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Front cover top:
Collecting water in rural Malawi
Front cover bottom:
BSc (Hons) Environmental Health students from the University of Strathclyde join primary school pupils in the Chikwawa region in southern Malawi

Back page top:
Steve 'Mac' Taulo, an Environmental Health lecturer from the University of Malawi's Blantyre Polytechnic, on a recent visit to Scotland
Back page bottom:
Members of the Sekeni Village Health Committee, Malawi
Photographs by courtesy of Tom Bell, Edinburgh, Scotland

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CONTENTS

Foreword

Sustainable development has taken centre stage in global discourse today because of the increasing and alarming rate of environmental degradation in all its manifestations. Deforestation, contamination of water resources, depletion of the ozone layer, and the emission of greenhouse gases are among the many environmental hazards negatively impacting on the environment. The IFEH journal enables researchers to deal with environmental issues which have a direct impact on local communities around the globe. The establishment of linkages between practitioners and the diverse research communities enhances the relevance and applicability of the various research endeavors in environmental health.

The papers presented in the current edition of IFEH journal deal with various aspects of health and the environment, particularly those intended to improve the quality of life of the rural poor in Malawi. Issues covered in the journal include the development of low cost technologies for water treatment, adoption of measures for sustaining existing water point sources (shallow wells and boreholes), the need to conduct civic education on water use and storage in homes in order to avoid contamination, and the necessity of including health hazards associated with respiratory diseases in all health education campaigns.

The provision of potable water supply and adequate sanitation facilities to the citizenry are central to the Millennium Development Goals (MDGs) being pursued by the Malawi Government. Availability of clean water supplies within walking distances of 500 m radius accords local communities the opportunity to concentrate on other economic activities as they make savings on time invested in water collection for domestic use. Adequate sanitation facilities are also key to breaking the cycle in the spread of water associated diseases. Thus, for the provision of clean water to be effective in reducing the spread of diseases, the availability of adequate sanitation is an absolute necessity. In this regard, the provision of both clean water and adequate sanitation, complemented with civic education, are essential ingredients for improving the quality of life. In the light of the above, attempts being made by various researchers to make clean water easily accessible to the rural communities through low cost technologies and civic education are a welcome development that should be supported by all stakeholders.

The foreword would not be complete without a word of thank you to Dr Tony Grimason (Head of Environmental Health, University of Strathclyde, Glasgow, Scotland) who has continued to make a very positive and lasting impact on the environmental health research agenda on the global arena and in Malawi in particular. The coordinating and mentoring role he continues to play will result in a body of knowledge which will shape the discipline as it unfolds in Malawi and globally.

Flossie Gomile -Chidyaonga
Deputy High Commissioner,
Malawi High Commission -London

Ecological Sanitation - Implementation Opportunities and Challenges in Chikwawa, Malawi

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" For most people, sanitation means sitting on a toilet and flushing away the excreta to waste or simply sitting or squatting on a pit toilet and letting the waste matter build up in a pit. In both cases the excreta is disposed of and forgotten in the quickest and most convenient way. But in a world which is becoming increasingly polluted from excreta, and where many of the world's population do not have access to a decent toilet at all, it does make sense to look at excreta in another way"

(Peter Morgan, Water Supply and Sanitation Consultant, Aquamor: Harare, Zimbabwe, and EcoSanRes Programmer, Stockholm Environment Institute, Sweden, 2004)

Abstract:
Ecological sanitation (EcoSan) in not a new technology but rather a recognition that human excreta is a valuable

natural resource (not a waste to be disposed of), containing plant nutrients which after containment and sanitization can be recycled in agriculture to enhance food production, with minimal risk of pollution of the environment and with minimal threat to human health. Various organizations are implementing EcoSan technologies in Malawi. Chikwawa is a rural district that is currently implementing EcoSan initiatives with resources from the Scotland Chikwawa Health Initiative and the US Ambassador's Self Help Fund. The benefits from EcoSan are clear. For example, EcoSan systems help reduce the risk of spreading diseases by containing and treating human excreta before collecting it; minimising surface and groundwater contamination and recylcing the nutrients found in excreta and returning them to soil to enhance food production. However, EcoSan poses some challenges in its implementation such as a correct utilization, acceptability and sustainability of the concept.

Keywords: ***Ecological sanitation, EcoSan, implementation, opportunity, challenge, Chikwawa, Malawi***

Introduction

Malawi is a small landlocked country located in Southern Africa. It is bordered to the west and northwest by Zambia; to the east, south and southwest by Mozambique; and to the north and northeast by Tanzania. The country is one of the poorest nations in the world. It is ranked 166th out of 177 countries listed on the human development index (HDI). Within the Southern African Development Community (SADC), only Mozambique has an HDI value less than that of Malawi. Two thirds of the country's population lives below the absolute poverty line – i.e. less than US$ 1 per day expenditure on basic needs(UNDP, 2006).The country has an estimated total population of 12.3 million people with an annual population growth rate of 3 per cent (GOM, 2005a). Approximately. 86% of the population reside in rural areas predominantly engaged in subsistence farming (GOM, 2000).

Malawi's health indicators are among the worst in sub-Saharan Africa. Under five mortality is one of the highest in the world with one in five children dying before their fifth birthday due to preventable diseases such as malaria, upper respiratory infections and diarrhoea. Life expectancy is one of the lowest in the world at 40.2 years, and these poor life expectancies for both adults and children can be expected to worsen due to a number of factors which include the HIV and AIDS pandemic whose prevalence rate stands at 14.1 per cent (UNDP, 2006), inadequate access to potable water and lack of improved sanitation and poor hygiene facilities and practices. These are compounded by the population's poor socio economic status and high levels of illiteracy with almost half (48%) of all women and one in three (30%) men functionally illiterate. This is mainly because of not having attended school.

In the world today, 2.6 billion people are without adequate sanitation. In 2004, only 61 per cent of Malawi's population had access to adequate sanitation (e.g. connection to a sewer or septic tank system, a pour-flush latrine, a simple pit latrine or a ventilated improved pit latrine(WHO/UNICEF, 2006). An excreta disposal system is considered adequate if it is private or shared (but not public) and if it can effectively prevent human, animal and insect contact with excreta (Chunga et.al., 2004). Most people in rural and high-density townships in urban areas use the conventional pit latrine, which are often in a state of disrepair and unhygienic. Efforts have been made to improve the structure of pit latrines by including a concrete sanitation platform and ventilation pipe to remove foul smells and trap flies. However, due to the costs involved, these have met with limited success (Grimason et. al., 2000). Also during the rainy season, many pit latrines collapse under their own weight due to poor soil structure and poor standard of workmanship and this further reduces the pit latrine coverage in Malawi. For those who do not have access to a latrine or cannot afford the cost of labour involved in constructing one, open defecation in the bush and water bodies is still a popular means of human excreta disposal. Chikwawa, with a population of over 400, 000, has a very low pit latrine coverage. At least 50% of the population have no sanitary facilities with the remaining using pit latrines of poor construction.

The Millennium Development Goals (MDGs) were agreed to in 2000 when all United Nations member states pledged, among other issues, to reduce by half the proportion of people without access to safe drinking water by 2015 (*http:/www.undp.org/mdg/basics.shtml*). This goal was completed at the World Summit for Sustainable Development (WSSD) in Johannesburg, South Africa in September 2002, as it was further agreed to reduce by half the proportion of people without basic sanitation by 2015. In order to step up efforts to meet this target, the UN has declared 2008 as the international year for sanitation. The development of appropriate technical options, such as ecological sanitation, plays a pivotal role in meeting these objectives.

What is ecological sanitation?

Ecological sanitation (EcoSan) is not a new concept. Many cultures have understood the value of urine and faeces for agricultural purposes for centuries, and latrine designs based on the concepts of ecological sanitation have been used in Asia and parts of Africa for hundreds of years. Those who have ever planted a tree in a full pit latrine can be said to be practising EcoSan (Figure 1).

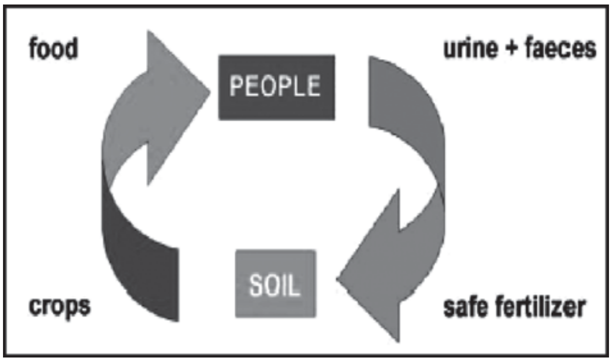
In simple terms, EcoSan in not a new technology but rather a recognition that human excreta and wastewater from households are a valuable resource (not a waste to be disposed of), which should be retained and rendered into an economically useful fertiliser. The basic principle of ecological sanitation is "Closing the Loop on Sanitation", which implies that the nutrients in human excreta – after proper sanitisation - are recycled as a

Figure 1. *A banana tree growing on an old Arborloo pit in Malawi (Morgan, 2007)*

fertiliser resource for crops which provide food for humans (Figure 2). Recycling sanitised human excreta also potentially restores the natural cycle that has been disrupted by current sanitation practices and reduces the need for chemical fertilisers. In summary, EcoSan:

- reduces the health risks related to sanitation, contaminated water and waste,
- prevents the pollution of surface and groundwater,
- prevents the degradation of soil fertility and optimises the management of nutrients and water resources

Figure 2. *Closing the Loop on Sanitation*



Source: Adapted from Schonning & Strenstrom (2004)

Like any other sanitation approach, the most important objective of EcoSan is to form a barrier against the spread of pathogens and parasites in human excreta. The majority of pathogens and parasites' eggs are excreted in faeces. Urine is usually sterile and poses a risk in special cases. It is well known that faeces are a major source of pathogens responsible for diarrhoeal diseases such as typhoid and cholera while the major health risk with urine is bilharzia. In composting EcoSan systems, pathogens are destroyed due to dehydration from the high temperatures they achieve and high pH as a result of the ash added to the latrine after each use. In urine diverting systems, pathogens in urine are destroyed due the effects of ammonia. It has been demonstrated that a temperature of above 60ºC will result in near instant kill of the majority of pathogens excreted in faeces with the exception of *Acaris lumbricoides* and *Cryptosoridium pavrum* oocycsts (Esrey et.al., 1998). Hence these two parasites are used as indicators for an effectively working dehydration sanitation system

Human excreta (urine + faeces) produced by one person in a year contains enough plant nutrients to grow 250 kilograms of grain, which is also the amount that a person needs to feed himself/herself in a year (Table 1). However, about 90 per cent of the plant nutrients in human excreta are found in the urine. On average, an adult produces about 500 litres of urine and 50 litres of faeces per year (Heimonen-Tanski & van Wijk-Sijbesma 2004). The former contains 4.0 kg of nitrogen, 0.4 kg of phosphorus and 0.9 kg of potassium (Drangert, 1998). Interestingly, these nutrients are in ideal forms for uptake by plants: nitrogen in the form of urea, phosphorus as superphosphate and potassium as an ion.

Table 1. *Fertiliser equivalent of human excreta to produce 250kg cereals*

	Nutrient, in kg			
Nutrient	In urine (500l/year)	In faeces (50l/year)	Total	Required for 250kg of cereals
N Nitrogen	4.0	0.5	4.5	5.6
P Phosphorous	0.4	0.2	0.6	0.7
K Potassium	0.9	0.3	1.2	1.2
Total (N+P+K)	5.3	1.0	6.3[1]	7.5

Source: Adapted from Drangert (1998)

[1] This is not equal to the required 7.5kg because of ammonia loss in urine. Most of the nitrogen in urine, which is initially in the form of urea, is quickly converted to ammonia within a collection and storage container. It is therefore important to minimize ammonia loss by storing urine in a tightly covered container.

EcoSan systems

EcoSan has been broadened to include very simple and relatively cheap to construct toilets, which are similar (if not identical) in their use to the standard pit latrine – the most commonly used excreta disposal system in the poorer countries like Malawi (Figure 3). There are three main EcoSan toilet systems. Two of these process the excreta in shallow pits. The third system keeps urine separate from faeces and these two products are processed separately These shallow pit systems have been given names – the Arborloo (a simple pit-toilet in which a tree is later planted), the Fossa alterna (a twin pit toilet which forms humus) and the Skyloo (a urine diversion toilet).

Figure 3 *A typical traditional pit latrine in Malawi*

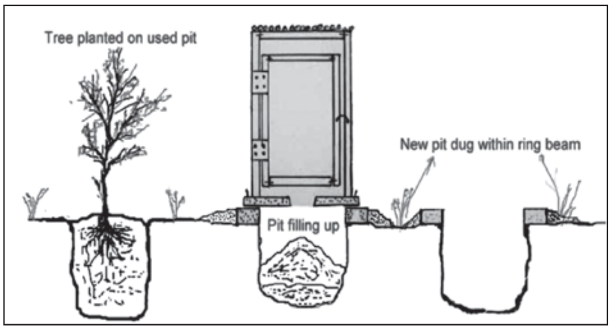
Urine diverting systems, like the Skyloo, are more complex and costly to build and may be beyond the scope of the less well off, which in a country like Malawi, comprises two thirds of the population.

However, there are several ways of collecting the valuable urine other than urine diverting systems. Urine can be collected in containers or bottles and stored and later mixed with water for application to the soil. In Malawi, pit latrines are seldom used at night for fear of snakes and urinating into a container inside the house and throwing it away at dawn is a common practice.

The Arborloo

The Arborloo is a very popular EcoSan concept in Malawi (Morgan, 2003). It is the simplest single pit compost toilet and one that involves the least amount of behaviour change from the conventional pit latrine. A shallow pit, about 1-1.5 m deep is dug and and a slab and easily movable superstructure placed on top of it. The family uses the latrine, adding a mixture of soil and ash after each use, until it is three quarters full (usually between six and twelve months). After this, the slab and the superstructure are moved to a new pit and the process is repeated (Figure 4a). A layer of soil is added to the full pit and a tree planted on it. The tree grows and utilises the compost to produce large fruits (Figure 4b). After a few years of latrine movement the result is an orchard that is producing fruits with a real economic value. The major advantages of an Arborloo include: minimal contact with faeces; easy to construct and no handling of faeces.

Figure 4a *The Arborloo*



Source: Morgan (2007)

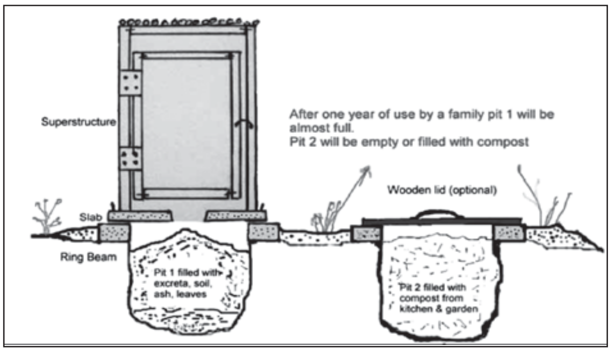
Figure 4b *A young tree has been planted in an Arborloo pit in Malawi*

Source: Morgan (2007)

The Fossa Alterna ("Alternating Pits")

The Fossa Alterna is similar to an Arborloo except two shallow pits are dug next to each other – about 0.5 – 1.5 metre deep (Figure 5). These are used like a twin pit latrine i.e. when the first pit is threequarters full, the concrete slab and portable superstructure are placed on the second pit. When the second is being filled the first one is maturing, and when the second is full, the first is emptied and used again. Just like with the Arborloo, dry leaves are added to the pit before use, and thereafter soil (and ash) are added after each defecation. After composting the contents of the first pit can be used as fertilizer. The best compost is obtained after more than 12 months.

Figure 5 *The Fossa Alterna*

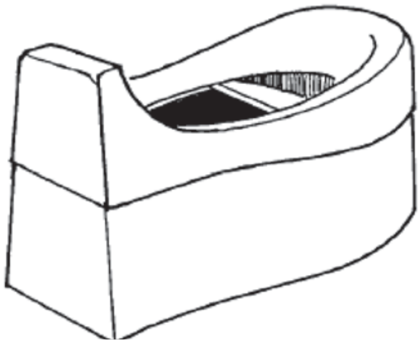


Source: Morgan (2007)

The Skyloo

The Skyloo is an above ground urine diverting latrine. It is constructed by building two brick and rendered vaults above ground level, placing latrine squatting slabs on top of the vaults and completed by building a superstructure on top of the slab. The faeces drop through a squat hole into the vaults where ash and lime are added and are left to mature. The vaults are rotated in a similar manner to the Fossa Alterna. After a suitable retention time, the contents of the vaults are placed on to the garden or farm. In most cases, the urine is diverted within the pedestal or squat platform (Figure 6a) into a pipe connected to a tank (jerry can) where it is stored for later use (Figure 6b). However urine can be collected in a variety of ways other than in urine diverting toilets. Men can urinate into bottles direct and women into a variety of buckets.

Figure 6a *A seat pan with urine diversion*



Source: Esrey et.al. (1998)

EcoSan Opportunities

In Malawi, inorganic fertilisers cost as much as 4000 Malawi Kwacha (US$30). This is a hefty expense in Malawi where two thirds of the population live on less than 1US$ per day. Human excreta is a natural resource and are freely available in all societies – even in the

Figure 6b *Skyloo with urine diversion into a plastic container*

Source: World Bank (2004)

poorest ones. Therefore, this "free" fertiliser should be promoted at all costs.

The use of human excreta for crop production is gaining popularity since 2001 (Sugden, 2003; Semu-Banda, 2007) as demonstrated by this quote:

"*My family and I use the type of latrine where we are able to add ash to our excreta every time we visit the toilet, and this turn ends up speeding decomposition. The decomposed product is mixed with soil after about six months, and that makes a very effective fertiliser. I no longer spend money on chemical fertilisers, and my annual maize and fruit yields have doubled since I started using fertiliser from human excreta*"

[Patrick Moyo – a farmer in an interview with IPS news (Semu-Banda, 2007)]

Namila and Mwanayaya villages, under the Scotland Chikwawa Health Initiative (SCHI), (Morse et.al., 2008) have an opportunity to close the loop on sanitation with funding from the US Ambassador's Self-Help Fund (US$8,000) and the SCHI (£10,000); respectively. EcoSan technologies to be implemented in Namila village are the ArborLoo and Fossa Alterna. In Mwanayaya, human urine is currently being collected in jerry cans at night among members of a vibrant village health committee (VHC) - a group of 10 elected members of the village concerned with any health issue affecting their village. The VHC is playing a lead role in accepting EcoSan in the form of Aborloos in the village.

Namila village is composed of 260 households and has a population of approximately 1,032 people. Along the northern side of the village passes the Likhubula River. The banks of the river are rich in alluvial soil which is excellent for the cultivation of a variety of crops (Figure 7a). People cultivate predominantly maize along the river banks throughout the year; the crops being irrigated by water abstracted from the river with the use of both watering cans and treadle pumps which are labour intensive processes. The project will, through the Department of Mechanical Engineering, University of Malawi – The Polytechnic, promote the use of ecological technologies for pumping irrigation water. The department will fabricate a low cost windturbine to pump water from the river to a storage tank. In collaboration with the Department of Mechanical Engineering at the University of Strathclyde, the Polytechnic is also looking into installing a submersible solar pump. From the tank a network of pipes shall be installed to irrigate the dambo fields (Figure 7b). The Department of Environmental Health will promote the Arborloo at household level and construct a demonstration Fossa Alterna to produce the compost for application in the gardens.

Figure 7a *Location of Namila village garden adjacent to the Likuhula river.*

Figure 7b *Namila village garden*

The village has a flat terrain with loose sandy soil. The latter is an important factor which contributes to the low pit latrine coverage in the village (<25%). Due to loose soil structure, most pit latrines collapse during the rainy season. Using the existing technologies, the community is being encouraged to put woven baskets (nkhokwes) in the dug pit to prevent collapse of latrines. People in the village already use small bamboo woven baskets to protect fruit trees from goats. Other factors affecting the low uptake of pit latrines (as a safe form of sanitation) are cultural, gender and poverty factors e.g. fear of developing hydrocele after using a latrine which has previously been used by a menstruating woman, witchcraft fears associated with stolen faecal matter, the fact that human excrement naturally repels people etc. These factors will be addressed through a combination of awareness raising, information sharing and mobilization through health education and promotion in conjunction with the VHC. The SCHI are in the process of acquiring a motorcycle Mobile Education Unit (MEU) for such purposes (Figure 8). The MEU comes equipped with everything needed to put on a video screening to an entire village *(www.southafrica.info/doing_business/trends/innovations/eranger.htm)*

Figure 8 *The Motorcycle Mobile Education Unit*

The overall goal of the EcoSan programme in Namila is to alleviate poverty by promoting agricultural productivity through the use of ecological technologies in water supply and sanitation and in a way contribute towards achieving MDG 1 (Eradicate extreme poverty and hunger) and MDG 7 (Ensure environmental sustainability) (*http:/www.undp.org/mdg/basics.shtml*)

During a community meeting in Mwanayaya village, one member of the VHC asked the visiting SCHI project team to explain about the "new types" of pit latrines he had seen at nearby Livunzu Primary Schools in the area. These demonstration EcoSan latrines were constructed by Water for People, a water and sanitation non-government organisation (NGO) operating in Chikwawa district. After the socio-economic benefits of the Skyloo and composting process was explained to the VHC, offering the potential to re-cycle urine potentially as valuable as commercial fertilisers, they expressed their unreserved willingness to participate in the study . The VHC members expressed a keen interest in taking the lead amongst other surrounding villages in evaluating the potential for recycling human excreta for crop production.

To this end, the project provided the VHC members with 5L containers to collect urine at night and store it in a 200L drum.They have also been provided with maize seeds to plant in a demonstration plot of about 30m by 10m, provided by the Village Headman.

With the available enthusiasm in the community, the SCHI plans to embark on a £10,000 irrigation project in the village. The project will encourage the use of human excreta as fertilizer for the various crops being grown..

The Challenges

EcoSan ranges from simply planting a tree on a disused toilet pit, through to composting human excreta and re-using the products in agriculture. EcoSan projects being promoted in Chikwawa are not without challenges.

Acceptance and sustainability: The most important factor in assessing the potential for increased use of any sanitation technology is the degree of acceptance in a community, as measured by willingness to adopt or invest in that technology. EcoSan latrines require use of cement for the slab (i.e. sanitation platform). At present, EcoSan projects in Chikwawa are either fully funded or subsidised by donors. This approach sometimes leads to participation even when people are not fully convinced of the merits of the technology, and active participation can wane with the realization of the technology's requirements. With the high poverty levels in Malawi, the cost of a bag of cement (£9 or US$18) is out of reach for many people, and although the communities have shown willingness to adopt EcoSans, they are unlikely to be sustainable in the long term. The SCHI hopes to overcome these issues with a partly subsidised programme to assist with cement, however all sanitation platforms are manufactured within the community, and the promotion of Aborloos means the pit, reinforcement and superstructure can all be made with locally available materials which are free to collect. Sanitation platforms are offered to the community at a small charge of 20 malawi kwacha (£0.07 or US$0.15) to ensure a sense of ownership. This money is placed in a community revolving fund which can be used in the future to make the programme self sustaining.

Correct management: EcoSan technologies are more complicated, or demanding of the user, than others. For example, the user has to remember to add soil and ash each time he/she uses a compost latrine, urine storage containers have to be tightly closed to avoid ammonia loss and ensure correct urine application in the field. Incorrect usage can cause anything from a minor inconvenience to a major system failure and/or health hazard. As such extensive health education is required when implementing the programme to ensure a good understanding of the methods, hazards and benefits.

Post donor support: Success is demonstrable when there is an increased demand for a 'product', or when the 'product' is replicated without subsidies or specialist inputs. It remains to be seen after the life of the projects if EcoSan will become widespread in a community. It is hoped that the revolving funds developed will assist with this sustainability. Maybe the potential for micro-finance projects to sustain construction in the long term should be addressed.

User education: Every sanitation technology needs some user education and EcoSan systems require even more. For instance, the simplest is about the addition of soil and ash after use. Fossa alterna pits should be rested for at least a year before digging out the compost. Health promotion specialists are well aware of the simple challenge of instilling the practice of hand-washing after visiting the toilet. EcoSan introduces another level of complexity and public health risk. Adequate resources are needed to make users fully aware of their responsibilities.

Conclusion

The concept of ecological sanitation has been welcomed in Chikwawa district. However, acceptability, sustainability and correct management of the EcoSan systems are the challenges which should guide the implementation of the concept in the district now and after donor support phases out.

