looking after those who are sick puts a huge drain on family resources. Children could spend the time attending school; and parents could be spending more time with their families or being more economically productive. Dignity robbed and pain caused by lack of adequate and private sanitation can lead to poor self-esteem, especially for women (Mathew, 2005). These effects can trap people in a cycle of poverty from which can be difficult to escape.

1.2 Water Quality

The focus of this paper is on drinking water, or potable water, which is defined as having acceptable quality in terms of its physical, chemical, bacteriological and acceptability parameters, so that it can be safely used for drinking and cooking (WHO, 2004b). WHO defines drinking water to be safe as long as it does not cause any significant health risks over a lifetime of consumption, and an effort should be made to maintain drinking-water quality at the highest possible level. Other uses of water for practices such as irrigation and sanitation also play significant roles in the cycle of improving the community's water and sanitation situation. These uses will be investigated on a second priority to domestic water uses.

Different developing countries maintain different guidelines for what constitutes safe drinking water. The approach adopted by the national guidelines involves reducing potential contamination of a water source through effective protection structures and storage systems. This approach is limited by several constraints considered by the guidelines, including the lack of funding and human resource capacity for water quality testing and monitoring programmes, and operation and maintenance of treatment processes to improve drinking water quality. To ensure water is free from toxic chemicals and pipe corrosion the guidelines suggest that local knowledge is the best indicator of either of these parameters being present in the water source. This dissertation examines the situation in terms of an engineering approach whilst also taking local knowledge and physical characteristics into consideration.

Microbial hazards are the primary concern and the greatest microbial risks are associated with water contaminated with human or animal faeces, a source of pathogenic bacteria, viruses, protozoa and Helminths (WHO, 2004b). The diseases they cause vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, cholera or typhoid fever (NHMRC & NRMMC, 2004). Over 3 million people die every year from diarrheal and malarial diseases of whom 90% are children under 5 and are mostly in developing countries (WHO, 2004a). Testing the concentration of various bacterial contaminants in water can be simplified by utilising the presence of an indicator organism, such as *Escherichia coli*. The presence of *E.coli* provides conclusive evidence of recent faecal contamination and should not be present in drinking-water (WHO, 2004b).

Health concerns associated with chemical constituents of drinking-water arise primarily after prolonged periods of exposure. Single contact with most chemical constituents will not result in any adverse health effects unless through a massive contamination of a drinking-water supply, at which the water usually becomes undrinkable due to unacceptable taste, odour and appearance (WHO, 2004b). Microbiological quality of water is given priority over the chemical quality unless the chemical contaminants are more harmful to human health than the risk from microbial contamination.

Consumer perceptions and aesthetic criteria require consideration when assessing drinking-water supplies and developing management guidelines (WHO, 2004b). Turbidity adversely affects the efficiency of disinfection and is also measured to determine what type and level of treatment is needed. Turbidity in drinking water can be caused by particulate matter present in source water, resuspension of sediment in the distribution system or the presence of inorganic particulate matter in some groundwaters (WHO, 2004b). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2004b).

1.3 Contamination of Water and Water Treatment Processes

In the absence of direct contamination, groundwater from deep and confined aquifers is usually microbially safe and chemically stable; however, shallow or unconfined aquifers can be subject to contamination from discharges and seepages associated with on-site sanitation and sewerage (eg. pathogens and nitrates), agricultural practices (eg. pathogens, nitrates and pesticides) and industrial wastes (WHO, 2004b).

Due to topographic and groundwater records being non-existent or destroyed during Indonesian conflict, determining the surface water and groundwater characteristics with topographic data is being investigated. This aims to determine how the anthropogenic activities can contaminate the water sources and impact the environment without the use of costly drilling and pump tests. Topography based hydrological models such as TOPMODEL have been developed to model these relationships and will be examined as part of this dissertation.

