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Appropriate Technologies for Water and Sanitation

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Abstract

This paper focuses on appropriate technology as it pertains to water and sanitation. Potable water availability and sanitary treatment and disposal of wastes are two critical prerequisites for the development and maintenance of healthy, viable and sustainable communities. This paper reviews rain water harvesting as an appropriate technology being implemented for water sourcing, collection, and treatment and biological waste treatment for environmentally benign management of wastes for sanitation. Conventional methods of waste disposal including land filling and incineration, while offering short term solutions to the problem of increasing waste generation, have severe adverse environmental impacts. More appropriate waste management technologies including biologically based processes that harness the potential of biological agents such as plants, microbes and earthworms, to treat contaminated effluents from industry as well as to remediate and decontaminate hazardous and contaminated sites, are available. These appropriate technologies for sanitation signal a paradigm shift recasting wastes as resources; it transforms the discussion from one of "how to dispose of these wastes?" to one of "what technologies will allow me to utilize these wastes as a resource to create added use value".

INTRODUCTION

On July 29th of this year, the United Nations (UN) General Assembly voted overwhelmingly to endorse "…the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights"[1]. One hundred and twenty two countries supported the resolution and not one single country opposed it. Forty countries, including some of the world's wealthiest democracies such as the United States, the United Kingdom, several European countries as well as Australia and New Zealand abstained; several of these countries instead pushed for a watered down UN Declaration that would declare "access" to water a human right. To its credit, the Bolivian United Nations Ambassador [1], who put forth the resolution, resisted, arguing that simply arguing for "access" would not ensure availability, especially with an implied message of water as a commodity that would need to be purchased even if access is provided.

The draft resolution for the Human Right to Water and Sanitation laid out, in its preamble, some very disturbing facts about the water and sanitation situation on this planet. Currently, almost a billion people – one out of every six humans – "…lack access to safe drinking water; over 2.6 billion do not have access to basic sanitation, and approximately 1.5 million children under 5 years of age die and 443 million school days are lost each year from water and sanitation related diseases." The right to water has been articulated and "codified" before on numerous occasions by various international bodies (see for example, The World Health Organization[2]) but never with the firm and explicit declaration that is outlined in the

[1] For the draft UN resolution, please see: http://www.blueplanetproject.net/RightToWater/UNDraftresolution-final.pdf
[2] http://www.who.int/water_sanitation_health/rightowater/en/

UN Resolution on Water and Sanitation, and that was just approved by an overwhelming majority in the UN General Body.

It is understood by development experts and lay people alike that water and sanitation are perhaps two of the most critical requirements for the establishment of healthy, viable and sustainable communities. Without clean potable water, there is no support for life. And with no sanitation, communities will eventually be sickened, poisoned and overwhelmed by their wastes. In the developed world, these are taken for granted. One need only turn on a tap to get clean potable water or pull a lever or a chain to sanitarily wash away one's wastes. Much of the developing world, especially poor urban and rural communities, lacks these two basic necessities of a healthy life. Images from the developing world of people swarming around a water tanker or crowded around a single water pump, all with water pots in hand, in a dry, parched and barren landscape are legion; so are images of open sewers and waste pits and piles in the mega-cities, towns and villages of the global south, where untreated effluents flow over pavements and streets and piles of waste smoke and smolder in hazy, dirty conditions, while rag pickers walk over these piles in the third world's most widely used version of a resource recovery system [2].

Developing a rationale and justification for availability and access to clean, potable water and environmentally benign sanitation are exercises in the re-invention of the wheel and the repeating of well established public health and sanitation policies, developed over decades of experience in addressing development. Numerous organizations and individuals [3] have argued for the establishment, codification and institutionalization of the basic human right to water. As oft repeated, the basic argument and rationale is that without water there can be no life. Now that the UN has declared it to be a basic human right, along with sanitation, despite the abstentions of developed countries more interested in promoting privatization and commercialization of water resources focused on supporting and enhancing profits for large multinational water companies, we have a consensus from the global South that access to clean water should be a basic human right. This should be the driver for governments and non-governmental agencies, as well as multilateral institutions and organizations, to provide the support in terms of resources, technology, and knowledge and technology transfer, to promote the development, adoption and implementation of situation-specific and appropriate technologies to satisfy human needs for water and sanitation.

The need for widespread development, dispersion, transfer and implementation of appropriate technologies to ensure that communities have access to clean water and sanitation is urgent. Hence the theme of this fourth international conference on appropriate technology (4th ICAT) and our lead focus on technologies for water and sanitation.