Acknowledgements

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A Preliminary Study of the Efficiency of Soche Wastewater Treatment Plant, Blantyre, Malawi: Compliance of Final Effluent with Design and WHO Recommended Standards

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Abstract

Municipal wastewater poses a number of problems both to humans and the environment if not properly treated. Wastewater comprising of human waste (faeces and sullage) contains pathogenic micro-organisms which cause water-related diseases such as cholera and other diarrhoeal diseases. In order to minimise the impact of the final effluent upon receiving watercourses, discharge standards are set by national enforcement bodies in addition to those recommended by the World Health Organisation (WHO). This preliminary study was carried out to assess the effectiveness of Soche Sewage Treatment Plant in Blantyre, Malawi which entails both primary (sedimentation) and secondary (biological) treatment. Data were collected through desk study, site visits and sample tests. Samples of final effluent were obtained over a period of six weeks to determine the Biochemical Oxygen Demand (BOD), Suspended Solids (SS), faecal and total coliform concentrations. Results reveal that SS, total and faecal coliforms were all within acceptable levels compared with recommended national and WHO standards; however BOD levels were twice the design standard of the treatment plant. Further work is required to determine the impact of the effluent upon the aquatic flora and fauna, the pathogen content of the final effluent and the risk to public health of users who abstract water from the receiving watercourse for domestic irrigation. In the interest of public health there is need to improve the efficiency of treatment by incorporating a tertiary treatment unit such slow the sand filtration units which are currently not utilised.

Key words: ***assessment, discharge standards, Malawi, wastewater.***

Introduction

Soche sewage treatment plant was constructed in 1958 as a direct response to the growth of Blantyre City, the commercial City of Malawi. The plant was initially constructed to serve the following locations of the city; Maselema, Kanjedza, Chitawira, Chichiri, Queen Elizabeth Central Hospital, Nkolokosa, Manja, Naperi and Zingwangwa. As a result of recent developments, the plant now receives sewage from two newly established locations i.e. Chinyonga and Soche East. The influent undergoes preliminary (screening and grit settlement), primary (sedimentation) and secondary biological (trickling filtration) treatment prior to discharge into Mlambalala River. The plant has a design hydraulic capacity of about 5450m^3 of wastewater per day with the total retention time of 8 hours. Initially the plant had one biological filter when it was constructed in 1958. A second biological filter was constructed in the 1960s in order to improve the efficiency as the plant was overloaded due the increased population. Average BOD values of the influent during the initial period of operation ranged from 200 mg/l to 300 mg/l, with current BOD values as high as 800 mg/l recorded. Slow sand filters are available at the works to tertiary treat secondary effluent prior to discharge but they are currently being by-passed due to negligence. As such, final effluent discharged into the receiving watercourse may be subject to nutrient overload as evidenced by the growth of aquatic plants in the river. Surface water from the stream is used by local residents to irrigate garden crops and by those who cannot afford to cover the cost of water rates as a source of drinking and bathing water. The aim of this preliminary study was to assess (i) the ability of a secondary treated sewage treatment plant could comply with national and WHO recommended discharge standards and (ii) the potential risk to public health of the quality of final effluent discharged into the receiving watercourse.

Materials and methods

Final effluent samples were analysed for BOD, SS (n=10), total and faecal coliforms (n=8) (using the membrane filtration technique) in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, 1985). Sampling and analysis was undertaken over a period of 6 weeks in July and August, 2007. Sampling was done during both morning and afternoon hours (Monday through Friday). The mean and standard deviation of the concentrations detected were computed using Microsoft excel.

Results and discussion

Soche sewage treatment was designed to treat wastewater in 1958. The plant was initially constructed to serve the following locations of the city; Maselema, Kanjedza, Chitawira, Chichiri, Queen Elizabeth Central Hospital, Nkolokosa, Manja, Naperi and Zingwangwa. Currently the plant is also serving two more newly established locations namely Chinyonga and Soche East. However, as a result of the increased input brought about by the increased population, it is now overloaded.

The design discharge standards of the effluent plant in terms of biochemical oxygen demand and suspended solids are 20mg/l and 30mg/l, respectively. In addition, the plant is expected to meet the World Health Organisation (WHO) recommended discharge standards for total (10,000 TC/100 ml) and faecal coliforms (1,000 FC/100 ml) set for developing countries (WHO, 1984). With this in mind, these standards were used to compare the effectiveness the plant to treat wastewater prior to discharge into Mlambalala River. The results of composite samples analysed are summarised in Table 1 below. Significant variations in the concentrations of all parameters were noted throughout the duration of the study (data not presented). This is most likely the result of sampling at different times throughout the day and week when the treatment works is under various organic (strength) and hydraulic (flow) loadings. Sewage treatment works are designed to cope with diurnal variations in flow and strength, resulting in variations in the organic and hydraulic loadings placed upon the plant. This is reflected in the BOD and SS concentrations recorded in this study. Shock loadings due to the discharge of industrial (e.g. dairy, abattoirs) and municipal (e.g. pit latrine collections) wastewater into the municipal sewer or inlet of the works will also cause significant variations in the flow and strength of sewage to be treated and subsequently the quality of the final effluent (Smith & Grimason, 2003).

Table 1. Range and mean concentrations of BOD, SS, faecal and total coliforms in final effluent.

Parameter (concentration)	Range	Mean Concentration	Discharge standards
BOD; n=10 (mg/l)	34 – 69	42 ± (16)	20
SS; n=10 (mg/l)	29 – 40	34 (± 4)	30
FC's; n=8 (cfu/100 ml)	610 – 1,137	848 (± 688)	1000
TC's; n=8 (cfu/100 ml)	2,227 – 3,800	3289 (± 2,596)	10,000

Faecal and Total Coliforms

All final effluent samples complied relatively well with the WHO recommended standards for total (< 10,000 cfu/100 ml) and faecal coliforms (<1,000 cfu/100 ml). Whilst all samples complied with the WHO TC standard, only two of eight samples failed to meet the WHO recommended FC standard (1,000 cfu/100ml) with approximate concentrations of 1,100 cfu/100 ml recorded. The presence of FC's in final effluent is 'assumed' to be indicative of a risk to the health of users/consumers of such water due to their 'apparent' association with the presence of enteric pathogens. Whilst TC and FC bacteria are natural inhabitants of the human gut and other warm blooded animals, incl. humans, TC's are also natural inhabitants of vegetation and soils and thus their presence may overestimate any risk to public health. In contrast, FC bacteria are a specific type of coliform bacteria which are found only in the gut of warm blooded animals and consequently their presence is more predicative that a risk to public health may be present. However, it should be noted that there is no positive correlation associated with the presence/concentration of TC/FC in final effluent and the presence/absence of pathogens. Whilst warm-blooded animals may excrete TC/FC on a daily basis, not all warn-blooded animals are necessarily infected and/or excreting gastro-enteric pathogens at the same time. Nevertheless, it should be noted that Soche wastewater treatment plant receives raw sewage from potential contributors of human (e.g. Queen Elizabeth (government) hospital) and animal pathogens (e.g. Blantyre dairy and abattoir). In addition, it also receives contributions from communities from the more impoverished areas of the city including high-density townships (e.g. Zingwangwa) where diarrhoeal disease is more prevalent.

In the interests of public health, the WHO further recommended a stricter FC standard (100 cfu/100 ml) where the final effluent of wastewater treatment plants is to be used to irrigate fields that grow crops for direct human consumption. Whilst not appropriate for this study, it was observed that a number of people living nearby Mlambalala River abstracted water to irrigate crops grown in domestic/communal gardens. Although the effluent discharged from the treatment plant in this study is dispersed and diluted by the receiving watercourse prior to being abstracted for irrigation purposes, further work is required to determine the occurrence and concentration of FC and other pathogenic organisms in such waters used for domestic irrigation purposes and the risk to public health of users/consumers of such water/produce.

Suspended Solids (SS) & Biochemical Oxygen Demand (BOD)

The data obtained for suspended solids revealed slight variations in the mean concentrations although no significant differences between sampling periods were detected. The [SS] ranged from 29 to 40 mg/l over the course of the sampling period, although the average concentration was within the expected range of the design standard (i.e. mean 34 mg/l v design 30 mg/l). Whilst the plant is designed to meet an effluent BOD standard of 20mg/l, every sample analysed in this study registered a BOD concentration on average double that of the design standard. This may be a reflection of a number of factors including the increased organic demand placed upon the treatment plant by the progressive development of new communities and industries that contribute to the municipal sewerage network. As such, this makes it difficult to compare the data obtained in this short study with the original design criteria and further analysis is required. To this end, the assimilative capacity of the receiving watercourse for this effluent requires to be ascertained to determine the impact of the organic loading in the final effluent upon the aquatic flora and fauna. A limitation of this study was the inability to determine the dissolved oxygen levels in the final effluent due to equipment failure and appropriate finance to maintain equipment; a common problem encountered by academics in universities from most developing countries.

Conclusion

To assess the treatment plants effectiveness, these parameters were compared with national and World Health Organisation (WHO) recommended discharge standards. Results reveal that SS, total and faecal coliforms were within acceptable levels compared with recommended national and WHO standards, however BOD levels were double the design standard of the treatment plant. Further work is required to determine the impact of the effluent upon the aquatic flora and fauna, the pathogen content of the final effluent and the risk to public health of users who abstract water from the receiving watercourse for domestic irrigation purposes. In the interest of public health there is a need to improve the efficiency of treatment by incorporating tertiary treatment such as slow sand filtration units which are currently not utilised.

Acknowledgments

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A Preliminary Analysis of the Scotland-Chikwawa Health Initiative Project on Morbidity

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ABSTRACT

The Scotland-Chikwawa Health Initiative (SCHI) is carrying out health interventions aimed at achieving measurable results in major causes of disease and death in four villages in Chikwawa, a southern district in Malawi. Four villages of Namila, Sekeni, Mwanayaya, and Mwalija were earmarked for the pilot study. A baseline survey was carried out in July 2006 in which, among other areas of interest, the role of environmental and socioeconomic factors in diarrhoea and malaria prevalence was investigated. *55%* of the households reported malaria illness in the previous two months. *84%* of households reported fever as a symptom for malaria and only *8%* of them mentioned additional symptoms. *3%* of the households mentioned either drainage of standing water or indoor and out door spraying of insecticides as a main preventive measure used to combat malaria. Malaria prevalence varied across the villages ($p=000$) and across different maternal age groups ($p=0.038$). Malaria prevalence also depended on the size of and in the type of windows used to the household ($p=0.079$ and $p=0.004$ respectively). A multinomial logistic regression analysis showed significant variation in the choice of treatment for malaria ailments. There were significant variations across the villages ($p=000$). Other important malaria risk factors included access to media, accessibility of a health facility, and in the type of windows used. *34* and *63%* of the children were reported to have diarrhoea illness in the last three and six months respectively. A bivariate regression analysis showed that children from households with no toilet facilities were more likely to have suffered from diarrhoea (odds ratio (OR)$=1.701$, $p=0.006$) than those that own such facilities. Children from households that use private taps ($OR=0.172$, $p=0.000$) and where each member uses own basin ($OR=0.382$, $p=0.003$) or running water from a tap ($OR=0.117$, $p=0.007$) for washing hands were less likely to have suffered from diarrhoea in the previous six months. *97%* of the households reported to have access to improved water supply surpassing the Millennium Development Goals (MDGs) of *70%* by 2015. In contrast, only *48%* reported to have access to improved sanitation thus lagging behind the MDGs targets of *74%* by 2015.

Key words: ***Southern Malawi, improved water source, improved sanitation, diarrhoea, logistic regression***.

INTRODUCTION:
It is well documented that malaria and diarrhoea are major causes of morbidity and mortality in developing countries. It is estimated that about 90% of all malaria deaths in the world occur in Africa, South of the Sahara [Roll Back Malaria, 2003; Suh et al., 2004]. On the other hand, it is estimated that one billion or more episodes of diarrhoea occur every year among children less than five years of age causing approximately 2.5 million deaths. 16% of deaths in African children younger than five years are directly attributable to diarrhoeal diseases [Kosek et al., 2003; Reither et al., 2007].

In Malawi, estimated national averages for malaria prevalence are in the range of 49% to 60% while diarrhoea morbidity is around 17% [World Resource Institute, 1999; Ministry of Health and UNICEF, 2003; Kandala et al., 2005].

Responses to the fight against malaria in Malawi have mostly been curative through the use of drugs such *sulfadoxine-pyrimethamine* to already malaria infected people. Other popular and widely used complementary strategies have been the promotion and distribution of free or cheap bed nets and indoor residual spraying. Studies on the fight against malaria have concentrated on the use of and behavioural attitude towards bed nets, and the resistance of malaria parasites to drugs [Rubardt et al., 1999; Sullivan et al., 1999; MacArthur et al., 2001; Holtz et al., 2002; Kublin et al., 2003; Hamel et al., 2005]. Solutions to malaria resistance of drugs have been through the introduction of alternative drugs

War on diarrhoea has chiefly been through civic education campaigns, studies on good hygiene practices, improved sanitation, safe water sources, and use of oral rehydration therapy (ORT) [UNICEF 2006; Peterson et al., 1998; NSO & Macro, 2000; Vaahtera et al., 2000; Jabu, 2006]

This paper analyses environmental and behavioural factors that affect the existence of malaria and diarrhoea prevalence in Chikwawa. It explores possible gaps in the current preventive practices and makes recommendations on possible intervention programmes.

BACKGROUND:
Chikwawa, a district in the southern tip of Malawi, has a surface area of 4,755 Km^2 and an elevation of only 100m above sea level. Out of a population of approximately 356,682, twenty two percent are women of child bearing age.

Chikwawa's climate is subtropical. The rainy season runs from November through April. There is little to no rainfall throughout most of the country from May to October. Chikwawa has an average monthly temperature of 28.4º C with a minimum of 15.2º C and a maximum of 45.6ºC (NSO, 2005). It is normally hot and humid in the months of November to April and hot, dusty and very dry in the months of July to November. Average rainfall in Chikwawa is around 915 mm/year mostly falling in November-March(NSO, 2005). Malawi's biggest river, which drains Lake Malawi and is characterised by big marshes, passes through this district. Chikwawa is also home to Malawi's biggest sugar plantation and two national game reserves.

Chikwawa is, therefore, faced with a number of socioeconomic and environmental problems that have an effect on the health status of the people. Fever and diarrhoea morbidity in the district are estimated at 52.9% and 24.4% respectively [Kandala et al., 2005]. These are statistically different from national averages of 41.7% for fever and 17.2% for diarrhoea morbidity.

A number of interventions have been introduced in Chikwawa by the SCHI in an attempt to reduce the major causes of disease and death. These include the provision of clean water at source and household level, improving sanitation, improving health facilities and access to health facilities, training of health surveillance assistants (HSAs), traditional birth attendants and voluntary community members who form village health committees and water point committees.

The project carried out an initial baseline survey in July to September in 2006 to assess health needs in four selected villages and to act as a reference point for future assessments on the performance of the whole project. Part of the results of this preliminary study is presented here.

METHODS

Data sources
A baseline survey was conducted in four randomly selected villages of Namila, Sekeni, Mwanayaya, and Mwalija in Chikwawa District from which self reported household data was collected. There were 652 households interviewed from the predominantly rural villages of Namila (*n=218*), Mwanayaya (*n=227*), and Mwalija (*n=207*) while 520 households were interviewed from the peri-urban village of Sekeni giving the sample a total of 1,172 households.

The survey randomly interviewed households from each village and only women, as custodians of household information, were targeted.

Five experienced baseline data collectors and one supervisor were recruited to conduct the interviews. They received two days training on the questionnaire and a pilot study was undertaken before the actual interviews. The questionnaire was developed to cover several environmental health topics including malaria and diarrhoea prevalence; sources of health information; known preventive measures; water sources; sanitation; hygiene practices and care seeking behaviour.

Malaria prevalence and two care seeking behaviour outcomes were modelled. One malaria care seeking behaviour model was chosen to observe associated environmental and behavioural risks when an under-five year child had malaria in the household while the other was chosen to model similar risks when an adult had malaria. This was to allow examination of behavioural factors in influencing children's and adult risks in care choices and the extent to which these risks vary.

A diarrhoea prevalence outcome was modelled to allow examination of environmental determinants (water sources) and behavioural determinants (sanitation and hygiene practices) of childhood diarrhoea after controlling for other socioeconomic factors.

The response variables derived for the malaria prevalence and care seeking behaviour outcomes are respectively *reported illness* in the last two months (1 = illness reported, 0 = no reported illness) and *choice* of treatment or diagnosis (home treatment with anti-malaria drugs = 1, health facility treatment = 2, and nothing or other traditional remedy = 3).

The following variables were derived as indicators for the binary and multinomial logistic models for the malaria prevalence and care seeking behaviour: respondent's *village* (Namila, Sekeni, Mwanayaya, and Mwalija); *age* of a responsible woman (respondent) in the household (<years, 15 to 25 years, more than 25 to 40 years, and above 40 years); *number of people* in each household (1 member, 2 members, 3 to 4 members, 5 to 6 members, and more than 6 members); *Religion* of household members (Catholics, Presbyterians, Pentecostals, and other religions); *house composite* (mud walls/bricks with grass roof, mud walls/bricks with metal/tiles roof, fired bricks/cement walls with grass roof, and fired brick/cement walls with metal/tiles roof); *windows* of the house to the household (no windows, open windows, and glass/screen windows); accessibility to health facility through (i) *bridge* (1 = bridge, 0 = no bridge) and (ii) prohibitive *costs* (1 = facility charges for services, 0 = facility does not charge for its services); availability of services at health facility such as (i) drugs (1 = drugs available, 0 = no drugs), (ii) *shelter* (1 = shelter, 0 = no shelter), (iii) *health personnel* (0 = no health workers, 1 = no complaint), (iv) *prompt treatment* (0 = long waiting hours, 1 = no complaint); health information dissemination channels through (i) *radio* (1 = radio, 0 = no radio), (ii) *drama* (1 = drama, 0 = no drama), *songs* (1 = song messages, 0 = no song messages), and *health personnel* officers (1 = messes form health personnel, 0 = no messages from health personnel); and lastly *malaria prevention* and *vector control* measures such as clearing of *weeds/bushes*, drainage of *standing water*, use of *mosquito nets*, spraying *of insecticide inside* house).

The response variable derived for diarrhoea prevalence outcome is *reported diarrhoea illness* in the last six months (1 = illness reported, 0 = no reported illness).

The following variables were derived as indicators for the binary logistic model for the diarrhoea prevalence: respondent's *village*; *age* of the responsible woman (respondent) in the household; *household size* (2 members = 1, three or four members = 2, five or six members = 3, seven or more = 4); *education* of the responsible woman (1 = no education, 2 = primary education, 3 = secondary education); *sanitation* (1= own toilet, 2= use public toilet, 3= have no toilet facility); *water source* (public taps = 1, well = 2, borehole = 3, private taps = 4); *hand washing method* (use cup to pour water from container = 1, one member uses basin = 2, all members wash in one basin= 3, use running water on tap=4).

As long as the environmental and behavioural variables were considered, only those whose independent relationships with either malaria or diarrhoea prevalence were statistically significant at $p \leq 0.25$ were included in the logistic regression models.

Statistical analysis

The binary regression model (Collet, 1994; Rasbash et al., 2004; Souza et al., 2004) is used to explain the probability of a binary malaria or diarrhoea prevalence outcome for children as a function of defined predictor variables. If a woman representing household *i* reported malaria or childhood diarrhoea, then the response variable would be defined as $y_i = 1$; otherwise $y_i = 0$. This becomes a Bernoulli distribution which is defined by the binary logistic regression model:

$$\log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots\ldots$$

where π_i is the probability that household *i* reports malaria or diarrhoea sickness, β_0 is the intercept, (x_{1i},x_{2i},......) are predictor variables for socioeconomic, behavioural, and environmental factors, (β_{1i},β_{2i},......) are corresponding regression coefficients for predictor variables (x_{1i},x_{2i},......). The odds ratio are defined by ($\exp\{\beta_1\}$,$\exp\{\beta_2\}$,......) and each measures the effect of a unit change of their respective predictor variables (x_{1i},x_{2i},......) on the response.

The malaria care seeking behaviour variable has three outcomes that are unordered: the choice of home treatment, health facility treatment or traditional/no treatment. The response variable would be unordered categorical and defined as $y_i = 1$ if household *i* chooses other treatment (traditional or none), $y_i = 2$ if household *i* chooses hospital (or any health facility) treatment, and $y_i = 3$ if household *i* chooses home treatment. In this case a multinomial distribution model is defined such that:

$$\log\left(\frac{\pi_i^{(s)}}{\pi_i^{(3)}}\right) = \beta_0^s + \beta_1^s x_{1i} + \beta_2^s x_{2i} + \ldots\ldots..$$

where category 3 (choice of home treatment) is used as a reference, $s = 1,2,3$ is the choice of treatment, π_i^s is the probability that household i would prefer treatment s, π_i^3, is the probability that household i would prefer home treatment, $\beta_k^{(s)}$ is the additive s effect corresponding to a unit increase in the predictor variable x_{ki} on the log-odds of choosing treatment s rather than home treatment. Like the binary logistic model it is more meaningful to use $\exp\{\beta_k^{(s)}\}$ which is the odds of choosing treatment s rather than home treatment and is defined here as its relative risk ratio (*RRR*).

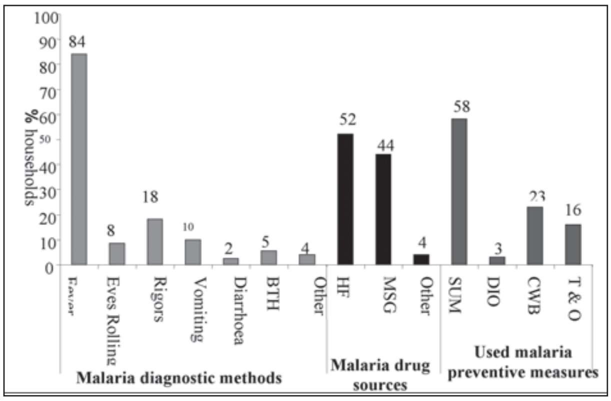
RESULTS

Descriptive summaries

Malaria

Figure 1 gives percentages of households based on their diagnostic, care seeking, and preventive methods for malaria. Fever was the most reported (84%) as a method for diagnosing malaria, followed by rigors (18%). Only 5% mentioned hospital diagnosis. Almost half of the households (48%) reported seeking medical care elsewhere other than a health facility when a household member is deemed to have malaria. Sleeping under a mosquito net was the most known (58%) preventive method followed by clearing of bushes or weeds (23%) around household premises. Only 3% mentioned indoor or outdoor spraying with insecticides or draining of standing water as known preventive methods.

Figure 1 *Household malaria diagnostic, care seeking, and preventive methods*



BTH = Blood testing at a health facility, HF = Health facility,
MSG = Market/Shop/Grocery,
SUM = Sleeping under mosquito net,
DIO = Draining standing water/Indoor spraying/Outdoor spraying, Clearing Weeds and Bushes, T & O = Traditional and other methods

Predictors of malaria risk model given in table 1 show significant variations at village level (X^2 = 29.35, p = 000) and at area of residence (X^2 = 8.01, p = 005) level. Age of a responsible woman in the household also showed notable variation with those below fifteen years of age having the highest reported proportion of malaria sickness in their families. The existence of a bridge to a health facility, availability of drugs at a health facility, and cost of medical services were also significant factors in the malaria status at household level.