Management strategies need to be developed to ensure sustainable solutions are implemented for community water systems. It is recommended to employ multiple barriers for the protection and treatment of community water sources as briefly outlined in Table 1. The first of these barriers between contaminants and the water source includes good sanitation and waste disposal practices (Gadgil, 1998). Protecting the water source from faecal contamination is a priority. Secondary barriers include appropriate settling, filtration and disinfection processes. The resulting reduced turbidity post filtration generally enhances the effectiveness of disinfection methods. Post-treatment systems, such as safe storage of water, and continuing hygiene and sanitation practices, also play a key role in avoiding recontamination of water.

Table 1. Various barriers available for protection and treatment of community water sources.

Barrier to Contamination	Description	Benefits of Barrier
Pre-Treatment:		
Protection of water source	Fence off water source; discourage upstream activities	Reduces contamination & treatment requirements.
Hygiene	Wash hands, cover food, keep animals away from food etc	Break the transmission route for pathogens
Sanitation	Use of a latrine that contains & decomposes excreta & wastes	Disease prevention & stopping the spread of pathogens from faeces to humans
Treatment methods:		
Sedimentation - Storing & Settling - Coagulation & Flocculation	 - stand water overnight - additives (eg. alum or dried beans) help particles merge & settle	Removes large particles and attached bacteria
Filtration - Straining - Slowsand filter - Cermaic filter	 - run water through a cloth - run water through layers of sand and gravel eg. Biosand filter - contaminants trapped in ceramic pores	Eliminate sediments, pathogens & other impurities. Can be made of local materials. Easy to operate & maintain.
Disinfection - Boiling & Pasteurisation - SODIS - Chlorine	Destroys organism cell walls by oxidation - Boil water -1min@100°C, 6min @70°C - leave in sunlight for 6 hrs - add bleach or sodium hypochlorite or salt	Temperature, UV-A light & chlorine induced chemical reactions destroys pathogenic bacteria and viruses
Post Treatment:		
Safe Water Storage	Use of a clean, disinfected &enclosed container with spigot	Avoids recontamination from hands etc

1.4 Integrated Project

The importance of an integrated approach is to ensure that the recommended solutions to be presented to the community will be of long term sustainable benefit to the community. The investigations and research conducted here are linked with the EWB *Water Supply* and *Sanitation and Waste Disposal*. Combining these individual projects completes the community water cycle, and aims to produce solutions that apply to the use, supply, management and disposal of water in the village.

The three water and sanitation EWB projects will produce a set of recommendations which will incorporate an engineering perspective with social, economic and environmental concerns. Some of the social and physical characteristics of the community include: cultural perceptions regarding water supply sources; understanding of the hydrologic cycle; ability of the community to assist with labour hours during project implementation; local climatic conditions; understanding of hygiene and sanitation practices; and topographical factors. Investigation of appropriate technology and techniques takes these factors into account to ensure the best solution for this village.

These recommendations will then be presented to the community to assist their decision-making process regarding their water and sanitation situation. This will provide the community with information that would have been unavailable to them without the assistance of the EWB project team, UNTL counterparts and the local government and non-government organisations. Presenting these solutions with education tools means the community will then be armed to make decisions based on more knowledge and information than they may have been able to previously. This will also ensure long standing operation and maintenance of any system implemented.

2.0 Methods

2.1 Field Trip

The first field trip in February for three weeks was to scope out the project details and initiate in-country contacts with various government departments, university institutions, local non-government organisations and previously established aid organisations. With assistance from the UNTL students, the project team conducted physical and social surveys in the community to determine the current situation in terms of water supply, health issues, sanitation and hygiene practices.

During the surveys of the village, water samples were also taken to test the quality of the water from each of the three water source sites in the community. The samples were taken to the government water testing laboratory to test for the presence of microbial, physical and chemical parameters. Pictures in Figure 2 show the author taking the water samples from the village's spring using plastic water bottles, and testing the parameters in the Department of Water and Sanitation (DNAS) Water Laboratory.

The lack of scientific records available from the Indonesian era meant it difficult to obtain hydrogeological and climatic data. With the assistance of an expert geophysicist a digital elevation map (DEM) was put together with a GIS map to look at topographical characteristics of the area. Further studies are being conducted to determine a relationship of the groundwater flows with the topography. This will assist investigations of contaminant transport in relation to the water sources.

