WATER FILTRATION

TIMOR-LESTE

Report Prepared by

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EXECUTIVE SUMMARY

Engineers Without Borders (EWB) is working with Plan Timor-Leste (Plan TL) to develop innovative and appropriate project solutions to contribute to the sustainable development of communities in the Lautem district, Timor Leste. There are seven design areas of which water supply, sanitation and hygiene was the one chosen for this report which addresses the issue of clean drinking water utilising ceramic filtration units that can be integrated into schools, community centres and individual homes.

The aim of this project was to find a water filtration and storage solution that would reduce microbial contamination and vector breading grounds therefore reducing the risks of contracting related diseases. It was noted however, that significant reduction in these diseases, implementing sanitisation systems and education on hygiene combined with safe drinking water, would have the greatest impact on improving health. Due to the scale of the issue, this report will assess options, make a recommendation and suggest implementation strategies of the filtration of drinking water.

By researching and gaining an understanding of the current situation a selection criteria to assess water filtration options was selected and prioritised. Utilising a weighted analysis the option of a ceramic filtration unit was recommended. The selection criteria included; ease of use, efficiency, cost, environmental impact and benefit to local industry.

The key attributes of a ceramic filtration unit are:

- Easy to use, clean and maintain
- Faster than boiling water with availability of safe drinking water at any time
- Cheaper than purchasing water
- No energy used to filter water only in the creation of the units, reduction in the use of plastic containers
- Potential to become a local industry but most of all skills and knowledge can be passed into other facets of life

Through the feasibility review environmental, cultural and social considerations were addressed. Environmentally this project will reduce the use of plastic containers therefore reduce waste. Culturally this project utilises skills and knowledge from the countries cultural practice of ceramics. This is important for the implementation process as the concept of ceramics is already present within the culture. Socially this project can become a local industry which will introduce new skills but also has the potential for generating wealth through sales of the filtration units to surrounding villages and maintenance of them.

Selecting an option that will suit the needs of the people is extremely important. However implementing the idea is just as important for the success of the project. Previous water filtration methods had been introduced but not sustained, it was suggested to be the result of a failed implementation process. This project addresses such issues and identifies options that could aid in the implementation. Predominantly giving information introducing new methods of information transfer, generating performance, aiding in problem solving, providing social support, providing access and a means to materials and promoting through media are the main techniques to implement this concept. The report will detail options for each of these in greater detail.

ACKNOWLEDGMENTS

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CONTENTS

TABLES

FIGURES

1 INTRODUCTION

1.1 Background

This report has been compiled by first year undergraduates in a Bachelor of Engineering (Honours) in Civil Engineering at Southern Cross University, Lismore, NSW. It is in response to a project designed by Engineers Without Borders (EWB) to design solutions to identified problems within a small town Codo in the Lautem district of Timor-Leste. Of the identified areas this project addresses Design Area 2, Water, Sanitation and Hygiene with a particular focus on household water filtration.

Clean water is a necessity. Access to safe drinking water in developing countries is limited and determined by many factors including location, resources, infrastructure, logistics, culture, skills, knowledge, hygiene and economy. The largest impact of unsafe drinking water is on health through water borne diseases. Statistics indicate that many child deaths in developing countries are caused by bacterial and protozoal diarrhoea from unsafe drinking water and unsafe water storage (CIA World Factbook, 2012).

There are many options available for viable water filtration however these are limited in developing countries due to constraints inherent to disadvantaged communities. Factors such as resources, technology, cost, skills and education need to be carefully considered when suggesting suitable options for water filtration to ensure the community's needs are adequately addressed (Barke & O'Hare, 1984). This report outlines a number of options for household water filtration in Codo the most viable is identified through a selection criteria process.

Currently water is sourced from natural springs up the mountain behind the village. The water is piped down the hill to several stands throughout the village (Figure 1). The water quality is relatively high with low level calcium carbonate contamination. Community members collect water from the tap stand in plastic containers and carry it return home for household use. Microbial contamination occurs from unclean storage containers and transportation from the spring to the village through the pipes. As a result of this contamination it is common practice to boil the water before drinking or purchase bottled water as it is easier and faster (Engineers Without Borders, 2013).

Figure 1: One of the four tap stands located in Codo.

(source: www.ewb.org.au)

The villagers would like to secure their water source and gain a filtration system that is cost effective, easy to use and maintain. To ensure a high take up education and training needs to be provided around the use and maintenance of the filtration system. As an added benefit if the units can be constructed locally, skills and revenue may be generated providing greater benefits to the village.

Recommendations have been made that best suit Codo and the Timor-Leste Governments wishes in reconstructing the country, its cultural heritage and rebuilding capacity. Implementation strategies suggested for the people to enhance their living standards are best suited based on the knowledge and information gained through the research undertaken.

1.2 Aims

The aim of this project is to provide water filtration recommendations that will:

- Address issues affecting water quality within the Codo village as identified by Engineers Without Borders (EWB) via household water filtration.
- Meet the WHO international standard for drinking water (World Health Organisation, 2008).
- Reduce current environmental impacts associated with attaining clean drinking water.
- Add economic benefit to the village.
- Create awareness on hygienic practices concerning water consumption.
- Be economic, easy to use and maintain.
- Consider the community, cultural practices, sustainability, feasibility and logistics to ensure successful adoption by the community.
- Recommend an implementation approach that will best suit the community.

1.3 Scope

Due to the remote location and inaccessibility to the client, educated assumptions were made when assessing the need for a water filtration unit. The educated assumptions were based on documented previous experience from other organisations that have implemented similar projects and not having access to the country and community.

As part of the implementation process and introduction of the concept we assumed the water committee would be able to travel to nearby towns to view the filtration unit working and see an example of a factory. It is understood that this may be difficult due to the condition of the local roads and cost involved however it is assumed that this is possible through government grants.

Families typically consist of 4 to 8 per household; therefore the water filtration units need to produce enough water to meet the needs of each household. The World Health Organisation (2003) makes a number of recommendations on water intake required depending on the person’s age, height, weight, location (climate) and task being carried out. These recommendations vary greatly depending on the situation however for the purpose of this project the assumption will be made that each person on average will need 2-3 litres of water per day. Therefore the unit recommended will need to create approximately 8 to 24 litres of drinking water per day.

It is assumed that clay is an available resource for Codo. Based on the fact that the Timor-Leste has a tradition of ceramics and Manatuto a town 125km away has a ceramic water filter factory in operation and there is an extensive list of the geology and mineral resources of Timor-Leste in which bentonite clay is confirmed to be found in the region (United Nations, 2013).

The clay filters consist of a mixture of clay and a porous organic substrate that is able to be burnt away during the firing process. As Codo is a town involved with agriculture it is assumed that a suitable substrate can be sourced and could include coffee grounds, grain husks or even coco nut husks. As a result of the unknown substrate to include in ceramic filters it is difficult to identify the possible water filtration rate. Therefore the assumption of 1-3 litres per hour is assumed to be achievable.

1.4 Outline

This report will outline the stages of addressing the need for water filtration in Codo, Timor-Leste. This will be completed through the identification of current issues, evaluating options and giving a solution to implementing a concept.

The project brief in section two will review background information to aid in identifying current issues, constraints and stakeholders that will need to be considered when researching water filtration options. A selection criteria will be developed that will be used to identify suitable water filtration options and aid in the analysis of the options to produce a recommendation.

The background information states the local area, its population, climate and environment. Current issues including infrastructure, water use, health, logistics, culture, skills and knowledge will be reviewed to create a foundation for identification of selection criteria. The constraints relating to environment, sustainability and cost along with stakeholders is discussed and also contributes to the selection criteria which includes ease of use, efficiency, cost and environmental impact.

Different water filtration or purification options including ceramic, slow sand, chemical, bio filters and precipitation are reviewed. Each option is assessed using the selection criteria and a weighted analysis conducted from which a recommendation of a ceramic water filtration unit is made.

Section three reviews the feasibility of the ceramic water filtration option and provides greater detail to the description of the concept, possible construction methods, cost analysis, identified environmental and cultural considerations.

Section four offers ideas on the implementation of the concept suggesting staging options, addressing education, maintenance, sustainability and identifying possible risks. Based on the reviewed issues within the report identification of a suitable process and its implementation are addressed to ensure the project is effective.

Section five concludes the report summarising the key points on the recommendation of a ceramic water filtration unit.

2 PROJECT BRIEF

2.1 Background and Preliminaries

2.1.1 Area / Town

Codo is within the Lautém district of Timor-Leste. Lautém is located in the north east of the island and Codo is situated part way up a mountain towards the western border of Lautém. Currently Lautém's economy is self-supported with most women and children in the district dependant on agriculture and with just under half the population below the age of 18, the people dependent on agriculture make up a significant portion of the population (Engineers Without Borders, 2013).

Lautém is the only sub-district to have abundant food stocks due to its distinctive climate but, also reports food shortage for large parts of the year.

There is a strong sense of community in Codo. The village is fairly isolated with the nearest town, Lospalos, being a two hour drive on broken roads. Most terrain is only suitable for four wheel drive vehicles making Codo difficult to transport food and goods (J. Turner, personal communication, March 13, 2013). Like most villages in Timor-Leste, Codo has a village leader, Chefe De Aldbia (Chefe) who is an active member of the community. The village has communal areas such as four tap stands and communal washing areas. Figure 2 shows a map of Timor-Leste highlighting Codo.

Figure 2: Position of Codo in Timor-Leste.

2.1.2 Population

The total population of Timor-Leste in the 2010 census was 1,066,582 (Government of Timor-Leste, n.d.) and the Lautém District had 57,453 inhabitants during the 2004 census (Government of Timor-

Leste, n.d.). Codo, being a small village has a population of 463 (J. Turner, personal communication, March 13, 2013) with an even distribution of males and females and like much of the country, a large portion of the population is under 19.

2.1.3 Climate and Environment

Due to Timor-Leste being between the Tropic of Capricorn and the equator, the climate in the country is tropical with heavy tropical rains. The climate of Timor-Leste can be broken up into three distinct seasons, wet season, dry season and the build-up season that acts as a transition between the wet and dry seasons (Engineers Without Borders, 2013).The wet season usually starts during December/January and lasts for two to three months where large scale flooding and subsequent lands slides occur cutting off roads and interfering with water supplies (Engineers Without Borders, 2013). As well as the flooding, the long wet season creates cloud cover for a large part of the year, drastically impacting the ability to produce crops. Timor-Leste's mountain ranges influence the rainfall patterns where more rain falls on the mountains than on the coasts (Engineers Without Borders, 2013) as Codo is located on a mountain this increased rainfall makes the town more susceptible to the harsh conditions of the wet season.