Table 1: Predictors used in the model of reported malaria prevalence in the last two months

Covariate		Malaria Prevalence	
		MPR[1]	Score *(p-value)*
Village			29.353 (*000*)
	Namila	45.7	
	Sekeni	51.1	
	Mwanayaya	64.5	
	Mwalija	66.0	
Area			8.005 (*0.005*)
	Rural	60.0	
	Peri-urban	50.7	
Age			8.439 (*0.038*)
	<15 years	66.7	
	15–25 years	56.4	
	>25–40 years	55.0	
	>40 years	50.5	
Number in household			8.373 (*0.079*)
	1 person	54.1	
	2 people	44.9	
	3–4 people	58.2	
	5–6 people	55.0	
	>6 people	56.4	
Religion			4.536 (*0.209*)
	Protestants	56.0	
	Catholics	56.0	
	Pentecostals	51.7	
	Others	60.5	
House composite[2]			5.484 (*0.140*)
	1	56.7	
	2	68.8	
	3	56.1	
	4	50.8	
Windows			10.952 (*0.004*)
	No windows	62.9	
	Open	52.5	
	Glass/screen	51.7	
No bridge	Yes	79.8	30.596 (*000*)
	no	52.7	
No drugs	Yes	61.8	10.872 (*0.001*)
	no	58.8	
Medical costs	Yes	22.9	6.623 (*0.010*)
	no	57.7	

[1]MPR-Malaria prevalence rate (%)
[2]1 = mud walls/bricks with grass roof, 2 = mud walls/bricks with metal/tiles roof, 3 = fired bricks/cement walls with grass roof, 4 = fired brick/cement walls with metal/tiles roof

Table 2 gives summaries of covariates used in the care seeking behaviour model. There was significant variation in behaviour amongst the villages and based on the structure of windows used in the households both in the adulthood malaria and childhood malaria models. Houses without windows had higher rates of malaria prevalence than those with either open or glass/screen windows. The proportion of households from Sekeni, a peri-urban area, that choose use of health facilities is smallest in relative terms of all the other villages that choose health facilities for treatment. However, Mwalija residence show the highest propensity (>78%) of using health facilities of all the villages.

Information from health officers (adult malaria *p=001,* child malaria *p=000*), availability of drugs (adult malaria *p=0.01,* child malaria *p=0.03*), and time patients wait to

Table 2: Summaries of covariates included in the multinomial logistic models for care seeking behaviour

Covariates	Care seeking behaviour - Adult malaria				Care seeking behaviour - Child malaria			
	Care-givers (%) 1= traditional or, nothing, 2= home care, 3= health facility			χ^2 (p-value)	Care-givers (%) 1= traditional or, nothing 2= home care, 3= health facility			χ^2 (p-value)
	1	2	3		1	2	3	
Village				52.211 (*000*)				54.355 (*000*)
Namila	18.1	15.4	66.5		8.1	13.1	78.7	
Sekeni	26.0	20.4	53.7		13.5	26.9	59.6	
Mwanayaya	10.5	20.2	69.3		7.9	20.2	71.9	
Mwalija	8.6	12.4	78.9		6.7	9.6	83.7	
Windows				13.327 (*0.010*)				9.377 (*0.052*)
No windows	22.3	20.5	57.3		11.6	22.0	66.5	
Open	15.2	16.9	68.0		8.9	19.5	71.6	
Glass/screen	22.4	17.4	60.2		11.9	17.9	70.1	
Radio: No	19.1	17.7	63.2	3.783 (*0.151*)	11.1	19.4	69.5	4.474 (*0.107*)
Yes	15.9	19.1	65.0		6.9	22.0	71.1	
Songs: No	18.3	17.7	64.0	5.818 (*0.055*)	10.0	19.7	70.2	3.569 (*0.168*)
Yes	21.4	42.9	35.7		7.1	42.9	50.0	
IHO[3]: No	26.4	19.0	54.5	13.359 (*0.001*)	18.6	22.9	58.4	22.712 (*000*)
Yes	16.5	17.7	65.8		8.1	19.2	72.7	
No drugs: No	22.1	16.2	61.6	8.937 (*0.011*)				7.087 (*0.029*)
Yes	11.6	21.3	67.1					
WLH[4]: No	27.1	15.0	57.9	12.993 (*0.002*)	16.1	19.3	64.6	11.599 (*0.003*)
Yes	14.4	19.4	66.2		7.5	20.2	72.3	

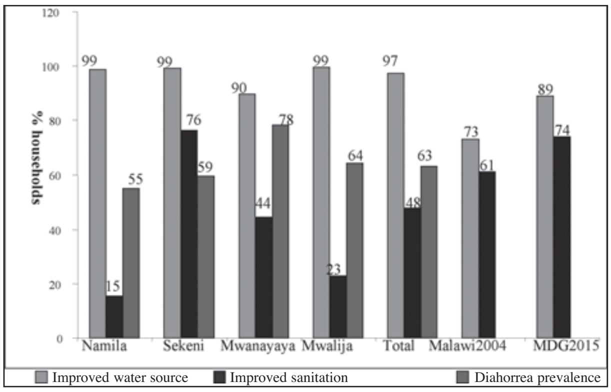
[3]IHO – information obtained from health officers

[4]WLH – waiting for long hours at health facility before treatment

receive treatment at health facilities (adult malaria *p=0.002*, child malaria *p=0.003*) also showed significant contribution to household care seeking behaviour when either an adult or a child were perceived to have malaria

Diarrhoea

Figure 2 *Improved water sources/sanitation sources and diarrhoea prevalence*



WHO definition of improved water source: *there must be at least household piped water connections, public standpipes, boreholes, protected dug wells, protected springs or rainwater collection available to the household*

WHO definition of improved sanitation: *there must be at least a connection to a public sewer, a connection to a septic tank, a pour-flush latrine, a simple pit latrine or a ventilated improved pit latrine available to the household*

Figure 2 compares percentages of improved water sources[5] between four villages with the National figures of 2004 and Millennium Development Goals (MDG) targets of 2015 [UNICEF 2006). It also compares percentages of improved sanitation[6] and diarrhoea prevalence amongst the four villages. All the four villages have surpassed the 2015 MDG-Targets and the 2004 national average on improved water sources. However, Mwanayaya village has a high proportion of unsafe water supply when compared to all other villages.

On improved sanitation, the three rural villages of Namila, Mwanayaya and Mwalija are lagging behind the 2015 MDG-Targets and the 2004 national averages. The situation is worse mostly in Namila and Mwalija with over 70% without improved sanitation. Only the peri-urban village of Sekeni has its targets well above the national averages and those of the 2015 MDG-Targets.

Turning to diarrhoea prevalence, Mwanayaya has the highest diarrhoea prevalence (78%) followed by Mwalija

[5]According to the World Health Organisation (WHO 2003) improved water source includes any of the following types of drinking water sources: household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection.

[6]Improved sanitation includes any of the following: connection to a public sewer, connection to septic tank, pour-flush latrine, simple pit latrine and ventilated improved pit latrine.

(64%) and the peri-urban village of Sekeni (59%). Coincidentally Mwanayaya has the highest proportion of households without improved water sources and lies along the river bank marshes that may be a source of water borne diseases. Although Sekeni and Mwalija have highest proportion of people with improved water sources, they also have slow moving streams and standing water bodies near them that are used for other household chores such as washing, bathing, and even drinking see plate 1.

Plate 1: Slow filthy moving stream along the Peri-Urban Village of Sekeni

Figure 3 *Concentration curves of diarrhoea prevalence vs. household pop. and school level*

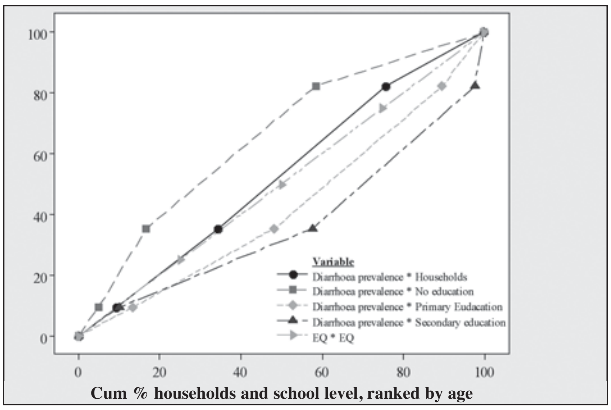


Figure 3 gives the concentration curves of childhood diarrhoea versus household population and school level. Diarrhoea prevalence is fairly distributed amongst all households with women of all varying ages. However for households with women who have not attended school, diarrhoea is concentrated amongst households with young mothers. On the other hand for those households with women who have attended at least primary education, childhood diarrhoea is concentrated amongst households with older mothers.

Malaria risk - binary logistic regression analysis

Binary logistic regression results of reported malaria sickness are reported in Table 3. Households from Namila (*OR=0.45, p=000*) and Mwanayaya (*OR=0.62, p<0.05*) were significantly less likely to have reported malaria sickness than those from Mwalija. Households from Sekeni showed no significant difference in reported sickness from those of Mwalija although they were more likely to have reported sickness in their families. Those that came from rural areas were more likely to have reported malaria illness in their families than those coming from peri-urban areas (*OR=6.31, P<0.10*).

Table 3: Odds ratio (95% confidence intervals) for the binary logistic regression fitted for reported malaria prevalence at household level.

Covariate		OR	95% CI
Village	Namila	0.45	(0.29,0.69)****
	Sekeni	3.53	(0.41,30.6)
	Mwanayaya	0.62	(0.39,0.99)**
	Mwalija	1.00	
Area	Rural	6.31	(0.74,53.8)*
	Urban	1.00	
Age	<15 years	1.91	(1.16,3.17)**
	15 – 25 years	1.32	(0.92,1.89)
	>25 – 40 years	1.10	(0.79,1.53)
	>40 years	1.00	
No. in household	1	0.67	(0.30,1.49)
	2	0.48	(0.29,0.81)***
	3 - 4	0.86	(0.57,1.30)
	5 - 6	0.80	(0.52,1.23)
	>6	1.00	
Religion	Protestants	0.86	(0.60,1.23)
	Catholics	0.75	(0.48,1.16)
	Pentecostals	0.69	(0.48,0.98)**
	Others	1.00	
House composite	mud walls/bricks with grass roof	1.12	(0.84,1.51)
	mud walls/bricks with metal/tiles roof	2.32	(1.04,5.18)**
	fired brick/cement walls with grass roof	1.07	(0.73,1.57)
	fired brick/cement walls with metal/tiles roo	1.00	
No bridge	yes	2.93	(1.71,5.02)****
	no	1.00	
Hospital costs	Yes	0.77	(0.58,1.02)*
	No	1.00	

* p<0.10, ** p<0.05, *** p<0.01, **** p<0.001

Households with women below the age of fifteen were more likely to have reported malaria illness in their families than those that were above forty years of age (*OR=1.91, p<0.05*). There was no significant difference in reported malaria cases for households with women between the ages of fifteen to forty and those above forty. Households with two members had less likelihood of malaria prevalence than those with six or more members (*OR=0.48, p<0.01*).

Pentecostals were less likely to have reported malaria sickness in their households in the last two months than non believers or those from other denominations other than Protestants or Catholics (*OR=0.69, p<0.05*).

Households with mud or mud bricks houses whose roofs were made of metal or tiles were more likely to have reported sickness in their families than those that lived in fired brick or cement walled housed with metal or tile roofs (*OR=2.32, p<0.05*).

Households that complained of a bridge problem were more likely to have reported malaria illness in their families (*OR=2.93, p=000*). Those that complained of costs to medical services were less likely to have reported malaria illness (*OR=0.77, p<0.10*).

Diarrhoea risks amongst children - binary logistic regression analysis

Bivariate logistic regression results of reported diarrhoea sickness amongst children in the last six months are reported in table 4. After controlling for all other variables, children from Mwanayaya were statistically more likely to have been reported sick with diarrhoea than those from Namila (*OR=2.530, p=0.000*). Diarrhoea prevalence rates from Mwalija and Sekeni were not significantly different at *p=0.05* from those of Namila in spite of having higher odds of diarrhoea prevalence.

Table 4: Logistic regression model fitted for reported child diarrhoea prevalence at household level in six months.

Variable	Category	OR	p-value
Village	Namila	1.000	
	Sekeni	2.343	0.113
	Mwanayaya	2.530	0.000
	Mwalija	1.471	0.111
Age of mother	Below 15	1.000	
	15 to 25	1.085	0.787
	25 to 40	0.946	0.852
	Above 40	0.341	0.001
Household size	Two members	1.000	
	Three or four members	1.462	0.264
	Five or six members	1.806	0.097
	Seven or more members	1.809	0.126
Mother's School	No school	1.000	
	Primary education	1.013	0.940
	Secondary education	0.583	0.078
Sanitation	Own toilet	1.000	
	Public toilet	1.141	0.473
	No toilet facility	1.701	0.006
Water source	Public water	1.000	
	Well	1.688	0.285
	Borehole	1.611	0.356
	Private taps	0.172	0.000
Hands washing	Uses cup to pour water from container	1.000	
	One member uses basin	0.382	0.003
	All members wash in one basin	0.810	0.449
	Uses running water on tap	0.117	0.007

OR = odds ratio

Children belonging to households with mothers above the age of 40 years were less likely to have been reported sick with diarrhoea (*OR=0.341, p=0.001*) in the last six months than children from households with mothers of ages 15 years or less. There was no significant difference between households with mothers between the ages of more than 15 to 40 years and those with ages of 15 or less.

Households with five or six members were more likely to have childhood diarrhoea than those with two members only (*OR=1.806, p=0.097*). The likelihood of diarrhoea prevalence increased with increasing number of household members.

Households with secondary school educated women were less likely (*OR=0.583, p=0.078*) to report diarrhoea sickness of children than those households with women that had no formal education. There was no significant difference in childhood diarrhoea between households with primary school educated women and those that had not attended any school.

Households with no toilet facilities were more likely to have reported diarrhoea sickness amongst its children (*OR=1.701, 0.006*) than those with an own toilet facility. However, there was no statistical difference between those using public toilet facilities and those with no toilet facilities.

Respondents that reported using private taps were less likely to have reported childhood diarrhoea than those using public or compound piped water (*OR=0.16, p=0.172*). There was no statistical difference between those using boreholes or wells and those using public or compound piped water.

Lastly, those women that reported using either running water on a tap or one person using a basin when washing hands were less likely to have reported childhood diarrhoea than those women that reported using a cup to pour water from a container (*OR=0.117, p=0.007 and OR=0.382, p=0.003* respectively). There was no significant difference between households washing their hands using a cup to pour water from a container and those that use one basin for all members for washing hands.

Care seeking behaviour on malaria - multinomial logistic regression analysis

The relative risk ratio (*RRR*) estimates of a multinomial regression analysis are given in table 5. The relative risk of seeking other treatment versus home treatment was higher for Namila than Mwalija (*RRR=1.93, p<0.10*) on adult malaria. However, no statistical difference (*p<0.10*) was observed between Mwalija and Sekeni or Mwanayaya villages. The likelihood of seeking hospital treatment relative to home treatment was lower for all the villages of Namila, Sekeni, and Mwanayaya compared to Mwalija village on adult malaria.

On child malaria households from Sekeni and Mwanayaya had lower likelihood of using either hospital or other treatments relative to home treatment when compared to households from Mwalija.

Households with glass/screen windows on their houses were more likely (*p<0.05*) to use hospital facilities than home facilities for childhood malaria when compared to households whose houses were either open or had no windows.

Table 5: Relative risk ratios (95% confidence interval) for the multinomial logistic regression fitted for the choice of treatments at household level

	Adult malaria (> 5 years) (Reference Category is home)				Child malaria (≤ 5 years) (Reference Category is home)			
	Other vs home		Hospital vs home		Other vs home		Hospital vs home	
	RRR	(95% CI)	*RRR*	(CI 95) %	*RRR*	95% CI	*RRR*	(95% CI)
Namila	1.93	(0.98,4.18)*	0.73	(0.41,1.29)	1.08	(0.43,2.72)	0.72	(0.39,1.33)
Sekeni	1.22	(0.61,2.46)	0.31	(0.19,0.53)**	0.44	(0.20,0.97)**	0.19	(0.11,0.32****
Mwanayaya	0.75	(0.33,1.66)	0.61	(0.35,1.04)*	0.57	(0.23,1.41)	0.45	(0.25,0.80)***
Mwalija	1.00		1.00		1.00			
No windows	1.08	(0.60,1.94)	0.64	(0.39,1.06)	0.77	(0.39,1.53)	0.52	(0.32,0.84)***
Open	0.78	(0.45,1.36)	0.86	(0.54,1.37)	0.58	(0.31,1.12)	0.58	(0.37,0.91)**
Glass/screen	1.00		1.00		1.00		1.00	
Yes	0.87	(0.52,1.45)	1.26	(0.85,1.87)	0.69	(0.37,1.30)	1.21	(0.83,1.75)
No	1.00		1.00		1.00		1.00	
Yes	0.49	(0.11,2.14)	0.22	(0.06,0.77)**	0.33	(0.03,3.01)	0.31	(0.10,0.99)**
No	1.00		1.00		1.00		1.00	
Yes	0.58	(0.36,0.93)**	1.21	(0.81,1.80)	0.45	(0.27,0.74)***	1.33	(0.91,1.93)
No	1.00		1.00		1.00		1.00	
Yes	0.54	(0.35,0.83)***	0.91	(0.63,1.33)	0.52	(0.31,0.85)***	0.98	0.69,1.38)
No	1.00		1.00		1.00		1.00	
Yes	0.52	(0.31,0.89)**	0.52	(0.36,0.77)****	0.49	(0.25,0.97)**	0.63	(0.43,0.93)**
No	1.00		1.00		1.00		1.00	
Yes	0.57	(0.35,0.94)**	0.71	(0.49,1.03)*	0.50	(0.27,0.91)	0.74	(0.51,1.06)
No	1.00		1.00		1.00			

* p<0.10, ** p<0.05, *** p<0.01, **** p<0.001

RRR = Relative risk ratio, CI = Confidence interval, IHO = Information health officer, NHO = No health officer, Other = traditional or other treatments

Households who reported being exposed to health education messages through songs were less likely to use health facilities relative to home facilities than those who did not mention being exposed to health messages both on childhood (*RRR=0.31, p<0.05*) and adulthood malaria (*RRR=0.22, p<0.05*). Similarly households that were either exposed to information health officers messages or those that reported too long waiting time before treatment had less likelihood of using other treatments relative to home treatment if any member of their household had malaria (*p<0.05*).

Absence of health personnel at health facilities was also a contributing factor to the choice of treatment. Those that complained of lack of medical personnel were less likely to use either health facilities (*RRR=0.52, p=000*) or other methods (*RRR=0.52, p<0.05*) relative to home facilities whenever a member of their household had malaria.

Lastly those that mentioned lack of drugs as a problem had less likelihood of using either health facilities (*RRR=0.71, p<0.10*) or other facilities (*RRR=0.57, p<0.05*) relative to home facilities when an adult had malaria.

DISCUSSION & RECOMMENDATIONS

Malaria

In spite of the fact that malaria is not the only disease that causes fever, evidently it (fever) is the most used and known diagnostic method for malaria in the communities. Few households mentioned additional symptoms other than fever as methods for certifying malaria. It is also a matter of concern that very few households recognise the importance of using health facilities for diagnosing malaria and that almost half of the households do not take their perceived malaria patients to a health facility for treatment. There are chances here that those perceived to have malaria may be suffering from other diseases that cause fever morbidity. Malaria treatment sought elsewhere other than a formal medical facility may not be the right prescription for the patients. This may lead to problems of drug resistance and death due to wrong prescription.

It has widely been documented that untreated falciparum malaria (common malaria in Malawi) contributes both directly and indirectly to the death of non-immune individuals, sometimes within hours of the onset of symptoms [Greenwood et al., 1987]. In addition, there is evidence that drug resistance may be responsible for increased mortality in Malawi and elsewhere in infants and children [WHO/UNICEF, 2003].

It is, therefore, necessary that people are taught the importance of diagnoses and prompt treatment at certified medical facilities. Emphasis must also be put on the consequences of delayed medical attention, wrong prescriptions, and drug resistance due to shortfalls arising from those with the responsibility to diagnose and prescribe treatment at home.

Use of mosquito net is the only known malaria preventive method to most households in the study area with an additional few mentioning clearing of bushes or weeds around their homes. Small proportions of people mentioned spraying of insecticides in their homes or surrounding areas as an option and none mentioned management of the environment in general as an alternative. This clearly shows that the popular preventive malaria knowledge known to the people of Chikwawa is the use of Mosquito nets. It seems very little or no attention at all is given to alternative strategies for reducing the burden of malaria as is evidenced from plate 2. Gullies are created due to brick-making near dwelling houses at Mwalija village. These gullies keep water during the rainy season which in turn provides sanctuary to malaria vectors. Coincidentally Mwalija village has reported the highest rate of malaria prevalence.

Plate 2: Gullies being created by brick-making at Mwalija village: these may become potential sanctuaries for malaria vectors in the rainy season.

As noted in literature [Lindsay et al., 2004] major reductions in mortality from infectious diseases, including malaria, in Europe and North America occurred using other environmental management control measures even before the introduction of effective drugs and vaccines. These investigators also claimed that the rapid development and spread of drug resistant organisms demonstrates that evolution cannot be halted and that environmental management must be considered as part of an integrated effort against malaria vectors.

It is important, therefore, that while short term measures such as use of treated mosquito nets and prompt medical attention are being recommended, integrated approach that includes environmental management in all aspects that controls malaria and social issues such as attitude and behavioural change in people are essential to meaningfully combat malaria in Chikwawa.

The magnitude and variation of malaria prevalence in the villages is mostly an indicator of differences in environmental factors existent in each village which may not have been captured in the models. The high prevalence of malaria in Mwalija may be due to standing water bodies and rice paddies existent within metres of the village while high prevalence in Mwanayaya village may be due to its location on the marshes along the Shire River banks. These environmental factors may be in addition to other human-made ecological transformations due to irrigated land and other activities. Currently more studies are underway to assess these factors with the view of making more informed decisions.

Number of people in a household also played a significant role in the prevalence of malaria. The smaller the number of people in a household the less likely they are to report a malaria illness in their family. Other studies that have similar results include a study in Tanzania [Mbango and Namfua, 1992].

On religious groupings members of the Pentecostal faith were less likely to report malaria illness in their families. More research is being conducted to determine the reasons for this observation.

Absence of a bridge on the way to a hospital was very significant as an indicator. Those that complained of a bridge were more likely to have also reported malaria illness in their families. Mostly people from Mwanayaya (38%) indicated they faced the problem of a bridge on their way to the hospital.

The lower likelihood of seeking treatment from a health facility relative to home treatment when a child had malaria by the households of Sekeni and Mwanayaya compared to households of Mwalija may be due to the fact that people from Mwalija are within walking distance to a free government hospital. In contrast people of Mwanayaya are more than five kilometres away from the nearest health centre while those of Sekeni have a private hospital nearby but it charges a fee for its services. It seems it is cheaper for people of Mwanayaya and Sekeni to buy antimalarials from an open market and administer them at home than walking the more than five kilometre distance or paying medical costs at a private hospital respectively.

The greater likelihood in using traditional treatments or doing nothing relative to home treatment in households in Namila when compared to people of Mwalija may be due to distance. Both residents of Namila and Mwalija report to the same free government hospital. Mwalija households are within walking distance and people of Namila have to walk a reported distance ranging from three and half to five kilometres to the hospital. While almost every adult from Mwalija would report at the hospital for treatment adults from Namila would rather use other traditional methods or do nothing at all when they are sick because of distance. These differences are a pointer to inequalities in health service provision.

Remedies in the village inequalities may include construction of a health centre or provision of mobile clinics to Mwanayaya and possibly Namila villages and removal of costs from a private medical facility located in Sekeni village through government subsidies.

The lower probability of seeking medical care relative to home care when a child is sick by those households that have no or open windows versus those that have glass or screen windows may be due to monetary reasons. Those whose houses have no or open windows are mostly the poor in rural areas while those with glass or screen windows are relatively well to do in their communities and may easily afford any hospital associated costs.

The results of those exposed to health information messages are rather mixed. Those that have been exposed to health education messages through songs are less likely to use hospital treatment relative to home treatment when compared to those who have not mentioned exposure to songs. This may be explained by the nature of the messages in the songs which may not be directly related to malaria messages. The likelihood of using traditional methods or doing nothing compared to home treatment is very small for those that have been exposed to health messages through health personnel versus those who have not. This suggests that those exposed to health messages from health personnel appreciate the importance of treating patients with scientifically approved medication as opposed to doing nothing or using other non-scientific (traditional) methods.

On problems faced by patients at health facilities, the problem of absence (or shortage) of health officers is an influential factor regardless of the nature of the patient. There is less likelihood of using health facility treatment versus home treatment for those that mention absence of health officers as a problem relative to those who did not. People choose home treatment because they know they won't be attended to by a doctor at a hospital anyway. Malawi has an acute shortage of medical personnel and the few that are available are mostly away doing other errands such as field work or workshops that bring them extra income [Masangwi, 2007]. On the other hand, those that have complained of absence of health personnel are less likely to use traditional methods or do nothing compared to home treatment. This may be explained by the fact that doing nothing or using traditional methods is not an option for not using health facilities in the absence of doctors. People would rather use home treatment instead. Another factor related to absence of health personnel at health facilities is that of long waiting time at health facilities. Those that mentioned long waiting time were less likely to use traditional or do nothing relative to home treatment for both child and adult malaria. Again this only confirms that those who complain of problems related to health personnel are more likely to opt for home treatment as an option compared to other methods if they choose not to go to the hospital.