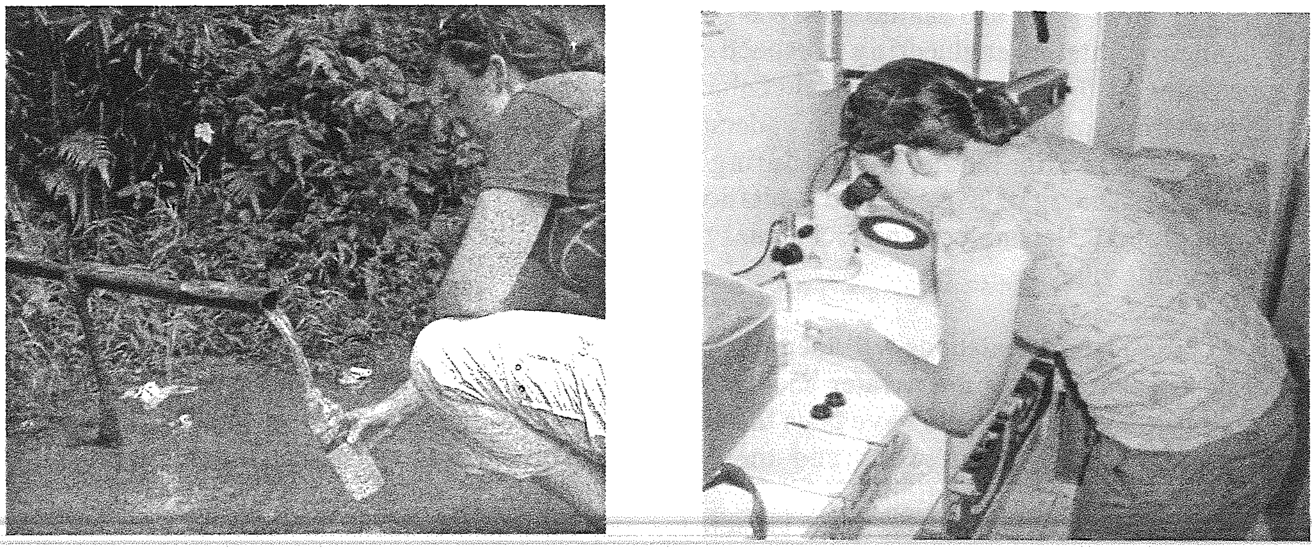

Figure 2. (a) Taking water samples from *Laratema* spring. (b) Counting *E.coli* under the micrscope in the DNAS Water Laboratory, Dili. (Photos by Phoebe Mack)

2.2 Capacity Development and Stakeholder Participation

Capacity development is considered an important tool in achieving sustainable solutions. It can be generally defined as 'the process by which individuals, organisations, institutions and societies develop abilities (individually and collectively) to perform functions, solve problems and set and achieve objectives' (UNDP, 1997). The economic, social and environmental situation varies for each developing community and understanding the current capacity of the community and stakeholders is essential to ensuring the implementation of sustainable solutions in terms of meeting basic human needs. Identifying these stakeholders was undertaken and relationships between them identified for various interests. An example of stakeholder interactions for a particular set of interests is illustrated in Figure 3, demonstrating that there are many complex relationships and interactions between stakeholders that require careful consideration for the development of the community's current capacity.

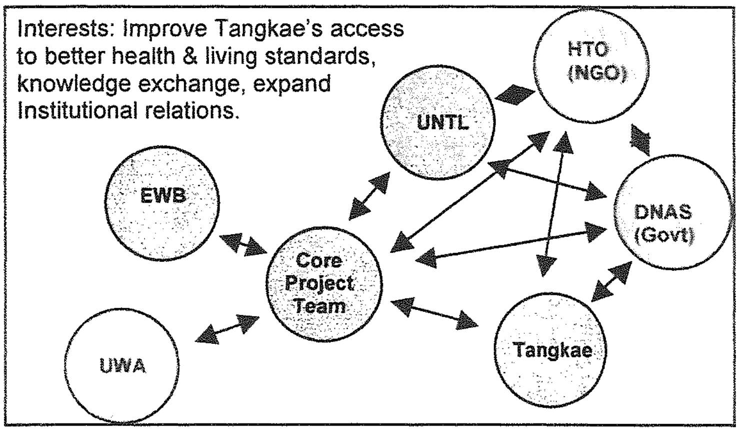

Figure 3. Stakeholder identification and analysis relevant to project interests.