Appropriate Technology

The widespread use of the term "appropriate technologies" requires a discussion and articulation of what exactly it means for a technology to be deemed "appropriate". Indeed, appropriate technology, or AT for the rest of this paper, has always been difficult to define. AT's development and implementation have been a source of debate for some time [4]. Nevertheless, over the course of the decades of discourse and discussion about AT and what exactly it constitutes, there has developed some general received knowledge about AT, including that it should only require small amounts of capital, emphasize the use of local materials, be relatively labor intensive and be small scale and affordable. A major tenet of the philosophy of AT grounds it within specific and individual communities – thus AT must be comprehensible, controllable and maintainable without the otherwise high levels of education or training that might be required for the maintenance and operation of more capital intensive and complicated and imported technologies. Further, true adherence to the ethic of AT requires that local communities must be included at all stages and phased, from technology innovation and development to implementation. Any technology that claims the mantle of "appropriate" should also be adaptable and flexible, while eliminating – or at least minimizing - adverse environmental impacts [5]. An earlier paper [6] provided a broad over view of appropriate technologies available for water collection, treatment and storage in the context of land reform and a more recent version updated appropriate water technologies in the context of public health.

Now, with the UN declaring the human right to water, there is new impetus to push forward with the development and dissemination of appropriate technologies for water and sanitation. There have been numerous collections of works on water policy, technology and development, with some recent critical and comprehensive reviews and policy perspectives from the Center for Science and Environment (CSE) based in New Delhi, India [7-9]. The CSE has developed and implemented groundbreaking and creative solutions to water resource management focused on rain water harvesting and ground water recharge as well as other resource-conservative technologies and policies that garnered them the Stockholm World Water Prize in August 2005[3]. Given the importance of water conservation and recovery, water harvesting is the first technology that must be dispersed and diffused through out the developing world.

Rain Water Harvesting

Water precipitating out of the sky in the form of rain, snow, sleet, hail or other precipitation percolates through the ground to replenish groundwater and feed subsurface aquifers and streams. Run off from impervious surfaces flow to surface water bodies or pervious soil where it percolates into the ground water. Water can also evaporate directly or through transpiration back into the atmosphere. The nature of the hydrologic cycle makes it difficult to mark a beginning or end to waters cyclic journey through the environment. Nevertheless, rain can be considered a primary source of water. Secondary sources of water include rivers, lakes and groundwater, all of which get recharged from primary water. Development experts and technocrats tend to focus on secondary water sources as the major input streams for water systems, but many communities are without easy access to these secondary water sources. Primary water sources must be incorporated into water resource conservation, management, and design and development technologies [10].

The principles underlying rainwater harvesting and the calculations that enter into the determination of the design are straightforward. If one knows the amount of rainfall that an area receives (in mm of rain), multiplying this by the efficiency with which the rainfall can be collected (or harvested, typically on the order of 40 to 70%) will provide the potential amount of recoverable water that can be harvested. Basically, the amount of rainfall multiplied by the area of 'catchment' will provide the volume of water that can be collected. Following the discussion in *A Water Harvesting Manual* [11] as an example, a rooftop with an area of 100 sq.m receiving 2200 mm of rain in a year could potentially provide 220 cubic meters (or 220,000 liters) of water. If the water harvesting system design permitted a water collection efficiency of around 60%, then at least 132,000 liters would be available.

In its simplest form, the basic elements of a rainwater harvesting system are shown in Figure 1 [as adapted from 12]. The catchment –or water collection - area is established first and then a conduit or pipe is connected to this area which permits the water to be sent to storage facilities and to ground water recharge facilities. The storage facility provides immediate water for ready use and can be below ground or above ground, while the recharge facility provides a mechanism by which longer-term water storage can be recharged for later withdrawal. The technology and material resources required for the development and

[3] http://www.siwi.org/press/presrel_05_SWP_Winner_Eng.htm

implementation of simple rain water harvesting systems are inexpensive and readily available in most towns. Actual construction and manufacture of jerry-rigged systems are not difficult and can be developed, implemented and maintained by local skills and expertise.

Falling rainwater will entrain and absorb dust and other pollutant particles. In addition, debris on the catchment surface will be washed into the RWH collection tanks. It is thus necessary to insert filtration mechanisms in-line with the output from RWH tanks. Filtration needs will depend on ultimate use of collected water. Water for irrigation can be used directly, while water for clothes washing, kitchen and bathroom flushing can be minimally treated with a coarse sand or fiber filter. Natural and locally available materials such as gravel and sand, and textiles or clothing and tailor shop wastes, can be used in filter configurations that filter harvested rainwater for those uses. More rigorous filtration, including deep-bed sand filters may be used to turn the harvested rainwater into potentially potable water [13]. Care must be taken to investigate the local health and disease conditions and situation to determine if some secondary treatment such as disinfection using boiling or the SODIS® technology [14] would be necessary to turn the water into potable-quality water that meets WHO and environmental standards for drinking water. Additional filtrations and treatments required for this potable water production may also include the slow sand filtration, which is a low-cost treatment technology that is often adequate for this end-use [13]. Slow sand filtration will clean water supply sufficiently to make a significant improvement in public health. For complete elimination of pathogenic organisms and to ensure that public health is maintained through the elimination of unclean water as a disease transmission vehicle, disinfection of the water will be required.