Timor-Leste's landscape is largely made up of mountain ranges that divide the north and south coasts and an abundance of trees such as Teak, Coconut, Eucalyptus and Sandal (Government of Timor-Leste, n.d.). Significant amounts of Timor-Leste's environment has been devastated by colonisation, Indonesian occupation (Engineers Without Borders, 2013) and over logging, however much of the environment still has vegetation. Figure 3 shows the terrain of the town and surrounding hillsides where buffalo owned by the villagers live.

Figure 3: A street in Codo and grazing land where the villager's buffalo graze.

(source: www.ewb.org.au)

2.2 Current Issues

2.2.1 Infrastructure

Currently there is a pipe running from a spring at the top of the hill to the village which is a twenty minute walk. The bamboo piping delivers water into four tap stands located at various locations in the village. The quality of the water as it comes from the spring is clean however, microbial bacteria grows in the pipe that feed the outlets from the water source and in the storage containers that are used to transport and store water (personal communication, Turner, March 13, 2013). In 2012 this infrastructure was in jeopardy of being disrupted by the monsoon weather systems as the ground that supports the piping is eroding. There is the possibility that the water source will be disrupted in the future (Engineers Without Borders, 2013).

Houses are made from a wide variety of materials (Figure 4). The 'traditional' homes are constructed out of stones and bamboo and use earthen materials for floors. In recent times there has been a shift towards metal and concrete homes as they are more durable and able to withstand the conditions of Timor-Leste. Kitchens are often separate to the living quarters (Figure 5). All buildings and other infrastructure such as furniture and irrigation systems are constructed by villagers.

Figure 4: Common home construction in Codo.
(source: www.ewb.org.au)

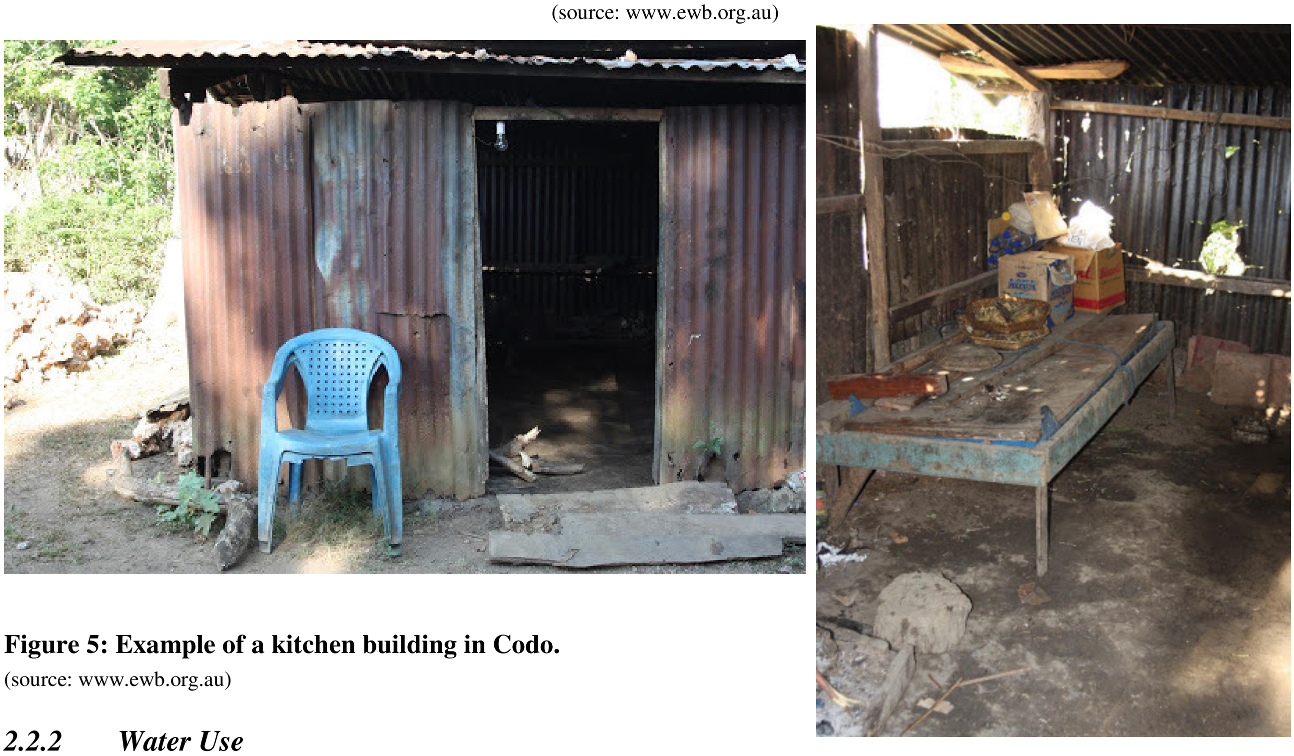

Figure 5: Example of a kitchen building in Codo.
(source: www.ewb.org.au)

2.2.2 Water Use

Water is used at a household level for drinking, washing, cooking and cleaning (J. Turner, personal communication, March 13, 2013). Currently households either boil or buy drinking and cooking water.

This report focuses on drinking and cooking water only and it is assumed that 2-3 litres per person per household is an adequate allowance for that.

Consideration needs be taken with respect to the containers that are used to transport and store household water. The current plastic containers (J. Turner, personal communication, March 13, 2013) need to be evaluated to make sure they have narrow openings for water incoming and outgoing to protect the water during transport and are completely covered in storage to protect from microbial contamination (Sobsey, 2002). An example of the current plastic containers used is shown in Figure 6.

Figure 6: Plastic containers used to transport water in Codo. Note the interaction between containers with water for human consumption with animals.

(source: www.ewb.org.au)

2.2.3 Health

Predominantly, the major diseases present in Timor-Leste are bacterial and protozoal diarrhoea from consumption of contaminated water, mosquito transferred malaria (parasite) and dengue fever (virus) (CIA World Factbook, 2012). As many diseases are spread in the same way, human contact, food, water, vector borne and animal interaction (World Nomads, 2012) controlling some aspects of how these are spread will reduce the likelihood of other diseases such as tuberculosis, typhoid and hepatitis. Figure 6 displays current interaction between humans and animals. Pathogens are often ingested due to poor hygiene; they are transferred using humans as breading grounds (Figure 7). Breaking this cycle will reduce the effects of these diseases. Education on preventing this interaction will aid in reducing contamination of water carting facilities. The impact of these diseases is compounded by the shortage of medical facilities, skilled health care workers and lack of transport (Merri Community Health Services, 2013).

Many studies have been conducted looking at quality hygienic water sourcing and sanitisation and the link between diseases in particular diarrhoea. It has been noted that to significantly reduce instances of diarrhoea a dual approach to improve drinking water and personal hygiene needs to be conducted (WHO, 2003).

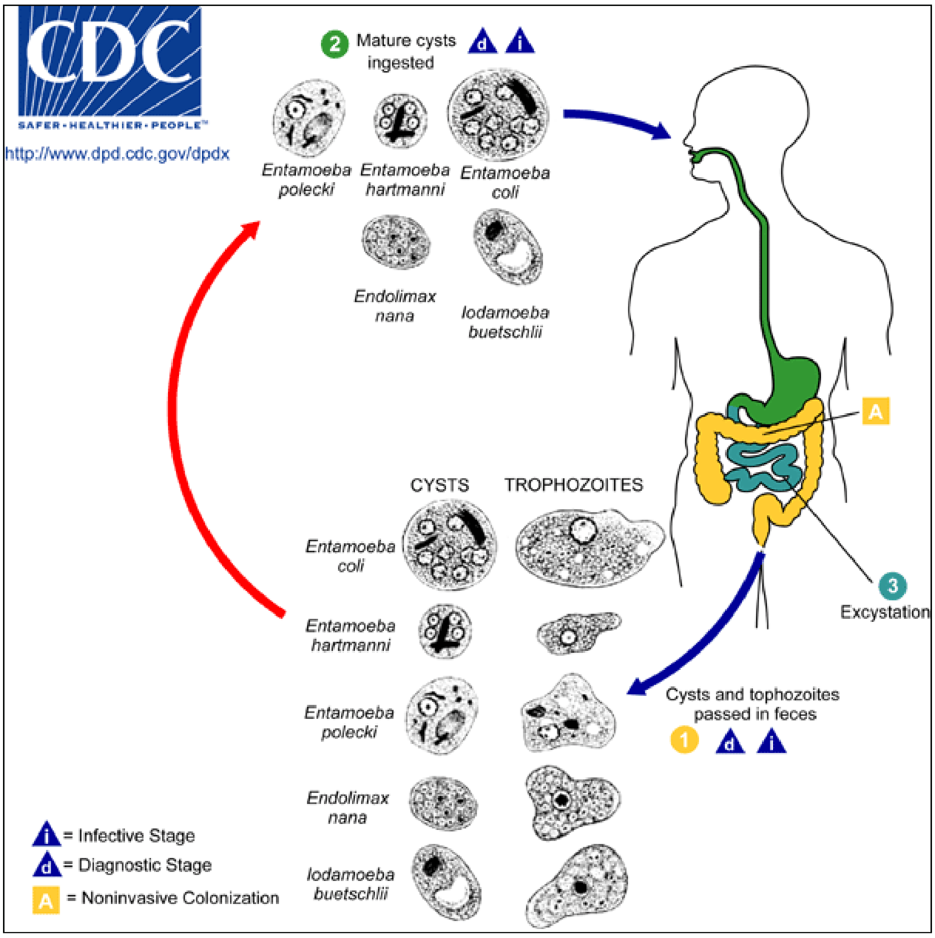

Figure 7: Diagram displaying the life cycle of intestinal amebae. Many common diseases in third world countries follow this infection process.

(source: http://factsanddetails.com/world.php?itemid=1197)

Mortality rates due to diarrhoeal diseases can be hard to determine as often diarrhoea will occur in conjunction with many other diseases. It is a high cause of death in developing countries for the 0-4 age group and accounts for 15.7 deaths for every 100,000 people in Timor-Leste (World Health Rankings, 2011). This rating is high in comparison to diarrhoeal disease deaths in the rest of the world. Malaria and dengue fever are also prevalent in Codo with regular outbreaks and are transferred between humans by mosquitoes. A number of ways to prevent the spread of these diseases through the eradication of mosquitoes can occur including spraying pesticides, using nets, screens and protective clothing to avoid human contact and medication however these methods are not suitable to Codo due to the living conditions and resources. Reducing still water is something that can be addressed and will reduce breeding grounds for mosquitoes and in turn reduces mosquito numbers (SEED Science, 2013).

Any improvement on water use and storage will help improve hygiene and health in Codo, Timor-Leste and other developing countries. Having this impact on health will help improve each person's ability to help them by reducing sickness, which affects education and contributes to poverty (The Water Project, 2013).

