ELHRA Small Grant Project Final Report

"High-science in low-tech emergency settings: a foreseeable horizon or height of folly"

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Introduction

Growing populations and the associated environmental pressures are setting the stage for rapid development in water- and wastewater-related technologies (e.g. nanotechnologies, membrane science, analytical methods, etc.) which are capable of delivering cleaner drinking water, improving wastewater treatment (i.e. sanitation), and providing cheaper and better sensors for contaminant detection/monitoring. Such developments have been fuelled by incentives from governments, research councils, and private sector. Yet, the benefits of these cutting-edge solutions to the growing environmental challenges being faced are likely to only be felt by those in richer nations.

Developing countries are exposed to the same (if not worse) environmental pressures but do not have the infra-structure to cope with such changes. Studies indicate that both natural and manmade (i.e. violent conflicts) disasters are on the rise[1,2], mostly affecting those in developing countries.

Provision of adequate water supply, sanitation, and hygiene promotion is vital for the prevention of infectious water- and excreta-related (diarrhoeal) diseases. These are one of the major contributors to the overall morbidity and mortality rates following a disaster[3]. Many advances in science have the potential to contribute to novel solutions to such problems. However, the reality is that many “novelties” that made the limelight decades ago still haven’t been absorbed in water and sanitation practice (or at least not effectively).

Previous research has shown limitations to many so called “advanced” technologies for emergency water treatment[4]. Some of the common shortcomings are the inability of these technologies to cope with field conditions typically encountered in resource-limited humanitarian emergency contexts. Arguably, this is also a shortcoming of the development process of these technologies. Even less progress has been made in the field of sanitation, which proportionally receives less attention than water supply and treatment. This is likely a reflection of the lack of relative importance it has (undeservedly) been given and its lag in terms of global coverage.

Advances in medicine are evidence that this does not have to be the case. That is, scientific breakthroughs have been translated into solutions for many diseases that affect developing countries. The difference is that (arguably) such solutions are more readily delivered/transferred in the form of new treatments and vaccines. Also, it must be borne in mind that such achievements occur at a much different scale and within well-established industrial backdrop.

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[1] Oxfam International (2007) From weather alert to climate alarm. Oxfam Briefing Paper 108.

[2] Toole (1997) Complex Emergencies: Refugee and other populations. In: Noji (ed.) The public health consequences of disasters. Oxford University Press: 419-42.

[3] Waring & Brown (2005) The threat of communicable diseases following natural disasters: A public health response. Disast. Manag. & Resp. 3(2): 41-7.

[4] Dorea et al. (2006) Particle separation options for emergency water treatment. Wat. Sci. & Tech., 53(7): 253-60.

The *status quo* suggests there is a gap between what is researched (i.e. academia), what is available (i.e. industry), and what is practiced (i.e. humanitarian NGO's and agencies) with regards to water supply and sanitation technologies. Arguably, this is could be due to the lack of interaction between the three sectors. However, there are interrelated uncertainties that are also important to consider:

- Do end-users have sufficient expertise (existing or potential) to absorb new technologies?
- Do academia and industry understand the constraints real-world humanitarian emergencies impose?
- Can humanitarian emergencies become commercially-viable markets for industry?

The overall project objective is to examine issues posing barriers to water supply and sanitation technological transfer to relief agencies and seek a strategy towards how to make effective use of scientific developments in humanitarian emergencies. A summary of the project and its findings (at the time of reporting) are presented.

Collaborative Partnership

In order to gain insight in the barriers within the transfer of technology for water and sanitation applications in developing countries a partnership between the University of Glasgow and Oxfam GB was formed under the Enhanced Learning and Research for Humanitarian Assistance initiative. Both organisations had existing rapports of working with academic and humanitarian partners on specific humanitarian water and sanitation projects in the past, allowing both partners to benefit from complementary insights into the working of each sector – a natural fit for this project.

Approach

Key activities were identified to address project aims. Our approach to these is described in this section.

Survey of current technologies. In order to gain a clearer perspective of the current landscape of technologies currently used for emergency water treatment a scoping exercise of existing technologies was undertaken. Sanitation systems were not considered due to the small variance of such systems in emergency response. This activity consisted of a review of the sector conducted through various sources, namely:

- Direct contact with manufacturers;
- Queries to humanitarian agencies;
- Literature search;
- Survey of internet, including online forums such as www.watersanitationhygiene.org.

An assessment of these technologies was made with regards to how well they fulfil the requirements of emergency responses. This was done by a cost-effectiveness analysis with regards to minimum standards in disaster response[5].

Advances with potential for application. Many new advances have the potential to bring benefits to water and sanitation operations in humanitarian emergencies. Such innovations can be at different stages of development and uptake in developing countries. This aspect of the work consisted of identifying and cataloguing such technologies and exploring their potential applications.

Analysis of current and required knowledge base for uptake of new technologies. The successful uptake of innovations warrants the necessary skill base from the end-users (i.e. humanitarian practitioners) to utilise such technologies effectively (i.e. understand, troubleshoot, operate, design, diffuse, etc.). To this end, an analysis of the available training courses catering to water and sanitation professionals was undertaken.

Interviews. Through meetings with both academic institutions and industries working with water and sanitation a clearer portrayal of the relationship between academia, industry and humanitarian agencies can be obtained. Semi-structured interviews with selected UK-based contacts were conducted to gain a deeper understanding of how water-related industry views the "humanitarian marketplace" for their services and products as well how they interact with academia in research and development. These interviews were also used as an opportunity to trial a survey.