Those who complained of drug shortages at health facilities were less likely to either use hospital facilities, traditional facilities, or do nothing versus home treatment only when an adult had malaria. This still solidifies the fact that those who have problems with hospital services would rather have home treatment than other traditional methods or doing nothing.

Overall, it is important to intensify health and civic education on malaria, prevention and proper treatment while working on long term strategies that may include, training of more health personnel, environmental management and rehabilitation.

Diarrhoea

Although there is adequate provision of improved water sources in the villages under study based on the 2015 Millennium Development Goal (MDG)-targets and 2004 national averages, there is need to focus attention on Mwanayaya village which has a higher proportion of households without improved water sources. A good number of households from Mwanayaya use unprotected wells as sources of their water. It seems more likely that the high prevalence rate of diarrhoea amongst children from this village is partly due to this problem apart from its being located along the marshes of a river bank. Table 4 confirms that those using wells (which are mostly unprotected) are more likely to have childhood diarrhoea in their households.

In spite of boreholes and protected wells qualifying as improved water sources based on WHO definition, there is need to teach households and more especially children about safe water usage and management at the water sources. It has been observed that poor hygiene practices at water sources may be caused by a number of reasons that include lack of knowledge on sanitary principles, water costs, inadequate safe water sources and problems of distance [Gilman et al., 1993]. In the case of the four villages, overcrowding, animals, garbage, poor water usage, and management (see plates 3 (a) and (b)) may be the reason why households using boreholes (although not significant) were more likely to have childhood diarrhoea (table 4). Cost of water and easy proximity to contaminated water sources such as the case in Sekeni and Mwalija is another important contributor to childhood diarrhoeal prevalence (plate 1). Although Sekeni is registered with highest improved water sources (99.23%), this may be misleading as many households collect water from a compound tap in the sugar plantation staff housing. This water is directly drawn from the Shire River with no treatment and so acts as a high risk water source. Furthermore, water has to be carried from the compounds. This is a prohibitive scenario and many households especially children

Plate 3a: Animals at a borehole in Namila Village

Plate 3b: Filth at a borehole at Mwalija village. A result of poor borehole management.

prefer to use other nearby contaminated water sources. This may explain the high prevalence of diarrhoea in Sekeni village in spite of using piped water for drinking.

There is a significant problem in relation to the availability of toilet facilities. All the rural villages of Namila, Mwanayaya, and Mwalija have sanitary provisions that are way below the 2004 national averages and the 2015 MDG-targets (figure 3). Logistic regression results in table 1 show that those with no toilet facility are more likely to have childhood diarrhoea in their households. This is consistent with studies in Eritrea [Woldemicael, 2001] and Ghana [Tagoe, 1995] that observed that the risk of having diarrhoea is significantly associated with a toilet facility. The studies further demonstrated that children living in houses with toilet facilities were less likely to contact diarrhoea than children living in houses without such facilities. However, this study did not find any significant relationship between disposal of young children's faeces and diarrhoea. An earlier study in Blantyre, Malawi [Grimason et al., 2000] found that a potential exists for widespread contamination of the surrounding environment and transmission of faecal-oral disease due to lack of attention afforded to the disposal of young children's faeces. It is essential; therefore, that emphasis should be put on improving sanitation especially in the three rural areas.

Currently the SCHI project has introduced Eco-sanitation[7] latrines (plate 4 (a) and (b)) in the four pilot villages of Chikwawa with the aim of empowering households to use local resources to construct improved toilet facilities. Improvements in sanitation have already been registered using other versions of Eco-Sanitation in other parts of Malawi [Sugden, 2003].

Plate 3a: A pit and a locally woven basket inside the pit.

Plate 3b: A complete fully covered Eco-sanitation latrine.

The results of the concentration curves of figure 4 and the Bayesian logistic regression analysis for reported childhood diarrhoea prevalence of table 1 show that childhood diarrhoea is high amongst households with young mothers who have not attended school. Experience may explain the difference in childhood diarrhoea amongst households with women who have not attended any formal education. Young mothers with no education may have no or little knowledge or experience in caring for children compared to older women who acquire their knowledge through years of child rearing and learning. This is consistent with another

[7] Eco-sanitation technologies are shallow pit latrines (about 1m) with locally woven baskets placed inside the pit and a movable superstructure placed on top of the latrine (see plates 2(a) and 2(b). The basket is meant to protect the sandy soil (common in Chikwawa) from collapsing. Every time a household member uses the latrine he/she adds a mixture of soil and ash to the pit. When it is almost full the superstructure is moved to another pit and the latrine is filled with soil. A tree or vegetables such as pumpkins are then planted utilising the composite on the filled latrine. After a few years of latrine movement the result can be a healthy orchard with an economic value to the household and community.

study in Malawi [Morse et al., 2007] which found that lack of education at household level is an implicating factor in the contraction of *cryptosporidiosis*. Thus short-term health planning should include educating young mothers on the benefits of proper hygiene practices, sanitation, proper stool disposal and use of treated water. For long term goals, emphasis should be placed on community awareness and benefits of sending a girl child to school.

Things being equal on educational levels, a plausible explanation for the increasing rates of diarrhoea amongst households with older mothers compared with those that have attained at least primary education is that such households are more likely to have bigger families hence more children than those with young mothers. The logistic regression results show that households with more members are more likely to have childhood diarrhoea than those with fewer members. These results are in line with a study in Eritrea [Woldemicael, 2001] which observed that diarrhoea prevalence increases with increasing number of children living in a household.

The lower likelihood for childhood diarrhoea amongst households with secondary education mothers in table 1 is consistent with a number of studies [Pebly and Stupp, 1987; Hobcraft, 1993; Manda, 1999; Kandala et al., 2005; Pongou et al., 2006; Osumanu, 2007]. Education translates to better skills and knowledge that are essential in understanding and using existent healthcare resources. Further, mothers with more education are said to overcome the adverse effects of some factors such as very young and old maternal age.

The increased likelihood of child diarrhoea amongst households that either wash their hands using a cup for drawing water from a container or those that use one basin for all household members is an indication of underlying poor hygiene practices. Use of a cup to draw water from a container provides a number of avenues for contamination. Members of the household with dirty hands, particularly children, may dip their hands into containers or may leave cups on unprotected surfaces and this may contribute to contamination. Similarly household members, who may have used a latrine, changed a nappy, or may have been in contact with faecal matter and may not have properly washed their hands, provide opportunities for contamination [Curtis et al, 2000]. Other authors have already demonstrated or observed that hand washing can help reduce diarrhoea [Steere and Mallison, 1975; Black et al., 1981; Khan, 1982; Aung and Hlaing, 1989; Gilman et al., 1993; Bartlett 2003]. It is important therefore in all health education messages to emphasise the good hygiene practice of using water for washing hands before taking any food, after using the toilet and on other occasions when hands have been soiled.

This study investigated morbidity due to malaria and diarrhoea in relation to varying environmental and behavioural factors in four pilot villages in Chikwawa District, Malawi. The results are based on retrospective reporting from cross-sectional data. This may result in possible biases due to incomplete and unrepresentative data. Furthermore, only information from surviving women that were present during interviews was recorded implying that no data was available for households of women who had died or were not available. During the survey the mothers were not given clear-cut definition of ill-health. Therefore, the questions relied on the mother's perception rather than medical or actual definitions or estimates. There can be differences in interpretation among different households and villages because perception of ill-health may not be the same across different groups of people. To reduce misrepresentations due to these methodological limitations, questionnaires from each enumerator were carefully audited and data were screened to ensure consistency and to determine if the data conform to expected patterns. Cross-sectional data remain an important tool of examining relevant health issues that may translate to informed decisions on the quality and magnitude of health development programmes in Malawi. This will remain the case in the absence of individual records (as is common in many developing countries), or in the absence of detailed longitudinal or clinical surveys.

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SCOTLAND CHIKWAWA HEALTH INITIATIVE
Improving Health from Community to Hospital

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Abstract
The Scotland Chikwawa Health Initiative is a three year programme funded by the Scottish Executive International Development Fund which aims to achieve measurable reductions in major causes of disease and death in four villages within the Chikwawa District of Malawi alongside improving the hospital environment for the good of both staff and patients. The initiative has developed a holistic approach to health improvements through the provision of infrastructure at both health facilities and within communities, and training of government personnel and community volunteers.

Specific areas targeted have included water and sanitation, maternal health, and communicable disease control with provision of training and materials to facilitate interventions and health education. At the end of the second year the programme has already seen reductions in diarrhoeal disease (30% overall in target communities), improved access to safe water, an increase in the uptake of growth monitoring and immunisations in children under the age of five years (15% increase since training volunteers), improved safe delivery of babies within the community (245 babies delivered safely in target communities with 25 referred due to complications) and increased community health activity (training and integration of village health committees, water point committees, traditional birthing attendants and health surveillance assistants).

The programme hopes to act as a model for the District to follow in other communities to achieve it's obligations under the Malawi Ministry of Health Essential Health Package.

Key words: ***Malawi, water, sanitation, community health, diarrhoeal diseases, maternal health.***

Introduction
Malawi and Scotland have long historical links. From the days of David Livingstone over 150 years ago, Scots have been travelling to the 'Warm Heart of Africa' to help develop this beautiful country, providing medical assistance, education, culture, faith, and most importantly all striving to improve the standard of living for Malawians. Hundreds of Scottish organisations travel to and fund raise for Malawi every year, and this link has become even stronger in the last two years with the involvement of the Scottish Government and formation of the Scotland Malawi Partnership (www.scotland-malawipartnership.org)

For over 10 years, the University of Strathclyde has joined this group by developing links between its Environmental Health Department and that of the University of Malawi. This link has allowed a transfer of knowledge between the two institutions through visits to both Malawi and Scotland of academic staff, postgraduate and undergraduate students, and practicing EHO's. The Royal Environmental Health Institute of Scotland (REHIS) is also participating in this link helping to re-establish the Environmental Health Officers Association of Malawi. This professional body was re-established last year after 10 years dormancy. As such the link between the countries in the area of environmental health has grown and flourished over the years to assist the development of the environmental health profession in Malawi and allow Scottish professionals to experience public health in a developing country.

The institutions have carried out extensive health research in one of the poorest districts in the Southern Region of Malawi, Chikwawa. This research has concentrated on sanitation, water quality and the transmission of diarrhoeal diseases (Morse, et al., 2007a). In an extension of that work, the University of Strathclyde Malawi Millennium Project was awarded a grant (£163, 000 over three years) from the International Development Division of the Scottish Executive to work with the District Health Office in Chikwawa and the University of Malawi to target holistic health improvements both at the District Hospital and at community level under the auspices of the Scotland Chikwawa Health Initiative. The funding covers a three year period (beginning February 2006) to allow the health initiative to be developed which integrates capital investment, training and community development.

Malawi is one of the poorest countries in the world. Under five mortality is one of the highest in the world with one in five children failing to reach the age of five due to preventable diseases such as malaria, upper respiratory infections and diarrhoea. Overall life expectancy is one of the lowest in the world at 40.2 years, and these poor life expectancies for both adults and children can be attributed to a number of factors not least HIV/AIDS, housing standards, quality and quantity of water, lack of sanitation and poor hygiene facilities and practices. These are compounded by a poor level of education and poor socio economic status of the majority of families.

Chikwawa, with a population of over 400, 000, has some of the poorest health facilities and infrastructure in the country (Figure 1). The majority of the population live in traditional housing (mud bricks and grass roof), with 2 rooms for an average of 6 family members. At least 50% of the population within the district have no sanitary facilities with the remaining using pit latrines of poor construction. 93% of the district population collect drinking water from communal sources with approximately 50% of these collecting from unprotected sources such as shallow wells and rivers (NSO 2005). Research in the district has also demonstrated that up to 30% of 'protected' water sources were contaminated with bacterial indicators of faecal pollution, and up to 90% of water stored within the household was also contaminated despite being collected from a microbiologically safe source (Morse, *et. al*., 2008).

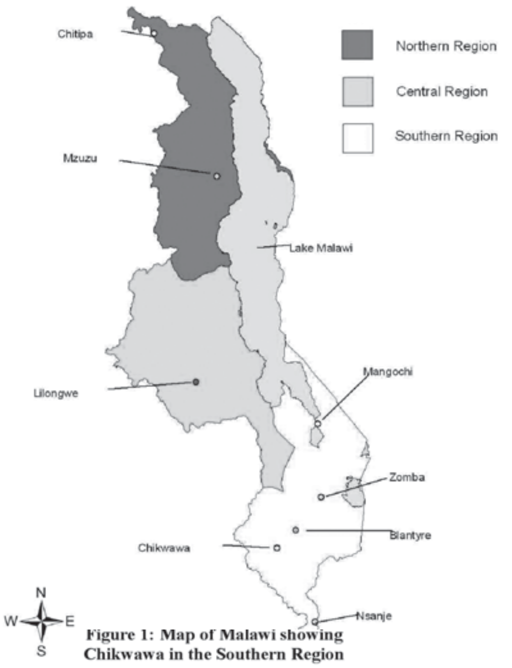
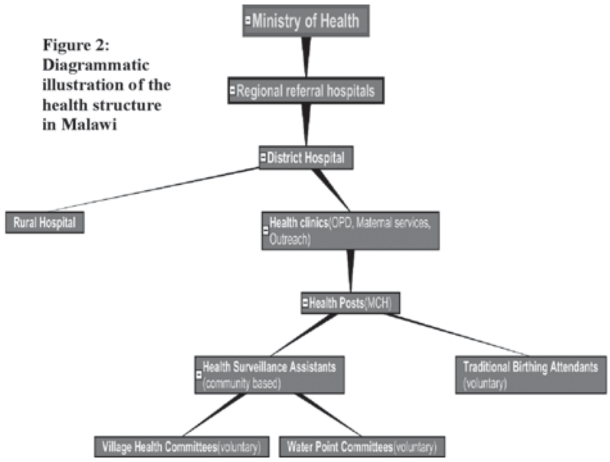


Figure 1: Map of Malawi showing Chikwawa in the Southern Region

The health system in Malawi is under the auspices of the Ministry of Health (MOH), which oversees all activities at all levels of care including central hospitals, district hospitals and health facilities. Overall there are 497 health facilities throughout the country ranging from Central Hospitals with a high level of specialist care and surgery, to rural health clinics with basic care from medical assistant and health surveillance assistants (Figure 2).

Figure 2: Diagrammatic illustration of the health structure in Malawi



In Chikwawa, the population is served by one district, one Christian and one rural hospital, and 15 health centres throughout the district which are manned by three doctors, 79 nurses, 12 clinical officers, 18 medical assistants, 5 assistant environmental health officers and 400 health surveillance assistants. Health surveillance assistants are normally based within the community where they work with them on basic areas of maternal and child health, water and sanitation. In addition, there are 19 environmental health staff who work with the HSA's on disease prevention, water and sanitation issues, and a number of veterinary staff who work with communities on appropriate animal rearing techniques.

The Health Service is managed by a District Health Management Team comprising a District Health Officer, District Nursing Officer, District Environmental Health Officer and District Health Services Administrator.

The District Health Officer (DHO) is responsible for medical staff: doctors, clinical officers (trained in medicine for four years though not fully qualified doctors) and medical assistants (trained in medicine for three years The District Nursing Officer (DNO) is responsible for nursing staff and for the training and supervision Traditional Birth Attendants (TBAs). There is a severe shortage of nurses throughout Malawi because many emigrate to developed countries for work, and others are able to obtain better-paid work in the many research institutes in Malawi.

The District Environmental Health Officer (DEHO) is responsible for trying to ensure a satisfactory supply and quality of the fundamental determinants of health – particularly water supply and sanitation. The DEHO's have responsibility for additional qualified environmental health officers and a substantial number of Health

Surveillance Assistants (HSAs). The HSAs promote the health and wellbeing (including water and sanitation) of the people living in groups of villages. They identify individuals who have a health problem, try to determine the cause and take any necessary action: for example treatment at home, referral to the clinical officer/medical assistant at a local clinic or transfer to hospital. HSA's have the additional responsibility of training and trying to ensure satisfactory standards of water supply and sanitation, as well as undertaking under five clinics where they carry out weight and height measurements and administer immunizations. The HSAs usually travel between villages by bicycle. With all of these responsibilities the HSAs have only twelve weeks of training and follow- up training is often sporadic. Only 54% of the rural population has access to a health facility within 5km.

Aims and Objectives

The overall aim of the three year project is to achieve measurable reductions in major causes of disease and death in four villages within the Chikwawa District of Malawi alongside improving the hospital environment for the good of both staff and patients (Morse, et al., 2007b).

This was to be achieved by:

- Assisting the retention of staff at the hospital through provision of accommodation
- Improving basic facilities such as water, sanitation, and transport within communities.
- Introducing preventative measures such as training, health education, provision of mosquito nets, immunisations, etc.
- Ensuring appropriate diagnosis and treatment of diseases by providing basic equipment, training in disease detection, ensuring a supply of medications, refurbishing laboratory facilities.
- Improving recording procedures to ensure that monitoring and evaluation are key components of the district health team from community to hospital level.
- Networking with other stakeholders
- Providing appropriate facilities for management of HIV patients.

All work is also in line with the Ministry of Health Essential Health Package and their year plan for improved health access in Malawi from community to referral hospital level. (MoH 2004). All work has also been done with constant discussion and collaboration between all stakeholders.

This holistic approach to disease prevention is aimed at reducing morbidity and mortality within the district and is hoped will act as a model for other communities and districts throughout the country.

Implementation and evaluation

Identification of training requirements, community needs and problem areas was achieved in several ways. During the first year of the programme, an extensive baseline survey was conducted to assess the knowledge, attitudes and practices of households in target communities with regard to household details and socio economic status, health access, malaria, diarrhoeal disease, upper respiratory infections, HIV/AIDS, maternal and reproductive health, sanitation, water use and awareness of health surveillance assistants and voluntary committee members. These data were used to ensure communities had the pressing areas of concern targeted. In addition, specific questionnaires to health personnel and volunteers, focus groups discussions and one to one meetings have been used to identify and address key areas.

Monitoring and evaluation have also been key elements of the initiative, with regular steering group meetings and focus groups discussions with all levels of personnel involved. An extensive data collection exercise was completed in November 2007 to assess the impact of training and interventions to date, the results of which are currently being analysed and will be used to ensure effective targeting of funding for the coming year.

Now nearing the end of our second year of funding, we have achieved a number of objectives of the programme and are currently assessing the efficacy of various trainings and interventions. These have been achieved not only with the funding of the Scottish Executive, but also through other donations from both organisations and individuals interested in the work in Chikwawa.

Capacity Building

All work in the health area requires capacity building with both staff and volunteers and as such, this has been one of the main investments made by the programme. This was seen as essential if the programme was to be sustainable at the completion of the funding. It was initially apparent that in many cases staff and volunteers were not working cohesively together or sharing information and therefore it was essential to open channels of communication between various stakeholders. In particular the programme targeted, health, water, sanitation and agriculture within the district, including government employees such as environmental health officers, water supervisors, nurses, midwives, clinical officers, health surveillance assistants, and voluntary members of the community such as traditional birthing attendants and village health and water committees.

The area which required the most input was the community level. Although the structure existed for health surveillance assistants, village health committees, water point committees and traditional birthing attendants, in many cases these were dysfunctional or lacked direction and coordination. One of the key areas of the programme was to get these groups working effectively together and to provide advice and mobility to their communities to achieve improved health and improved health seeking behaviour. All training of voluntary committees and HSA's was conducted by

District Health Office staff who were experts in the appropriate areas thereby ensuring that the training was replicable for future groups (Figure 3). To compliment the training, the programme has also provided materials to allow staff and volunteers to implement their training as detailed below.

Figure 3: Traditional Birthing Attendants receive training

Initial assessments of the community sector efficacy has found some improvements in the initial year since training, particularly in the communities' awareness of their roles and responsibilities. This will be further developed through community wide training using a mobile multimedia education unit. Committees working together with a spirit of cooperation is slowly being achieved and it is hoped that this area will be well developed by the end of the programme offering an example for other communities.

Another key area of capacity building has been in disease diagnosis. At remote health clinics, diagnosis of malaria, bilharzia and tuberculosis is often achieved through assessing clinical symptoms, or samples are sent long distances for diagnosis meaning a waiting period of several days for the patient. In order to improve this system a group of health surveillance assistants have been trained in microscopic diagnosis of these three diseases allowing it to be achieved in remote health centres using solar powered microscopes (Figure 4). Their abilities as microscopists are being constantly assessed by the senior laboratory technician at the District Hospital and several update training sessions have been undertaken.

Figure 4: Health Surveillance Assistants receive microscopy training

Retention of staff

Chikwawa suffers both from a lack of health staff and a fast turnover due to it's remote location in one of the hottest parts of the country. Improved housing is seen as an incentive to retain staff, and therefore part of the programme was to develop better facilities for staff and patients within our target areas. Initially this has concentrated on the construction of staff housing at the District Hospital. The initiative undertook to construct one senior staff house and a nurses hostel. The senior staff house is now completed and the hostel (now a series of small terraced houses suitable for small families) is to begin construction in March 2008.

Health surveillance assistants are predominantly placed within communities and tend to have to rent housing from their already low salary. As such, HSA's tend to move between catchment areas frequently leading to a lack of consistency for the community. With this in mind, two houses for health surveillance assistants have been constructed in target communities as an incentive for them to remain in the area.

Improved facilities for staff and patients

In addition to these buildings funded through the Scottish Executive, donations from other organisations have allowed us to construct further facilities at the District Hospital and Rural Hospital level (www.strath.ac.uk/malawi/projects/chikwawa/)

An HIV clinic, providing voluntary counselling and testing (VCT) services and the distribution of ante retroviral (ARV) drugs, and a sorely needed administrative office extension was provided through the Lord Provost of Glasgow's office under the supervision of Brian Kelly, another Scottish environmental health officer. The HIV patients previously received ARVs in the tuberculosis ward of the hospital thereby increasing their risk of infection. The new facilities are located discretely within the hospital grounds and are already showing an increase in the number of patients seeking VCT at the hospital.

Funding from Glasgow National Health Board and the University of Strathclyde Malawi Millennium Project also built a ward for malnourished children, accommodating 24 patients (Figure 5). During their

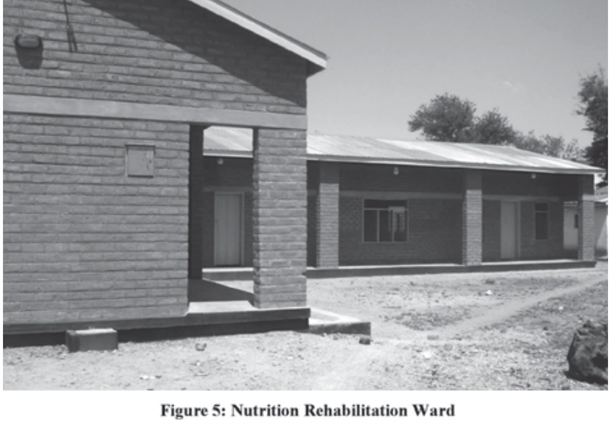


Figure 5: Nutrition Rehabilitation Ward

rehabilitation these children under the age of five were previously sleeping in the open and exposed to infections such as malaria in their already immuno compromised state.

Through various donors, equipment has been provided to both the health facilities and communities. These have included, hospital beds, autoclaves, refrigerators, cookers, bicycle ambulances, bicycles (for HSA's), computers, medical equipment, and drugs.

Improved water and sanitation
Water and sanitation are key in the reduction of disease within Malawian communities. With such a low latrine and protected water source coverage many communities suffer from preventable diseases such as cholera. As such the programme looked to target water and sanitation in several ways:

Improvement and repair of water sources
Many water sources were in a poor state of repair due to the unsustainable nature of community maintenance of the water point. These were put back in order and protected where appropriate.

Formation and training of a water point and health committee within each community
In order to ensure sustainability of water sources and sanitation programmes in the future, committees received extensive training on maintenance, health education, community participation, etc.

Promotion of affordable appropriate sanitation technologies
Chikwawa suffers from sandy soils and therefore latrine collapse in the rainy season. In target communities, pit latrine ownership averaged 48% with open community as low as 14% and well below the Millennium Development Goal of 74% by 2015 (UN 2000). The introduction of simple ecological sanitation technologies has been well received. This not only makes latrines affordable with local materials but also provides much needed compost for food production. Latrines are also provided with sanitation platforms to reduce the transmission of soil mediated infections. The initiative hopes to achieve an 80% latrine coverage by December 2008.