2.2.4 Logistics

Transporting items needed for construction and implementation will be restricted by the fact that transport is expensive and the roads quite rough and filled with large potholes and are subject to flooding in the wet season. Petrol costs $1.30 per litre and most village people live on $2 per day or less (Engineers Without Borders, 2013). The nearest large town, Lospalos, is two hours' drive away by

4WD or motorbike only and is not an industrial town so it is unlikely to be able to provide a wide variety of resources if needed (J. Turner, personal communication, 13 March, 2013). The recommendations made will reflect this possible difficulty. Figure 8 shows a cart that is used to transport water; this demonstrates the primitive nature of the transport available. Generally villagers primarily use horses or walk long distances to get around, with only some having access to motorised transportation methods (Engineers Without Borders, 2013).

Figure 8: A cart used to transport water throughout the village.

(source: www.ewb.org.au)

2.2.5 Culture

The culture of a nation is defined by the heritage, rituals, traditions and beliefs generated and practiced overtime through societal values. To win the support and respect of the local people towards the construction and creation of this project, knowledge and understanding of their cultural values is needed.

Timor-Leste has varying districts where certain aspects of cultural and societal values differ between each group and community. The population around Codo consists of the Fatalaku community who speak a Papuan based Fatalaku language (Engineers Without Borders, 2013). Their cultural society is governed by a hierarchy known as Ratu which consists of three inherited classes. The highest class is given the term Ratu and includes the most proliferate of Lautem groups; these groups hold the most power over decision making. The Paca class represents the smaller subordinate clan category, while the third and lower caste is known as Akanu and consists of members who derived from ancestors who were war captives, slaves or disgraced in some way (Engineers Without Borders, 2013). Although in more recent times the relevance of this hierarchy has deteriorated the persistence of these cultural categories continue to influence their everyday life.

All Timorese share a powerful connection between individuals, communities, the environment, history and cultural traditions. Due to this the Timorese share a common set of beliefs and values in regards to sacred sites. With over 70% of the population of Timor-Leste living in rural areas they have developed a strong connection to the natural environment and landscape with natural sites such as the water source for Codo being sacred (Engineers Without Borders, 2013). Despite being relatively isolated, with limited means of communication to the outside world, creative aspects of their cultural diversity have been maintained with the role of traditional arts such as tais weaving, ceramics and wood carving being considered important among many rural communities (Engineers Without Borders, 2013). As well as this there has been a strong tradition of poetry within the country.

After the Japanese occupation during World War 2 and the Indonesian rule from 1975 to 1999 the people of Timor-Leste have generated superstitious beliefs. Timorese are superstitious with houses and buildings. It is believed to be bad luck to burn or destroy existing structures as a result they do not demolish any structures (N. Chesworth, personal communication, February 27, 2013). Due to these superstitions Timorese would rather restore a ruined house than see it taken down.

In more modern times the country developing new cultural practices as they reinforce the idea of an independent nation. The majority of the population's religious beliefs are catholic influencing their opinions and practices (J. Turner, personal communication, March 13, 2013). The nation's government has been highly active in promoting a sense of nationalism throughout the country, protecting culture and guiding it as a form of national identity. The government has been implementing this idea by imbedding aspects of cultural value into their economic development (Engineers Without Borders, 2013).

The people of Timor-Leste hold cultural traditions and values in high regard, considering it a fundamental feature of national identity. For this project to succeed it is imperative that these cultural beliefs values and traditions are taken into serious consideration, responding to both the societal and creative aspects of Timor-Leste.

2.2.6 Skills and Knowledge

As a developing country Timor-Leste has limited technical skills and knowledge base however the people are willing to learn new concepts and there is a large labour force. (N. Chesworth, personal communication, February 27, 2013). It is important to have a holistic approach when introducing people to new technology, concepts or items that will improve their well-being. If the information is not delivered in a way that can be understood the concept will not be used (J. Turner, personal communication, March 13, 2013). Barke and O'Hare (1984) state that the best way to help a developing country is to empower the people by developing their knowledge and skills so they can change their own conditions. The greatest impact in changing behaviour is to utilise a number of techniques which would include information, performance, problem solving, social support, materials and media (Briscoe and Aboud, 2012). If this transfer of knowledge and resources occurs the people will accept the concept as there would be numerous health and financial benefits to the village and country. An appropriate option for water filtration will therefore be simple, easy to use and maintain and add value by using local products and labour.

2.3 Constraints

2.3.1 Environment

The environment of Timor-Leste has already been greatly damaged over the past few decades. Conflict and civil unrest due to foreign occupancy and deforestation through continued logging have had a significant impact (Engineers Without Borders, n.d.). In rural communities the current practices regarding the disposal of waste, including plastic and human waste, involves dumping it into the nearby environment or gathering the rubbish and burning it (Engineers Without Borders, n.d.). Currently in rural areas of Timor-Leste, recycling is not practiced and most of their goods come in single serve packages (Engineers Without Borders, n.d.), this has lead to an increased volume of waste being disposed of in environmentally harmful ways.

Currently the main means of obtaining safe consumable water involve either boiling water to purify it or the simpler and the more increasingly widespread option to just buy bottled water (Engineers Without Borders, n.d.). These practices are having further negative effects on the environment creating excess rubbish and the inefficient use of burning wood to make energy and boil water. As a result, the need for a simple, easy to use, effective and environmentally friendly method of water filtration is essential.

2.3.2 Sustainability

An education program for the community to increase buy in and uptake of the filters and develop their understanding and knowledge of the reasons behind water filtration is important for sustainability of any introduction of new technology that will require behaviour change. Codo has had previous interaction with household water filtration methods particularly sand filtration which was deemed too slow and was discontinued. This experience developed the view that all water filtration is slow and they now prefer buying or boiling water (J. Turner, personal communication, March 13, 2013). For the sustainability of this project the education program will need to directly address this view.

Implementation and sustainability of introduced changes to behaviour are best maintained if the community themselves take control and see it as value adding for themselves (Shen, L. Tam, V. Tam, L. & Ji, Y, 2009). Consideration is given to local construction and maintenance of the filtration method that best suits the community of Codo with the recommendation of creating a business or industry for the town. This will be a chance to empower the town's people in their own development of health and wellbeing and reduce reliance on outside bodies for this assistance which will increase the possibility for sustainability and ongoing life of the design.

2.3.3 Cost

One of the major constraints when considering projects in developing countries is cost. Due to the economic position of Codo, it is important to provide a solution that is effective but affordable. 77% of the people in Timor-Leste are currently living off approximately $2 a day or less (United Nations Development Programme, 2013). Consumables such as washing powder are purchased in single serve packages (Engineers Without Borders, 2013) and could be considered expensive when related to the other living expenses. When purchasing bottles of water they are paying around 33c per litre which is expensive for people who live on $2 or less a day, so any filtration method selected must be cheaper and easier or they will be reluctant to change that practice.

2.4 Stakeholders

Any recommendation made in attempt to solve the issues idntified will have an impact, positive or negative, on certain groups of people. For this project the most important stakeholders are the people of Codo who will have access to clean, safe drinking water. Other stakeholders are the people who currently make a living selling bottled drinking water as they can potentially lose business. However to minimise negative effects there is potential for the creation a business with production and maintenance of HWF which could develop into a more productive and widespread business involving more of the community.

2.5 Water Filtration Options

2.5.1 Background and Constraints

The water filtration unit will need to address microbial contamination and secure storage to prevent vector breading grounds. Each of the options researched will be assessed on:

- Ease of use
- Efficiency
- Cost
- Environmental impact
- Benefit to local industry

The selection criteria will be weighted based on the requirements of the village with relation to their water source. Quality of water after filtration is the main aim for the process, selection of the best process will be completed by rating the identified criteria for each of the filtration options. The level from most important to least will be ease of use, efficiency, cost, environmental impact and benefit to local industry. Any other significant advantages or disadvantages relating specifically to each option will also be considered and weighted.

2.5.2 Option 1 – Ceramic Filters

Ceramic water filtration has been used extensively in developing countries as an effective, low cost method of keeping water safe from microbial contamination. Since 2001 Cambodia, for example has established production of ceramic water filters on a large scale and has had successful results in reducing bacteria's and other related water borne issues that are detrimental to health (Brown & Sobeys, 2007). Ceramic clay filters up to 99% Escherichia coli, protozoan bacteria's and particles via gravity filtration. To make the filter effective in long term bacterial prevention, they can be treated with a coating of colloidal silver (Potters for Peace, 2013).

Flow rates are usually 1-3 litres per hour which is relatively quick and addresses previous problems that were due to slow filtration. The holding receptacle holds 20-30 litres of water and the top filter holds 6-8 litres. The water containers used to get water from the tap stands to the homes are 5-10 litres and the households make several trips a day to this water source. Therefore the holding capacity is sufficient for their daily practice and the program will not need to create changes in this part of their daily habits.

Evapotranspiration cools the water and if a good storage receptacle is used the water can be safely stored. It is important to keep the temperature of drinking water down not only for the pleasure of drinking cool water in hot weather but also to minimise bacterial growth that favours warmer temperatures. Using a sealed storage container also helps to keep mosquito larva from breeding reducing the spread of malaria.

There is no taste associated with the ceramic water filtering unlike some chlorine based treatment processes. Ceramic filters are easy to use and require no external energy source. The filters range between US $5-$25 per filter (Brown & Sobeys, 2007). A concept of the filter and storage container is portrayed in Figure 9.

It is possible to make the filters locally as has been done in many third world areas. This project recommends collaboration with Potters for Peace a group who assist set up of factories. Timor-Leste has suitable clay available to make this a viable option (Carvalho & Lisboa, 2005). Table 1 summarises the attributes of the ceramic filter against the selection criteria.

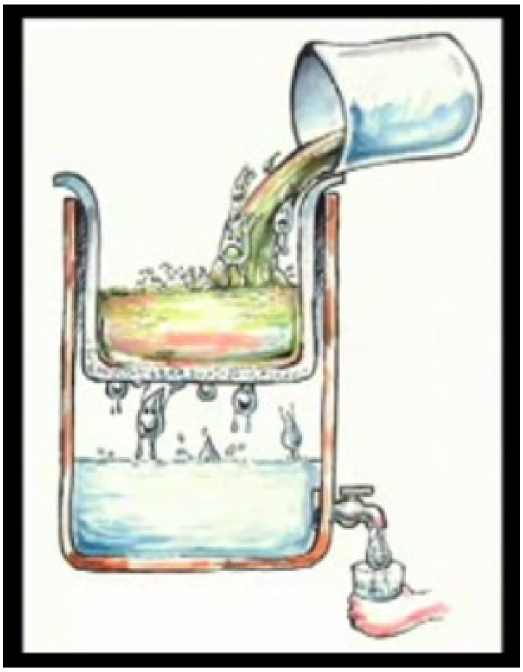

Figure 9: Cross cut of a ceramic water filtration unit displaying the filter and water storage vessel.