Disinfection of water may be accomplished through various additional point-of-use technologies such as boiling, chemical disinfection or filtration. Boiling is most effective in sterilizing water but energy requirements are high and add cost to public water users. Additionally, requiring the public consumer to boil water prior to consumption carries the risk of many failing to do so and thus raising the risks to public health. Chemical disinfection is quick but requires addition of disinfecting agents that may not be locally and readily available. Chlorination of water is known to generate harmful byproducts and this method, although easiest and cheaper then boiling, may have long-term adverse consequences for public health.

Perhaps the simplest and least expensive method is through in-line filtration devices built into the water harvesting, collection and storage system design. Simple layered filter materials, with gravel overlain by sand which is then overlain by charcoal, provides a point-of-use filter that can be locally assembled and distributed. Sand and charcoal, layered one over the other and sandwiched between two coarse-pebble or gravel layers, facilitates percolation of water and prevents clogging of the filter. Sand efficiently removes particulates and charcoal adsorbs microbial contaminants, other colloidal and suspended contaminants and also serves to remove organics and metals. An example of a simple low-cost filtration media configuration is shown in Figure 2. This filtration set up has been shown to remove pathogenic bacteria as well as other microbes such as parasites and amoebas, the causative agents in dysentery and diarrhea.

Other simple methods of water disinfection have been developed, such as distillation. A recently developed low-cost, low-maintenance solar disinfection unit has demonstrated quite a bit of promise as an appropriate, low cost technology for the production of potable, disinfected water. This unit eradicated over 99.99% of bacteria in water samples and was able to provide six liters of pure drinking water on a daily basis [15].

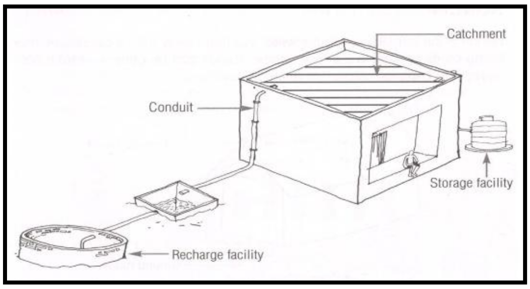

Figure 1: Basic elements of a rainwater harvesting system. From [12]

Potential contamination problems for the stored water are real, and can be avoided by implementing suitable measures to minimize the risk and prevent contamination. These include regular cleaning of storage tanks (especially prior to start of the rainy season), sweeping and clearing of catchment areas, maintenance and regular clearing of water conduits for the conveyance of harvested water to storage receptacles and use points. Any in-line filtration apparatus must be regularly cleaned, either through back flushing or filter media surface-scraping and removal so that water can percolate freely through the filter media and the filter media can continue to retain contaminants and pathogens. For end-use, it is necessary to change charcoal and sand filter media on a periodic basis. When the filter media are changed, it is important that the new filter media be flushed completely prior to the water being used as potable water.

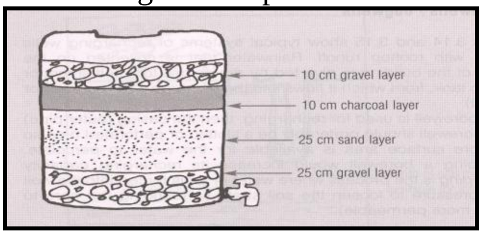

Figure 2: Basic elements of a sand-charcoal filter configuration, from [11].

The size of the filtration set-up can be increased with ease and material costs are very low. Also, novel designs are being developed at smaller scale including some portable filtration/purification units at increasingly lower costs.

The potential for problems with contamination of the stored water are real but can be avoided with the implementation of suitable measures to minimize the risk and prevent contamination. It is important that the storage tanks be cleaned prior to the start of the rainy season and the catchment area be swept and cleaned as well. Conduits for conveyance of the harvested water to the storage receptacles should be kept clean and unclogged. The in-line filtration apparatus must also be cleaned and maintained so that the water can freely percolate through the media. This might require periodic cleaning out of the filter. In terms of end-use, it would be necessary to change the charcoal and sand media in the sand-charcoal filter on a periodic basis. When the filter media are changed, it is important that the new filter media be flushed completely prior to the water being used as potable water.