Web-based survey. Web surveys directed at technology developers/suppliers (i.e. academia and industry) and practitioners (i.e. relief workers) were prepared based on previous interviews. Through these a measure of how well actors in research and development

[5] The Sphere Project (2004) Humanitarian Charter and Minimum Standards in Disaster Response, Oxfam Publishing.

understand the needs of humanitarian water and sanitation sector as well as to complement the semi-structured interviews through an understanding of how these three sectors interact. In addition to this, the practitioner-oriented survey was designed with the intention to assess their awareness, willingness and capacity to absorb new technological developments in addition to the identification of the areas in water supply and sanitation that warrant technical solutions. Web-based surveys were targeted at specific groups through relevant contacts, mailing lists, research consortiums, and professional organisations.

Case study. A partnership between an NGO, a manufacturer and an academic partner in the development of a new emergency water treatment technology was used as a case study. This allowed observations to be made on how such a collaboration could be replicated and further exploited in other circumstances.

Principle Activities

Survey of current technologies.

Currently there is an array of emergency water treatment technologies available that can be utilised to produce clean drinking water in humanitarian disasters. However, varying field conditions can make the process of selecting the most appropriate water treatment technology challenging. Systems that are inadequately designed without knowledge of such conditions can result in underperformance with regards to the water supply requirements of humanitarian emergencies.

In the aftermath of catastrophic events it becomes necessary to re-establish the supply of water to prevent outbreaks of disease (alongside sanitation and hygiene interventions). Such circumstances require the supply of sufficient quantities of water of adequate quality [sphere]. In such cases, the quantity of water is prioritised over the quality[6]. This does not imply a neglect of aesthetic and microbiological quality considerations. However, it is the case that water-related disease transmission in emergencies is as much likely due to insufficient quantities for personal and domestic hygiene as to contaminated water supplies[7]; thus defining the requirements for emergencies.

A variety of water treatment technologies were identified. Performance data was evaluated against humanitarian emergency water supply objectives. Considering that such systems also vary significantly in price and that these are considerable investments for humanitarian agencies, a cost-effectiveness analysis could reveal the adequateness of such technologies for emergencies. The basis for this analysis was with regards to the prices of these systems relative to the yield of water these can produce. That is, most of the surveyed information indicated that minimum levels of water quality were achievable with the identified treatment kits; thus water yield was the basis of the analysis.

A summary of the cost-effectiveness analysis is presented in Table 1 with five representative examples of the surveyed technologies. Names and manufacturers of each treatment kit will not be disclosed. Instead, each treatment kit is described according to the classification of such treatment kits as defined previously[8].

Notably, there is a wide range in capital cost of such units. Based on either reported specifications in the literature or information provided from the manufacturers on the yield of such systems the cost per yield of treatment systems can vary by as much as an order of magnitude. Although such an analysis did not take into consideration other cost-related factors (i.e. running costs, staffing, transportation, etc.) an assumption was made that such costs will not vary significantly between each variant. This scoping exercise can already identify the technologies which provide improved cost-benefits to relief agencies.

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[6] Smith M. and Reed R. (1991). Water and sanitation for disasters. Trop. Doct., 21(suppl. 1), 30-37.
[7] The Sphere Project (2004) Humanitarian Charter and Minimum Standards in Disaster Response, Oxfam Publishing.
[8] Dorea et al. (2006) Particle separation options for emergency water treatment. Wat. Sci. & Tech., 53(7): 253-60.

Table 1 – Summary of cost-effectiveness analysis.

Treatment Kit	Treatment Method	Capital Cost (£)	Cost per Yield (£/m^3h)
A	Mobile unit (coag./media filtration- based)	36500	7300
B	Mobile unit (media filtration-based)	24000	2000
C	Mobile unit (coagulant/media filtration-based)	10500	2625
D	Modular unit (coagulant-based)	4600	660
E	Mobile unit (coag./media-filtration-based)	4200	1050

Further to the noticeable differences in cost-effectiveness with regards to yield, it was also noticed that Treatment Kits D and E have been closely developed alongside relief agencies (with inputs from academia). This raises the question whether other more expensive (on a cost-effectiveness basis) options have adequately taken into consideration the actual performance requirements of water treatment in humanitarian emergencies.

Further information on the performance of such treatment kits with regards to emergency water quality objectives would allow such an analysis to incorporate other factors. Unfortunately, such information is not always available. This is important as based on the technologies employed; some of these kits are likely to be producing small amounts of excellent quality water at the cost of a low yield. This results in systems that are inadequately over-engineered for their purpose; ultimately, leading to an expensive technology.

The above issues illustrate the value of collaborations between the humanitarian sector with industry and academia. Also, there is a need for an improved reporting of the performance of available technologies. The inherent risk is that such reporting would be done in an inconsistent and non-standardised format. Testing and reporting protocols exist for other forms of water treatment technologies[9] and a similar approach could be adopted for emergency water treatment technologies. This could in turn aid the development of more cost-effective systems that can provide efficient and effective solutions to emergency water supply.

[9] USEPA (1987). Guide standard and protocol for testing microbiological purifiers. US Environmental Protection Agency.

Advances with potential for application.

Whilst many of the activities in this project focused on currently- or readily-available technologies and innovations for water and sanitation interventions in humanitarian emergencies, many "high-science" advances with the potential to improve such operations were identified. These have not been previously identified in other similar landscaping exercises and are briefly described here. Many are in different stages of understanding and development, but serve to illustrate that lateral thinking can offer potential solutions to water- and sanitation-related problems.