(source: www.wateraid.org/news/photography)

Table 1: Ceramic water filtration unit assessment.

Description	Water is put into a double bucket ceramic receptacle. Water passes through into a holding bucket filtering microbes and sediment. There is a tap in the bottom for ease of use.
Cost	US$10 - US$25 per permanent filtering system SU$2-$5 per renewed filter 0.03c per litre water - med to low set up - low maintenance.
Ease of use	Simple to use
Efficiency	98% removal of microbial contamination
Local industry	Initial purchase from nearby town, local industry can be created.
Environmental impacts	No harmful by-product waste
Advantages	Cheap, no electricity needed for household, health benefits maximised by being a household treatment system
Disadvantages	Possible breakages.

2.5.3 Option 2 – Slow Sand

Sand filtration has been tested comprehensively finding that it is a viable method of filtering water in developing countries, effectively removing 96% bacteria, 71% of viruses, and 89% turbidity (Jenkinsa, Tiwarib, & Darbya, 2011). It was found that construction methods suited developing countries, for example using one layer of river sand, locally supplied and processed from a river as opposed to the recommended 2 layers of manufactured sand produced equivalent results in the process (Jenkinsa *et al*. 2011).

Sand size is the most important factor in the filtering process according to Jenkinsa *et al.* (2011). It is recommended to have a procedure in place to monitor this part of the process to ensure that the quality required is achieved on all mechanisms. Reducing the sand size indicates a more efficient filtering process for bacteria, but does not have a consistent effect on virus filtration (Jenkinsa *et al*. 2011).The length of time water takes to get through the sand filter does affect the filtering process. The longer water takes to go through, the more efficient the filtration.

Table 2 shows the list of sand filter attributes against the selection criteria. Figure 10 demonstrates the process of a typical sand filter.

Sand filtration would not be such a good method for Codo as they have already had experience with this kind of process. The end resulted with the villagers no longer using the filters because the process was too slow. The fact that the method had been introduced previously could also impact the view of the village people to utilise this method again.

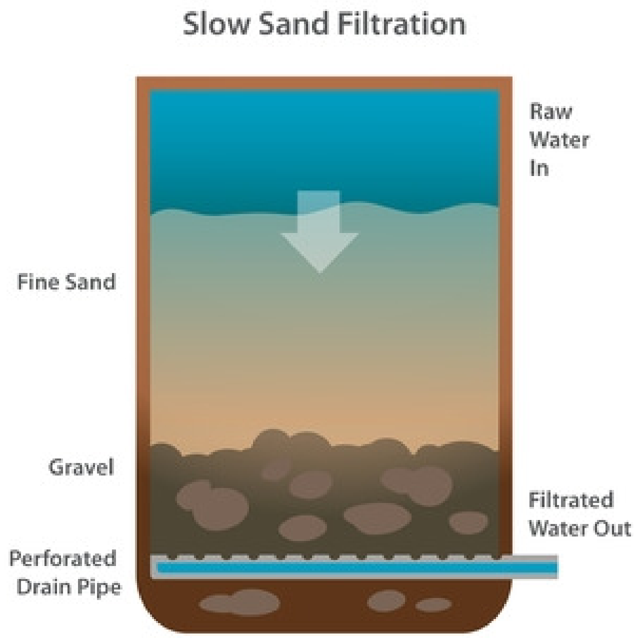

Figure 10: Concept of a sand filter.

(source: www.water-filtration-thi.blogspot.com)

Table 2: Slow sand filters addressing selection criteria.

Description	Water is sent through clean sand to remove sediment and most harmful organisms. From there the water is sent through very thoroughly washed sand to filter out smaller organisms and ultimately completely clean the water.
Cost	Medium initial cost Low maintenance cost
Ease of Use	Simple to operate Materials fairly easy to obtain Requires little maintenance
Efficiency	Up to 98-99% removal of harmful bacteria and viruses (The household slow sand filter, 2005)
Local Industry	Sand and container materials need to be purchased from outside Codo
Environmental Impacts	Produce no harmful by-products
Advantages	No electricity, chemicals or replaceable parts required
Disadvantages	Requires frequent cleaning

2.5.4 Option 3 – Chemical

There are a number of chemical treatments that can be used to purify water for human consumption, many of which have been practiced since ancient times (World Health Organisation, 2013_2). The condition of the original water source will influence which chemical filtration option is best suited. More often chemical treatment of water does not remove contaminants alone but will kill pathogens and microbes in the water. Some chemical treatments require a second process to complete the removal contaminants from the water (World Health Organisation, 2013_2). Due to the Comparison of a range of chemical water purification processes are displayed in Table 3.

Table 3: Lists different chemical processes for water purification focussing on the selection criteria.

	Coagulants	Absorbents	Ion Exchange	Disinfectants
Common types	Various salts of aluminium, iron, lime, inorganic or organic chemicals	Clays, charcoal, activated charcoal, crushed organic matter seeds, rice etc.	Exchange resins	Chlorine, chloramines, ozone, chlorine dioxide, acids
Cost	Moderate to High	Low to Moderate	High	Low to High
Ease of Use	Skills required, some options need specialised equipment	Skills required	Skills and resources required.	Varies, some skills required for simple options. More technical skills required for complex options.
Efficiency	Good, typically used on community water, not household use	Often poor microbe absorption, charcoal good to remove taste and smell	May not inactivate microbes.	Easy to use, effective against most pathogens
Local Industry	No	Charcoal generation could be an option	No, technology too complex.	Education and training options
Environmental Impact		Vegetation needed to make charcoal, agriculture needed for organic options. Correct clay needs to be available.	Spent resin replacement and disposal required.	Stable residue
Advantages	Simple technology	Charcoal often readily available	Easy to use	Chlorine and electro-chemically generated oxidant from NaCl are cheap and easy to use option. Other options can become expensive with specialist skills and equipment required.
Disadvantages	Some chemicals hard to come by, training and equipment needed for maximum optimisation	Poor microbe absorption, training and equipment needed for maximum optimisation	Does not inactivate microbes. Risk of some products leaching into water. Often not available in some parts of the world.	May not be available worldwide. Change in taste and odour can occur and be unpleasant.

Coagulation-flocculation is a process where particles including microbes are atomically destabilised making them connect with other particles to make them larger. The larger particles can then be removed by gravity or filtering (WHO, 2013). This process is ideal when water sources have high turbidity.

Absorption methods often overlap with other processes such as filtering as the method involves passing water through a type of media such as clay, charcoal, glass and other organic matter. However due to the cost or inefficiency of the media are not suitable for the water filtering required in Codo. One option that may be possible is the use of carbon which is valuable in removing taste and odour compounds in water (WHO, 2013). Carbon is efficient in removing microbes however dissolved organic matter readily takes up the absorption sites creating a biofilm eliminating carbons ability to remove microbes by absorption.

Ion exchange processes are expensive and are often used to soften water. The process can be a point-of-use treatment to disinfect water however due to its cost is not a suitable option for the village people in Codo.

Chemical disinfection is a direct treatment of water used to inactivate or destroy pathogens and microbes. This method of water purification is widely recognised and used at a community and point-of-use level around the world (WHO, 2013). Due to cost and ease of use chlorine is the most widely used chemical however it does have a disadvantage of adding an odour and taste to water and it is not available worldwide.

As many of the chemical treatment options are expensive, technically advanced or too hard to source the only viable chemical treatment option to consider for Codo will be the use of chlorine. This process involves the addition of chlorine tablets or liquid which kills pathogens and microbes The main issue with this option will be education and development of skills as it requires measured amounts. This method of water purification is typically not used at the household level, it could however be an option during outbreaks of health issues as a quick means of attaining safe drinking water.

2.5.5 Option 4 – Bio Filters

Biofilters are a filtration method that involves the use of organic subject matter to remove bacteria and contaminants with elimination capacities achieving 95-99% (Swanson & Leohr, 1997). The method of biological filtration is described as “a biological air pollution control technology for volatile organic compounds (VOCS)” (Swanson & Leohr, 1997). The performance of biofilters shows they can maintain a high efficiency and effectiveness for a reasonably long term operation (Kim, Kim, Chung, & Xie, 2002). By employing natural materials as the main source of filtration biofilters are environmentally friendly and leave little impact on the surrounding natural areas. There are two main forms of biofilters, naturally constructed benthic biofilters and artificially manufactured biofilters.

In respect to the filtration of water, using a benthic biofilter involves the process of creating a living wall of water plants, which capture pollutants from the water as it passes through. Once planted, the process is naturally occurring becoming a low maintenance option, however it takes time for the benthic environment to grow into an effective filter making this method a long term project. The quality of water from the natural spring where the people of Codo source their water is good but gets contaminated by the condition of the pipes and containers through which the water is transported (J. Turner, personal communication, March 13, 2013). Due to this a benthic biofilter situated at the source of the water will not have the best effect.

Manufactured biofilters consist of a constructed casing containing a packing of organic material as a source of filtration. Biofiltration is a simple and cost effective technology; however a skilled technical understanding in the function and operation is necessary to maintain optimal performance. The procedure of biological filtration involves an acclimation time; this is a period during the start-up process in which removal steadily increases. This time taken is necessary for the biofilter to reach 95% or more of its removal capacity (Swanson & Leohr, 1997). The operation term for a manufactured biofilter lasts about 240 days after which its removal capabilities reduce significantly due to the accumulation of metabolic products on the packing material during extended operation (Kim *et al.*, 2002). The local environment and industry of Timor-Leste would benefit from the national production of biofilters as the use of biofiltration contributes both economic and environmental advantages (Swanson & Leohr, 1997)

Although biofilters are an efficient form of water filtration, placing a manufactured biofilter at Codo's water supply would not be practical due to the time taken for the filtration process to occur. In order to obtain both sufficient quantity and quality of water, the method of biofiltration would predominantly have to be a large scale operation, which would become too space consuming for the small town of Codo.

2.5.6 Option 5 – Precipitation

As a form of water filtration the method of evaporating contaminated water and condensing it into clean water is incredibly effective. It is how the natural water cycle works however on a much larger scale. Water from the ocean, ground, plants and animals is evaporated into water vapour and gathers to form clouds and when condensed in the clouds turns to clean, distilled water (rain). This method of purifying water can also be done at a micro level where a small amount of contaminated water can be purified and distilled to make it safe for drinking. This technique also referred to as a solar still and condensation trap can be used to extract clean water from the earth or out of a container with contaminated water, salt water, urine and even toxic plant sap (Survivor Magazine, 2010).