Provision and promotion of household water treatment
Despite the provision of safe water at the source, in many cases household water is faecally contaminated by the time it reaches the home (Swerdlow *et al.,* 1997; Trevett, et al., 2005a; 2005b, Morse, 2006). To reduce the risk of waterborne disease transmission by this route, chlorine can be added to household containers. A reduction in diarrhoeal disease was seen in each community between 2006-2007 which may be partly attributed to when the chlorine treatments were distributed (Figure 6). However, other factors may also have led to a reduction in diarrhoea including the increased availability of food in 2007 leading to improved nutrition and health. In particular, significant improvements have been seen in Mwalija and Namila with a lower diarrhoea prevalence (48%, *p=0.003* and 46%, *p=0.0006*) respectively) when compared to an average village (58%). Mwanayaya and Sekeni (55%, *p=0.715* and 60%, *p=0.698* respectively) are not different from the average prevalence rate (58%), although demonstrating a reduction from the rates of infection detailed in the data collected in 2006.

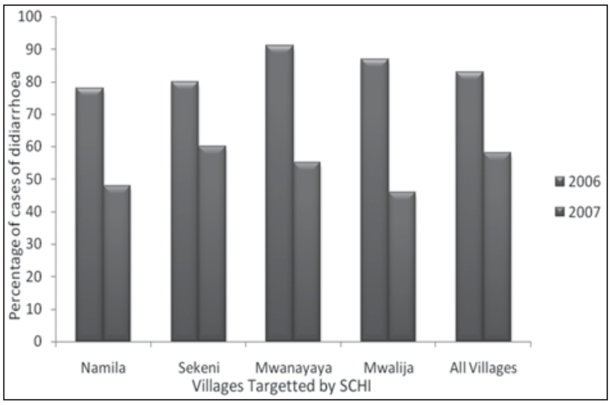


Figure 6: Percentage reduction in diarrhoea seen in target community populations

Maternal and Child Health
Within the community, health posts and birthing facilities have been constructed/rehabilitated and furnished at five locations to provide shelters for growth monitoring, immunisations and safe, hygienic deliveries. These buildings are constructed in cooperation with the communities with their contribution of bricks and sand in order to ensure a sense of ownership for the buildings and therefore their sustainability. The presence of these buildings, in combination with staff and community training, is already demonstrating an increased attendance at growth monitoring and immunisation clinics which it is hoped will be sustained, for example Mwanayaya under five outreach clinic clinic had a 74% attendance in December 2006 which was increased to 88% since the completion of the growth monitoring training. A seasonal difference in attendance is seen with a reduction in the harvesting months due to mothers being active in the gardens. It is hoped that house to house visits and regular growth monitoring by volunteers will help to overcome this and maintain a high level of attendance throughout the year.

Health posts and clinics have also been provided with bicycle ambulances, which can be used to carry incapacitated individuals to the nearest health centre when necessary and bicycles for the village health committee to manage, for example, the bicycles are used for health education, notification of immunisation dates and travelling to health centres.

Traditional Birthing Attendants (TBA's) are voluntary individuals within the community who have had their skills passed from generation to generation and conduct deliveries at home. They have limited training and their homes/clinics often suffer from a lack of materials and sanitary facilities. All traditional birthing attendants within the target communities now have safe and clean facilities and delivery kits to perform deliveries, and have been trained in effective management of their patients, which has also led to an increase in the number of referrals to health centres due to complications. In 2007, a total of 270 women attended the TBA's in the programme for deliveries (n = 8). Of these 25 (9.3%) were referred to health facilities for various reasons including, first pregnancy, over 4^{th} pregnancy, prolonged labour, previous scar, twins, HIV status, and anaemia. This has subsequently ensured the maternal and infant mortality rates were zero within the target communities. In line with the Ministry of Health policy on traditional birthing attendants, the initiative will be working closely with TBA's to increase the referral rate to health centres for delivery by qualified midwives wherever possible.

Communicable disease control

In addition to the work already described for reduction of waterborne diseases, communities have also been involved in the distribution of insecticide treated nets (ITN's) and their subsequent retreatment in the battle against malaria. Village health committee members have also been trained in the identification of potential disease cases, such as tuberculosis, in the community and to ensure their referral to the health surveillance assistant to seek medical care. It is hoped that this improved health seeking behaviour will help reduce infection rates and ensure timely diagnosis and treatment to reduce morbidity and mortality. This is to be assessed from the 2007 survey.

Revolving funds

A limitation of sustainable water sources, mosquito net provision, and investment in a healthy environment by communities is the lack of resources. Community participation can be poor and with the majority of people being subsistence farmers with minimal monetary income, the simple repair of a borehole can be neglected for many years. In order to alleviate this problem, the initiative is working with communities to develop sustainable revolving funds. In order to begin these funds, SCHI have provided mosquito nets, water treatment and materials for the construction of sanitation platforms to the village health and water point committees free of charge. Subsequently these are sold to the community at 20 Malawi Kwacha - 0.07 pounds sterling (US$ 0.15) each to give a sense of ownership, and to provide funds to the committees for their activities. This can raise a significant revenue for the revolving fund which must then be maintained by the committee with the sale of further products as they deem fit, or collecting funds from the community. The efficacy of this system will be tested throughout the final year of the programme.

In an extension of this, two communities are now being provided with improved irrigation systems for their communities which will be used in conjunction with the ecological sanitation. A proportion of the income/produce from these agriculture activities will also be contributed to the community fund for health activities, orphan feeding, home based care and community development.

Conclusion

After the initial two years of the programme, the SCHI is now making headway in the overall aim to reduce major causes of disease and death in four villages within the Chikwawa District of Malawi alongside improving the hospital environment for the good of both staff and patients. Many lessons have been learned along the way and it is hoped that the integrated approach the initiative has developed to community health will be adopted and expanded by the District Health Office in order to fulfil it's obligations under the Essential Health Package Strategic Plan.

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Challenges in Maximising and Sustaining Health Benefits of Environmental Health Projects in Rural Communities - A Case Study from Southern Malawi

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Abstract

Non-governmental organisations (NGOs) play an increasing role in rural health and development in developing countries. However, planning, monitoring and evaluation (M&E) of their programmes usually focus on indicators directly related to their respective areas of operation. The result is missed opportunities to enhance impacts with simple, cost-effective measures. This paper presents results from focus group discussions undertaken during a study on the long term health impacts, constraints, and potentials of a water supply and sanitation (WSS) programme implemented by a British NGO in southern Malawi.

Methods: Between Aug. and Nov. 2006, focus group discussions (FGDs) with village health and water committees (VHWCs) and randomly selected women were carried out in two rural villages in Thyolo District, where the WSS programme was implemented before 2004. Other participatory methods were used in the study; however, this paper focuses on the FGD results as correlated to the others.

Results: The most significant indicator was time spent collecting water. Most women still spend at least 1hr/trip collecting water. One of two boreholes in one village and one of three in the second were non/poorly functional; the main obstacle cited was financial constraints. Also problematic were defaulting of the trained VHWC members, absence of VHWC refresher training and a functional support network for complicated technical, and community management problems. Despite an overall good knowledge of WSS-related diseases, both communities still use hand-dug unprotected shallow wells and streams for non-drinking purposes to reduce time spent collecting from the boreholes.

Conclusions: Although boreholes provide safe water to rural communities, they are unsustainable under a weak support network and lack of a communal income source of maintenance funds. High construction costs result in fewer provisions of boreholes, women/young girls still spend long times collecting water, and unprotected water sources are still used. Where feasible, it would be reasonable to protect existing sources at much lower cost, providing more safe water sources and increased time savings. Respiratory diseases should routinely be included in the health education component of all such projects.

Key words: ***rural environmental health, sustainable development, impact assessment, water and sanitation, health education, Malawi***

Introduction

Globally, an estimated 23% of all deaths, and 36% in the 0-14yrs age group, can be directly attributed to environmental health (EH) factors (Prüss-Ustün and Corvalán, 2006). EH-related illness both cause and are exacerbated by "non-EH" conditions. For example, malnutrition is both a cause and effect of gastrointestinal (GI) infections, and has been cited as a root cause of at least 50% of under-5 child deaths in developing countries (Fewtrell et. al., 2007). In turn, about 50% of malnutrition is caused by poor sanitation and repeat infections from unsafe water, sanitation and hygiene (Paunio and Acharya, 2007; Fewtrell et. al., 2007). Poor EH conditions are also particularly dangerous in those with compromised immunity (from HIV, malnutrition, etc.). This paper presents results from focus group discussions (FGDs) and observations carried out as part of a study on the health impacts of an NGO's water supply and sanitation (WSS) project in two rural communities in Thyolo District in rural Malawi, and puts forth recommendations based on the findings.

Malawi, in south-east Africa, is one of the poorest countries in the world, with a life expectancy at birth of 41 years. Over 80% of the 12.9 million population is rural, with a heavy dependency on agriculture for their livelihood. More than 65% of Malawians live below the national poverty line. The World Health Organisation estimates the environmental burden of disease in Malawi at 27% (WHO, 2007), with diarrhoeal diseases alone causing 18% of all deaths in children under age 5 (WHO 2006b). The coverage of safe water and sanitation, especially in rural areas, is low (WHO, 2006c). Combined with a national HIV prevalence of at least 14%, poor EH conditions are particularly devastating, and place a heavy burden on an already fragile healthcare system.

Countries such as Malawi often cannot afford adequate long-term investment in healthcare and infrastructure, and government healthcare tends to have a greater curative rather than preventative component. Directly and indirectly, this results in resource diversion from other sub-sectors. Non-governmental organizations (NGOs) play an increasing role as major partners in development and health in such resource-poor settings. They have several advantages in terms of resources and resource allocation, representing part of an entirely different funding (and therefore accountability) pool. They become an important conduit for knowledge transfer between developed and developing communities on a national, regional, and international scale.

Health impacts of interventions (by NGOs and others) are difficult to quantify, for many reasons. One of these is the inherently interdisciplinary nature of health, which cannot be defined as simply the "absence of disease". Also, the greatest burden is felt in the poorest, least developed populations, where data are unreliable at best and many difficulties present themselves in obtaining raw epidemiological data from the affected populations (especially rural). Health impacts of projects will always have wide-reaching implications across sectors (health, economic, educational). However, multi-sectoral approaches to health improvement projects are not the norm; although such approaches are more cost-effective in the long run, as costs are shared by multiple sectors and benefits magnified (Listortu and Doumani, 2001). As such, the use of multi-disciplinary indicators becomes uncommon, and, in Malawi, intersectoral collaboration is weak (Government of Malawi, 2006).

Retrospective impact assessment of programmes provides "lessons learned" for planning future ones. Findings can also be integrated into existing projects, which is more cost-effective than setting up new ones for different, but ultimately connected, targets. It is important to consider both direct and indirect impacts in all impact assessments; indirect impacts (positive and negative) are as significant as direct impacts. However, in practice, indirect impacts are not often taken into account (Listorti and Doumani, 2001).

Keeping in mind the above factors, this research involved, and was directed by, the communities themselves. The programmes in both villages ended by 2004, and focused on provision of safe water supply, sanitation, and hygiene education. A village health and water committee (VHWC) was nominated by each of the communities, with each group composed of 10 men and women (roughly half each). These participated in a one-week training course in basic borehole maintenance, simple repairs for village-level operation and maintenance (VLOM), and construction of pit latrines and sanitation platforms. In conjunction with the Malawi Ministry of Health and Population, basic health education was carried out, covering waterborne diseases and hygiene.

Methodology

Study Area

For selection of the two communities in the study, the NGO provided a list of locations in Thyolo District where they had implemented water supply and sanitation (WSS) programmes in previous years. After a Traditional Authority was selected, the NGO was asked to nominate a number of communities they had been involved in before 2004, on the basis of their perceived response to the water and environmental sanitation programme ("good", "medium", and "poor"). From this list, two communities rated as "medium" were approached for the study, based on size and the budget available for transportation for the study. Meetings were requested with the Village Headmen, making it clear that (a) participation was strictly voluntary, and any participants were free to withdraw from the study at any time, (b) the research is independent from the NGO, and no remuneration would be provided for the participants, (c) the research findings would be communicated back to the community and NGO, and any implications discussed.

The population of Village A is 405 people with 110 households (HH), while that of Village B is 1,094 with 255 HH. The former used to have 293 HH, but the original village had split up recently due to disagreements. Village A has two boreholes (>25m depth) and two protected shallow wells (<5m depth), as well as a small stream; three unprotected shallow wells were also identified, which the community said are used only for watering crops. Village B has 3 boreholes, and a small seasonal stream; there is also a river which is sometimes used, about 45 minute's walk from the centre of the community, and sporadic shallow wells dug as needed. Only one borehole in each community was drilled by this particular NGO.

Focus Group Discussions (FGDs)

FGDs were first held with the village health and water committees (VHWCs) of both communities. Topics covered were related to training, operation and functioning of the committees, and borehole maintenance issues.

Participants for subsequent FGDs (with women) and the surveys were randomly selected. Women were targeted for these activities because they are responsible for household chores, fetching water and firewood, and cooking; also, they have the responsibility of children's health and that of the household (Blackden and Wodon, 2006). All houses in the communities were numbered in chalk and the name of the head of each household recorded (for later reference, when the chalk wore off). These numbers were written on pieces of paper, placed in a hat and shaken. The chief of each village was invited to pick the first number, and the "head" woman in the corresponding household was asked if she would participate in a FGD (no one refused). This participant then pulled another number from the hat, and the procedure repeated until 10 women were picked for each of two FGDs (total of 20 per village).

All FGDs were digitally recorded, after obtaining permission from all individuals. Information obtained from the first round of FGDs was used to direct the research; for example, the women identified the health centres most frequently used by their communities and so these centres were where the data was collected from out-patient department (OPD) registers. As a feedback system, data from these health centres were correlated with information from the FGDs, which was used in the second round of FGDs. In this way, a more participatory approach, rather than top-down one, to data collection was ensured. A number of specific questions, dealing with risk factors for diarrhoeal diseases, were also presented to the women's groups.

Rural Health Centre Registers

Permission was requested from the Director of the District Hospital to access OPD registers for 3 rural health centres (RHCs) from previous years. The RHCs were identified by the communities themselves during the FGDs. The following information was sought for patients presenting to the OPD from both villages: date, village, age, gender, diagnosis (or diagnoses), and disease code for diagnosed condition(s).

We recognize the problems with epidemiological information in such settings, where diagnostic and data collection/record-keeping capacities are limited. The aims of this exercise were to a) get an idea of what people sought medical care for, b) to correlate information obtained at the RHCs with findings in the communities, and c) to aid in the planning of further FGDs. Data from health centres are not presented in this paper but are referred to in the context of the major issues that both communities seek medical care for. This will become important in the discussion of results from the FGDs.

Surveys

Knowledge, attitude, and practice (KAP) surveys were administered to 1/3 of the households in each village. Two women in Village A and 3 in Village B were identified and trained to administer the surveys, which had the text in both English and Chichewa (the local language). Random sampling was by the procedure previously described. Again, this paper focuses on the results from the FGDs, so only select results of the surveys will be referred to.

Results

Village health & water committees FGDs

Both VHWCs stated that the WSS programme addressed a crucial need in their communities. "Before [WSS programme] we had *kwambire kutsegula m'mimba* (very much diarrhoea)". In both villages, most of the initial 10 people trained in the VHWCs are no longer serving. In Village A, 6 of the initial 10 trained "defaulted". In Village B, the committee was "dissolved" in 2004 because of "misappropriation of funds", and only one man remains. The need for refresher training was voiced by both committees.

Parts for maintenance and repair of the boreholes are locally available; both communities knew where to acquire them and have an idea of their cost. Although a [government] system exists to help with complicated repairs, it is poorly supported in terms of accessibility (cost for repairmen, contacts, etc.), and neither group knew where to go for difficult technical problems. People, especially in Village A, are frequently reluctant to contribute MK20 (< 10 pence or $0.15) monthly to a borehole fund.

One out of two boreholes in Village A and one out of three in Village B were broken down or functioning poorly. In Village A, a borehole technician from the NGO classified the problem as wear and tear and poor maintenance. This borehole was observed by the researchers to be in the same state of disrepair in each visit from August 2006-August 2007. "Money" was the reason given for it not being repaired. However, in Village B, the "broken" borehole was in fact vandalized and not "malfunctioning". The stolen parts were replaced, and stolen again within weeks. Another borehole was temporarily out of commission due to silting up; a problem not possible to be fixed by the committee. This was rectified months later by an unknown third party, after money was collected for this purpose. The community now pays a watchman to guard the main (central) borehole at night.

In Village A, lack of confidence in the VHWC contributes significantly to community members' reluctance to pay for borehole upkeep and repair. For example, while collecting contributions, committee members are faced with comments like: "we gave before and the borehole is still not working properly. Why should I pay if I have to pump for a long time?" During the first day of discussions, the Health Surveillance Assistant (HSA) for the village was visiting from the rural health centre, apparently to distribute ivermectin (for onchocerciasis control) and record demographic information for the village. He stated that, since the committee is a voluntary one, many (sometimes 40%) of the members do not show up for regular meetings. Although securing money regularly for the borehole fund is also a problem in Village B, the community is clearly more cohesive in keeping the borehole in good condition. Every month, the VHWC presents to the rest of the village how much money has been contributed to the fund, and any expenditures. They also employ a "name and shame" system, whereby those households who have not contributed that month are identified publicly.

One observation worth noting is the difference in the involvement of women in the committees. Although women made up roughly half of both VHWCs, there were stark contrasts between the two groups. The women in Village A's VHWC barely participated in the discussions, and appeared to be overwhelmed by the men in the group. This was not the case during the women's FGDs, where they engaged in enthusiastic and animated discussions. However, whenever there was a discussion where men were present, they would withdraw unless asked a question directly; in some cases they would still mirror the opinions voiced by the men. On the other hand, the women in Village B's VHWC (and indeed the rest of the community) are very involved, and play a leading advocacy role; for example, promoting sanitation and pushing for latrine construction during rainy seasons.

Women's FGDs

The main concern the women in both communities have with water collection is not **distance,** but **time.** Although the safe water sources (borehole + shallow wells) in Village A are all within a few hundred meters from most households, the community still uses unprotected shallow wells (and a stream). This is because two (large) neighboring communities also use their water sources (one of these year-round); in addition to long waiting times (particularly in the dry season), the heavy usage places an increased burden on the groundwater aquifer. All women stated that they would rather walk further to collect water where the waiting time was less, than use a nearer, more crowded source which prolonged matters.

Most start water collection at or just before sunrise; one woman voiced a concern the others laughingly agreed with:

> "Instead of being nice to our husbands in the morning, we have to go collect water. Our husbands get angry because we take so long; sometimes they think we are meeting other men."

Many women spend over an hour per trip collecting water. A knowledge, attitude and practice (KAP) survey (results not included here) showed that over 95% (N=114) make multiple water collection trips daily. "We don't have time to work in the gardens or make our own business," was a common statement from the women during the FGDs and when speaking to others in the community.

All respondents knew that sleeping under mosquito net reduces malaria, and that stagnant water in/around the house contributes to the disease. Yet, few respondents claimed to own/use a mosquito net. Amongst those who did not have mosquito nets, cost was the main factor, followed by discomfort under net ("too hot").

Interestingly, in the course of collecting data from the OPD registers at the health facilities, we noted that there was generally a low uptake of health services from the communities, especially Village A (174 OPD consults out of 521 from Dec. 2004-July 2006). Following this, we arranged another series of FGDs with the women, in order to ascertain the reasons for the low uptake. When we commented on the relatively low uptake of the health services, they enthusiastically started talking about their problems accessing proper healthcare, in particular maternal health services. Whereas all stated they attend ante-natal clinics (ANCs), and child immunization clinics, the opposite is true for other health problems. Due to problems with transport/distance, drug availability, healthcare worker attendance, and most importantly, "the way we are received", confidence in the government-run healthcare system is low. As in many other countries, many (again, particularly in Village A), opt to seek healthcare with a traditional healer (Courtright, 2005), or simply buy drugs from the market. This is true for most medical ailments, except severe *"malungo"* (malaria), "cholera", and broken bones.

We observed this in several instances. For example, on one occasion we spoke with a 26yr old woman with an almost gangrenous hand and an 89yr old woman with dysentery, both of whom had refused to go to hospital. While this may be due to stronger faith in traditional medicine, every person we spoke to said they would think twice before spending hours (often an entire day) of their time accessing health services. This again illustrates the value communities place on time, as well as the problems with collecting epidemiological data where people will/cannot access health services.

Knowledge on select health issues

The knowledge on association of diarrhoeal diseases (DDs) with drinking water was virtually total. Over 70% (N=114) could list at least three risk factors for DDs (including sanitation and/or hand washing). After contaminated water, flies were the next most commonly identified risk factor. All respondents knew and could demonstrate the 2-cup system for pouring water, and recognize that covering stored water prevents contamination. Two thirds report ever treating drinking water with a "chemical". However, there is variation between the two communities. For example, over a quarter in Village A report "0" steps being taken to prevent DDs at home, whereas at over 80% of respondents in Village B employ at least three or more measures to reduce DDs. Only about a third of respondents in Village A recognize that clean-looking water can cause disease, compared to over two thirds from Village B. Despite this, both communities have, and use, unprotected surface water sources routinely. Although this was initially denied, it was observed on several occasions (Fig. 1 & Fig. 2).

Figure 1: Unprotected spring in a field in Village A. This source is used for all purposes, including drinking.

Figure 2: Children washing clothes in stream in Village A. Schistosomiasis is a particular concern here.

As for healthcare seeking, malaria and respiratory diseases (RDs) were the main reasons for visiting the OPDs in the rural health centres, comprising 45% and 14.8% respectively (N=521) of diagnoses from December 2004-July 2006. The issue of respiratory diseases was discussed with women in both communities, to ascertain their perceptions of these. When men were asked about what they think of these, the common answer was, "we suffer from them a lot; it must be something with the weather." When asked about who gets RDs, they said that almost everyone got them, but mainly women and children. Upon asking the women, they too attributed RDs largely to the weather. There did not appear to be significant knowledge on the risks from cooking over wood fires (often with children strapped to their backs) and indoor dust. However, almost all women could connect pneumonia in a young child with rapid, shallow breathing.

Discussion

Problems with community maintenance of water sources are not unique to Malawi (or indeed any country or region), nor are they necessarily due to lack of community motivation. Problems with raising funds at village levels, in the absence of a communal income and strong government partnership, have long been recognized, and operation & maintenance of water supplies is the most problematic area in water supply programmes (Cairncross & Feachem, 1983). Internal problems within committees are a major contributing factor for many of the aforementioned issues regarding the VHWCs, and represent one of the problems faced in managing boreholes at the community level (WHO, 2006a).

The malfunctioning borehole in Village A serves to illustrate this. Although the VHWC had initially claimed that maintenance service was carried out routinely (three times a year), this is debatable as the original trained committee had long been disbanded. One year from the first visit to the community, the borehole still hadn't been repaired, and it soon became clear that each was waiting for another person to initiate steps, and there were no serious efforts to collect funds from households. Problems such as these result in people having less confidence in the committees, which in turn impacts the resources made available for the committees to carry out their jobs (De Gabriele, 2002).

In this study, there were noticeable differences between the VHWCs of the two communities. The involvement of women may very likely be a strong contributing factor. Being responsible for water collection and the health of their families, they represent the primary user group for the programme. Although women were well represented in numbers in both committees, their actual level of participation is different. In Village B, where their involvement is clearly much more prominent, there is likely much more incentive to employ a vigorous and proactive approach to the upkeep of the village water supply. Nevertheless, using financial incentives, such as a small gratuity for members of the VHWCs, might be one way of improving the functionality of the committees (Kleemeier, 2000).

In these two communities, time was the most important concern (after diarrhoeal disease reduction) for the women who collect water; this is despite many being within a few hundred metres of the protected sources. Use of unprotected water sources (both surface and groundwater) occurs as a result of the time spent collecting water. Overcrowding at protected sources, combined with long pumping times during dry season, mean that many women may resort to using existing (albeit potentially unsafe) alternatives. Apart from concerns about microbial quality of the water, these practices expose them to other water-related diseases, particularly schistosomiasis (Bilharzia).