Nanotechnology[10,11] – Nanotechnologies have a clearly defined use in the treatment of water and wastewater, where the key role for nanomaterials is their use in membrane filtration processes. Nanomaterials have nanoscale dimensions (1-100nm) and have the ability to be manipulated in novel ways that change their physical, chemical and biological characteristics. At present, this type of technology is still under preliminary research and laboratory-scale testing; however there is scope for the application of nanofiltration to emergency water treatment kits. This brief will serve as an introduction to the different types of nanotechnologies that could serve as future additions to emergency water treatment systems.

Nanotechnologies can be classed under the following categories: Nanostructured Membranes, Nanoreactive Membranes and Polymer-Supported Filtration. There two paths down which the design of such filters can proceed, the first is to create a nanofilter which utilises the physical flexibility of nanostructured membranes or the creation of a nanomaterial which can serve to enhance the filtration properties of an existing material. Thus the nanomaterials outlined in these categories exhibit varying properties that can range from highly efficient filtration characteristics (i.e. nanostructures) to specific compound affinities that retain target contaminants on the membrane surface. Nanoparticles have demonstrated their ability to serve as highly selective and efficient contaminant removal media. However, the development of this technology is still at an early stage with limited testing at a laboratory level and has unanswered questions related to the social costs and impacts on human health and the environment.

Molecular biotechnology[12,13] – Recent advances in molecular techniques coupled to next generation sequencing are transforming our understanding of the microbial world. Metagenomics enables us to characterise the relative abundance and identity of organisms

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[10] Theron, J., Walker, J. A., & Cloete, T. E. (2008). Nanotechnology and Water Treatment:Applications and Emerging Opportunities. Critical Reviews in Microbiology , 43-69.

[11] Colvin, V.L. (2004). The potential environmental impact of engineered nanomaterials. Nature Biotechnology. ,21(10):1166-70.

[12] Grazer, A.N. and Nikaido, H. (2007). Microbial Biotechnology: Fundamentals of Applied Microbiology. Cambridge University Press; 2nd ed.

[13] Rittman, B.E. and McCarty, P.L. (2001). Environmental Biotechnology: Principles and Applications. McGraw-Hill Higher Education.

in complex communities by directly sequencing their DNA. This avoids the major drawback inherent in culture based methods that only a small minority of species can be isolated and grown in laboratories. Coupled to high throughput sequencing techniques, such as 454 pyrosequencing, it provides a description of a microbial community, of unparalleled depth, that can be resolved temporally and spatially over large scales. It also provides information for further environmental genomics techniques. For example the data can be used to design probes for particular groups of organisms, these can be used in quantitative PCR (qPCR) to obtain absolute abundances and in fluorescence in situ hybridization (FISH) to resolve the locations of individual microbes.

Microbial ecology and molecular microbiology are increasingly applied in biotechnology to understand and engineer wastewater treatment in developed countries. For example, information on the composition of complex microbial communities (many times present as biofilms) in treatment systems can be linked to process performance and used to predict operational problems. Furthermore, these techniques are also showing promise with regards to the development of methods of rapid detection of contamination. That is, detection and quantification of specific microbes (e.g. pathogens) can be done much quicker than through conventional culture-based methods. To this end, some advances have already been done and it is conceivable that such technology could be readily applied in humanitarian emergencies. Currently, specialised equipment and laboratory infrastructure are needed to support this technology.

Quorum sensing[14] – Through quorum sensing bacteria can communicate with one another using chemical signal molecules (i.e. autoinducers). In higher organisms such signal molecules are utilised to coordinate specific activities in a large group of cells. Through such process bacteria can monitor their environment for other bacteria and change their behaviour as a community in response to specific changes. This ultimately, enables a community of unicellular organisms to behave in a similar fashion to multicellular organisms. Knowledge of such a phenomenon could be put to use in several applications, such as the control of unwanted biofilms and treatment of waste streams. These sort of applications are still in initial stages, but have the potential to lend themselves very useful for environmental engineering applications including some in water and sanitation contexts of humanitarian emergencies.

Microbial fuel cells[15] – Microbial Fuel Cell (MFC) technology and their potential applications have been known for almost a century. However, recent interest has been sparked due to developments in the appreciation of microbial physiology, which can help increase the understanding of MFCs and work towards addressing the search for a sustainable and low-cost energy generation technologies. MFCs have the ability to generate electricity from bio-

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[14] Waters, C.M. and Bassler, B.L. (2005). Quorum Sensing: Cell-to-Cell Communication in Bacteria. Annu. Rev. Cell Dev. Biol. 21:319–46

[15] Logan et al. (2006) Microbial Fuel Cells: Methodology and Technology. Env. Sci. & Tech. 40:5181-92.

convertible substrates such as wastewater, glucose and acetate. This technology has the potential to provide a solution to both the looming energy crisis and can offer possibilities in terms of development as a biosensing technology.

Currently, the ability of MFCs to provide a commercially-viable method of energy generation coupled with an effective carbon-neutral means of wastewater treatment is still unknown. Their variable and unstable power output still needs to be overcome. Producing MFCs at a commercially-viable scale is may be possible with a clearly identifiable market. Current systems are operating only at a laboratory-scale. Use of MFCs as biosensors are also not fully developed with a potential to contribute to rapid methods of water quality assessment.

