Institution: Leeds Metropolitan University

Unit of Assessment: 16 Architecture, Built Environment and Planning

Title of case study: Reducing waterborne diseases from shallow wells in the developing world

1. Summary of the impact

This study analysed the shallow well drinking water quality of 17,000 rural Malawians. Water officials were advised interim precautions to take regarding grossly contaminated wells. *Inter alia*, the 'Water Resources Investment Strategy', World Bank funded, captured this data to help develop policy. A new MSc course was established to educate water officials. Workshops/Fieldtrips integrated this research into the undergraduate curriculum. An indigenous sustainable natural water purification system was developed to reduce contaminates at source. Initial data indicates that water quality can be improved by up to 80%. This has the potential to improve the water quality for 1.5 million Malawians.

2. Underpinning research)

Water-related diseases are responsible for 80% of all illnesses in developing countries and kill more than five million people every year. Non-governmental organisations (NGOs) construct shallow wells to try to meet the 2015 MDG – target 7c; however they have not implemented monitoring programmes to ensure that the water remains potable. The preconception is that because these people have an engineered well, they have an adequate drinking water source – this is often far from the case. Hence, there is a vital need to develop cheap, sustainable ways to significantly improve the quality.

To provide a detailed investigation of shallow well water quality, a database from six districts in Southern Malawi was developed. Over 2,700 samples were analysed (2005–07) for chemical, microbiological and physical contamination.[1,2,3,7,8]

The most suitable method to remove coliforms and turbidity from water is via the process of coagulation. The two chemicals commonly used are aluminium sulphate and ferric sulphate. The limited availability and relative expense of these chemicals has led to other more widely available indigenous coagulants being sought for developing countries. Natural plant extracts have been available for water purification for many centuries. However, the science and engineering application of the use of plant extracts have not, really, been developed. To address this, an inventory of plant extracts was formulated. A prioritisation system was derived (in 2008) to select the most suitable extracts, which took into account such criteria as availability, purification potential, yield and costs[4,8]. An empirical parametric study was then undertaken (2008–10) to optimise the performance on the most promising plant extracts together with initial cytotoxicity analyses, both in the laboratory and in the field[9]. Laboratory experiments were undertaken in the microbiology and civil engineering laboratories at Leeds Met, forming an interdisciplinary element to the project [e.g. 5,6]; data from these experiments were then fed into field studies in Malawi (2010–11) regarding the development of a water purification system[11].

The first stage the full-scale Malawi field trial commenced July 2013. The trial consists of a shallow well with a 'bolt-on' water purification system, housing a low cost telemetry cell phone network system to remotely monitor the performance of the well[12].

A new MSc programme was established in Malawi (2009) to increase the level of knowledge of water officials, stakeholders and the alike [10]. Engagement workshops and laboratory sessions also ran throughout 2012/13. These sessions were precursors to the international volunteering field trial, which included 14 multi-disciplinary undergraduate students from both Malawi and the UK.

Dr Martin Pritchard, a Reader at Leeds Met, overall directs this research work. Dr Alan

Edmondson, a Principal Lecturer in Microbiology at Leeds Met; Dr Andy Swan, a Senior Lecturer in Civil Engineering at Leeds Met; Professor Theresa Mkandawire from Malawi Polytechnic and Professor Gary O'Neill from Creh Analytical all contributed towards the success of this project. The work to-date has included three PhD projects – ranging from monitoring in the field in Africa, to undertaking laboratory trials in the UK, to becoming a hybrid of both.