The concept of the solar still has been described since the 4th century (Wieman, n.d.) and has been largely and effectively used as a survivalist's method of accessing water. The basic method is to dig a hole in a sunlit place, put a container in the middle and place a plastic sheet over the top, weighing down the sides, and weight down the centre of the sheet with a rock. This method evaporates the moisture from the ground and condenses it on the plastic sheet causing the water droplets to run down into the centre and into the container providing clean drinking water. The other method commonly used today is to have a container of contaminated water underneath the plastic sheet that evaporates and condenses into clean water inside a second container instead of using moisture from the ground.

The method of filtration selected will have to be usable at a household level which would make the second method described the more appropriate for implementation in Codo. There are modern filter designs that work off of the method of evaporation and condensation from dirty water, namely "The Watercone" (Mage Water Management, n.d.) The Watercone is a simple but effective water purifier that can hold up to 1.7 litres of dirty water at a time (Harrison, 2009) and can purify up to 1.5 litres of clean drinking water in 24 hours (Mage Water Management, n.d.). The contaminated water is placed in a bottom tray and when it evaporates and then condenses on the sides of the plastic cone it runs down into a catchment trough and then can be reclaimed by unscrewing the top of the cone and pouring the clean water into a drinking container (Figure 11).

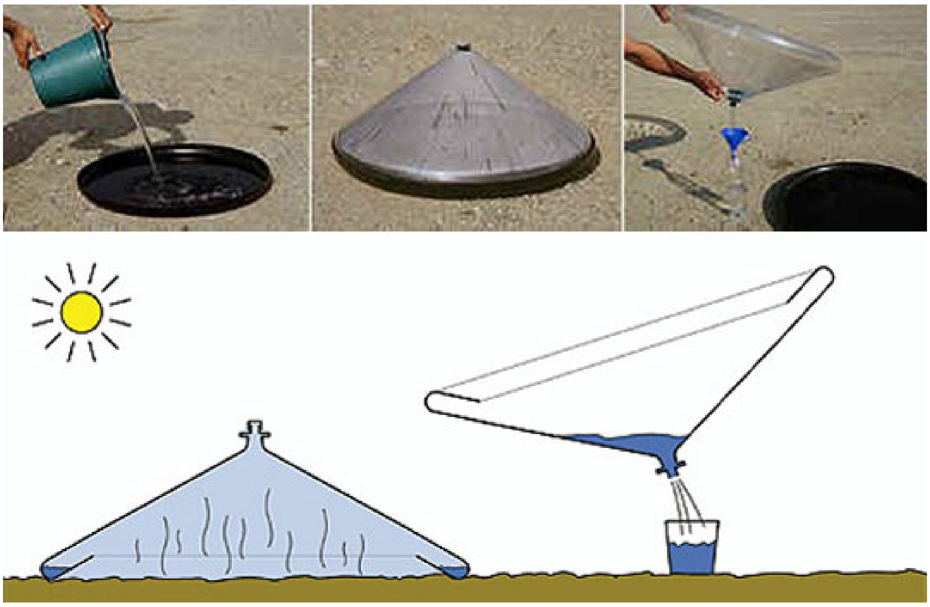

Figure 11: Visual demonstration of the use of a Water cone.

(source: Electric Tree House, 2011.)

While the evaporation and condensation method, and more specifically the Water cone, is a very effective form of water filtration and purification, for the purposes of this report it is an unviable technique to introduce at the household level in Timor-Leste. Any implemented water filtration system would need to be effective enough to have a supply of clean water for a full family of up to 10 people daily, the speed of the Water cone is not efficient enough as it takes roughly 24 hours to purify up to 1.5 litres each household would require one per person. The Water cone also requires sunlight to operate meaning that they would not be as effective and as efficient during the long wet season with heavy rain and cloud cover blocking sunlight. Due to these reasons the Water cone, or evaporation and condensation method of water filtration is better suited to survival or disaster conditions rather than to purify the already relatively clean water of the people in Codo and would not be a viable option for implementation.

2.6 Analysis

Criteria		Ceramic			Sand			Chemical			Bio Filter		
Description	**Rating**	**Description**	**Rating**	**Score**	**Description**	**Rating**	**Score**	**Description**	**Rating**	**Score**	**Description**	**Rating**	**Score**
Ease of use inc maintenance	10	Easy	10	100	Easy	10	100	Medium	6	60	Easy	10	100
Cost of implementing and operating	8	Low / Med	7	56	Low	10	80	Low	10	80	Medium	5	40
Efficiency – Speed	8	Good	10	80	Slow	2	16	Good	10	80	Slow	2	16
Efficiency – What it removes	6	Not viruses	6	36	Good	6	36	Good, does not remove, just kills	10	60	Good bacterial & contaminants, no virus	6	36
Technicality	6	Medium	6	36	Medium	6	36	Medium / High	2	12	Medium / High	2	12
Environmental Impact	4	Minimal / low	6	24	Minimal / Low	6	24	Low	10	40	Minimal / Low	6	24
Local Industry	2	Potential	10	20	No	2	4	Small Potential	6	12	Small Potential	4	8
Comments	5		10	50	Previously introduced and now no longer used.	2	10	Requires training and not recommended for household use	6	30	Recommended for larger scale, time consuming	6	30
TOTAL	49		65	402		44	306		60	374		41	266
WEIGHTED SCORE				**8.20**			**6.24**			**7.63**			**5.43**

2.7 Recommendation

The investigation of each option has led to the discovery that many different filtration systems are efficient in the removal of water contaminates but not all options are viable for Codo. Through close analysis it is recommended that a ceramic filtration system will be the most suitable solution to improve the water for the town of Codo, Timor-Leste.

Ceramic water filtration was chosen due to a number of factors that were analysed. The system proves to be very efficient filtering up to 99% E. Coli, protozoan bacteria's and particles via gravity filtration at a rate of 1 – 3 litres per hours. Clay filtration provides a simple easy to use system that can be easily maintained and will last for a minimum of one year maximum 5 with replacements parts available.

A ceramic water filtration unit has a relatively low cost, with production cost ranging from $5 to $25 US per filter, although the possibility to make the filter locally, by providing education, skills and training, would result in an even cheaper production. As a ceramic filtration system has the potential to contribute as a local industry its implementation could benefit the local economy.

The introduction of a clay filtration system would contribute positive Environmental impact, as it would eliminate the need to boil water, reducing time and the need to burn wood. Ceramic filtration is a self-sufficient system enabling efficient use of energy as it does not require any energy source to operate using gravity instead. The manufacturing of ceramic filters would utilise the countries natural local resources of clay averting purchase of materials elsewhere. Overall it is evident that the implementation of a ceramic filtration system will be the most viable and potentially productive option for the Timorese people and the town of Codo.

3 FEASABILITY OF RECOMMENDED OPTION

3.1 Description of concept

Due to the fact that it is difficult to protect the people from water borne diseases along the transport chain getting water to the households, a household water filtration is the best option (Brown & Sosbeys, 2007). The design concept of a ceramic water filtration unit is a simple household water treatment system easy to install in each household of the community. As the households are small the filter can be placed on a stand or table outside. If the kitchen area is outside it is well placed in that area.

Ceramic filtration units can vary in size however uniformity will be generated through the creation of a mold which will benefit maintenance, spare parts and repair aspects. The constraints limiting the size will be a balance between filtration capacity needs and ability to move the units if and when needed. Most suitable option will be to have the units filled a couple of times a day as is the current practice in collecting water and hold enough water to cater for a family of up to eight people, 16 to 24 litres. The size of the filter will need to be approximately 30cm high with a diameter of 30cm or a configuration similar to this that would hold approximately 20 litres without being too top heavy to ensure there are no safety issues. The storage section would not need to hold the same amount of water as the filter will work as water is drawn out of the unit. The rate of the filter flow is 1-3 litres per hour. Sections that make up a ceramic filtration unit are displayed in Figure 12.

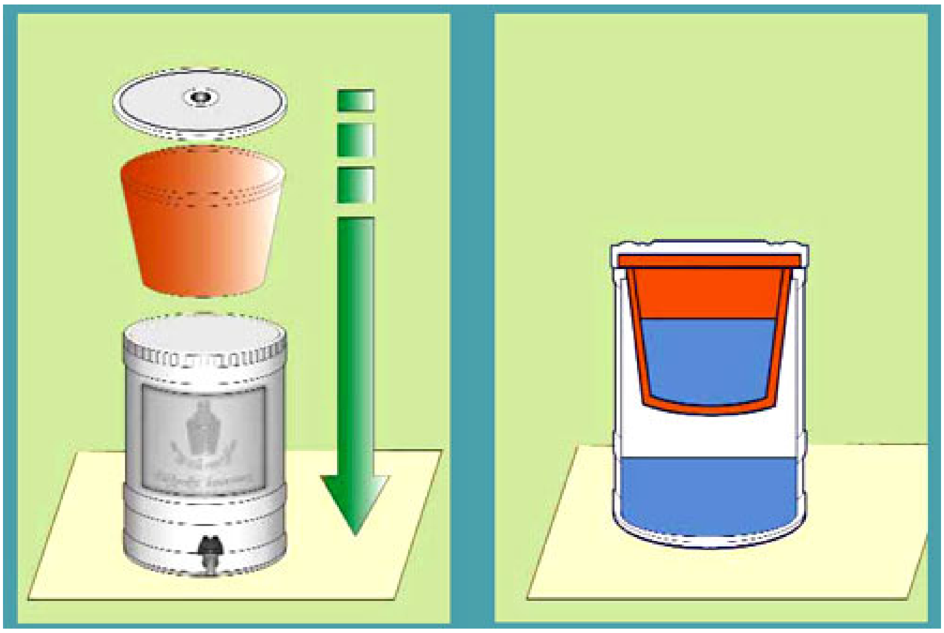

Figure 12: Diagram displaying the components of a ceramic filter.

(source: www.fieldnotes.unicefusa.org)

3.2 Construction Methods

Ceramic filters are constructed with porous fired clay. A 50/50 mix of combustible additives is introduced to the clay mix which when fired burns out and creates minute holes which become the filter by capturing particles and preventing them from travelling through to the water outlet. Additives must be a very fine product to ensure the holes made are small enough (1-6 microns) to be a barrier to microbes. By-products like sawdust, rice husks and coffee grounds are used effectively. Different ratios of the materials have been tried and have found that the 50/50 rate is best for effectiveness, speed of flow and durability of the clay (Andropedia, 2013).

Figure 13: Example of a press used to create the ceramic filters.