Aquaporins[16] – Aquaporins are protein molecules that facilitate the transfer of water through an impermeable barrier. This type of molecule plays a fundamental role in transferring ions, water and other molecules between hydrophobic fatty layers in living organisms. In particular the role of Aquaporins is important to physiological processes such as absorption of water by the kidneys or the uptake of water in plant roots. First discovered in 1992, aquaporins have been closely studied and modelled with significant levels of research pursued at an atomic scale. The particular task of water transport is carried out by Aquaporin water channel proteins where these molecules have the ability to selectively pass water molecules through a membrane depending on specific signals received at an intra- or extra-cellular level. One of the key beneficial features of Aquaporin molecules is their ability to prevent the passage of large molecules such as salt ions through the membrane whilst still maintaining high rates of water permeation. Figure 1 below shows an Aquaporin water channel permitting the flow of water between an impermeable cell membrane.

Harnessing the ability of aquaporins to selectively filter water at high permeation rates has highlighted many industrial and household-scale applications in the field of water treatment and purification. In particular the use of Aquaporins incorporated into artificial membranes will significantly reduce the capital cost and energy required to desalinate brackish waters using conventional methods such as Reverse Osmosis. In this case Aquaporins use the electrostatic properties of molecules to restrict the passage of salts thus providing purified water. According to Danfoss, the company leading the development of this technology, “Aquaporins operate at the thermodynamically lowest energy level for water purification” with up to 5 times increase in efficiency compared to conventional desalination methods. However, such a technology is still at a very initial developmental stage.

[16] Agre, P. (2006). The Aquaporin Water Channels: Proceedings of the American Thoracic Society Proc Am Thorac Soc Vol 3. pp5-13.

Analysis of current and required knowledge base for uptake of new technologies.

Humanitarian practitioners have evolved from individuals equipped with generic technical skills and good intentions to sometimes now relatively more highly-specialised professionals with relief-focused post-graduate preparation. This difference reflects the changes that have occurred in humanitarian relief response. Similar changes have also occurred in the training sector catering to humanitarian relief. However, if technological step changes in emergency water and sanitation response are to occur a concomitant change may also be needed with regards to the skill set of those utilising such advances.

In this module a survey of available training courses and opportunities revealed a wide range of course formats, durations and contents. Albeit non-exhaustive a summary of such courses is presented in the Appendix of the report. The key observation from this exercise is that there are an abundance of training courses available. These target people from different backgrounds. Most short courses consist of training sessions to prepare individuals who want to initiate a humanitarian career, refresh concepts to already practicing professionals or provide new skill sets to professionals who have the necessary skill set, but require them to be adapted and focused to the context of humanitarian emergencies. Longer courses are mainly postgraduate level programmes with a varied curriculum and with scope to incorporate latest thinking and expand the core knowledge of trainees on fundamental science and engineering concepts that could allow innovations to be more effectively utilised in humanitarian emergencies.

Interviews.

To gain an insight into current practice and relationships amongst academia and industry in the UK, a number of interviews/visits were conducted. Professionals from each sector were interviewed to gain an understanding of their attitudes and opinions related to the issues raised through this project. The interviews also served to shape online survey outlined in the following section. Key issues raised in interview discussions were therefore developed for further pursuit and investigation by a wider audience accommodated by the survey. The surveys also acted as a means of qualifying and complementing key themes identified during the interviews.

Analysis of Responses – A number of concurrent themes were identified throughout the interview process. Firstly the notion of trust between each sector was raised on a number of occasions by the interviewees. Trust was thought to be one of the factors which may result from poor communication between each sector. This can add a degree of suspicion over the motives of the partners which could be detrimental to the partnerships. This point was also raised in an industry interview where it was argued that there should be improved mechanisms to engage field workers with other sectors and there has to be greater mutual respect and appreciation of each sectors' talents and opinions. In addition, another industry representative agreed with this point, where those who are involved in the research of a particular innovation are not necessarily aware of how the business/commercial world functions and brings technologies to the marketplace.

It is clear that work therefore needs to be done to embrace the different mindsets and agendas of each sector. Thus, one of the fundamental points is establishing to what extent the relationship between academia/research and industry is supporting or limiting the movement of innovations from lab scale products to fully functioning field equipment. A particular example given by a representative of both industry and academia was that developers may not be aware or willing to release a significant percentage of their potential product to industry. This issue is critical for industry as the risks involved in investing in a new technology may be very high and need to be justified to investors. One case was highlighted where the developer changed their terms after the original agreement was made resulting in a breakdown of the working relationship and the product development was halted.

It should be noted that the relationship between those who develop new technologies (academia) and bring them to market (industry) did not dominate discussions for this topic. An interesting point was raised by one of the academic interviewees, where, in their opinion, the trust issue between the beneficiaries and those delivering a technology was more important to the success of an innovation. Lack of ownership, maintenance and operation were some of factors that have resulted from poor communication with end-users and caused the failure of projects.

Once the perceived issues had been established, the interviewees were directed towards discussing possible solutions.

Independent testing – Currently water and sanitation technologies are designed to the required guidelines set out by SPHERE Standards (Sphere, 2004). Although most technologies will achieve (and surpass) these guideline parameters, it is often the case that other more contextual factors such as environmental/resource constraints and user (e.g. operator or beneficiary) acceptability are overlooked until the problems are experienced in the field. Many interviewees shared the opinion that many that the basic parameters set out by SPHERE but also those additional factors mentioned above should be tested before field deployment of any technology. Such type of testing would require a standardised protocol and trilling period. This could be achieved by an independent organisation with experience in the area. In some cases it was felt that academia could fulfil this role. This organisation would be well placed to advise companies and research groups on the needs of end-users and likely scenarios in which their technologies will be placed. Therefore, the advice and testing given by this third party organisation can be trusted allowing NGOs and end-users to compare appropriate innovations which may be of use and will also limit poorly performing innovations that could waste valuable time, money and lives from being deployed. The scope to develop such an organisation was discussed during the field visit to India.