3.0 Results

3.1 Tangkae Community Survey Results

The local community of Tangkae was registered on the government's priority listing requiring assistance in the fields of health, water supply, sanitation and infrastructure. The results of preliminary social and topographical surveys are outlined in Table 2.

Table 2. Survey results for Tangkae village 20.02.06.

Location	20km south of Dili, (45 minute drive on sealed, windy roads)
Elevation	750m about sea level
Population	264 people (57 households)
Water sources: 2 springs, 1 well	Laratema - about 300m downhill via a rugged steep and slippery path. Mainly used water source. Fatnamudu ~ 3km through dense vegetation, damaged pipe system. Airabat ~ 2km on outskirts of village boundaries.
Water collection	Carry 5L or 10L containers, approx. 20-50 per household/day (Dry season = long waiting times)
Water culture	Boil water before use (due to intuition about germs & bacteria), wash food with spring water before eating.
Sanitation	3 x western style non-flush latrines linked to cement pit each 2m deep x 1m width, no base. Generally, hole in pig pen (not enough water to wash waste away therefore left for pigs to consume)
Solid waste	Discarded anywhere on ground or in river
Health/ Illnesses	Coughing, fever, headaches, running nose, diarrhoea and worms, particularly in the children, who are sick all the time.
Mortality rates	In the last 5 years approximately 5 babies in the village died.

The preliminary water quality tests concluded a definite presence of microbial contaminating bacteria. Table 3 illustrates the significant counts of Total Coliform and *E. coli* in two of the three water sources. Turbidity levels were high in one of the springs, *Fatnamudu,* and of concern in another, *Laratema.* Corrosion controlling parameters such as pH and calcium hardness are found to be within WHO standards.

Table 3. Water Quality results tested 20.02.06, Tangkae. (NS = No Set Standard)

	Tangkae Water Sources			
Parameter tested	**Laratema**	**Airabat**	**Fatnamudu**	**WHO standards**
Physical:				
pH	6.9	6.0	6.8	6.5 – 8.5
E. Conductivity	108.1	50.9	109.9	NS
TDS	54.0	25.4	54.9	1000 mg/L
Turbidity	0.9	4.6	10.1	5 NTU
Microbial:				
Total Coliform	826	494	1172	0
E.Coli	2	0	64	0
Chemical:				
Hardness	50	65	90	200 mg/L
Total alkalinity	70	70	75	NS

4.0 Conclusion

The preliminary water quality results indicate that further investigations are required in order to establish a more accurate water and sanitation profile for Tangkae. A primary step is to examine potential contamination sources and methods to minimise the risk of contamination. If high turbidity levels remain, sedimentation and filtration steps may be required prior to disinfection treatment processes. Further testing will also involve examining the effects of the water quality on piped systems and storage tanks, particularly corrosive properties. Additional investigations will enable a better selection of barriers to be implemented for safe drinking water purposes.

Water and Sanitation are the fundamental building blocks for basic human needs to be met. The integrated approach conducted with the EWB *Community Water Supply* and *Sanitation and Waste Disposal* projects, together with hygiene education tools and community consultation processes, will ensure lasting solutions are established to improve the community's access to safe water. Careful consideration and participation of stakeholders in these processes will increase the capacity of the local community and project team to improve the quality of life of Tangkae community.

For the solutions to be effective, consideration of relevant local conditions (including economic, environmental, social and cultural conditions) and financial, technical and institutional resources is required. Future implementation will be provided with a detailed investigation of various water and sanitation solutions that are economically, environmentally and socially feasible and applicable for the community of Tangkae.

5.0 References

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