(Source: www.appropedia.org/Ceramic_water_filters)

Once mixed up the clay is formed into a large wedge which is put through a press forming the clay into the correct size and shape for uniform receptacles. A simple press is a hand-operated hydraulic jack incorporated with an aluminium mould (Figure 13). The formed pot is then put through a firing process in a kiln. Temperatures in the kiln are controlled being raised 75 degrees Celsius per hour until reaching 350 degrees; this is done so that the water inside the clay can dry out at a rate that doesn't damage the pot in the process. The temperature is then increased by 100 degrees per hour until 900 degrees and kept at that temperature for one hour and then slowly cooled (Andropedia, 2013). The filters are then tested for flow rate to make sure they meet the standards required and if they do are painted with colloidal silver or silver nitrate which dramatically increases the effect of bacterial filtration on a continued basis (Luby, S., Agboatwalla, M., Raza, A., Sobel, J., Mintz, E., Baier, K., Rahbar, M., Qureshi, S., Hassan, R., Ghouri, F., Hoekstra, R., & Gangarosa, E, 2001). As a means of reducing the use for energy the kiln used by Potters for Peace which uses 50% less fire wood than previous kiln designs will be used (Potters for Peace, n.d.$_2$). The structure is similar to Figure 14. Initially the kiln will use wood as an energy source however as other forms of energy become available or more efficient to use the kiln could be converted to sources such as gas or electricity.

Figure 14: Example of a kiln which is designed to use 50% less fire wood.
(Source: www.pottersforpeace.org)

The construction is basically one clay pot inside another. The dimensions are 27.5 cm wide by 25 cm deep. They hold between 20-30 litres of water. The filtering pot sits inside the water storage container and water is poured into it, which seeps through extracting impurities as it goes. The clean water is stored in the bottom container. A tap mechanism is built into the bottom section of the filter which is then easily available to the user from the tap.

Filters can last up to 5 years if cleaned regularly by scrubbing off collectables from the surface which also affect speed of water flow (Lantange, 2001). It is recommended to replace the filters every 1-2 years, however if they are known to provide adequate protection for 5 years then there is no reason why they cannot last for 5 years (Lantange, 2001).

3.3 Cost Analysis

- Costs of filters – one filter initial outlay = US$10 - US$25
- Replacement filters US$2-US$5 Per 1-5 years
- Comparison of costs (Table 4)
- Initial costs for purchasing filtration units in Manatuto (Table 5)

Table 4: Comparison of costs

Buying water	Filtered water
50c per 1.5 litre or 33c per litre	0.001c per litre

Table 5: Initial costing for filtration unit for the school.

Description	cost
Travel to Manatuto for factory visit - petrol *	$40
Filter system x 1 for school	$25

* Calculation = $1.30 per litre petrol 250 km (based on 4wd fuel consumption of 15 litre per 100km)

Setting up a factory costs between $1200-$30,000 depending on the local resources (written communication, Kaira Wagoner, 26 April, 2013). The factory when set up and functioning properly can produce up to 50 filters per day.

3.4 Environmental Considerations

The impact each filtration option would have on the environment was a major part of the evaluation criteria. The environmental constraints in the EWB brief stated that any option implemented would need to either not cause any further negative impact on the environment, or more preferably reduce the impact. Ceramic filters achieve this goal well. If the design for a household ceramic filter is implemented and is adopted by the people in Codo it has the possibility to reduce impacts on the environment the people are currently causing by reducing burning wood for boiling water and reducing the amount of waste plastic bottles from buying water which is currently a large issue for Timor-Leste (Engineers Without Borders, 2013).

Currently in Codo the people frequently cut down many trees for wood to burn to boil water. The logging required for the process of boiling water is damaging the landscape. Stopping at least some of the logging on the nearby area could improve the stability of the mountain which is prone to landslides (J. Turner, personal communication, March 13, 2013). It also removes any risk of damaging the water supply.

3.5 Cultural Considerations

It is understood that there is a powerful connection within the cultural society between individuals, communities, the environment, history and cultural traditions in Timor-Leste (Engineers Without Borders, 2013). A concerted effort must be made not to interfere with or disrupt such links but rather demonstrate respect towards them and help to develop them. Ceramics is a part of the culture therefore the introduction of this project would assist in the reconstruction of their culture.

The government is looking to strengthen the cultural integrity by promoting cultural heritage, incorporating it through economic development (Engineers Without Borders, 2013). Production of this water filtration system is intended to develop into a business project that would provide jobs and contribute to Codo's economy

By incorporating traditional practices into the construction methods it will improve the chance of provoking a positive reaction among the local communities. The decision to take a clay filtration system approach not only provides a viable option but also respects and reinforces the important role of the countries traditional arts through the use of ceramics. The decision to use a clay design honours a long tradition of pottery, abiding by and contribution towards their culture and national identity.

Cultural traditions and practices are highly valued within the community of Codo. In their traditional culture the older ratu male siblings hold authority (Engineers Without Borders, 2013) and so for this form of filtration to be adopted it is a priority to influence this part of the family. Primarily introducing the filtration units within the schools will aid in the recognition and use of the units by school children, primarily the male siblings as being beneficial and encouraging the practice to be transferred into home life.

Cultural values and national identity are being promoted and reinforced through the government of Timor-Leste, by incorporating and strengthening these ideas within the project the chances of obtaining support and funding from the national government of Timor-Leste will increase.

4 IMPLEMENTATION OF CONCEPT

In the past 14 years Timor-Leste has experienced much dominance and control over their country with violent Indonesian take over and many well-meaning governments and NGO groups coming into the country often without due consent and collaboration with the Timorese people (Neves, 2006). With this in mind this report aims to allow the people to reconnect to their own cultural practices and with other members of their country to help their own capacity building with guidance and support where needed. The engineer's role here will be to provide the idea, research, connections and assistance with technical aspects. The schools role will be to introduce the product and educate the children on why it is needed so that it becomes a part of the future generations. The school can also create theatre and story around the issues related as a way to educate the community and spread the word through families. The community's role will be to ensure the project continues and is developed as a way of life, to create a group or assign an individual who takes care that the project is maintained and developed to its full potential. The engineers will remain available throughout the whole time as a point of contact, assistance, advice, means of networking and developing. Essentially this project is aimed at initiating a new behaviour and new technology into an area and it will be the community who will need to develop it and maintain it. For this to occur a good introduction and ongoing support is essential.

Government assistance

It will be important to acquire support from the government to facilitate the full extent of this program. It has stated in The Program of the V Constitutional Government 2012-2017 Legislature that the government will invest in major water and sanitation works in rural areas and schools. This project may fall within this goal (Government of Timor-Leste, 2013). The Timor-Leste government is also supporting the Academy for Cultural Creative Arts and Industries by promoting a School of Fine Arts whose aim it is to develop technical and artistic skills via providing training in ceramics and other traditional arts. Regional Cultural centres in each district will be established by 2030 as a place for theatre and art, dance, cultural hubs for the communities for rational and inter-regional cultural expressions. The centres will have media centres for new technology, and internet access, a library and meeting rooms which would be places that continued education in regards to the filtration systems could take place. This project would fit well within the government's statement of support. It is stated that the government is focusing on making sure that the Timorese people are provided support and access to finance and business training needed to succeed in business and enterprise. Business Development Centres have been set up in Lospalos and other towns by the institute for Business Support where training is provided in starting, improving and developing business. This asset can be taken advantage of to assist in the development of a factory, and in some cases will provide relevant technical skills training. Cost sharing of product costs to 'share the load' could be an option for an increase in projects viability and expansion potential. Micro financing is available through The National Commercial Bank of Timor-Leste providing services to enterprises.

4.1 Staging Options

4.1.1 Stage 1

The introduction of this project will begin with a visit to a group of potters in Manatuto a town on the northern side of Timor-Leste approximately 125km from Codo. This group has a factory already set up and running that was implemented with the help of Potters for peace (

Figure 15). They make and sell the same filtration systems that are proposed for Codo. At this visit a meeting will be arranged to show how the factory works and discussion with the people who have implemented it with the aim of getting a good understanding of what is involved and what they will have to consider so that they themselves can make the necessary decisions of incidentals, where it will go, who will best run it, how many people will need to be involved, how much training will be needed, learning from successes and mistakes and seeing the idea in action.

Having this direct connection and advice will help to see the viability of the factory as a business and begin to see how it will benefit their community. They will learn how the ceramic filters have affected the health and well-being of the community, and ask relevant questions, for example; how long did it take to have an effect, what effects has it had. There will be a vast amount of valuable knowledge that can be attained at this meeting and other meetings that can be organised. There will also be a detailed discussion about the factory that is set up and running there, the set up process, working with Potters For Peace, how has it been for them, how viable is it, what is needed to make it viable, has it created positions for their community, has it helped in any way, what obstacles have there been and other relevant information.

The visit will also be used to purchase at least one, if not more filters. The purchased units will return to Codo and be placed in schools, community centres and testing households within the town along with an education program informing people of the units, what they do, how they work and why they are important. The education aspect is discussed later in this report.

Once the system is introduced, being used and interest increases enough to begin making them, which if the education program is designed well, will happen, the next stage will begin.

Figure 15: Potters for Peace logo.

(Source: www.pottersforpeace.org)

4.1.2 Stage 2

The next stage is to implement a development program where the filters can be made within the village. This will be done with the assistance of Potters for Peace by setting up a factory. Potters for Peace are an organisation based in Central America but working world wide to assist communities within developing countries to set up factories for the production for ceramic water filtrations systems (Appendix A). Potters for Peace do not provide finance or own any materials, they have a good design, access to the machinery needed and the know how to set up, train people in the use, train on marketing and all the running aspects of creating a factory and making it work for the community as their own business (Appendix B). This is the creation of a new industry within the town where the units can be made and sold within Codo and to neighbouring villages if and when demand for the systems is sufficient. Figure 16 shows an example of commercial ceramic filters ready for firing.

Figure 16: Ceramic filters drying in preparation to be fired in a kiln.

(Source: www.theinnovationdiaries.com)

4.1.3 Stage 3

Once the factory is built and operating there will need to be followed up with the community to see how they are going and if there is any support needed (Figure 17). Setting up a business and sustaining it for the long term will not be easy for these people as it is assumed since it is a small town and very little industry (Written communication, EWB discussion board, J. Turner, April 30 2013), there will not be role models or mentors in business for these people to turn to. It would be an advantage to stay connected to the people of Manatuto and with business enterprise centres that are opening up in regional centres for support with this. The engineers involved in this report will be available for any support that is needed with connections, advise, help sourcing information and anything that can feasibly done to help.

The business has the potential to expand to making filters for neighbouring towns. The factory can make up to 50 filters a day. There will need to be a regular maintenance system set up which would best be organised by the group who run the factory or those associated with it. There is great potential for many members of the community to be connected to this project in different ways. There will need to be: filter makers, machinery maintenance, quality control, business administration, delivery, monitoring regular check-ups of filters, client relationships, intercultural connections and information days, training and education. There are many more ways that this project could be developed to include more members of the community and it has the potential to build capacity within the people of Codo.