Improved education and communication strategy – The reasoning behind this potential intervention is simple. Most of the interviewees, especially those from industry, believed that each sector should be made aware about how each other operates. On more than one occasion it was raised that lack awareness of each sectors' objectives and limitation as well as the role they would play has led relationships to breakdown and technology development to halt. This problem could therefore be addressed by facilitating regular forums for discussion to engage the three sectors and allocate collaborative partnerships that allow companies, researchers and field workers to fuse ideas and work towards a common goal.

One particular example of a similar service has been shown by the significant growth in assistance provided by research and enterprise services established at universities. The work of R&E departments is to aid the development of research and facilitate the transition of cutting edge research into industry in preparation for the marketplace. One of the most common methods is through the use of Knowledge Transfer Partnerships where advantages of academic research skills and industrial product development experience are combined to accelerate the production of world-changing technologies with real-world applications.

Marketing – Marketing is another issue which was brought up in the interviews. Marketing strategies have been used in other realms of water supply and sanitation (e.g. household water treatment products, ecosan, etc.); however, we are still learning about the long-term effectiveness of these. Nonetheless, they provide a useful platform from which to build on with regards to the uptake on further innovations in the water and sanitation sector granted allowances are made for the inherent differences in the humanitarian emergency contexts.

Micro-finance Initiatives – The use of small-scale micro-finance to empower the local people and stimulate growth of a small economy based on the provision of water and sanitation technologies was also considered. Many believe that encouraging self help and regional preparedness ensures the long-term success of any technology as it ensures long-term stability of supply chains for consumables and spares for maintenance. Again, these are issues that have been mainly explored in the context of development work and should be further studied with regards to humanitarian emergencies.

Web-based survey.

Assessing the perceptions of each sector in relation to the issues raised was central to the objectives of this project. Therefore, a questionnaire survey was administered using an online platform (Survey Monkey) with the specific aim of targeting professionals from each sector (i.e. industry, practitioners and academia). Due to number of questions and responses received, concurrent themes have been summarized and will be outlined below for each of the following thematic titles which were used in the survey.

Survey questions and topics were designed based on preliminary results from interviews, published work and the problem statement used to set out the project. For all the surveys, there were four main themes under which varying questions (depending on the sector) were placed. This allowed the surveys to be better tailored to each sector and allowing for more targeted discussions. Over 70 valid responses were gathered which lead to a considerable volume of opinions and attitudes being collated. A summary of these is presented with regards to each of the thematic sections.

Innovations in water and sanitation technologies – There was much consensus that there is a place for high-science in low tech emergency settings. However, for these to be fully embraced and ultimately successful the technologies need to consider local constraints and be developed with the appropriate capacity-building. Currently, there is limited uptake of high-tech water and sanitation equipment in emergencies due to a number of factors which were raised by survey participants. There were strong opinions towards the lack of consideration of indigenous knowledge and practices in the design process. This demonstrated that user involvement is key to gaining acceptance and technology diffusion into the local community.

Survey revealed that some also believed that the choice of technologies is often determined by what senior officers (and procurement staff) know and select as being appropriate. This in turn makes it difficult for newer technologies to be utilised without the presence of an appropriate method to compare and review what is available. Thus the use of peer-review systems or standardized testing may provide the means for effectively comparing technologies. The possibility of such a review system was discussed in this section and although the majority of responses agreed with it in principal, there were some concerns raised. In particular, diversity of ground conditions and influencing factors means standardized tests would have to cover considerable breadth and depth to allow an accurate idea of the feasibility of a new technology in a new situation.

Although some argued for the potential use of innovations, there was also the opinion that what is available works and new innovations are unnecessary. Coupled with this is the point that innovation is driven by demand and this in turn is driven by the success of marketing and a proven track record. Reporting of disasters and in particular the global water crisis in the media has resulted in the development of many new products. This is seen by many practitioners to have limited value and doesn't reflect their true needs but rather what media and marketing bodies perceive as their needs. The problem that this has now created was mentioned in the survey responses where the belief is that the interest of industry lies in what provides financial gains and this is most likely where the media attention and marketing is focused. The long-term legacy of this problem is that novel high-tech fail to make it out the laboratory and prototype stages in favor of more generic and accepted technologies. However, when questioned regarding this issue, practitioners felt there should be a mechanism in place to overcome this problem and better disseminate key findings and research to a broader audience, in particular governments and funding agencies who could facilitate the transfer of technologies between sectors.

Needs and constraints of disaster affected communities – Needs and constraints in the field is an important issue for the successful uptake of technologies intended for use in emergencies. It was highlighted that overall in the NGO sector, assumptions are used more than trials in field conditions. Neglecting to ask the end-users what is needed is one of the most critical shortcomings of many technologies is where a lot of problems could be solved through basic lines of communication.