3. References to the research

Publications:

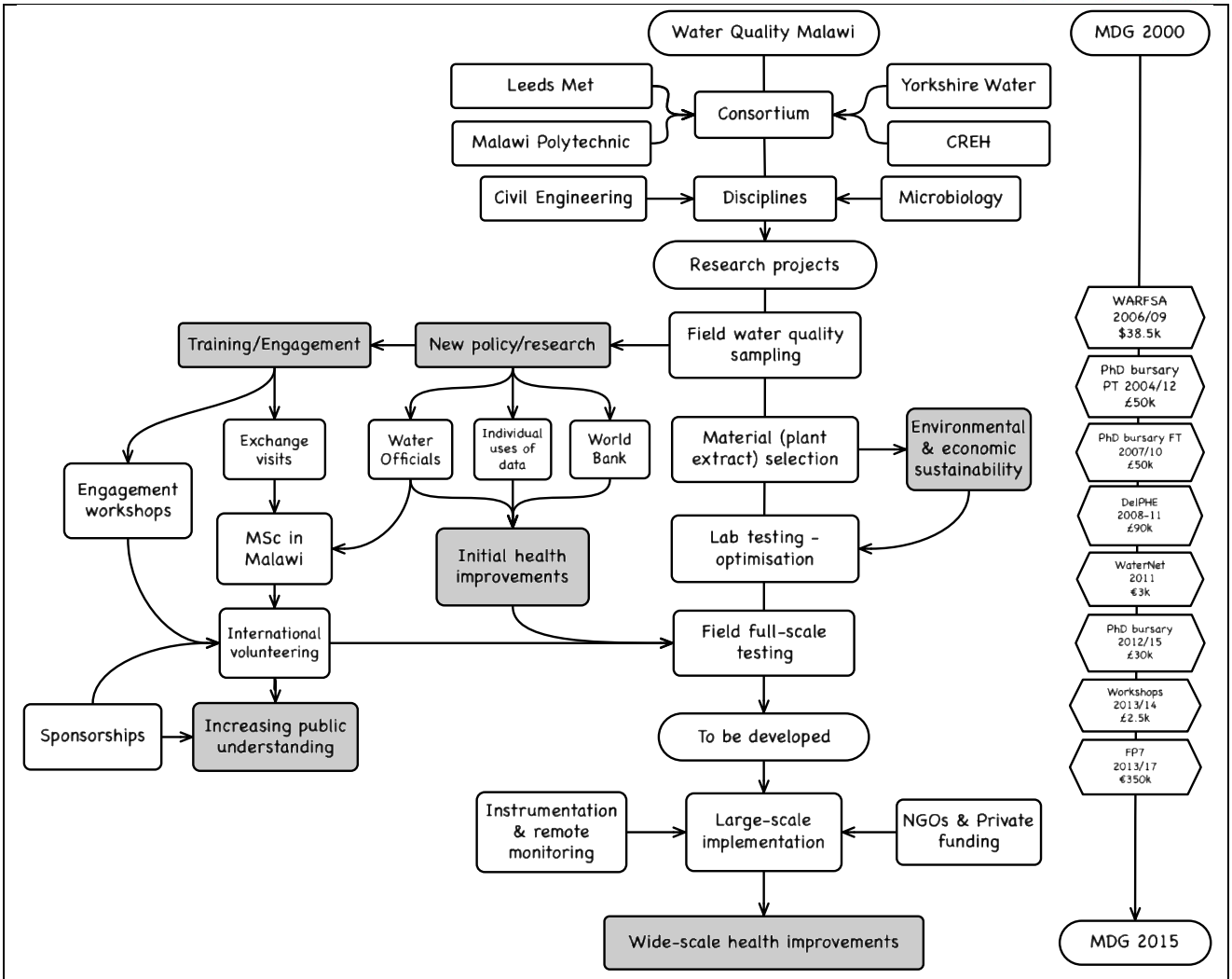
1. Pritchard, M., Mkandawire T. and O'Neill, J.G. (2007) 'Biological, Chemical and Physical Drinking Water Quality from Shallow Wells in Malawi: Case Study of Blantyre, Chiradzulu and Mulanje', Physics and Chemistry of the Earth Journal, Vol. 32, Aug. pp. 1167–1177, ISBN 1474-7065 - Peer-reviewed, impact factor 0.653, 5-year impact factor: 1.171.
2. Pritchard, M., Mkandawire T. and O'Neill, J.G. (2008) 'Assessment of groundwater quality in shallow wells within the southern districts of Malawi, Physics and Chemistry of the Earth Journal, Vol. 33, Aug. pp. 812–823. ISBN 1474-7065 - Peer-reviewed, impact factor 1.362, 5-year impact factor: 1.138.
3. Pritchard, M., Mkandawire, T., O'Neill, J.G., Edmondson, A. and Craven, T. 'Water Quality Monitoring from Shallow Wells in Malawi: Case Study 2005–2007' Chapter 6 in Columbus, F. (2009), 'Water Quality: Physical, Chemical and Biological Characteristics', Nova Science Publishers, Inc. ISBN: 978-1-60741-633-3.
4. Pritchard, M, Mkandawire, T., Edmondson, A. O'Neill J.G. and Kululanga, G. (2009) "Potential of using plant extracts for purification of shallow well water in Malawi", Physics and Chemistry of the Earth Journal, Vol. 34, Aug. pp. 799–805. ISBN 1474-7065 - Peer-reviewed, impact factor 0.975, 5-year impact factor: 1.292.
5. Pritchard, M., Craven, T., Mkandawire, T., Edmondson, A. and O'Neill J.G. (2010) "A comparison between *Moringa oleifera* and chemical coagulants in the purification of drinking water – an alternative sustainable solution for developing countries", Physics and Chemistry of the Earth Journal, Vol. 35, Aug. pp. 798–805. ISBN 1474-7065 - Peer-reviewed, impact factor 0.975, 5-year impact factor: 1.292 (based on 2009 data).
6. Pritchard, M., Craven, T., Mkandawire, T., Edmondson, A. and O'Neill J.G. (2010) "A study of the parameters affecting the effectiveness of *Moringa oleifera* in drinking water purification", Physics and Chemistry of the Earth Journal, Vol. 35, Aug. pp. 791–797. ISBN 1474-7065 - Peer-reviewed, impact factor 0.975, 5-year impact factor: 1.292 (based on 2009 data).