Many children were observed helping the women collect water (Fig.3), during what are normally school hours. Resource collection is negatively correlated with children's (particularly girls') education. Young girls are more likely to be involved in water collection while simultaneously going to school, which may affect their performance in the latter. In fact, children in Malawi spend almost 70% of the time that their mothers spend involved with water collection (Nankhuni and Findeis, 2003). For women, the time used in water collection could be used in other activities to improve their economic status (Mulwafu and Msosa, 2005), a point repeatedly brought up in the communities. The time factor should be routinely included in all stages of WSS programmes, as it serves as an indirect indicator of their potential effects on poverty. An example is the health benefits arising from the use of water for non-drinking purposes, such as cultivation (Billig et. al., 1999). Families in both communities have small gardens, where they grow vegetables for consumption and sale. Long water collection times mean that its use must be prioritised, limiting the amount used on gardening during the dryer seasons. In this and other manners, any WSS programme will invariably have one effect or another on food security (Birley, 1992).

Figure 3: Woman and young children collecting water during school hours.

Although knowledge on basic health issues related to WSH is relatively high, particularly in Village B, practice is another thing. Similarly, having a clean source of water does not guarantee safe water at the point of use (Fewtrell et. al., 2007). For example, in another study in Chikwawa District in southern Malawi, 100% of water stored in homes in two villages tested positive for total coliforms, with at least 80% testing positive for *E. coli, a* bacterial indicator of faecal pollution. Water from the boreholes used tested negative for any of these (Jabu, 2007). To our knowledge no similar studies have been carried out in the research communities in Thyolo District; however, two points are worthy of mentioning. The first is the number of young children engaged in water collection, who may be more likely to contaminate the water being transported through contact with their hands (Trevett, 2002; Jabu, 2007; Morse, 2006). Second is the sanitation situation in the communities. In 2004, a survey conducted by the NGO in 2004 reported basic sanitation coverage of 101% in Village A and 85% in Village B. We visited the HH in the communities (2006) and found the numbers had dropped to 48% and 78%, respectively.

It is important to remember that pit latrines are prone to collapse during the rainy seasons, so that they must be rebuilt every one or two years (Grimason et. al., 2000). Although the communities knew how to build latrines and sanitation platforms, the main problem cited was shortage of funds for cement for the sanitation platform and wire to prevent the pit from collapse. Again, lack of resources at the community level is the major hindrance to sustainability of the positive health impacts of the programme, since low sanitation coverage will likely offset the health benefits from improved water supply.

A final point is the relatively weak knowledge of the link between respiratory diseases and indoor air quality (and outdoor cooking). This is something that can be incorporated into the health education component of programmes such as this. To our knowledge, none of the programmes in the area have a component on RDs, despite these being one of the biggest causes of morbidity and mortality nationally and globally, particularly in children.

Conclusions/Recommendations

Boreholes in rural communities in Malawi (and other similar situations), in the absence of a strong support system from other major partners (especially government), are generally unsustainable in the long run. This is not necessarily due to infrastructure, maintenance difficulty, or programme efficiency but to difficulty in operation and maintenance in a community setting, and in ensuring continuity of skills/knowledge within the dynamics of the villages. Both communities in the study showed frustration at lack of (or difficulty accessing) long-term support from other sectors (e.g. government agencies for complicated maintenance), despite the initial WSS programme providing a strong foundation for positive change. However, it is important to note potentials for success when there is a functioning support network combined with a dedicated community. Otherwise, communities become discouraged and positive impacts are not sustained.

If the time required to collect water is excessively long, communities default to the use unprotected sources, even if the unprotected source is located further away than the protected source. Safe water source does not always translate into safe water consumed, since significant contamination often occurs during transport or in the houses themselves. Where possible, protection of existing shallow wells and similar sources used by the communities should be opted for; of course, in some areas this may not be geologically feasible. Shallow wells can be protected at a fraction of the cost of drilling new boreholes. This will address the time issue (in particular waiting times), which is more important in this case than absolute distance to source. Time savings potentially have a big impact on HH income and food security, and by extension (in theory) nutritional status. Thus, programme impacts on water collection time represent a relatively uncomplicated indicator for both planning and ongoing monitoring and evaluation purposes. Members of the communities can and should be involved in developing and collecting such data.

Seeing the invariable link between HH water situation and economic productivity, it is reasonable to suggest that WSS programmes be implemented alongside (or within) poverty reduction (e.g. microfinance) initiatives. This will allow the commissioning of technicians from outside the community for advanced repairs, or even nominating dedicated members of the VHWCs to receive further training and be appointed caretakers of the water sources on a paid basis. This will augment the positive impacts of both improved water quality and of time savings in water collection for the communities.

The importance of health education components of projects cannot be understated, and it is recommended to combine intensive health education and protection of existing water sources in order to increase the quantity of water and decrease collection time; where the latter is not practical, point-of-use treatment can be used at the HH level. A section on respiratory diseases, namely their relationship to cooking and indoor air, should routinely form part of the health education component of all similar projects.

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Epidemiology of Cryptosporidiosis in Rural Malawi

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Abstract
A hospital and community based study was conducted in Malawi, within a rural population over a 23 month period, to identify the incidence, causative species and possible determinants for cryptosporidiosis in under fives. 5.9% (25/423) of samples collected were positive for *Cryptosporidium* oocysts of which 18 amplified by PCR-RFLP indicating the following species: *C. hominis*, *C. parvum*, *C. meleagridis* and *C. andersoni*. Consenting positive cases were included in a case control study. 96 home interviews were conducted in 24 communities (cases n=24; unmatched controls n=72). A total of 61 risk factors were investigated with a questionnaire, and combined with quantitative data from samples of domesticated animal stools and drinking water. Oocysts were not isolated from domesticated animals or water samples. Multivariate logistic regression of questionnaire data revealed an increased risk of cryptosporidiosis associated with ownership of pigs (OR 7.2, 95%CI 1.9–27.5, p=0.004), presence of diarrhoea in the household (OR 8.8, 95%CI 1.8–53.4, p=0.008), bathing in the river (OR 76.7, 95%CI 1.1–23.8, p=0.037) and no education within the household (OR 3.6, 95%CI 1.1–11.8, p=0.038). Bacteriological results indicating faecal contamination of both drinking water stored within the home (76%), and the surface of guardians' hands (75%) were indicative of poor hygienic practices and potential sources of infection.

Key words: ***Cryptosporidium, community, epidemiology, health education.***

Introduction
Diarrhoeal diseases in children under five years old are a significant cause of morbidity and mortality in the developing world (WHO, 2005), and in Malawi, they are thought to be the 6^{th} leading cause of mortality which currently stands at 182/1,000 live births (NSO, 2001). Cryptosporidiosis is an acute, self limiting diarrhoeal illness in immunocompetent patients, but in the immunocompromised and the malnourished the disease can be severe, protracted, debilitating, and may lead to death. In many regions of the world, *Cryptosporidium* constitutes part of the complex group of parasitic, bacterial and viral diseases that impair the ability to achieve full potential and impair development and socio-economic improvements. All diseases included in the World Health Organisation (WHO) Neglected Diseases Initiative have a common link with poverty and, as the current view is to take a comprehensive approach to all these diseases, *Cryptosporidium* was included in the 'Neglected Diseases Initiative' in 2005. Major hopes were that molecular methods would generate significant insight into *Cryptosporidium* biology and host-parasite interactions (Savioli et al., 2006).

In Africa, cryptosporidiosis has been associated with 3.8 - 26% of all diarrhoeal illness in the paediatric population (Chunge et al., 1989; Amadi et al., 2001), and has been diagnosed in at least 47% of African countries. In Malawi, up to 10% of diarrhoea in children under the age of five years is attributable to *Cryptosporidium* infection, with up to 21% reported in the immunocompromised population (Pavone et al., 1990; Perez A., pers comm). Of the currently accepted 'valid' species of *Cryptosporidium*, seven (*C. hominis, C. parvum, C. meleagridis*, *C. felis*, C. canis, *C. suis* and *C. muris*) infect humans (Xiao et al., 2004; Ryan, et al., 2004). In sub-Saharan Africa, four of these species have been found in humans, namely *C. hominis, C. parvum, C. meleagridis* and *C. muris* (Morgan et al., 2000; Leav et al., 2002; Gatei et al., 2003; Peng et al., 2003; Tumwine et al., 2003).

Most studies investigating *Cryptosporidium* infections in the tropics, including Malawi, have concentrated on the incidence of infection in hospitals and health centres. Few studies have investigated the sources of infection within a population, and the interventions that can be implemented effectively to reduce the risk of disease. Transmission of human cryptosporidiosis can be either zoonotic or anthroponotic, and while direct links in transmission have been determined in some instances (Elsser, *et al.,* 1986; Navarette *et al.,* 1991), they have been established primarily by statistical association between the presence of disease and exposure to risk factors (Chunge *et al*., 1992; Newman *et al*., 1999; Pereira *et al*., 2002). Neither zoonotic nor waterborne transmission has been documented, using either descriptive epidemiological or molecular tools, in sub-Saharan Africa although the occurrence of human-infectious species in domesticated and wild animals and drinking water sources identifies their potential (Hunter *et al* 2003; Kelly *et al.,* 1997; Mtambo, *et al*. 1997; Molbak *et al*., 1994; Niyezi *et al*., 2002).

The WHO Health Village Initiative and Water Safety Plans provide set systems by which communities can improve their health holistically, including a reduction in cryptosporidiosis, but an understanding of disease prevalence and sources is required before appropriate controls and interventions can be identified (Howard, *et al.,* 2002; WHO 2006). Here we present data, accrued over 2 years, of the incidence of cryptosporidiosis in children under the age of five in Malawi, using conventional microscopic and molecular species typing tools, and an assessment of the risk factors to which cases were exposed using both qualitative and quantitative data collection methods with a view to controlling infection within the rural community.

Methodology

The two aspects of the study were conducted simultaneously. These were to identify positive cases of cryptosporidiosis and to assess potential routes of infection within their communities.

Hospital based sample collection

Sample Procurement

Permission to conduct the study in Chikwawa District of Malawi was obtained from the National Health Sciences Research Committee (Ministry of Health and Population, Malawi Government). Samples were collected from both the District Hospital and Health Centres throughout the District. Case control data for cases and controls were collected at the homes of the participants.

Stool samples were collected from children under five years of age with diarrhoea. Diarrhoea was defined as an increase in the frequency and/or change in the consistency (to loose or watery) of the stool as determined by the child's mother/guardian. Samples were procured by medical staff who requested that guardians supply a stool sample from the child in a 30 ml plastic container (Enterprise Containers, Blantyre, Malawi). Guardians who provided base line information; received advice on reducing and treating diarrhoea and were provided with soap for hand washing and oral rehydration salts for treatment. Stool samples were transported in a cool box and stored in the laboratory at 4ºC until tested.

Detection methods

Cryptosporidium oocysts were detected using both microscopic and molecular methods within Malawi and the UK (Scottish Parasite Diagnostic Laboratory (SPDL), Glasgow, UK; Morse *et al*., 2007).

Water samples

Water samples were procured from both the household drinking water container and the water source to assess the presence of coliforms, *E. coli* and *Cryptosporidium* spp.

Testing drinking water for coliforms and E. coli

One sample was procured from each household drinking water storage container and three samples were procured from each water source. Water samples were collected in 100ml IDEXX Colilert® bottles, and at the point of sampling, were sealed and stored in cool boxes until returned to the laboratory (University of Malawi – The Polytechnic) for testing. Presence/absence of coliforms and *E. coli* was determined using the IDEXX Colilert® substrate (IDEXX Laboratories, 2003).

Testing drinking water for Cryptosporidium oocysts

A one litre sample was procured from household drinking water storage containers and water sources. Samples were stored in sterile sample bags at 0-4ºC and returned to the testing laboratory (University of Malawi – The Polytechnic). Samples were stored between 0-4ºC for a maximum of one week prior to being concentrated to 2 ml pellets (repeated centrifugation at 2500 x *g* for 10 min followed by aspirating the supernatant). Distilled water was used to rinse centrifuge tubes. The final concentrate was stored in 2 ml microcentrifuge tubes, stored at 0-4ºC and forwarded to SPDL for further processing. Water sample concentrates were resuspended and subjected to immuno-magnetic separation (IMS) using DYNABEADS™ (Dynal Biotech Ltd, Wirral, UK) according to the manufacturer's instructions and the resultant fluid (100μl) was applied as two 50μl aliquots onto two wells of a four well multispot slide (Henley, Essex, UK) and air dried. Oocysts were identified by fluorescence microscopy following the application of a fluorescein isothiocyanate conjugated monoclonal antibody (FITC-*C*-mAb; Cryptoglo, Waterborne Inc. New Orleans, USA) and the nuclear fluorogen 4'6-diamidino-2-phenyl indole (DAPI) (Grimason, *et al*., 1994; Smith *et al*., 2002). Nomarski differential interference contrast (DIC; x1250 total magnification) microscopy was used to confirm oocyst morphology.

Microscopy

An Olympus BH-2 fluorescence microscope equipped with Nomarski DIC optics was used for the analysis of prepared slides**.** A blue filter block (excitation 490 nm; emission 510 nm) was used to visualise FITC-C-mAb localisation and an ultra-violet (UV) excitation (excitation 355nm, emission 450 nm) was used to determine the presence of DAPI stained sporozoite nuclei.

Hand washing samples
Mothers/guardians were asked to wash their hands in sterile water using small sponges to facilitate organism removal. Sponges were pre-sterilised in sealed bags containing 500 ml of tap water at 121ºC for 15 min. All bags remained sealed until used on site. 100 ml of the water used to wash their hands was poured into an IDEXX Colilert® container and the presence/absence of coliforms and faecal coliforms was determined using the IDEXX Colilert® test (IDEXX Laboratories, 2003).

Animal stool samples
Samples of animal stools found within the perimeter of the household were procured. The species of animal excreting the stool was identified, and the sample was placed in a sterile sampling container. All stool samples were concentrated using formol ether (Allen and Ridley, 1970) and the resultant pellet was resuspended and applied to a microscope slide, allowed to air dry and methanol fixed. Fixed samples were stained with modified Ziehl Neelsen (mZN; Casemore, 1991) and examined for the presence of *Cryptosporidium* oocysts at x400 magnification.

Human stool samples
Cryptosporidium oocysts were detected in direct faecal smears by mZN and auramine phenol (AP) methods (Casemore, 1991). Sub-samples of all stools were stored without preservative at 4ºC and subjected to further microscopic and molecular analyses at SPDL as described by Morse *et al*. (2007). Putative mZN and/or AP positive samples were confirmed by immuno-fluorescence (IF) microscopy as described above.

Case control community based study
Twenty four positive cases were used for the community based approach in this study. Three controls per case (3:1) were identified from the same village as the case. Controls were under the age of five years and did not have diarrhoea in the two weeks prior to the interview. Controls were chosen at random and were not matched for age or gender.

All interviews and sample collections were carried out within one week of the stool sample being submitted at the appropriate health clinic, with guardian permission. Data were collected from all participants in the form of a qualitative questionnaire, environmental samples, and stool samples. All data collection tools were the same for both cases and controls.

Questionnaires
Questionnaires covered the areas of socio-economics, housing standards, water use, personal hygiene practices, sanitation, food hygiene and animal contacts. Questionnaires were translated to the local language and pre-tested. The questionnaire was conducted with the primary child care giver (guardian).

Data analysis
Data were entered and analysed using SPSS 13.0. For dichotomous data, the odds ratio and confidence intervals were estimated using the Mantel - Hasenszel χ^2 test. In the case of continuous data, logistic regression of variables was carried out and were summarized by logistic regression odds ratios (exp (β)) and 95% confidence intervals. A multivariate logistic regression model was devised to include variables which had a p value less than 0.25 in the initial univariate analysis. Variables with a p value above 0.05 were subsequently excluded from the model by stepwise regression analysis. Analysis was only carried out on whether *Cryptosporidium* oocysts were present or absent in the stool, as sample numbers were too small to carry out full analysis based on the *Cryptosporidium* species present.

Results and Discussion

Cryptosporidium species
423 diarrhoeal stool samples were collected between February 2001 and December 2002, of which 25 contained *Cryptosporidium* oocysts and / or DNA using a combination of microscopy and molecular techniques (Morse *et al*., 2007). The species of *Cryptosporidium* infecting these children are shown in Table 1. *C. hominis* accounted for 36% of positive samples and *C. parvum* for 12%. Three samples generated amplicons typical in size and RFLP profiles to *C. hominis*/*C. parvum* using the nested 18S rRNA (N18S rRNA) locus of Nichols *et al*. (2003) (Morse *et al*., 2007), but PCR amplification the *Cryptosporidium* oocyst wall protein (COWP) gene loci (Homan et al., 1999) and the N18S rRNA locus of Xiao (1999) failed to generate amplicons, indicating that these two loci were not sufficiently sensitive at detecting the small numbers of oocysts present in our samples. A further sample generated a typical *C. andersoni* RFLP profile with *Dde*1, but insufficient sample was available for confirmation. Seven samples did not generate a PCR product despite containing oocysts. Two of these samples were inhibitory when an internal control was used (Morse *et al*., 2007) however, no inhibition was evident in the remaining five samples, which were all positive when direct smears were examined by at least two microscopic methods. Examination of the water ether concentrate failed to identify oocysts in four of these, and the remaining sample was found to have a number of empty oocysts with no DAPI positive nuclei evident.

Age distribution.
The median age of cases was 11 months (IQR = 9.5) and the median age of participants was 10 months (IQR = 11). Eighty three percent of cases were under 2 years of age, and all cases were under 4 years of age. Neither age nor gender were influencing factors with regard to species distribution in cases. The majority of cases occurred in the 0-24 month age bracket (80%), and may, in part, reflect the high percentage of children from this age group that were sampled (79%), which in turn may reflect the vulnerability of children in this age bracket to contracting diarrhoeal illness. Thirty five percent of cases

were between 7 and 12 months old indicating a significantly higher number of cases in that age group (χ^2 = 22.1, 7 degrees of freedom, p <0.005). This general trend was also noted in a previous Kenyan study (Simwa *et al*., 1989), and can be attributed to the reduction in passive immunity contributed from breast feeding at that age. Partial immunity from previous exposure may then protect the higher age groups from a similar rate of infection. This is a phenomenon that requires further seroepidemiological investigation and should be the subject of a further cohort study.

Very few studies have been conducted in sub-Saharan Africa to assess the diversity of *Cryptosporidium* species present in a population. Previous microscopy-based studies in developing countries assumed that the infecting species was *C. parvum*. More recent molecular studies in Kenya, Uganda and Malawi have identified the presence of *C. parvum, C. hominis, C. muris* and *C. meleagridis* (Leav *et al*., 2002; Gatei *et al*., 2003; Peng *et al*., 2003; Tumwine *et al*., 2003). Our data indicate the presence of four *Cryptosporidium* species in children under five years old. Different species may have different implications for infection sources, subsequent risk assessment and epidemiology. *C. hominis* is mostly associated with outbreaks of cryptosporidiosis in developed countries with *C. parvum* being the main cause of sporadic cases (McLaughlin *et al*., 1999). In this, and other studies in sub-Saharan Africa, the dominant species has consistently been *C. hominis* in sporadic cases thereby indicating the potential for anthroponotic transmission in this environment.

Case control study

During this 23 month study, a total of 96 home interviews were conducted in 24 villages in Chikwawa District (cases n = 24; controls n = 72). The mean age of participants was 14.3 months (S.D. 9.457) with 87% of participants being <24 months old. 45% of participants were female.

Data affecting individual risk factors were assessed and compared to national data where appropriate. A total of 61 risk factors were assessed for their effect on the presence / absence of cryptosporidiosis (defined by oocysts being present in diarrhoeic stools). Analysis conducted to identify determinants for cryptosporidiosis was limited by sample number. Six variables were discounted from analysis as they were consistent for both cases and controls. Thirty variables were included within the multivariate logistic regression based on significance. The R^2 values indicated that the model only accounted for 28 - 41% of cryptosporidiosis cases [0.28 (Cox and Snell) and 0.414 (Nagelkerke)]. This low variance indicates that, while this model can identify determinants which influence the acquisition of childhood cryptosporidiosis, we cannot infer that they are the sole risk factors. Some important limitations in our data collection included the lack of height and weight data to assess malnutrition levels, the lack of awareness of HIV status in children, and the lack testing for other concurrent (viral, bacterial and parasitic) infectious diseases.

Socio-economic status

Possessing no education in the household was found to be an implicating factor in infection [OR = 3.6: CI(95%) 1.1 - 11.8, p = 0.04]. The total lack of education has not been reported as a determinant for cryptosporidiosis, previously, and this positive correlation is indicative of further risk factors which may be influenced by education, such as poor personal hygiene and poor child care. Occupation, house construction, the number of occupants in a house (including overcrowding), the numbers of siblings for a case were not significant for cryptosporidiosis in any model tested.

Drinking water

Sources

Drinking water is a well established route of *Cryptosporidium* transmission in developed countries and has been predominantly associated with supplies which were subject to insufficient water treatment (Smith and Grimason, 2003). In sub-Saharan Africa, the potential for waterborne transmission was identified by Kelly *et al*. (1997), who demonstrated a significant association between increased cases of cryptosporidiosis and the consumption of drinking water in Zambia. Statistical associations between water consumption and cryptosporidiosis were also reported in sub-Saharan regions (Gascon *et al.,* 2000). Five types of drinking water source, representing 28 separate supply points, were used by respondents in this study, namely boreholes (n = 17), unprotected shallow wells (n = 2), gravity tap systems (n = 6), and rivers (n = 2). When divided into protected and unprotected sources, all unprotected and 23.5% of protected water sources were contaminated with *E. coli*. These were predominantly associated with gravity fed systems which collected water to a settlement tank from a catchment area, and which was subsequently distributed to taps located within the surrounding communities. This water was not subjected to treatment. Although the presence of *E. coli* is not an indicator of the presence of *Cryptosporidium*, it does indicate that a water system is faecally contaminated, possibly following indiscriminate defaecation by human- and non-human hosts. Oocysts can remain viable in human and animals stools for up to six months (Jenkins, *et al.,* 1999; Robertson, *et al.,* 1992) and, when exposed to rainfall, can be released from faeces in high concentrations, and transported by runoff into drinking water systems (Davies, *et al.,* 2004; Schijven, *et al.,* 2004). Thus, if oocyst-contaminated faeces are present within the water catchment area, they could be transported into the water system from which the gravity fed system is derived. This increase in oocysts in water systems and the consumption of oocyst contaminated drinking water correlates with the seasonality of infection, as 60% of our cases occurred in the rainy season (rainy season 7.4% vs. dry season 4.5% incidence). This has also been demonstrated in other studies (Nchito et al., 1998; Steele et al., 1989). The type of water source and the microbiological quality of the drinking water, at source, did not have a significant effect on childhood cryptosporidiosis.

Drinking water in the home

All respondents collected water in metal buckets (ndowa) and stored it in locally produced clay pots. Microbiological examination of drinking water from clay pots demonstrated that, despite collection of drinking water from a 'clean' source, 76% of household water was faecally contaminated (Figure 1). Immersion of hands and utensils has been reported to be an associated risk factor in the contamination of drinking water (Swerdlow *et al.,* 1997; Trevett *et al.,* 2005a; 2005b). In our study, seventy five percent of guardians' hands were contaminated with *E. coli* at the time of interview. This high level of faecal contamination enhances the likelihood for contaminating water during collection, storage and retrieval of drinking water, and requires further investigation.

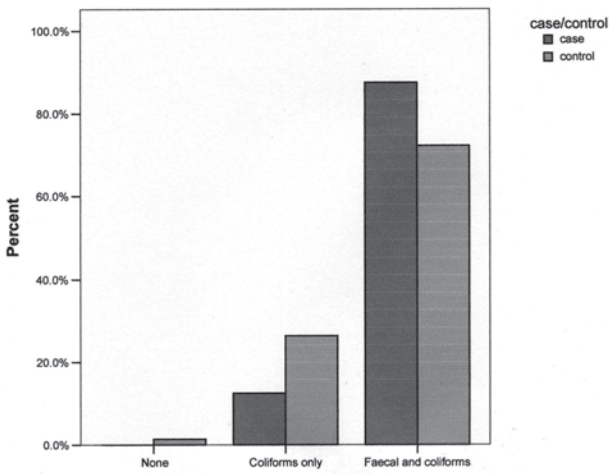

Figure 1: Microbiological quality of household drinking water for cases and controls

Nine of ten (90.6%) children consumed drinking water stored within the household, three quarters (74.7%) of whom drank *E. coli* contaminated drinking water. However, a child who drank household water did not have a significant association between the presence or absence of cryptosporidiosis [OR = 0.4: CI(95%) 0.01 - 1.5, $p = 0.17$], although drinking water is a potential vehicle for transmitting diarrhoeal diseases, including cryptosporidiosis.