Exploring the relationship between NGOs, Industry and Academia – Examples of working relationships between each sector seem highly variable. Typical views expressed by academia and practitioners in this survey are of minimal problems. However the views of some industry respondents are quite the opposite. Views were of poor access to practitioners to showcase new developments and a reluctance to assist in product development. To some extent this may be the case however it is unclear if the reasons are due to a sector-wide breakdown in communication or individual cases of misunderstandings. There is considerable scope in the notion that increased transparency of the intentions, duties and capacities of each sector to assist in developing new interventions needs to be carried out. By understanding these factors, each sector may be able to establish improved working relationships that allow greater flow of novel ideas and innovations into the marketplace. In addition, there has also been an observation from responses that technologies experience a greater reception from NGOs if a rapport has already been built between the organizations involved. This may present a difficulty for those outwith such circles to establish a competing technology.

Overall attitudes and opinions – It was highlighted that the definition of "high-tech" may be a limiting factor as those who are poorly informed tend to relate the term to a product which is also highly complicated and unsuitable for the field. However, examples such as high-tech filtration media can demonstrate that high-science can be harnessed to improve the efficiency and longevity of a simple process.

Case study.

A useful activity of this project was to conduct a case study in Pune (India). There a partnership, where a collaborative partnership between a manufacturer, NGO (RedR India) and a university had been established. The main purpose of this partnership was to aid in the development of a new packaged water treatment kit for humanitarian emergencies. At the time of the visit, the product was entering the preliminary stages of field testing where each party had an input.

Working closely with each of the stakeholders in the partnership and a number of interviews were conducted in order to assess the effectiveness collaborative partnership. This activity therefore helped identify issues which were deemed important to the successful development of technologies and have been outlined in the sections below. Discussions were also held with regards to views on the development of such partnerships.

Interviews were conducted with representatives from each sector in this collaborative partnership. Academic interviews highlighted that there was lack of high-tech development in this sector, but for good reasons. The majority of arguments state that they believed for high-tech solutions to work, there needs to be an educational infrastructure in place to support the understanding and troubleshooting aspects of deploying such technologies in the field. The practitioners and industry representatives felt that there should be a movement towards simpler technologies that are more intuitive and rely on empiricism gained over time by local people, rather than reliance on highly trained fieldworkers who will only be present for a temporary period.

It was also highlighted that increased use of more mechanically sophisticated components may create faster improvements in water and sanitation technologies than equivalent advances in high-tech systems that require electronic components. This opinion has been formed as a result of the strong belief that mechanical function is easier to understand than electronic systems, especially in harsh field conditions where mechanical spares may be easier to source or repair.

All sectors were also in broad agreement regarding the need for communication and education between sectors. It was mentioned that the use of forums and training to enhance fieldworkers' scientific knowledge and academic/industry's field experience was of paramount performance if;

1. Fieldworkers/NGOs are going to able to appreciate the scope of emerging technologies, and;

2. Academia and industry are going to understand the environmental, operation and resource constraints presented to fieldworkers during humanitarian disaster response efforts.

During the visit it became apparent that there was a mutual ambition to establish a method of standardising and creating a benchmark for developing new technologies. As discussed earlier in the UK interviews section, the need for a mechanism which can assess the applicability and efficiency of new technologies for use in the field is crucial. This could be achieved in the form of a centre dedicated to testing and research of technologies destined for use in humanitarian emergencies (and also development contexts). Such a centre could serve as a pilot example in establishing protocols for testing technologies. Such protocols would complement the basic guidelines set out in SPHERE standards to ensure future technologies have the robustness and longevity to face the environmental and resource challenges experienced by end-users.

The discussions revolving around the development of such a facility were highly topical and relevant to the project. In particular, basic aims encompassed the growth of inter-sector communication and knowledge transfer; benefitting each sector in different ways, namely:

• Academia will become more involved at a field level ensuring technologies are more conscious of the environment in which they will be utilised. They will have access to a facility which students and researchers can use at minimal cost; expanding their research opportunities and links with industry and NGO's.

• Industry will be able to have their ideas and products tested in a way which is relevant to the humanitarian sector and benefit from impartial guidance and support.

• NGOs will no longer have to be responsible for arranging any product testing or take unnecessary financial risks on unproven products. They can have confidence in the selection of tested technologies and will benefit from a higher standard of product development in which they have the opportunity to contribute.

Final Thoughts and Future Steps

Final thoughts

The project has identified a broad spectrum of issues related to the transfer of technologies and innovations into water and sanitation humanitarian practice.

A review of water treatment technologies currently-available revealed that many of such "kits" are "overengineered" with regards to their performance and the requirements of humanitarian water supply response. On that basis, some technologies weren't deemed to be cost-effective. Interestingly, technologies that have been known to be developed through a collaboration between practitioners, industry and academia were the most cost effective. Thus, highlighting the potential for such partnerships.

Many new advances, some of which have still not found applications in developed-world contexts, were identified due to their potential applications in water and sanitation issues. Most were still at early developmental stages, but could lend themselves useful in applications ranging from better contaminant detection to a better understanding and control of pollution treatment through novel (and not necessarily more sophisticated) methods. Thus, albeit not an exhausting catalogue of potential technologies, possibilities do exist to develop new tools for water and sanitation provision in humanitarian disasters. For this, the appropriate links between developers (i.e. academia and industry) and practitioners will need to be established. Otherwise, the all too common failure of innovations in the field is likely to occur.

Ultimately, for new technologies to be effectively applied to humanitarian emergencies, end-users will need to be well-equipped with the necessary skill base to master and diffuse such innovations. The available training courses focused on humanitarian water and sanitation seem to cover most basic concepts necessary to utilise currently-available water and sanitation methods. It is conceivable that as new technologies are introduced this sector would need to incorporate any training related activities with it.