Grants & Awards:

7. US$38,500 – Water Research Fund for Southern Africa (WARFSA) 'Plant Extracts to Improve Groundwater Quality in Shallow Wells', Project P232, July 2006–09.
8. £50,000 – PhD bursary, 'Plant Extracts to Improve Groundwater Quality in Shallow Wells'. July 2004–12.
9. £50,000 – PhD bursary, 'A novel water purification system using *Moringa oleifera* for shallow wells in Malawi', July 2007–10.
10. £90,000 - DelPHE round 4 'Sub-BE' No. 603 – PI, funding to develop an MSc programme for the Polytechnic University of Malawi, Sept 2009–12.
11. €3,000 – WaterNET – 'Development of a novel water purification technology using plant extracts for rural villages in Malawi – site trial', SDF, April 2011 to Sept 2011.
12. €350,000 – FP7 – IRSES: AguaSocial (Social Innovation in the Water Sector), 2013–17.

4. Details of the impact

The flow chart below outlines the work undertaken to demonstrate the types of impact achieved:



Water quality results indicated that shallow well water was heavily polluted with both total and faecal coliforms, especially after the on-set of the rains. About 95% of all the wells tested failed to meet safe drinking water values for untreated water in the wet season, while about 80% of the wells failed in the dry season[1,2,3]. It was noted that the main forms of contamination from shallow wells emanate from bacteriological and physical constituents; in contrast, the main form of contamination from boreholes stem from chemical elements. The detrimental impact on human health of chemical contamination normally requires many decades of exposure before it can be recognised. Where life spans are short due to high incidence of infectious diseases emanating from bacteriological contamination, it is this form of contamination that needs to be addressed first for the developing world. To immediately try to minimise water related diseases, Water Officers and Village Chiefs were informed (2006–08) of the wells, which were yielding grossly biologically contaminated water[A]; and hence advised to either just use this water source for washing or to boil the water for at least one minute before consuming.