Figure 17: Community members using a new water filtration unit

(Source: www.pottersforpeace.org)

4.2 Education

How a new concept, piece of equipment or technology is introduced to people is important. Aboud and Singla (2012) note that researchers, other than social marketers, rarely assess how improvements to a person's being will be delivered to the target audience during the development process. Educating the village people on water filtration, the unit supplied, how it will work and its benefits will be the major part of addressing water purification needs and 'selling' the concept. Briscoe and Aboud (2012) note that using a number of techniques in educating and changing behaviour will result in better take up of the idea than using one technique alone. Having the community engaged in the concept will aid in the promotion of learning and help to maintain the new practice. Some of the techniques to use to engage people include:

- Information
- Performance
- Problem Solving
- Social support
- Materials
- Media

Information on the water filtration unit and how they work will start with an introduction phase where information is given showing how the units work. The instructions will need to be very visual with a focus on pictures to tackle any deficiencies in literature.

Performance techniques include demonstrations and rehearsals on how to use the water filtration units. Giving people the chance to see, feel and use the water unit will create a familiarity and start the education process. It will also allow the opportunity for villagers to ask questions and gain an understanding how to maintain the units. Manatuto, a town close to Codo is already using and producing ceramic water filters. Villagers could visit the town to see similar filters in use and bring the knowledge back to Codo. This would aid in the implementation of the project as peers teaching peers can be a valuable way of sharing knowledge. Once an introduction to the units has been completed the visual instructions will be easily understood.

Problem solving can be initiated by the water committee. If there are barriers as to why people are not taking up the new water filters the committee could help to give ideas on how to make them work better and be a point of contact with the engineers and Potters for Peace who can also help in the long term. This could involve informing villagers to set a time they refill their water filters to ensure enough drinking water is available when it is needed to avoid the filters being branded too slow. Having a water committee will create social support within Codo and create a means for the villagers to openly communicate any issues they may have with the water filter. This will also aid in identifying common issues amongst villagers so the water committee can address them widely to ensure there is a good understanding.

Initially to get the people familiar with the household water filtration units some will be given to key areas within the community. This could include the school, community centre, key people / families within the community. By giving the units or even the materials to have the units created within the village will allow villagers to talk about them and generate interest.

As a wide spread means of communicating the benefit of the water filtration units and their importance media can be used. This could include radio, newspaper or pamphlets if they are available however other means such as dramatic roles plays and songs, particularly with children will aid to distribute and reinforce the information. The Timor-Leste government is keen to promote creative industries (Engineers Without Borders, 2013).

Initially education in the water filtration units will need to be broad, include as many villagers as possible and delivered using numerous techniques. Once the concept and units have been introduced, further promotion will need to occur and be driven by a water committee or the business involved in the factory, to ensure proper use and maintenance of the units is occurring. Due to the need to improve health it would be recommended that any education on the water filtration unit be integrated with education on hygiene in particular washing hands. World Health Organisation (2013) note that for a reduction in health issues both clean water and sanitisation are recommended for the greatest impact.

If a well thought out introduction to children can occur perhaps the new generation will be better informed and appreciate the transition to a suitable household water filtration. An example of this in the developed world is with Apple computers. Initially when computers were introduced into schools, Apple supplied them. This meant a generation of school children learnt how to use the brand, grew up using the brand and as adults were choosing to buy the brands. The water filtration units, although not as technologically advanced could have a similar introduction and education process to promote their use and uptake in the future.

4.3 Maintenance

Maintenance of the filters is an important part of the effectiveness of the filtering process. It is recommended that a person in the community is delegated the responsibility of monitoring maintenance. Areas of the filter that need maintenance are:

- Cleaning the surface area of the filter on the inside
- Tap mechanism may need to be replaced if there are breakages
- Breakage of the filter can mean a replacement of either the top filter or the bottom water holder.

Parts for maintenance can initially come from the factory in Manatuto then once a factory is set up in Codo the maintenance and parts will be supplied by this business. Accessing these parts can be assisted by Potters for Peace (Appendix B).

Cleaning

The filters are cleaned very easily using a scouring method that best suits the resources of the household. A scrubbing brush is usually sold with the filtration units. The filter will get a film of scum or dirt depending on the water, which is simply scrubbed off with usual kitchen cleaning methods. The filtering process will slow down when it gets clogged up so it will be obvious when it needs to be cleaned. It can also be seen within the filter so it is recommended for the owners to regularly check and clean their filter. It requires no sophisticated or technical methods or products to clean The cleaning of the filters will need to be monitored during the initial stages of the implementation for a period of time it has been found that monthly visits from a community stakeholder was strongly associated with continued use (Donachy, n.d.).

Maintenance will also cover replacement of the filters as needed. Once a year is recommended, however filters do last for years effectively if cleaned and maintained properly.

4.4 Sustainability

The implementation of ceramic water filters and a factory to produce them would cause minimal environmental impacts such as the mining/collection of raw materials (e.g. clay) and also wood required to operate the kiln. The environmental benefits of the ceramic filters however are that with full integration into the lives of the people in Codo there is the potential to completely remove the peoples dependence on buying bottled water which could drastically reduce the amount of plastic waste thrown out each year. The other common practice of the people in Codo is to purify the water from the tap stands by boiling it; this practice requires an excessive amount of wood to be burnt each year just in the attempt to obtain clean water. Reducing the amount of wood burnt to boil water will be a great advantage to the environment. The kiln used to fire the ceramics will require wood to be burnt however there is a commonly used design that reduces the amount of wood required by 50% (Potters for Peace, n.d.$_2$). With the overall reduction in wood required to be burnt to access clean water and the reduction in plastic waste the implementation of ceramic filters is more environmentally sustainable that the current practices of the towns people.

Constructing a factory to produce these filters would also provide social benefits to the village. The factory would provide a chance for people to learn new skills which they can adapt to other facets of their lives and would also provide the village with new jobs without reliance on agriculture which is very dependent on the weather conditions. These new jobs and skill sets would be a great addition due to the young populations desire to learn and improve their skills. In addition, cleaner drinking water would also lead to better health which could in turn reduce infant mortality rate and help the people stay healthier for longer portions of their lives which provides better social conditions for the town.

On top of the social benefits of constructing a factory there are also some foreseen economic benefits. The main benefit being that the factory would provide people with jobs stimulating the local economy. The factory could also have the option to begin selling the filters to other nearby towns and even to the cities and would need to import materials such as the clay form other nearby towns which would lead to an improvement of the economy of the country. These additional jobs at in the town would create better economic sustainability as the town is largely reliant on agriculture and for large portions of the year during the wet season most people are without work or a source of income (Engineers Without Borders, 2013).

With all of these added benefits and the few downsides of implementing the ceramic water filters, implementing them into the town could prove to create sustainable conditions for the people of Codo which would potentially spread to other places within the country.

4.5 Risks

Throughout the project development, assumptions were made about the people and area of Codo where information was lacking. Like most projects, making such assumptions can lead to a set of risks involving the stated assumptions being incorrect which can cause the implementation to be less successful. If an assumption regarding the people’s willingness to accept a new form of water filtration is incorrect then it can lead to a major failure of the implementation as some types of filters have been tried and already failed to be sustained. Similarly if the ceramic filters selected for implementation are not fast enough at filtering water they can meet a similar failure. There are also risks in assumptions made about the design of the filters and if they're not made to a certain specification they may not be able to properly filter water.

The ceramic water filters will have to be placed outside which causes issues with the housing of the filters. They will require a stand, either manufactured or makeshift stand. Being off the ground produces the risk of the filter being knocked off the stand and, as it is ceramic, being broken without the possibility of being repaired. Other risks include further feasibility studies showing that the implementation of a household filtration system to be un-achievable due to inability to easily obtain and transport materials required for making ceramics or the filters being too expensive for the local people of Codo to purchase. There is a chance that the people will also have a poor perception of the product, due to unsuccessful past implementation attempts of water filtration systems, and insufficient planning of stages of implementation.

The communication barrier with the local people of Codo has also been considered and identified as having the potential to cause issues during the stages of implementation. Ways to minimize the risk of misunderstanding the processes involved with the use and maintenance of using the ceramic filters have also been considered. If a program to implement the filters is used and relevant education on how to properly construct and maintain them is offered but is not continued to be taught and retained throughout the community, it runs the risk of the locals losing faith in the efficiency of the filters due to improper use and the program being abandoned all together. A way to counter this risk would be to continue to check that the proper construction and maintenance systems are remaining in place to ensure proper use and to maintain the effectiveness of the project.

5 CONCLUSIONS AND RECOMMENDATIONS

The use of ceramic water filters proved, through this report, to be the most effective household water filtration to be implemented in the households of Codo in Timor-Leste. The ceramic filters meet the aims of the project by improving the water quality to meet the WHO standards for drinking water (World Health Organisation, 2008). In addition to improving the quality of drinking water health issues affecting the people of Codo such as diarrhoea and malaria should improve. The effectiveness of the filters also meet the aim of reducing the environmental impact of obtaining clean drinking water by removing the need for buying bottled water or burning wood to boil water which are currently the main practices in Codo. The possibility of constructing a factory gives the potential to add an economic benefit to the village by creating a new industry and giving the people the chance to learn a new set of adaptable skills.

As a means of utilising an organisation that has experience in implementing household water filtration in developing countries, Potters for Peace have had success in implementing ceramic water filters in countries in Central America, Africa, Asia, and South America. Potters for Peace have also have built a factory within Timor-Leste in the town Manatuto and therefore they understand the risks with implementing a factory within Timor-Leste and provide evidence that it is a viable option. Potters for Peace would also be able to offer insight into other related issues that have not been addressed within this report.

There is also the likelihood of the implementation of this project to gain support by the government of Timor-Leste due to their “Program of the V Constitutional Government 2012-2017 Legislature” (Government of Timor-Leste n.d.) which seeks to improve health, environment, education, infrastructure and economic growth while promoting their culture and a national identity. As Timor-Leste has an old tradition of ceramics. It is believed that the implementation of the ceramic water filters and factory fits well with the government’s program to improve water quality and sanitation whilst keeping to their traditions.

Based on the information presented in this report ceramic water filters are a viable option to provide the people of Codo with clean drinking water. This recommendation needs further exploration of the potential benefits and risks of implementing ceramic water filters and the possibility of constructing a factory for the production of the filters into the town of Codo. It is also recommended to add the integration of a sanitation education program into the implementation process to teach the people that with proper sanitation the health benefits of filtered water are increased significantly.

A reflection of the teams experience in this project can be found in Appendix C.