A number of important issues were raised during the interview process. It is apparent that a great deal of work must be done to standardise the current methods of developing technologies for field use. The sector could benefit from an organisation that could offer robust testing protocols and design assistance. There is also much scope for the use of local markets in disaster prone areas to assist in contingency planning and preparedness if they work in partnership with foreign investors and micro-finance schemes. These could offer scope for improvement on the uptake of technologies in the field and maximise the impact of cutting edge research.

Overall the Web-based Survey highlighted a number of key issues in current practice. Opinions were firmly in favour of improving a number of areas which were deemed to be poor and restrict the movement of emerging technologies into the field. These key areas have been identified as the following:

- Poor education and awareness (mainly on behalf of those developing the innovations) related to the need of emergencies and field conditions;
- Lack of an effective review system to enable fair comparison of currently available and emerging technologies
- Lack of effective fora for new innovations to be showcased to practitioners and end-users.

The Case Study undertaken was highly relevant as it was perceived to validate the points risen in other activities. Valuable insights were gathered related to the dynamics of a successful relationship between an NGO, a manufacturer and a University. This model was based on a working understanding of each sector's contribution and limitations and could be further developed and replicated in other contexts.

Future Steps

At the time of reporting, this collaborative partnership has identified several key areas to further pursue through research projects. Currently, four proposals relevant to the scope of this project have already been submitted (e.g. Royal Society, DFID, etc.) and others are in the preparation stages. Some of these have been prepared in partnership with industry in an attempt to overcome the communication gaps identified in this project in order to streamline the development of cost-effective water and sanitation technologies for humanitarian aid.

Partnership Assessment

Partnership Assessment

The ELRHA initiative provided the project partners with a formal platform on which to work. Few such opportunities do exist. Both partners had a previous working rapport, which was maintained over the years (informally for the most part). Hence knowledge of how each partner works made for a productive work relationship. The common interests in water and sanitation technology research and development meant that, albeit from different perspectives, both partners were able to explore common grounds and questions posing barriers to the streamlining of innovations to humanitarian emergency interventions in the area.

The inherent difficulty in such a research project was how central research activities are to each partner. Whereas research is part of the day to day activities in academia, the same does not necessarily apply for the humanitarian partner. In fact, due to the very nature of their field of work, many times planning of some activities became challenging with humanitarian disasters that occurred during the course of this project (i.e. Haiti earthquake and Pakistan floods). This is not to diminish the value research has to the long-term operations in humanitarian emergencies, but the undertaking of research activities becomes secondary in face of the unpredictable and urgent needs after the onset of a disaster. It is difficult to imagine how such working challenges could be overcome, but the previous working rapport between the partners meant that each one’s expectations could be calibrated against their understanding of their roles.

Overall, it was felt that this was a fruitful and productive relationship and many other collaborative ideas have been generated through this opportunity. Hopefully, the collaboration formed through this project can serve as a springboard for further projects. Other funding applications have already been applied for or are in the process of preparation. This however, is limited by the availability of suitable funding initiatives (at least with regards to water and sanitation activities). Further funding opportunities promoting such collaborations are encouraged. The key issue is identifying and forming the right partnerships between the two sectors.

Appendix

Humanitarian Water- and Sanitation-Related Training Courses

Organisation	Course Title	Qualification Type	Curriculum Details	Notes:	Reference:
RedR (UK)	Essentials of Humanitarian Practice	Short Course (5 days)	Mainly practice based learning however it does mention the teaching of theory and the "latest thinking on humanitarian practice".	Cost dependent on employment status. This particular course may be too general to be of any value to the investigation.	http://www.redr.org.uk/en/What_We_Do/training/UK_training/uk-training-calendar.cfm/09015-EHP-Nov
RedR (Sri Lanka)	Introduction to Health & Hygiene Promotion in Emergencies in Collaboration with Oxfam GB	Short Course (3 days)	Scientific/practical training for field officers/health promoters involved in WASH projects.	Residential course based in Sri Lanka	http://www.redr.org.uk/en/What_We_Do/training/sri-lanka-training-programme/sri-lanka-training-calendar.cfm/introduction-to-health-hygiene-promotion-in-emergencies
RedR (UK)	Needs Assessment in Emergencies	Short Course (5 Days)	Theoretical training to prepare relief workers with necessary skills to conduct an effective needs assessment in the field. Not directly related to water/public health engineering but will affect ability to choose the appropriate tech.		http://www.redr.org.uk/en/What_We_Do/training/Course_Calendar.cfm/needs-assessment-in-emergencies
ICRC & Univ. Of Neuchâtel Centre of	Water and Sanitation Engineering:	Short Course (8 days)	Covers a broad syllabus related to water treatment and sanitation and is aimed at providing engineers and	Residential Course at Univ. Of Neuchâtel	http://www2.unine.ch/webdav/site/foco/shared/documents/Watsanprogra