As with any appropriate technology, the design and configuration of the RWH system including the filtration and disinfection set-up, will depend on the community and environment the water collection system is being developed and implemented in. Rural area RWH designs and systems will naturally be different from those implemented in urban settings. Despite this, the basic components of these systems – a catchment area, conduits to channel the harvested water, means for filtration and disinfection, and storage reservoirs – will be the same. As in the development and implementation of any appropriate technology, the specific system to be established and the specific design to be implemented and constructed will necessarily be highly dependent on the local situation. The configuration that is finally settled on within a particular context must be thoroughly examined and tested through actual use. Amounts of water that are harvested, water quality and the time required for collection must be recorded and these results need to be evaluated after a given period of use. Depending on the situation and the local context, there may be a need for redesign and reconfiguration. This is part of the process of technology development and implementation and must not be neglected so as to optimize the final design that is implemented on a larger scale within a given region and context.

As with the process of any development technology that is being designed and implemented, serious and critical consideration must be given to how well the local community's needs are being met and what the benefits and costs of the technology implementation are. Care must be taken that the community feedback is taken into account and that the community is itself engaged in the entire process. Successful development and implementation of appropriate technologies will only result if the local community that the technology will serve is engaged in the process from the outset. This would necessarily include community training and knowledge technology transfer so that community input forms a substantive and integral part of the design and implementation process.

Appropriate Technologies for Sanitation

Determining what to do with our wastes is the other critical issue facing developing communities and emerging economies. Conventional methods of waste treatment and management include, and are usually limited to, incineration and/or land filling for solid wastes, and discharge into sewage treatment systems that utilize conventional and well established waste water treatment technologies and management systems, for liquid effluents and wastes [16].

For liquid wastes, conventional sewage treatment systems are capital intensive and require large infrastructural investments that are beyond the reach of most developing communities. More appropriate waste water treatment technologies need to be developed and implemented, such as the DEWAT[4] systems installed in Pondicherry in south India, referring to decentralized wastewater treatments system. DEWATS applications are based on the founding principle of low-maintenance since most important parts of the system work without technical energy inputs and cannot be switched off intentionally – these systems epitomize the characteristics of an appropriate sanitation technology as they provide a state-of-the-art-technology at affordable prices using local materials. DEWAT's includes primary treatment with sedimentation and flotation followed by secondary anaerobic treatment in fixed-bed reactors (either baffled upstream reactors or anaerobic filters) and finished with tertiary aerobic treatment in sub-surface flow filters or in polishing ponds. DEWATS treated water meets requirements stipulated in environmental laws and regulations.

As has been discussed before, incineration and land filling, the major technology choice for solid waste and refuse management, have problems associated with their implementation that have the potential to result in more environmental degradation and discharge that the treatment technology mitigates! Incineration is expensive costing more over $2,300/ton, primarily due to the high transportation and energy costs associated with centralized incineration facilities and processes. At the same time, the complete destruction of hazardous compound is not assured. For example, polychlorinated biphenyl's will not be destroyed unless the temperature rises above 1200oC, which is not likely in most incinerators, especially the low cost and inefficient and ineffective ones that dot the developing world, especially its hospital grounds. This (incomplete) combustion leads to the production and emission of dioxins, benzofurans and other secondary air pollutants that are highly toxic and

[4] DEWATs systems are supported by the Bremen Overseas Research and Development Organization, http://www.borda-net.org/modules/cjaycontent/index.php?id=29

harmful to human health. Finally, incineration is an e*x situ* technology, requiring the excavation and transport of the wastes which increase costs as well as increase the potential for accidental releases and discharges.

The alternative of land filling is often chosen as it is much less expensive, especially when large unused and waste land areas are available. This is okay for a large country such as Australia or the USA; nevertheless, land filling is a very poor choice of land use. In addition, land filling waste disposal strategies result in secondary pollution hazards which must be monitored and minimized. These include the emission of volatile hazardous compounds, the leaching of hazardous compounds and the subsequent contamination of groundwater. For proper landfill design, leachate control technology needs to be incorporated, off-gas emissions need to be controlled, and strict long term monitoring should be put in place to ensure that contaminants and wastes do not migrate beyond the demarcated fill boundaries. All of these requirements contribute to raising the cost of land filling. In addition, there may be contaminant specific issues when using landfills as the disposal mechanism for certain process industries.