From this data a series of publications were formed[e.g. 1–6]. *Inter alia,* these fed into the Government of the Republic of Malawi Ministry of Irrigation and Water Development, Second National Water Develop Project (NWDP II - 2011) entitled 'Water Resources Investment Strategy', World Bank funded[B]; hence used to developed policy. The field sampling data has also been presented to MPs at the House of Commons and has provided direction to others researchers[e.g. C–H].
Laboratory trials were undertaken on *Moringa oleifera, Jatropha curcas* and Guar gum extracts. Toxicity tests were also conducted on these extracts. These trials showed that the addition of plant extracts can considerably improve the quality of shallow well water. About 70% reduction in TC

and FC was noted on average. At optimum dosage, turbidity reduction of water ranged from 10–100% for the three plant extracts. All three extracts proved non-toxic at the recommended concentrations for water treatment based on the ecotoxicity results.
To implement the use of local plant extracts, grown throughout rural villages, a novel small-scale 'bolt-on' shallow well water purification system has been developed. Initial field data demonstrates that improvement in shallow well water quality of around 80% can be achieved. Hence, if implemented for every shallow well in Malawi around 1.5 million Malawians could have significantly improved water sources. Interest in applying the technology on a larger-scale has been expressed by NGOs and the private sector(G) and will be further developed once the full-scale site trial has been completed. It is hoped that such a system will provide a unique sustainable and economical solution to significantly reduce waterborne diseases to some of the poorest people in the world.

In addition to actually conducting the research work, funding from DelPHE (2009–12) was awarded to develop a new style MSc course, in conjunction with the Polytechnic University of Malawi(10). Prior to the onset of this course people in the public or industrial sectors had to leave their jobs (travel overseas) and thus become a full-time student to gain a higher qualification, due to the limitations of available courses in-country. The associated costs, both financial and emotional for studying overseas are high. Also, what they are taught and encouraged to research, in general, targets the cultural and economic situation in the host country; little benefit may accrue to the student's country of origin. In addition, after they have gained their qualification it might be a few years before they gain employment again in their home country. A market had developed for good quality assured postgraduate courses that can be delivered in-country at an affordable cost, enabling students to maintain full employment during their studies. A total of 39 students are currently (2013) studying on this programme.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. Water Officers in Malawi have used this data to select which wells should be directed towards supplying drinking water or providing water for washing.
B. Data from this study has been fed into the: 'Water Resources Investment Strategy, Component 1 – Water Resources Assessment' Government of the Republic of Malawi Ministry of Irrigation and Water Development Second National Water Development Project (NWDP II), April, 2011. Funded by the World Bank.
C. An individual user, of the published data at Washington State University in the United Sates in Environmental and Natural Resource Sciences has recently (January 2012) undertaken a 'replica' study in northern Malawi based on the findings from our study in southern Malawi.

Places where our work has been cited include, e.g.:

D. Terms of Reference for the Study on Drinking Water Quality for Low Cost Water Sources in Malawi, funded by Unicerf, Code/ SC/2007/00664.
E. Monjerezi, M., Vogt, R.D., Aagaard, P., Saka, J.D.K. (2011) 'Hydro-geochemical processes in an area with saline groundwater in lower Shire River valley, Malawi: An integrated application of hierarchical cluster and principal component analyses', *Geochemistry*, Vol. 26, 8, pp. 1399–1413.
F. Chidya, R.C.G., Sajidu, S.M.I., Mwatseteza, J.F., Masamba, W.R.L. (2011) 'Evaluation and assessment of water quality in Likangala River and its catchment area' *Physics and Chemistry of the Earth,* Vol. 36, issue 14–15, year 2011, pp. 865–871.

Interest in large-scale implementation of technology include:

G. NG Bailey and Drop4Drop.