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APPENDIX A

Email communication. April 26, 2013 from Kiara Wagoner, Potters for Peace representative.
pottersforpeace@gmail.com

Hi Lisa,
Thank you for your email and interest in the ceramic water filter. You are correct regarding how PfP works. We act as consultants which help to set up ceramic water filter production facilities. We would be happy to collaborate with you in this respect.
Attached are some documents that may assist you with pricing of equipment. We are currently offering a free press and free molds (including shipping to the nearest port) with the price of consultancy. Consultancy costs are cost of travel, room, board and a $300 daily stipend. Factory establishment generally requires 4-5 weeks and we recommend a feasibility study (1 week) a few months beforehand (if funding is available) to help get everything in place for the consultants arrival.
Please let me know if you have any other questions, and if there is anything I can do to be of assistance.
Peace and best,
Kaira

APPENDIX B

Recommended Equipment, Supplies and Materials for Ceramic Filter Production

Item	Specification	Quantity	Availability	Price
Ceramic Filter Construction				
Clay	high plasticity	as needed		
Burnout material	fine sawdust or rice husk, uniform if possible	as needed		
Press	Manual or Electric, at least one manual recommended if power failures common	1 or 2, depending on desired production	Nicaragua or Kenya	Electric ≈ $2000 Manual ≈ $900 plus shipping
Molds	male & femal, cast aluminum	1 or 2, depending on desired production	Nicaragua	$1075
Press Plates	Round, flat plates to fit bottom of female mold - make sure to make them sturdy, as thin plates will cause uneven filter base, and lead to cracking during drying	100		
*Mixer	Motorized, dough mixer preferred	1		$1500 - $3000
*Hammer mill or grain grinder	2-3 hp electric motor, interchangeable sieves	1		$1000 - $2000
Sieves	#30 mesh	2 1x0.5m hand-held or 1 vibrating table		
Large Scale (Balance)	25 - 50 kg capacity	1		
Hydraulic Jacks	20 ton (standard truck jacks)	3		
Buckets	Must be able to suspend filter, usually 5 gallon/ 20L	20		
Tarps	Large enough to spread raw material for drying	2 or 3		
Wheel Barrows	sturdy	2		

Recommended Equipment, Supplies and Materials for Ceramic Filter Production

Item	Specification	Quantity	Availability	Price
Storage Sacks	Woven plastic recommended	75 -150		
Serial Number Stamp	large enough for easy identification	1		
Graduated Flask	1-2 liter, plastic	2		
Plastic Bags	can replace with coconut or palm oil if using electric press	2 per filter, sometimes reusable		
Car Wax	wax press-molds to ease separation after pressing	as needed		
Rubber Mallet	used to encourage separation of press-molds when wax isn't sufficient	1		
Production Log	In addition to matching serial numbers with flow rates, keep track of press, fire, and silver application dates for all filters.	1		
Safety Equipment	goggles, gloves, face masks (for dust)	enough for each employee		
Turn Table	optional	1 or 2		
Pug Mill	optional	1		
Silver Application				
Silver	Colloidal Silver	1 kg to start		
	OR Silver Nitrate ($AgNO_3$)	1kg to start	Laboratorios Argenol, Spain http://www.laboratorios-argenol.com/	≈ $1800 - depends on current market price of silver
Small Scale (Balance)	Digital, 0.001g accuracy	1		
Paint Brushes	Broad, for application of silver	1		
Plastic Container	Light-proof, for storage of stock silver solution, 2L	1		

Recommended Equipment, Supplies and Materials for Ceramic Filter Production

Item	Specification	Quantity	Availability	Price
Filter Firing				
Kiln	Mani Kiln ≈ 1700 bricks, (400 at 5x10x20cm for roof, 1300 at 7.5x12.5x25 cm for fireboxes, chimney, and walls, and 15 at 5x35x35cm for table) angle irons, steel rods, metal wood supports	1 or 2		
Digital Pyrometer / Thermocouples	Two-terminal	1 pyrometer, 2 t-couples	http://www.grainger.com/Grainger/EXTECH-IR-THERMOMETER-DUAL-INPUT-TYPE-K-W-9T296?Pid=search	pyrometer = $350 2 t-couples = $160
Pyrometric Cones	010, 012, 014	200 each		≈ $200
Kiln Fuel	wood, sawdust, agricultural waste or recycled oil	as needed		
Axe	only if chopping own wood for fuel	1		
Pencils	Mark flow-rate on lip of each filter - #2 or darker	as needed		
Fire Log	record firing data	1		
Filter Finishing				
Filter Receptacles	Plastic and Ceramic, with lid, no handles - mouth should fit filter, minimum 5 gallon, silk screening if possible	1 per filter		
Faucets	sturdy, plastic or metal	1 per filter		
Packaging Material	Cardboard boxes, 2-ply, corrugated	1 per filter to be shipped		
Instructional Stickers / Silk screening	Translate to local language(s)	1 per filter		
Brush - optional	Laundry brush for filter cleaning, to rejuvenate flow rate			

Recommended Equipment, Supplies and Materials for Ceramic Filter Production

Item	Specification	Quantity	Availability	Price
Infrastructure				
Factory Site	Covered Building, minimum 50m x 50m	1		
Shelving	Sufficient for drying and storage of at least 1000 filters, open for air circulation, 8-10cm taller than height of filter mold			
Soaking Tanks	drainage system with capacity for 50 filters, if possible			
Kiln Shelter	Build after kiln construction, basic, all-metal construction if possible	1		
Other				
Skilled Potters	Access to clay and equipment, skills for making mini-filters, ceramic filter receptacles, and for finishing of filter after pressing	At least 2		
Marketing and Promotional Materials	Brochures, radio and TV adverts, signs, newspaper ads, coloring books, mini-filters, live demonstrations etc	The more marketing, the more sales		
Occasional Laboratory testing	Reliable microbiological testing to ensure quality filter performance	Frequent testing initially to ensure quality product, occasional but regular testing once production is consistent		

Worksheet for Budget
to begin production of ceramic water filters

INSTRUCTIONS

To complete this worksheet, please do the following:

1 In the following sheets, please enter the unit costs and transportation costs in the GREEN cells only:

- Infrastructure
- Machinery
- Supplies
- Labor
- Other
- Training

In these cells, you can change the numbers in the QTY column

2 Please DO NOT enter data in RED cells

3 Please DO NOT enter data in the following sheets:

- Summary
- Detailled Summary

Password: CPP

APPENDIX C

Reflection

In our first year of the Bachelor of Engineering (Honours) in Civil Engineering at Southern Cross University, Lismore, subject Engineering Project, we worked in teams for the 2013 Engineers Without Borders (EWB) Challenge. Our task was to research and design a viable option to assist the town Codo in East Timor in one of the many design areas suggested by EWB. The challenge gave us the opportunity to develop team skills and work on a humanitarian engineering project which we all found a rewarding and valuable part of the degree.

Throughout the semester we learnt specific skills for working in teams and valuable known processes that on reflection we recognised that we did not fully utilise these in our team development. Identification of team roles and each member's strengths and weaknesses is one of the first steps recommended in building effective teams. It was evident later on in the project how necessary this step is in forming working groups to understand and effectively utilise the skills of each member. As a result the group ended up having to find its way late in the piece, recognising member traits as a matter of consequence and not having a good representation of roles to fulfil the needs of team work. This may have occurred as a result of each team member finding their place at the university and no one being familiar with any others' personalities and attributes. When working in teams again identifying roles needed and who best to fill them would be integrated in the beginning stage of building the team. The following is a description of traits our team exhibited and responsibilities taken.

Team Roles as per Belbin Team-Role Types (Grellier & Goerke, 2006).

Dylan Fletcher was a great implementer and completer finisher. He was reliable, disciplined, would do what he said he was going to do and turned ideas into practical actions. Dylan took the role of setting up the group Wiki site to share information. Dylan's research in the project included the background information of Codo, environmental issues and constraints, climate, cost constraints, stakeholders involved, the evaporation and condensation method of water filtration, the conclusions and recommendations and assisted in the editing process.

Ben Gavin was a team worker and completer finisher. Particular characteristics Ben showed of these roles were cooperation, mild demeanour, diplomatic and particular about finishing with a well-rounded coverage. Ben researched the infrastructure of Codo, logistics, risks and the sustainability of the final design.

Beau Monks showed characteristics of the completer finisher, team worker, and the specialist role. Particular characteristics of these roles Beau showed were working his sections of the research to a very detailed degree and being a cooperative, diplomatic team member. Beau's tasks were to research and report on the culture of Codo, the filtration method of Bio filters and logistics of implementation.

Corelle Forster took the role of shaper, implementer, coordinator and team worker. Corelle assisted in the drive to get the researching and report writing done, took on the chairperson role when needed, created goals, assisted in decision making and delegated tasks. Corelle's input into the report included the introductory headlines, executive summary, background, aims, scope, outline and the editing process. Corelle researched health in current issues, chemical filtration, and education in regards to implementation and provided the framework for the criteria analysis.

Lisa Hansberry displayed the characteristics of the plant role through solving problems and creativity, the coordinator role, clarifying goals and decision making and the monitor evaluator role through being strategic, discerning and judging well. Lisa also acted in the resource investigator role exploring opportunities and creating contacts and also team worker role, listening and building. Lisa’s research included skills, knowledge and water use as current issues, sustainability constraints, ceramic and sand water filtration methods, and the feasibility aspects of the project including the description, construction methods, maintenance, cost analysis. Lisa worked on the implementation section including the description of the concept, government finance, and the staging options. Lisa and Corelle edited the report.

The main challenge we faced within this team was relying on team members to work to deadlines and it not being done. Tensions grew amongst members and it delayed a good working development for the project in the timeframe given. A number of techniques were used to try to remedy this such as varying communication methods, extra meetings, agendas identified and additional personal communication. In the end the project came together and we were happy with the work we had done. We felt the project on the whole was a success, but on reflection other communication and team skills such as team role identification, team rules and a discussion and agreement on the level of input needed could be developed and employed to avoid such problems.

The process we used as a team included at first doing a brainstorming and mind mapping session to bring in any and every possible facet that might need to be included in the research. The mind map set up the structure of our report and we allocated tasks for each team member to research for scheduled meetings. Weekly meetings were set to begin with in which we would come together with information gathered and report back to the group. At the meetings we would discuss other aspects that needed to be covered that surfaced as a result of the searches done, discuss the project in general and allocate new research tasks. A second weekly meeting was set up during the semester as a means for us to gather and see how each member was going with their allocated task and if they needed any help. A group Wiki was set up to collate the material so that we could all see how the report was progressing, what needed doing and what information we currently had to work with. Towards the end of the semester we had a session of researching and writing all together as a group which we found very productive, fun and a great way to share knowledge, learn from each other and bond as a group which was also recognised as a great tool for team work.

During the course of the challenge and through to the finalisation of the report we saw improvement within our own and other team members communication and team member skills. The team improved listening, reading, writing and researching skills and developed new methods of communication including the ability to explain information and ideas clearly. We all valued the experience highly in regards to our own personal development, learning about working in teams and learning about Codo and humanitarian engineering.