A truly appropriate technology alternative to land filling or incineration is to invert the question and determine what resources can be regained from the waste streams that are being generated and whether anything needs to actually be incinerated or buried. Using biological methods for the waste treatment and management provides environmental, cost and social benefits over and above conventional incineration and land filling technologies. Biological treatment of wastes is well understood and the requirements for successful treatment and transformation of contaminants by biological mechanisms have been well established. Requirements include having an adequate number and type of microorganism with the metabolic capabilities to biotransform and biodegrade the contaminants, bioavailability of the contaminants to the micro-organism, the existence of a suitable electron acceptor/donor enabling the targeted metabolic pathways to be active, and a habitable environment with no toxicity to the microorganism so it can thrive and through so doing, biodegrade the contaminants into harmless compounds.

Sanitation, waste treatment and management strategies must undergo a paradigm shift in order to move towards appropriate technologies and all that this means. First and foremost requires a transitioning from the late 20th century cradle-to-cradle waste management and tracking approach to a 21st century approach that envisions cradle-to-cradle [18] materials and energy resource recovery system and paradigm, where wastes have now been re-conceptualized as input streams into innovative processes that should be developed to target the waste as a raw material or a resource.

Conclusion

The initial selection of the ‘right’ appropriate technology from a range of choices is the key element in determining long-term success in terms of implementation, adoption and operation and maintenance of the chosen technology. Considerable research has been done on technology choices in developing communities, and analytical, evaluative and assessment heuristics have been developed, such as the SHTEFIE analysis [19]. This heuristic algorithm is a valuable tool for evaluation of technology development alternatives.

Access to clean potable water supplies and adequate and appropriate sanitation systems are critical to sustainable development and improvements in the quality of life for the world’s billions that lack access to these basic human necessities and rights. The use of appropriate technologies to develop water resources and make clean water available to all is crucially important to this objective. The design, development and implementation of specific water harvesting systems must take into account the context-specific situations and factor in community and infrastructural considerations as appropriate water resource technologies are developed and put in place. The same considerations must be given to sanitation systems and technologies that will address this need. Finally, throughout the appropriate technology innovation, development and implementation process, rigorous assessment and evaluation should be conducted to reveal what is the most appropriate and optimum technology choice for water treatment and sanitation in a given situation.

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Sustainable Fresh Water Supply for Chennai city, Tamil Nadu, India A Status Update

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Key Words: Rain water harvesting, Sustainable water supply, Urban fresh water.

Abstract

Chennai city, one of the major metropolises of India, is situated at the northern coastal edge of the State of Tamil Nadu. The city is more well-known by its older name of Madras. Currently, Chennai is inhabited by more than 7 million people in an area of 176 sq km. Water supply for this population is maintained by tapping a combination of surface storage reservoirs and aquifers. The Chennai Municipal Water Supply and Sewerage Board (CMWSSB), a statutory body established in 1978, is responsible for water supply and sewerage services in the Chennai Metropolitan Area. The main sources of public water supply in the city are the three reservoirs — Poondi, Redhills and Cholavaram — with an aggregate storage capacity of 175 million cubic metres (MCM). The other major resource is groundwater from the well-fields in the Araniar-Kortaliyar basin and the southern coastal aquifer, and also a large number of wells and tube-wells spread all across the city (Figure 1). Over-extraction of groundwater resulted in a rapid ingress of seawater, which extended from 3 km inshore in 1969 to 7 km in 1983 and 9 km in 1987[1]. Groundwater levels within the city also fell and brackish water began to appear, even in localities which earlier had good quality groundwater sources. The CMWSSB calculates water availability based on surface and aquifer contributions under its direct control. Since it perceived reservoirs and other surface supply as more significant for a long time, very little attention was paid to subsurface storage or ground water recharge. As an outcome of research, done by several agencies the CMWSSB embarked on a campaign to create ground water recharge facilities in the city, and later throughout the State. This led to significant changes in ground water levels and to the quantum of water available to the population of a growing metropolis.

Introduction

The Chennai Municipal Water Supply and Sewerage Board (CMWSSB) is solely responsible for providing drinking water and sewerage services to the residents of Chennai. One of India's major metropolises, Chennai is situated at the northern coastal edge of the State of Tamil Nadu. The city is more well-known by its older name of Madras. Currently, Chennai is inhabited by more than 7 million people in an area of 176 sq km. The CMWSSB depends on surface reservoirs and ground water sources to maintain water supply to the residents. Supply is maintained through multiple means. Since Chennai is essentially low-lying and water supply is intermittent, most residents build underground sumps that store the water. Subsequently, the water is pumped up to an overhead tank. In other cases, water tankers are dispatched by CMWSSB to various localities and the sumps are filled from the tankers. In other localities, CMWSSB has put in place above-ground water tanks and these are filled by the water tankers. In yet other places, residents collect water directly from the tanker, see Figure 2.