Appropriate treatments can reduce the contamination of household drinking water by pathogens. With respect to the risk of contracting cryptosporidiosis from household water, our questionnaire concentrated on boiling as an effective treatment for rendering oocysts non infectious. Although a small percentage (14.6%) of respondents indicated that they boiled drinking water prior to its consumption, little improvement was detected in the microbiological quality of their household drinking water (40% were *E. coli* positive). This may be as a result of post treatment contamination, inadequate heating or providing 'expected answers' to the interviewer.

Environmentally and economically friendly, alternative, treatment systems exist for disinfecting *Cryptosporidium* and other diarrhoeal agents. Mendez-Hermida *et al.* (2005) demonstrated that, under laboratory conditions, solar disinfection can render *Cryptosporidium* oocysts non infective after 12 h of exposure.

The control of water safety within the rural community resides with the health surveillance assistants (Government employed) and the water point committees (volunteers). Their training must include details of Water Safety Plans in the future to provide them with the necessary skills to identify and assess hazards within their communities and subsequently control them at source, collection point and household levels. Such capacity building at community level could help to reduce the reliance on non Governmental organisations and district water offices in the control of safe drinking water (WHO, 2006).

Cryptosporidium oocysts were not isolated from either source or household water samples. The sampling method used was simplistic and limited because of the equipment and facilities available within Malawi. Small volume samples contain relatively fewer oocysts than large volume samples which reduces the number of oocysts detected, while long term storage of sample concentrates (maximum 2 years) can influence oocyst structure, thereby reducing the efficacy of the IMS and IF methods we used. Further sampling of water for oocysts should focus on the collection of larger volumes where possible, and the use of an additional or alternative concentration method such as membrane filtration or $CaCO_3$ flocculation (Vesey *et al.,* 1991).

Sanitation

More than half of all respondents (52.2%) did not have pit latrines. No significant association between pit latrine ownership, pit latrine structure, the disposal of child excreta and *Cryptosporidium* oocyst positive cases was found in this study. Previous studies identified poor sanitation and lack of latrines as determinants for *Cryptosporidium* transmission in sub-Saharan Africa (Gascon *et al.,* 2000; Nizeyi *et al.*, 2002). Traore *et al.* (1994) demonstrated that the risk of children contracting diarrhoeal illnesses was 35% higher in individuals living in households where human faeces were observed on the ground, while van Derslice *et al.* (1994) found that reducing environmental contamination with faeces reduced the risk of diarrhoeal illness. As such, the indiscriminate disposal of faeces cannot be discounted as a potential route for the direct or indirect transmission of *Cryptosporidium* spp. oocysts.

Studies on the disposal and handling of excreta in Malawi identified lack of funds and lack of technical expertise as major factors in the absence of latrines (Grimason *et al.,* 2000). As such, household members, particularly in rural areas, may choose to defaecate in open areas, or construct poor quality latrines that may be abandoned due to collapse or malodours. As no sanitation policy exists currently within Malawi, there is little guidance for households on the benefits of latrines, their placement or construction, which leads to little encouragement for their use.

The presence of filth flies and cockroaches in poorly maintained latrines also offer a further transmission route for diarrhoeal disease agents including *Cryptosporidium* spp. Studies indicate that adult and larval stages of filth flies which fed on oocyst contaminated faeces can transmit *Cryptosporidium* oocysts to distant surfaces in their faeces and following direct contact with their contaminated outer surfaces (Gracyk *et al.,* 1999; Getachew *et al.,* 2007). The ubiquitous presence of flies in the latrine, home and surrounding area must be considered as a potential route of infection for cryptosporidiosis as the ID_{50} can be low (Okhuysen *et al.*, 1999).

Household hygiene

We assessed various aspects of household hygiene, including personal hygiene, food hygiene, and management of diarrhoea.

Personal hygiene

Respondents were asked open questions with regard to hand washing practices to reduce the likelihood of giving 'expected answers'. The majority (84.4%) of guardians indicated that they washed their hands after using the toilet and before preparing / eating food (85.4%), but no guardian stated that they washed their hands after handling their child's faeces. Hand washing prior to eating is a consistently observed custom in Malawi (Morse, T.D., personal observation) however, washing hands after visiting the toilet is perhaps not as consistent. Mariun'Ebo *et al*. (1997) stated that mothers over reported hand washing practices, and a similar effect cannot be ruled out here. Although the majority of respondents were aware that their hands should be washed after defaecating, the practical limitations of hand washing reduce the probability of performing the practice. Here, systems using locally available products should be encouraged, yet, during the period of this study, the majority of households used the traditional methods of hand immersion in basins used by several persons, and the pouring of water over hands, which requires two persons for hand washing. Poor personal hygiene practices are risk factors for contracting cryptosporidiosis in developing countries and are associated with institutional settings such as hospitals and day care centres (Navarette *et al.,* 1991). Improved maternal hand washing reduces the incidence of diarrhoea in children (Han and Hlaing, 1989).

The presence of soap in a household is significantly associated with the reduction of diarrhoea in household members (Peterson *et al.,* 1998). In our questionnaire, the use of soap for hand washing did not have a significant effect on the absence of cryptosporidiosis in this study. Only 27.1% of guardians possessed soap at the time of interview and soap usage varied widely between cases and controls [OR = 0.3: CI (95%) 0.1 – 1.1, $p = 0.06$). Low soap usage may be a reflection of the low socioeconomic status of families within the rural communities of Chikwawa. Apart from hand washing, soap will be used for household duties including cleaning food utensils, washing clothes and bathing therefore, using soap to wash hands may be a low priority. Effective, low cost alternatives to soap are available: ash can improve the efficacy of water in removing dirt and microorganisms from skin (Hoque et al 1991) and the promotion of ash as a hand cleaning agent should be addressed within communities at health education sessions in order to improve the efficacy of hand washing.

Three-quarters (75%) of participants had faecally contaminated hands however, this was not a determining factor for cryptosporidiosis (Table 2). Nevertheless, this level of contamination is indicative of poor hand washing practices and may indicate an incorrect reflection of practices identified by guardians in the questionnaire. Hand cleanliness was not associated with the presence of soap in the household ($\chi^2 = 1.1$, df = 1, $p = 0.29$), or the method of hand drying [shaking: ($\chi^2 = 0.06$, df = 1, $p = 0.81$; cloth: ($\chi^2 = 0.06$, df = 1, $p = 0.81$]. Faecally contaminated hands may enhance person to person transmission of diarrhoeal diseases, particularly to susceptible, young children, and, in our study, the presence of diarrhoea in other household members was a significant determinant for the presence of cryptosporidiosis in children less than five years [OR=8.8: CI (95%) 1.8 – 53.4, p=0.008], indicating the importance of person to person transmission for cryptosporidiosis. In one household, both the case and a sibling excreted *C. hominis* oocysts. Studies conducted in other developing countries have shown a similar association between diarrhoea / cryptosporidiosis in the home and transmission to other members of the household (Newman *et al.,* 1994; Pereira *et al.,* 2002; Rahman *et al.,* 1985).

Bathing children was performed in a bucket or basin in the home (89.6%), in a bathing shelter at the home (2.1%) or in a nearby river (8.3%). Following multivariate analysis of risk factors for cryptosporidiosis, only bathing in a river was found to be a determining factor for cryptosporidiosis (OR= 6.7: CI (95%) 1.1 - 23.8, $p = 0.04$). The multiple use of open water systems, such as rivers, for bathing, washing clothes, retrieving drinking water, and as a source of drinking water for domesticated (and feral) animals makes them ideal sources for the transmission of diarrhoeal diseases.

Grimason, *et al*. (2000) identified the urban Malawian phenomenon whereby one third of respondents believed that stools from babies were 'less harmful' than those from adults and therefore did not require sanitary disposal. This belief may also have influenced the fact that no guardians indicated that they washed their hands after handling excreta from children. Appropriate disposal of stools from children was found to significantly reduce household diarrhoea in Burkina Faso

(Curtis *et al.,* 1997). The method of disposal for children's stools was not found to be a significant risk factor in the presence/absence of cryptosporidiosis.

Food hygiene

Poor food hygiene is a well recognised transmission route for diarrhoeal diseases. Foodborne cryptosporidiosis has been associated with street vended foods, fruit, vegetables and unpasteurised milk in tropical countries (Elsser *et al.,* 1986; Quiroz *et al.,* 2000; Sterling *et al.,*1986; Monge *et al.,* 1996; Ortega *et al.,* 1997). The location of fruit and vegetable vendors, the use of fertilisers, the washing of fruit and vegetables before consumption and the specific area for food preparation in the home were not significant risk factors for cryptosporidiosis. However, the presence of oocysts on locally produced fruit, vegetables and meat cannot be discounted: carcasses are exposed to faecal matter and filth flies during slaughter, faeces can contaminate water, soils, sewage, while poor food handling / personal hygiene also increases the risk of foodborne contamination. 80.2% of children in our study were breastfed (cases = 75%; controls = 82%), but no significant difference was found between the incidence of cryptosporidiosis and the practice of breastfeeding [OR = 0.7: CI (95%) 0.2 – 2.0, p = 0.5]. Childhood *Cryptosporidium* infection rates increase up to two years of age, after which time, active immunity from repeated exposure to infection reduces disease. Breastfeeding children up to six months old can reduce the risk of cryptosporidiosis in this age group (Simwa *et al.,* 1989; Zu *et al.,* 1994).

Domesticated animals

Livestock, particularly neonatal cattle and sheep, are a reservoir for the zoonotic transmission of *C. parvum*, (Konkle *et al.,* 1997; Smith *et al.,* 2004). No *Cryptosporidium* oocysts were detected in 195 samples of animal stools using mZN. *C. parvum* oocysts were isolated from cattle in Chikwawa District in 2002 indicating both the presence of this zoonotic species and the potential for disease transmission within the rural population of this District (Banda, 2008). Siwilia *et al.* (2007) reported the zoonotic transmission of *C. parvum* between dairy farm workers and cattle in Zambia, and *C. parvum* oocysts have been detected in pigs (Zintl et al., 2007). Zintl et al. (2007) detected *C. parvum* only in two sows in their study of intensively farmed pigs in Ireland, and stated that whilst *C. parvum* infection in pigs was rare, it would be of concern to animal handlers.

The ownership of cattle, pigs and cats was higher in cases than in controls (Cows: Cases n = 20.8%, Control n = 6.9%; Pigs: Cases n = 41.7%, Controls n = 9.7%; Cats: Cases n = 41.7%, Controls n = 15.3%). On the basis of the number of animals observed around each home and the number of stools observed, exposure to animals was similar in cases and controls. Ownership of pigs was found to be a significant determinant of cryptosporidiosis in cases [OR = 7.2: CI (95%) 1.9 – 27.5, *p*=0.004].

Statistical associations between cryptosporidiosis and animal contact have been reported previously in the tropics. Cattle, pig, dog and cat ownership were all reported to be a significant risk factor for the presence of cryptosporidiosis in Guinea Bissau (Cartensen *et al.,* 1987; Chunge *et al.,* 1992; Molbak *et al.,* 1994; Niyezi *et al.,* 2002).

Conclusion

This study builds an effective picture of faecal-oral disease transmission in rural Malawi. The use of qualitative, quantitative and observational data has allowed the demonstration of critical disease transmission routes, not only for *Cryptosporidium*, but also for other diarrhoeal disease agents. The importance of water hygiene, particularly after drinking water collection, animal control, sanitation and hygiene education are highlighted as key areas which require further attention at community level if disease transmission is to be reduced in children under five years old. The implementation of programmes such as the WHO Healthy Village concept in conjunction with Water Safety Plans to build capacity and provide an holistic approach to health improvement at rural level in Malawi are essential in diarrhoeal disease reduction.

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Table 1. *Cryptosporidium* species infecting rural Malawian children under five years old.

Sampling Area	Species of *Cryptosporidium*						
	C. hominis	*C. parvum*	? *C. hominis* / *C. parvum* (partially typed)	*C. meleagridis*	*C. andersoni*	No amplicon	**Total**
Rural	9	3	3	2	1	7	25

Table 2. Microbiological quality of guardians' hands at the time of interview by case and control.

Respondent	Microbiological Result of Hand Swab	
	Coliforms only	*E. coli* and coliforms
Case (n = 24)	4.2%	95.8%
Control (n = 72)	31.9%	68.1%
Total (n = 96)	25.0%	75.0%

Comparison of Sanitation Coverage amongst Rural Villages located around Lake Malawi with Government of Malawi and Millennium Development Goal Targets: Case of Monkey Bay

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Abstract

This paper presents the findings of a preliminary study undertaken to estimate the degree of sanitation coverage and mode of construction of pit latrines in rural areas with waterlogged sandy soils in Monkey Bay, Malawi. The aim of the study was to generate baseline data on the provision of sanitary facilities in rural villages to identify the investment required in order to meet the demands of the Millennium Development Goals (MDGs) and sanitation goals set by the Government of Malawi (GoM, Ministry of Health [MoH]). Data were collected through a household survey comprising 21,314 households in the Monkey Bay health zone. Overall coverage of improved latrines (5%, n=1,064) and ordinary pit latrines (49.6%, n=10,583) was 54.6%, which complies with the 50% basic sanitation coverage MDG but is below the 75% adequate sanitation coverage standard set by the MoH. Significant differences were noted between sub-zones (ranging from 31% to 70% for ordinary and 0% to 13% for improved) and villages (ranging from 6% to 100% for ordinary and 0% to 79% for improved latrines). Factors contributing to latrine construction included initiatives by NGOs, soils with high bearing capacity, economic activities and literacy level. A combination of effort by Government, NGOs and community is required to achieve the MDG for all villages and the GoM target.

Key words: ***Dome slabs, improved latrines, Millennium Development Goals***

Introduction

It is estimated that more than 2.4 billion people in the world lack access to adequate excreta disposal facilities which can lead to widespread open defecation and its inherent health risks (Cairncross, 2003; Thompson and Khan, 2003). Infections from human excreta account for 80% of sickness in developing countries with 10-20 million deaths reported per year worldwide due specifically to water-borne infections (Jha, 2003; Dzwairo *et al*, 2006), many of which are recorded in the poorest developing countries like Malawi. The country has an annual gross national product of US$ 166 per capita resulting in two thirds of the population having to live below the absolute poverty line (Chunga *et. al*. 2004). Forty percent of the population has to live on less than US$1 per day and three quarters of the population on less than US$2 per day, predominantly from rural areas. Within the Southern African Development Community, only Angola and Mozambique have a human development index (HDI) value lower than that of Malawi. It is categorized within the lowest human development category, ranked the 162nd out of the 175 countries listed. Government reports state that 10% of Malawi's population has access to any form of 'basic' sanitation and 6% of the population to 'adequate' sanitation (Ministry of Water Development, 1998; Government of Malawi, 2001). 'Basic' sanitation refers to sanitary facilities such as pit latrine without features such as a tight fitting drop hole cover, key shaped drop hole and foot rests that guide the appropriate positioning over the drop hole. 'Adequate' sanitation refers to facilities with the features previously highlighted that include an impermeable floor such as a sanitation platform (National Sanitation Policy, 2007).

Adequate and improved sanitation is crucial in arresting the spread of water-borne and sanitary-related infections. Such infections are high in rural areas with waterlogged sandy soils such as Monkey Bay, where 50% of infections are water related (MOWD, 1998). In these areas, poverty-stricken communities lack access to potable water supplies and rely on shallow wells for their daily water needs. Simple low-cost on-site sanitation methods are used to dispose of faecal matter, mainly because of their economic advantage (Dzwairo *et al*, 2006). The impact of properly constructed pit latrines is profound particularly in rural areas where the soils are sandy and waterlogged. This averts contamination of groundwater sources which are the main source of water supply for rural people (Dzwairo *et al*, 2006). Pit latrines fail by cracking and sinking, which has been attributed to low bearing capacities of sandy soils and high water tables (Mbewe, 2002; Dzwairo *et al*, 2006).

The Millennium Development Goals (MDGs) were agreed to in 2000 when all United Nations member states pledged, among other issues, to reduce by half the proportion of people without basic sanitation by 2015. The goal for Malawi, which is in tune with MDGs, is to achieve universal access to improved sanitation, and safe hygiene behaviour by the year 2020 (NSP, 2007). To this end, a study was undertaken to determine the current state of sanitation coverage in five sub-zones of the Traditional Authority Nankumba, Mangochi District comprising 98 villages and 21,314 households in Monkey Bay, Malawi.

Methodology

The study was conducted in Monkey Bay Health Zone in Traditional Authority Nankumba, Mangochi District, Malawi (Figures 1 and 2). The study included households in Nankhwali (n=1315), Nankumba (n=5,135), Malembo (n=4,084) and Mkope Health Centres (n=4,134) and Monkey Bay Community Hospital (n=6,648). The latrines of 21,314 households were inspected as part of an extended study (Table 1). The survey was carried out between March 2004 and October 2006.

Figure 1. Map of Malawi with surrounding countries

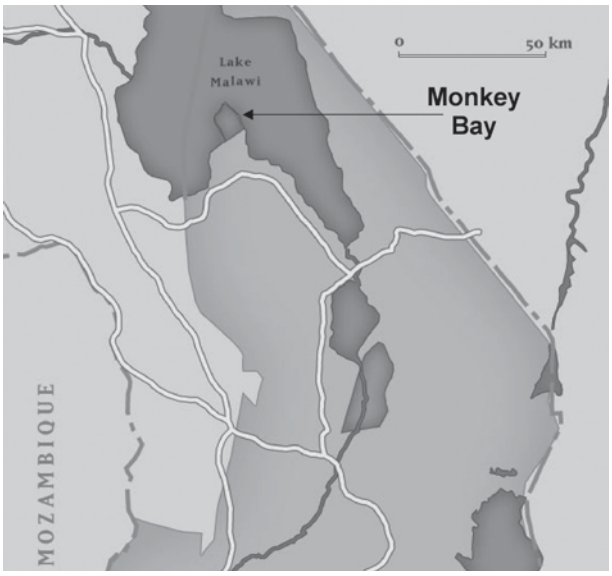


Figure 2. Location of Monkey Bay, Southern Region of Malawi

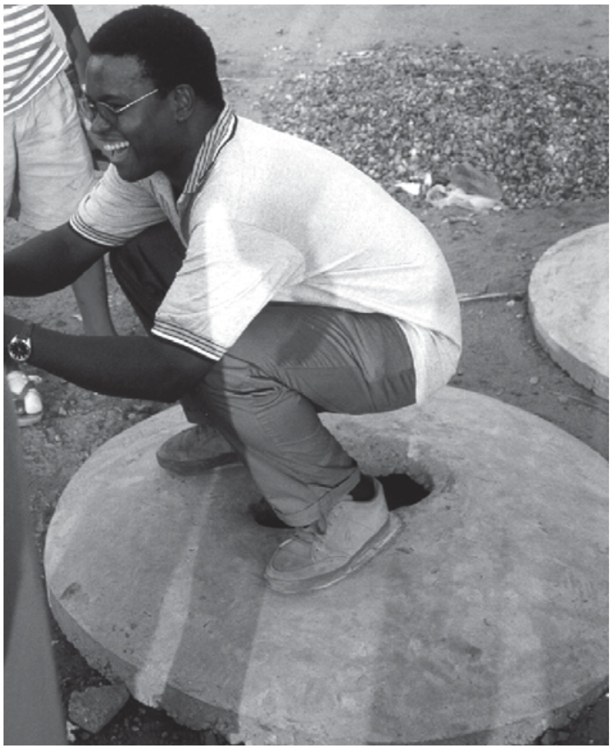
Results and Discussion

Construction of pit latrines

The majority of households had traditional (ordinary) pit latrines that consisted of an unlined pit about 1 m deep and floors made of mud smeared on wooden poles laid across the pit with a squat hole inserted in the middle. The traditional pit latrine with mud floor can be 'improved' with the installation of a sanitation platform (San-plat) (Grimason et. al., 2000; Branberg, 2001). A San-plat is a prefabricated concrete floor designed to offer structural stability and sloped to prevent pools of urine from forming and facilitates direct targeting of faeces whilst defecating. Incorporated into the design of the San-plat are keyhole shaped squat-holes and footrests that make it easier for users to position themselves over the squat hole. Unlike the sanitation platform, the surface area of earthen floors was highly variable, often uneven and slippery underfoot.

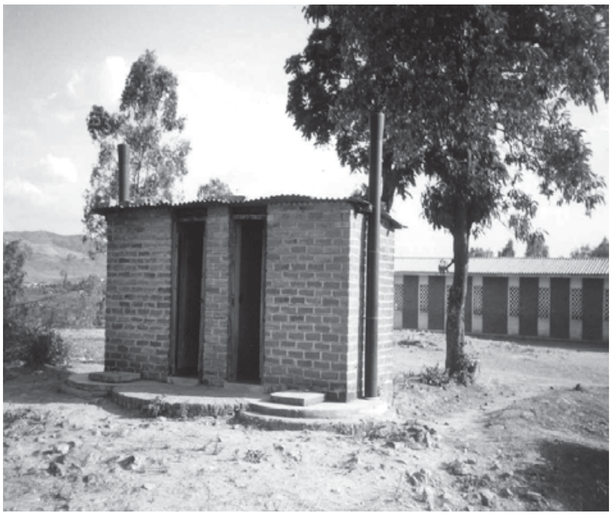
Surface erosion of the earthen floor means that the floor has to be periodically re-laid by re-applying a new surface layer of mud by hand. Faecal contamination of the earthen floor, lack of material for anal cleansing and subsequent re-application of the mud layer are all factors which may contribute to the burden of diarrhoeal disease in the communities through the faecal-oral route. Improved or adequate latrines had circular pits about 1.5m deep which were lined with bricks and cement mortar. These latrines also had dome slabs (Photograph 1). About 65-70% of latrines had walls of unburnt bricks and 30% had walls made of thatch grass reinforced with either bamboo or very slender wooden poles. Most latrines (70%) were thatch roofed to keep prevent water ingress. On dambo land (wetland), the latrines had walls made from poles and mud, and earth bricks. Upon visual inspection of the latrines a number of structural defects were noted; 30% had no roof and 50% no door. Sacks hung between two door posts were used by some households to provide a degree of privacy and were often used as a means of hands drying after use.

Construction of pit latrines took place in the dry season because the water table is at a lower level than in the wet season. The soil condition requires that pit latrines be



Photograph 1. Example of a 'domed' sanitation platform

lined to avert pit failure and slab cracking. Several pit latrine failures by crashing, cracking and sinking were noted which can be attributed to waterlogged sandy soils because of the low bearing capacity and shear strength of the units. This reduced the number of pit latrines available in certain health zones and villages forcing the inhabitants to opt for the bush rather than construct a pit latrine which is likely to collapse (Mbewe, 2002). A number of older people stated that they preferred to make use of the bush to defecate, where they have privacy, a clean spot to squat, and leaves available for anal cleansing. Such indiscriminate defecation in the environment increases the potential for zoonotic and vector-borne disease as animals are allowed to roam freely around villages and flies are naturally attracted to faecal matter.



Photograph 2. Example of improved pit latrine

Ventilated improved pit latrines are attractive to users as they are easier to maintain in a hygienic state and prevent nuisances associated with odours and flies (Photograph 2), however the drawback is that local people simply cannot afford to build them due to the inherent costs involved. In this study, the cost of constructing an improved pit latrine varied between US$23.00 and US$28.80 depending on whether the pit was lined or unlined. The cost covers cement, poles, steel reinforcement, coarse aggregate, burnt bricks and thatch grass but excludes labour costs. Malawi is one of the poorest countries in the world with most rural people surviving on less than $1/day. As such, many people in the area under investigation cannot afford the luxury of constructing a VIP. In contrast, the traditional (ordinary) latrine is regarded as being a more flexible; a temporary rather than permanent structure; relatively simple to re-construct should the pit collapse or become full; and does not have the problems and costs associated with pit emptying (Grimason *et. al*., 2000). Cost of construction and materials for anal cleansing, smell, flies, fear of children falling through squat hole and social, cultural and maintenance issues are all factors that have been reported as reasons for people not constructing latrines in Malawi (Grimason *et. al.,* 2000).

Sanitation coverage according to health sub-zones and villages

Of 21,314 (100%) households visited approx. one in two (10583; 49.6%) had an ordinary (traditional) latrine and one in twenty (1064; 5%) an improved latrine. The remainder of households had no form of sanitation coverage whatsoever and either defecated in the bush or made use of a neighbours' latrine. Sanitation coverage at 54.6% on average for all five sub-zones is significantly lower than the 75% target of adequate sanitation coverage recommended by the Ministry of Health.