Hydrogeology	From Emergency Towards Development		scientists with technical/practical skills		mme09.pdf
BushProof	Water and Sanitation for Development and Emergencies	Short Course (13 days)	Heavily practical and also theoretical course concentrating on equipping participants with the ability to transfer knowledge to their own projects.	Residential courses based in either Singapore or Madagascar	http://bushproof.biosandfilter.org/index.php?id=127
WEDC, Loughborough University	Infrastructure in Emergencies	MSC, PG Dip, PG Cert	Broad course covering the whole subject area. Provides students with the ability to engage in the design and implementation of technologies used in emergencies. Given that this course is run by WEDC it is assumed that there would be capacity to embrace new/emerging technology		http://wedc.lboro.ac.uk/learn/learn201.html?c=1
WEDC, Loughborough University	Water and Environmental Management	MSC, PG Dip, PG Cert	Multi-disciplinary degree covering water resource, supply and sanitation issues related to low-middle income countries. Not directly related to emergencies as such, however may provide students with the relevant skills in disaster situations.		http://wedc.lboro.ac.uk/learn/learn201.html?c=2
Netwas International	WASH in Emergencies: practical interventions	Short Course (1 week)	As with the majority of courses, it covers theory and practical sides of training with the inclusion of case-studies and discussions. The most important feature of this course is its objective of providing “professionals with the essential knowledge, tools and skills to identify and implement sustainable measures in disaster response”. In particular, the course aims to equip participants with the technical knowledge to select appropriate technologies as it has identified that currently few professionals have limited capacity to	1 week residential , Nairobi , Kenya	http://www.netwas.org/index.php/Training/WASH-in-Emergencies-practical-interventions.html

			make such decisions.		
Netwas International	Scaling up community management for sustainable water supply and sanitation programmes: from systems to service	Short Course (2 weeks)	Key Objectives: "To establish a common understanding of definitions, concepts and current approaches in scaling up community management of water supply and environmental sanitation Projects/Programmes. To share experiences and learn on current practices in scaling up community management and take stock of best practices. To positively influence the participants attitudes towards communities abilities to effectively play a bigger role in managing and sustaining expanded projects. To enhance participants knowledge and skills in management and technical aspects and use of participatory methodologies necessary for working with communities. To develop individual/group strategies and work plans to implement appropriate community management approaches."	Target Group: Staff who plan and manage community-based water supply and environmental sanitation projects/Programmes; Staff working in development Programmes ; Leaders, Managers and Trainers of community based organizations, Donor Agencies, NGOs and Government agencies; Tutors and Lecturers from sector training institutions Programme Managers of funding agencies	http://www.netwas.org/index.php/Training/Scaling-Up-Community-Management-for-Sustainable-Water-Supply-and-Sanitation-Programmes-from-systems.html
Netwas International	Sustaining water, sanitation and hygiene (WASH) in schools and in communities: promoting sustainable	Short Course (2 weeks)			http://www.netwas.org/index.php/Training/Sustaining-Water-Sanitation-and-Hygiene-WASH-in-Schools-and-in-Communities-promoting-sustainable.html

	approaches				
Netwas International	Environmental Health in Emergencies	Short Course (1 week)			http://www.netwas.org/index.php/misc/Capacity-Building-and-Training-Services.html
REDR India	Engineering in Emergencies	Short Course (1 week)	Practical and theoretical course related to all aspects of emergency response requiring engineering solutions. Covers key initial response considerations-providing protection, shelter, clean water and food.		http://redrindia.org/Trainingcalendar2010.aspx
	Environmental Health in Emergencies	Short Course (1 week)	Theoretical and practical course addressing the principles and practicalities relating water and sanitation to health in humanitarian relief operations. Course covers: • Sanitation and vector control in emergencies • Water supply, distribution and treatment in emergencies • Water source development in emergencies	Target participants: All environmental health relief workers including: NGOs, and Government Institutions	http://redrindia.org/Trainingcalendar2010.aspx
	Managing Public Health in Emergency Response	Short Course (4 days)			http://redrindia.org/Trainingcalendar2010.aspx
RedR India/Unicef	ECOSAN and Emergencies	Short Course (4 days)	Half the course concentrates on understanding ecosan and the remainder addresses how to synthesise this theory in the context of sustainable emergency sanitation.	Location: RedR Pune Target Participants: NGOs, public health engineers and promoters, government public health officers	http://www.scribd.com/doc/26192893/Course-Detail-of-Ecosan-and-Emergencies

Cranfield University	Community Water and Sanitation	MSc/MTech/PgDip/PgCert	"provides students with the essential skills and knowledge required to plan and implement, with communities, water supply and sanitation projects and programmes worldwide, particularly in less developed countries".		http://www.cranfield.ac.uk/students/courses/page1249.jsp
WEDC, Loughborough University	Emergencies, Management and People	1 week intensive	"The aim of this module is for you to understand the key characteristics of disasters and emergencies; the principles of effective humanitarian relief; the importance of adequate assessment, planning and management of emergency response; and how communities and individuals may be affected by disasters." If the course delivers on its aims, then it should be particularly useful in improving the understanding of the environmental/resource constraints of disaster affected communities. Although it doesn't provide the practical experience, it should identify the key factors to be considered.	Target group: Policy makers, government officials and NGO staff working in the emergency and relief sector, who are interested in learning more about the principles of effective humanitarian relief, and the theory, practice and policies of emergency response	http://wedc.lboro.ac.uk/Learn/Learn230.html
WEDC, Loughborough University	Water and Environmental Sanitation	1 week intensive	"The aim of this module is for you to understand the range of sustainable technologies for water supply and engineering management of liquid and solid wastes in low- and middle-income countries; the basic principles of how to assess and control pollution resulting from human activities; and the links between human health, water and waste management and hygiene promotion." The aims of this course are promising with respect to	Target group: Civil engineers, environment consultants, government staff and NGO staff interested in learning more about the theory, practice and policies of water supply and	http://wedc.lboro.ac.uk/Learn/Learn230.html

			building knowledge related to water and sanitation technologies but I would question whether “high science” will be accounted for under their definition of sustainable technologies. It also doesn’t appear to consider emergencies.	waste management in low- and middle-income countries.	