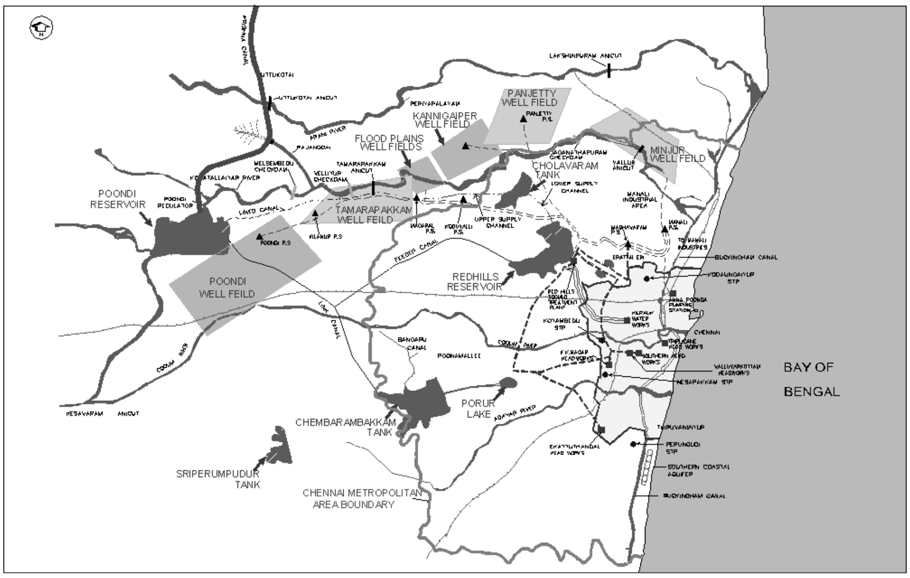

Figure 1.

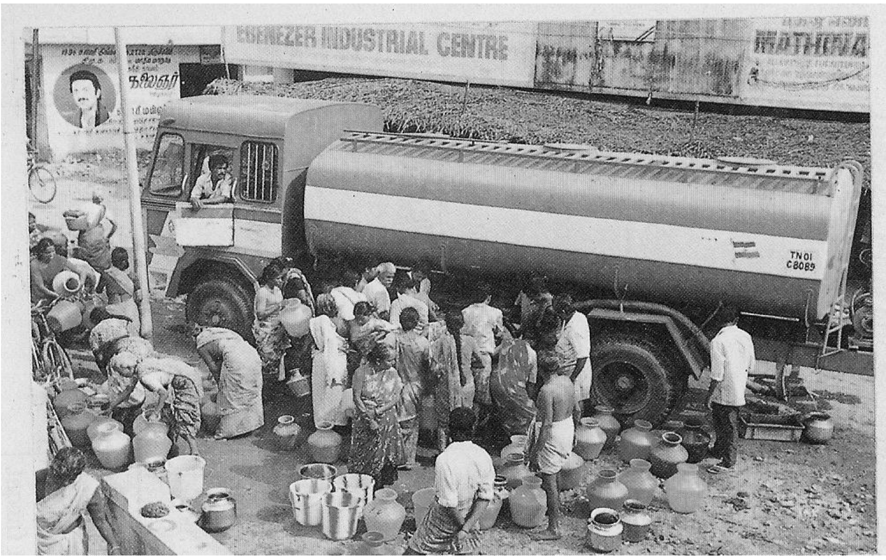

Figure 2: Drinking water collection from tankers directly by residents.

Despite the seemingly abundant sources of water, Chennai suffers continuously from water stress since the entire basin is dependent on rainfall. The annual rainfall in Chennai is 1200 mm [2]. This quantum is, given the size of the Chennai basin, sufficient to meet the needs of the population. The problem is with the distribution of the rainfall. There are two rainy seasons in Chennai. The first is the Southwest monsoon, which has patchy rains and contributes about 25% of the total rain and falls between May and September. This does not do much for ground water recharge. However, the Northwest Monsoon (Oct to Dec) is usually characterized by a series of storms that brings the remaining 75% of total rain in extremely short bursts. During this time, Chennai is prone to flooding and, before 2003, a large part of this water would have been lost as run-off into the sea.

CMWSSB traditionally focused its attention on increasing surface storage, transporting fresh water from long distances. Like the Telugu Ganga project - probably one of the longest canals built for water supply to the city that failed to ease the water problem. Another attempt was to divert water from Chembaramabakkam and Veeranam tanks whereby the water rights of the agrarian community were infringed. Drilling of borewells in the Cuddalore belt and installation of turbine pumps to tap 100mld whereby the groundwater which again supports the local agriculture community was depleted. None of these solutions were sustainable in the long run and yet CMWWSSB paid very little attention to ground water recharge that had that potential.