Significant differences were observed in sanitation coverage between sub-zones (Table 1) and between villages (Figure 1). Basic sanitation coverage comprising an ordinary pit latrine ranged from 31% (Mkope Health Centre) to 70% (Nankumba Health Centre). Health zones/villages such as Mkope which are located closest to the lakeshore often have poor soil stability with low bearing acapacity. This often results in pit collapse during the rainy season and may be a factor which dissuades people residing around the lakeshore from constructing latrines. In contrast, health zones/villages located further inland from the lakeshore (e.g. Nankumba) with good soil stability had significantly greater sanitation coverage. The percentage of households with access to adequate latrines was poor ranging 0% to 3% in four out of five of the sub-zones; however Monkey Bay Community Hospital in contrast had significantly better coverage (13%). This may be because this area is also a major trading centre in Monkey Bay and has a higher literacy level. The percentage of households with no access to sanitation coverage ranged from 39% (Nankumba) to 66% (Mkope) in all five sub-zones.

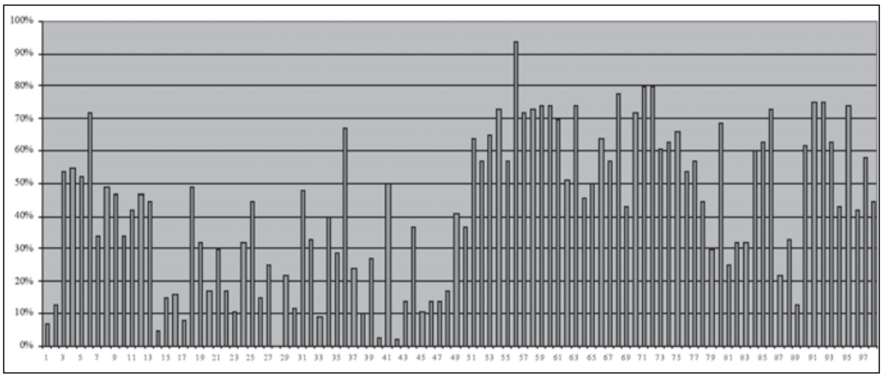


Figure 1. Percentage of households within the five Health sub-zones and 98 villages without sanitation coverage

Four of 14 villages in Nankhwali Health Centre zone do not comply with the MDG goal of 50% basic sanitation coverage (Kasankha 1 = 41%, Machilika = 45%, Kasankha 2 = 48% and Mbwana = 28%). Coverage of ordinary pit latrines for the remaining villages was as high (Kamphande 1 = 50% to Mpango = 95%). Households with no access to any form of sanitation

Table 1. Sanitation coverage of five Health sub-zones & 98 villages in Monkey Bay

Village number & Name	No. households	Ordinary pit latrines	% coverage	Latrines with dome slabs	% coverage	% no Coverage
Sub-zone 1. Nankhwali Health Centre						
1. Mbeya	113	86	76%	19	17%	7%
2. Mtewa	108	94	87%	0	0%	13%
3. Kasankha 1	288	118	41%	16	5%	54%
4. Machilika	42	19	45%	0	0%	55%
5. Kasankha 2	39	20	48%	0	0%	52%
6. Mbwana	83	23	28%	0	0%	72%
7. Kamphande 2	41	27	66%	0	0%	34%
8. Kamphande 1	88	44	50%	1	1%	49%
9. Mwenda	81	43	53%	0	0%	47%
10. Yesaya	86	57	66%	0	0%	34%
11. Kazembe	26	15	58%	0	0%	42%
12. Mbapi 1	47	25	53%	0	0%	47%
13. Kapichi	208	108	52%	7	3%	45%
14. Mpango	79	75	95%	0	0%	5%
Total	1315	708	54%	43	3%	43%
Sub-zone 2. Nankumba Health Centre						
15. Nankumba	489	399	82%	13	3%	15%
16. Kansiya	198	146	74%	0	0%	16%
17. Chimphepo	62	47	76%	10	16%	8%
18. Mthereleka	124	63	51%	0	0%	49%
19, Mbapi	439	297	68%	0	0%	32%
20. Nchantulo	399	293	73%	0	0%	17%
21. Chinganji	128	90	70%	0	0%	30%
22. Sosola	122	102	83%	0	0%	17%
23. Saidi Matola	258	230	89%	0	0%	11%
24. Chamba	189	129	68%	0	0%	32%
25. Lumwira	148	82	55%	0	0%	45%
26. Sokole	199	169	85%	0	0%	15%
27. Kamangazula	97	73	75%	0	0%	25%
28. Molongeni	193	193	100%	0	0%	0%
29. Binali	169	132	78%	0	0%	22%
30. Saitítiputipu	149	115	77%	17	11%	12%
31. Chilonga	612	316	52%	0	0%	48%
32. Kaiche 1	240	156	65%	5	2%	33%
33. Makokola	210	191	91%	0	0%	9%
34. Kela	352	204	60%	0	0%	40%
35. Jumambanga	269	190	71%	0	0%	29%
36. Kaiche	89	29	33%	0	0%	67%
Total	5135	3611	70%	45	1%	39%
Sub-zone 3. Malembo Health Centre						
37. Chigonere	168	128	76%	0	0%	24%
38. Zimbayuda	212	190	90%	0	0%	10%
39. Mkupa	110	80	73%	0	0%	27%
40. Matapang'ombe	165	160	97%	0	0%	3%
41. Jalazi	80	40	50%	0	0%	50%
42. Katole	200	195	98%	0	0%	2%
43. Chilawi	70	60	86%	0	0%	14%
44. Mputa	238	151	63%	0	0%	37%
45. Kalowa	132	118	89%	0	0%	11%
46. Zimbawadi	114	98	86%	0	0%	14%
47. Mtola	169	131	76%	0	0%	14%
48. Mselema	168	140	83%	0	0%	17%
49. Mbinda	144	85	59%	0	0%	41%
50. Matakwe	166	105	63%	0	0%	37%
51. Chilimba	786	284	36%	0	0%	64%
52. Khombe	101	43	43%	0	0%	57%

53. Manzi	193	68	35%	0	0%	65%
54. Simoni	228	62	27%	0	0%	73%
55. Katole 1	207	88	43%	0	0%	57%
56. Domwe	16	1	6%	0	0%	94%
57. Kholowere	215	61	28%	0	0%	72%
58. Mwalala	202	56	27%	0	0%	73%
Total	4084	2320	57%	0	0%	43%
Sub-zone 4. Mkope Health Centre						
59. Chiwalo	998	245	25%	4	<1%	74%
60. Mkungwi	421	106	25%	3	<1%	74%
61. Mthunya	224	68	30%	0	0%	70%
62. Mwanyama	256	53	21%	72	28%	51%
63. Matayo	47	12	26%	0	0%	74%
64. Liganga	89	38	43%	10	11%	46%
65. Lizimba	138	60	43%	10	7%	50%
66. Sombe	153	45	29%	10	7%	64%
67. Nona	74	32	43%	0	0%	57%
68. Guma	94	21	22%	0	0%	78%
69. Kamwetsa	14	8	57%	0	0%	43%
70. Chilembwe	98	27	28%	0	0%	72%
71. Magumbi	221	45	20%	0	0%	80%
72. Mdala Chikowa	226	46	20%	0	0%	80%
73. Masanje	99	39	39%	0	0%	61%
74. Mpeta	112	41	37%	0	0%	63%
75. Chindongo	169	58	34%	0	0%	66%
76. Tukululu	96	44	46%	0	0%	54%
77. Mwalembe	196	84	43%	0	0%	57%
78. Kalumba	101	56	55%	0	0%	45%
79. Kanyenda	131	92	70%	0	0%	30%
80. Chididi	109	34	31%	0	0%	69%
81. Mambo	68	51	75%	0	0%	25%
Total	4134	1287	31%	109	3%	66%
Sub-zone 5. Monkey Bay Community Hospital						
82. Mbwazulu	368	62	17%	187	51%	32%
83. Nsumbi 2	1296	887	68%	0	0%	32%
84. Namaso	236	95	40%	0	0%	60%
85. Namakoma	275	102	37%	0	0%	63%
86. Chizula	364	99	27%	0	0%	73%
87. Chirombo	382	32	8%	267	70%	22%
88. Balamanja	180	120	67%	0	0%	33%
89. Madzedze	246	19	8%	195	79%	13%
90. Nangoma	149	57	38%	0	0%	62%
91. Chimphamba 2	126	32	25%	0	0%	75%
92. Nsumbi 1	719	181	25%	0	0%	75%
93. Mvunguti	371	137	37%	0	0%	63%
94. Zambo	119	68	57%	0	0%	43%
95. Chizale	54	14	26%	0	0%	74%
96. Chembe	1132	481	42%	184	16%	42%
97. Msaka A	343	114	33%	31	9%	58%
98. Msaka B	288	157	55%	0	0%	45%
Total	6648	2657	40%	867	13%	47%

cover ranged from 34% to 72% (median 46%). Only 3% of households within the sub-zone had improved their latrine to adequate status. Within the area under investigation, only four villages had households that had improved latrines: Mbenya (17%), Kasankha 1 (5%), Kapichi (3%) and Kamphande 1 (1%).

No village in Nankumba Health Centre zone met the MoH target of 75% adequate sanitation coverage. Coverage of latrines with dome slabs ranged from 0% in 18 villages to 16% (Chimphepo), with a mean coverage of 1%. Average coverage of ordinary pit latrines was 70% with Kaiche 2 village the poorest at 33% coverage. Overall, 21 of the 22 villages (95.5%) met the MDG sanitation goal. The percentage of households with no access to sanitation cover ranged from 0% to 49% (median 24%). It is of note that the village of Molongeni had 100% sanitation coverage in the form of basic latrines.

Over half of all the villages (14/22) in the Malembo Health Centre zone contained households which met the MDG sanitation target. Three villages exceeded 90% coverage (Zimbayuda, Matapang'ombe & Katole). Four villages had coverage ranging from 50% to 74% and 8 villages below 50% (6% - 43%). Interestingly, no households within any of the villages had improved their latrine to adequate status. The percentage of households with no access to sanitation cover ranged from 3% to 94% (median 37%). In 2005 the American Peace Corps (APC) implemented a sanitation improvement project focused upon behavioural change in Malembo Health Zone and donated 600 dome slabs. This may explain the increased sanitation coverage in this health zone.

In the Mkope Health Centre Zone only three villages complied with the MDG sanitation goal of 50% basic sanitation coverage (Kalumba 55%, Kanyenda 70% and Mambo 75%). This zone had the lowest mean percentage ordinary sanitation coverage (31%) amongst the five zones inspected in Monkey Bay (Nankhwali 54%; Nankumba 70%; Malembo 57% and Monkey Bay Community Hospital 40&). Six villages had households with improved latrines ranging from <1% to 28%. The overall percentage of coverage of pit latrines with dome slabs was 3%, 72% short of the MoH target. Mwanyama village had the greatest percentage of households with improved latrines (28%, n=72) compared with ordinary latrines (21%; n=53). Despite this, over half of households in this village remain without any form of sanitary convenience. Overall, the percentage of households in the zone with no access to sanitation cover ranged from 25% to 80% (median 63%).

Monkey Bay Community Hospital zone recorded the second lowest (40%) ordinary pit latrine coverage but highest (13%) improved sanitation coverage of all the five zones. To this end, the zone does not meet the MoH target. About 24% (4/17) villages met the MDG sanitation goal with a coverage range of 55% to 68%. Only 1 village (Madzedze, 79%) in the Monkey Bay Community Hospital zone currently complies with the MoH target. One reason for this may be due to the affluence generated by the large number of commercial activities in the village. Five villages have households with improved latrines ranging from 9% to 70% (Mbwazulu, Chirombo, Madzedze, Chembe and Msaka A). The percentage of households with no access to sanitation cover ranged from 13% to 75% (median 58%).

Conclusions and Recommendation

Malawi is one of the poorest countries in the world. Under-five mortality is one of the highest in the world with one in five children failing to reach the age of five due to preventable diseases such as malaria, upper respiratory infections and diarrhoea. Overall life expectancy is one of the lowest in the world at 40.2 years, and poor life expectancies for both adults and children can be attributed to a number of factors not least lack of sanitation (Morse *et. al*, 2008). These factors are compounded by a poor level of education and poor socio economic status of the majority of families such as those in the study area under investigation. Coverage of both improved latrines and ordinary latrines in Monkey Bay (54.6%) met the MDG goal of 50% basic sanitation coverage. However, the percentage of latrines with dome slabs failed to comply with the desired 75% adequate sanitation coverage target set by Ministry of Health. Nankumba Health Centre sub-zone had the highest (70%) ordinary pit latrine coverage and Mkope Health Centre sub-zone had the lowest (31%). Improved pit latrine ranged from 0% for Malembo Health Centre to 13% for Monkey Bay Community Health Centre. Households without any sanitation coverage ranged from 39% for Nankumba sub-zone to 66% for Mkope sub-zone. Coverage of improved sanitation was higher in villages that benefited from sanitation interventions by NGOs working in the study area. Overall, sanitation coverage was higher in health zones and villages located further inland from the lakeshore due to better soil stability preventing the potential for pit collapse during the rainy season. In an effort to meet the MoH target, existing traditional pit latrines could be improved by installing sanitation platforms over drop holes. Despite 54.6% overall sanitation coverage, about 40% (39/98) of the villages are yet to comply with the MDG. Realistically this will have to entail a combination of Government, NGO and community partnerships. Further work is ongoing to statistically analyse the data gathered in order to estimate the investment required to meet the MDG and MoH targets by the relevant dates.

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Potential for Water Distillation by using Solar Energy in Malawi

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Abstract
The potential for solar water distillation in Malawi has been modelled. Mean monthly global solar radiation (H) data from 19 sites spread all over the country was used to compute the mean monthly daily distillate productivity (M). Results show that H varies from 15.3 MJ m-2 to 27.8 MJ m^{-2} while M varies from 1.0 kg m^{-2} to 2.5 kg m^{-2}. Distillate productivity is high (up to 2.5 kg m^{-2}) during the dry season, in phase with the shortage of water supply. It appears that there is enormous potential for harnessing solar radiation to improve the quality of drinking water in the country.

Introduction
Clean water is essential for good health, which relates to socio-economic development. Nevertheless, safe drinking water is scarce, especial amongst rural communities in the developing countries due to financial and other constraints. Sophisticated technologies for water treatment are not affordable in such countries. Consequently, simple technologies for water disinfection and desalination are suitable.

It is important to choose a sustainable source of energy for improving the quality of drinking water. Renewable energy (RE) can provide a long-term sustainable solution. Previous studies have shown biomass to be the major source of energy in most developing countries (Kristoferson and Bokalders, 1991) but the large dependence on fuel wood is contributing to deforestation and other environmental problems. In contrast, solar energy is more sympathetic to the environment and available even in remote areas. Con-sequently, there is potential to exploit appropriate solar technologies for water treatment in developing countries.

Saito and El-Ghetany (2002) evaluated the efficiency of a pilot solar water disinfecting system in Japan. In their work, contaminated water (with 167, 000 Col/ml of coliform bacteria) was put in a cubic glass container and the container was placed in a box with double glazing on its top part. The system was exposed to solar radiation for 4 hrs on a sunny day. They found that coliform bacteria were inactivated after a period of 3 hrs exposure to sunlight. Craggs et al. (2004) studied the effect of sunlight on inactivation of Escherichia coli in waste water stabilization ponds in New Zealand. They found that sunlight action accounted for 75 % of the removal of E. coli. More recently, Méndez-Hermida et al. (2007) exposed water samples (contaminated with *Cryptosporidium parvum* and placed in transparent containers) to natural light in Southern Spain. It was observed that exposures of 8 and 12 hrs reduced *C. parvum* oocyst viability from 98 % to 11.7 % and 0.3 % respectively, Whilst disinfection can reduce the percentage of viable microorganisms it does not reduce salinity nor heavy metals (Hanson et al., 2004). In contrast, solar distillation reduces both chemical and biological contaminants. This can be achieved with the use of solar stills.

A basic solar still has a thin layer of water in a shallow basin, transparent cover over the water and a channel for collecting the distillate. Saline water in the basin is heated by solar radiation that passes through the transparent cover and is absorbed by the bottom part of the still basin. Vapour rises from the hot water and condenses when it gets into contact with the inner surface of the transparent cover. The condensate (clean water) is collected through a channel fitted along the lower edge of the transparent cover. According to Bouchekima et al. (1998), improvements in solar distillation technology makes it the ideal technology for remote isolated areas with water demands less than 50 m^3 per day.

Objective of present study
The objective of this study was to assess the potential for solar water distillation in Malawi.

Study area
Malawi is a developing country in Africa located in the tropics between latitudes 9º 22′ and 17º 3′ S, and longitudes 33º 40′ and 35º 55′ E. The country has a population of 12,884,000, with 83% living in rural areas (World Health Organisation, 2006). The major sources of water in remote areas are shallow wells, boreholes, gravity-fed piped systems, springs, rivers and lakes. However, water sources are threatened by depletion and degradation mainly due to population increase, improper disposal of wastes and poor agricultural practices (Mumba et al., 1999; Lakudzala et al., 1999). Pritchard et al. (2007) studied 21 protected and 5 unprotected shallow wells during four different times of the year. They found that drinking water was significantly polluted with faecal waste. Over 50 % of 176 boreholes studied by Msonda et al (2007) had fluoride concentrations exceeding the World Health Organisation limit of 1.5 mg l^{-1}. Several other authors report on the low quality of drinking water, especially in rural areas of Malawi. The World Health Organisation (2006) reported that 68 % and 98 % of the population in rural and urban areas respectively have access to improved drinking water sources.
In Malawi, water distillation is predominantly carried out using electrical heaters. The distillate is used in the chemical industry and laboratories where water of analytical grade is required. Distilled water is also needed in batteries for cars and photovoltaic systems that are used even in rural areas. Consumers of distilled water in rural areas find it difficult to source the product. Moreover, grid electricity is not available to power distillation equipment in such areas. So, an alternative source of energy is needed. Solar energy has been applied in vaporization of water in the production of salt from saline soils, in which the condensate was not recovered (Gondwe, 2004). Madhlopa (2006a) studied the performance of single-slope conventional still (Fig.1) under outdoor conditions in Blantyre, Malawi. The system produced up to 4.8 kg m^{-2} per day under favorable climatic conditions. Nevertheless, very limited work has been done on solar distillation in Malawi.

Methodology
Mean monthly daily global solar radiation (H) captured at 19 different sites (spread all over the country) was

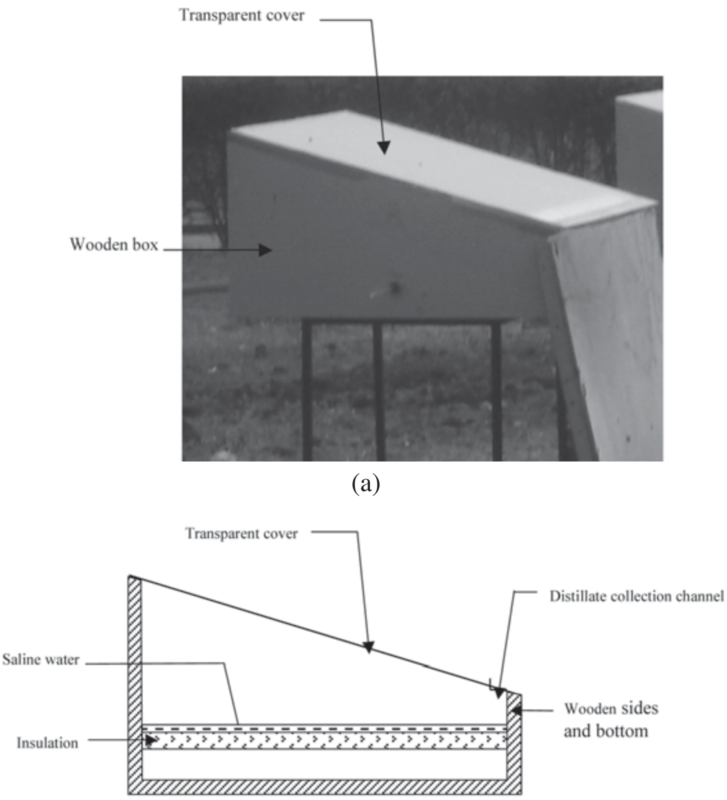


Figure 1: a) Perspective view of a single-slope conventional solar still placed on a table during outdoor testing at the Malawi Polytechnic (15º 48′ S, 35º 02′ E), and *b) cross-section of the still.*

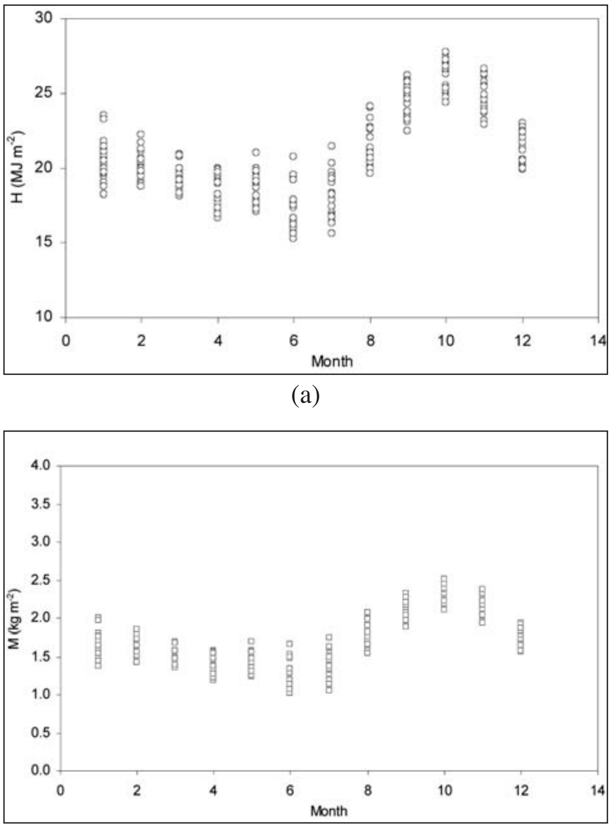
obtained from the Department of Meteorological Services in Malawi. A simple linear model (Tiris et al., 1996) was used to compute the mean monthly daily productivity of distillate production (M):

$$M = a_o + a_1 H \qquad (1)$$

where a_o and a_1 are correlation coefficients evaluated using local experimental data obtained by testing a conventional solar still with a horizontal black-painted basin and saline water level of 4 cm (Madhlopa, 2006a). This correlation exhibited a root mean square error of 0.1 kg m^{-2}. It should be mentioned that distillate productivity is also affected by design, operational and environmental factors. Variations in these factors would therefore affect the performance the model.

Results
Figs. 2 and 3 show variations of mean monthly daily global solar radiation (H) and distillate production (M), respectively. H varies from 15.3 to 27.8 MJ m^{-2} while M varies from 1.0 to 2.5 kg m^{-2}.

Discussion
Results show that H is highest in October and lowest in June. It is also observed that there is some variation in the spatial distribution of solar radiation (data points in a given month do not coincide for all the sites). These observations are consistent with previous findings. Zingano (2001) observed that lowlands have the highest values of global solar radiation while uplands have the



(a)

(b)

Figure 2: Variation of mean monthly a) global solar radiation (H), and *b) distillate productivity (M).*

lowest in Malawi. Diabate´ et al. (2004) found that the index of sky clearness was highest in September for the class II solar climate located in Malawi and Madagascar. More recently, Madhlopa (2006b) identified four seasonal classes (D1, D2, R1 and R2) based on two major climatic conditions (dry and wet seasons) of the country. Generally, solar radiation is most abundant during the dry season D2 (from August through November). The variation in the distribution of solar radiation in time and space indicates that distillate productivity would also vary with time and location.

It is pleasing to note that the mean monthly distillate output is generally high during the dry season, in phase with the problem of water supply in Malawi. The values of distillate productivity observed in the present study compare very well with findings (0.48 – 2.21 litre m^{-2}) of Tiris et al. (1996) for a conventional solar still with a black-painted basin liner and saline water level of 3 cm (1 litre of water ≈ 1 kg of water).

Conclusion

The potential for solar distillation at 19 sites in Malawi has been modeled. Results show that the mean monthly daily distillate productivity attains a peak level at all the sites during the dry season, commensurate with the daily global solar radiation. The distillate productivity is in phase with the supply of water. It appears that there is enormous potential for harnessing solar radiation to improve the quality of drinking water in the country.

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