In 1997, at the Shri AMM Murugappa Chettiar Research Centre (MCRC), Chennai, [3] a study was conducted to understand the user experience. The study surveyed 10,000 households in 155 corporation wards of Chennai. The focus was on how residents get their water needs met and how the water is utilised. Raw data from this study was further analyzed by Dr. A Vaidyanathan and J. Saravanan [4]. These studies clearly established that the contribution of ground water could be as high as 80% in some cases.

The next section will take up a quick summary of the research and the subsequent sections will deal with the steps taken by CMWSSB and other civil society organisations to get rain water harvesting introduced. The final section will describe the results of these efforts on the ground water table.

The research and changes

The survey conducted by MCRC was across 10,000 households, representing a roughly 1 percent sample. Another 2500 surveys across, business, educational, institutional, governmental and industrial establishments were undertaken between September, 1995 and January, 1996. The analysis phase took up another year. The main recommendations of the study were to a) encourage public participation in water conservation and ground water recharge b) promote and propagate water saving/replacement technologies in the domestic sector c) use surface water to reduce ground water usage d) encourage ground water recharge by adoption of low-cost water harvesting systems, cleaning of water-ways and renovation of existing recharge structures, such as temple tanks.

In 1999 a National Water Harvesters' Network was set up by the Centre for Science and Environment (CSE) water harvesters' advisory committee in New Delhi. Members suggested that a regional network be initiated in Tamil Nadu to promote rainwater harvesting in Chennai [5]. Professor M. S. Swaminathan, provided office space for the network unit in Chennai and Prof. A. Vaidyanathan agreed to chair the group. The Tamil Nadu unit of the national water-harvesting network was launched in April 1999. The network was meant to: (i) provide an opportunity for individuals and institutions actively engaged in water harvesting, in Chennai, to share their knowledge and experience and promote free and open interaction among them; and (ii) to reach out to a wider public in the city and outside to propagate the role of urban rainwater harvesting in terms of technology, experience and its potential contribution in meeting urban water needs. It was Prof. Vaidyanathan who then asked for the raw data from the MCRC study and did his own assertion of the data and analysis.

In the background paper that came out of the analysis [3] the following was stated: "The present paper is meant to give an overview of the present and future needs of the city, the limited and expensive scope for augmenting surface supplies, the need for a two-pronged strategy of conservation/recycling and Rain Water Harvesting (RWH) to increase ground water recharge." This confirmed the results of the MCRC study.

Both the MCRC study and the CSE study highlighted the dependence of people on multiple sources for their water consumption rather than just CMWSSB and the heavy dependence on groundwater by both. Thus the RWH campaign was backed up by strong research results of

MCRC and CSE. These studies were necessary to convince the public and the policy makers. It should be mentioned here that the then Chairman and Managing Director of CMWSSB, Ms. Shanta Sheela Nair understood these results and backed the RWH movement fully.

In a 2006 publication [6] Prof. Vaidyanathan and his colleague, J. Saravanan summarized the action of the government as follows: "In Chennai, the capital of Tamil Nadu, the growing dependence on groundwater since the 1970s is evident in the sinking of increasing numbers of open wells and deep bore wells. This trend, a symptom of the increasing water scarcity in the city, led to a progressive decline in groundwater levels as well as seawater intrusion in coastal aquifers. Faced with this crisis, the State government passed the Chennai Groundwater Regulation Act in 1987, which sought mainly to curb the commercial groundwater exploitation within the city limits. In 2001, rainwater harvesting (RWH) became mandatory in multi-storeyed buildings. The unprecedented and severe droughts in the ensuing two years intensified the groundwater crisis to such a degree that, in August 2003, the government passed an ordinance making RWH mandatory for all buildings (existing and new) in the city and throughout the State. It further set a deadline of October 31, 2003 for this process to be completed.

A vigorous publicity drive convinced the public that the government was serious about implementing the programme and providing technical advice and help in the design and construction of RWH structures. This led to unprecedented activity across the towns and cities of the State, especially Chennai city, and the programme was seen as successful. In this endeavour, however, very few turned to the municipal corporation, private consultants or NGOs with the relevant expertise for assistance in designing and building their RWH structures. Most relied on plumbers or their own expertise. Independent experts pointed out several problems with the programme, noting that

a) the time given for the implementation of this ordinance was too short;
b) there were far too few professionals with the knowledge and experience needed to design appropriate systems for the widely varying conditions;
c) the supply of trained and skilled labour to implement the works was also inadequate to cope with the scale and speed of the programme;
d) the availability of quality materials for implementation was also inadequate; and
e) there was hardly any systematic follow-up to check the quality of the works reported to be completed.

There were widespread but unverified reports that, simply in order to meet the stipulations, grossly inadequate RWH structures had been put in place; the capacity as well as quality of design and implementation leaving much to be desired.

This was an instance of decentralisation that, despite the presence of a "felt need", occurred without adequate consultation. The legislation in regard of RWH was welcome but the actual programme was poorly implemented and monitored. Although the programme applied to all classes of housing, it ignored those living in informal settlements such as slums within the city limits. These areas could have benefited from RWH in public building and public spaces — an aspect that received very little attention. Moreover, no steps were taken under this programme to reclaim tanks and wetlands in the city that, in the past, not only functioned as recharge structures but were also used as sources of domestic water by communities."

The Government has since 2009 been working towards cleaning up the waterways of Chennai. This effort has seen the government draw on municipal corporation, private consultants and NGOs with the relevant expertise to work on this massive effort. There is a project with an outlay of Rs 1,400 crore (approx US $300 million) to make the city flood-free[7].

In March 2010 the Chennai Metropolitan Development Authority held a Seminar on Waterways in Chennai. The proceedings [8] contain a list of 36 recommendations and some of them are re-produced here:

1. The sequence of actions to tackle the problem may be –
   (a) flood alleviation
   (b) prevention of pollution to the waterways
   (c) cleaning up of the waterways by removing encroachments & obstructions
   (d) restoration / improvements to the waterways and its continued maintenance.
2. Floods are opportunities to augment ground water recharge to be facilitated by construction of check dams, filter wells, and underground tunnels/storage reservoirs, if the soil conditions and slopes permit.
3. Flood plains should be developed along the waterways in the areas outside the towns and cities, adopting the retention model, as a solution against flood hazards; these flood plains could be developed as parks or green belts for recreation such as camp sites.
4. Eco-engineering should also be adopted as a solution to bring nature back and rejuvenate the rivers.
5. It is recommended that corporate sector participation, and general public participation, in planning and improvement of lakes and rivers should be encouraged. Cleaning up of rivers and conservation of water bodies should be thought of as a movement with the participation of all stakeholders including the general public.
6. Adequate public awareness about the hazards of pollution of water bodies and the remedial measures has to be created by organizing community education campaigns. Getting the citizens involved is important, 'Saving Waterways' should become a people's movement.
7. Use of sewage for power generation and recycling of waste water should be encouraged.
8. Area development plans prepared at micro level, such as Detailed Development Plans, should contain plans for ground water recharge, at least in large premises such as schools and public places. Sustainability measures should form part of the Integrated River Restoration Plans.

What is evident here is that the outcomes of studies take time to percolate down to the agencies mandated to make the changes required for sustainability. It also requires a good amount of political will. Much of the change of attitude of governmental institutions can also be traced backed to strong political thrust to implement the changes.

Results

Data on change in groundwater quantity and quality has to be presented here, mostly based on media stories. Some researchers feel that the effects of rain water harvesting and subsequent ground water recharge are so noticeable that quantifying is not a priority. The Table below (Figure 3) shows the number of rain water harvesting structures built by the Corporation of Chennai, as reported on its website.

Rain Water Harvesting done by Corporation of Chennai

Corporation owned buildings	1344 Structures
Flyovers and Bridges	29 Structures
Open low-lying areas	242 Structures
Road Margins	945 Structures
Corporation Streets	2698 Structures
Corporation pond	1 No.
Temple Tanks	16 Nos.
Residential / Commercial / Institution Buildings	329959 Buildings

Figure 3[9]

An article published in a leading daily in Chennai, *The Hindu*, dated January, 31 2009 had many interesting points to make about the results of RWH and ground-water recharge.[10]

"The CMWSSB study of 759 RWH observatory wells shows that ever since the installation of RWH structures in about 500,000 of its consumer households was made mandatory in 2004, there has been a 50 per cent rise in the water level. According to the CMWSSB officials, over the last five years, the water level across the city has gone up by three to six metres. Similarly, the water quality in several areas has also showed improvement. The sustained normal rainfall since 2004 and the proper maintenance of RWH structures in most households have been the principal reasons.

Following the drought period in 2003, when Chennai received only about 690 mm of rainfall as against its normal of 1,200 mm, the water table had receded and, on an average, was at 7-8 metres below ground. In many places it was at 10 m depth and, in some, it was at 10 m. Following a good monsoon (2,064 mm) in 2005 and rainwater harvesting, the ground water table saw an appreciable rise in several areas and the water table reached 1 m depth below ground.

The total dissolved solids (TDS), which were earlier as high as 4,900 parts per million (ppm) in some areas, dropped to permissible levels of 500 ppm, greatly improving the quality of water (see Figure 4).

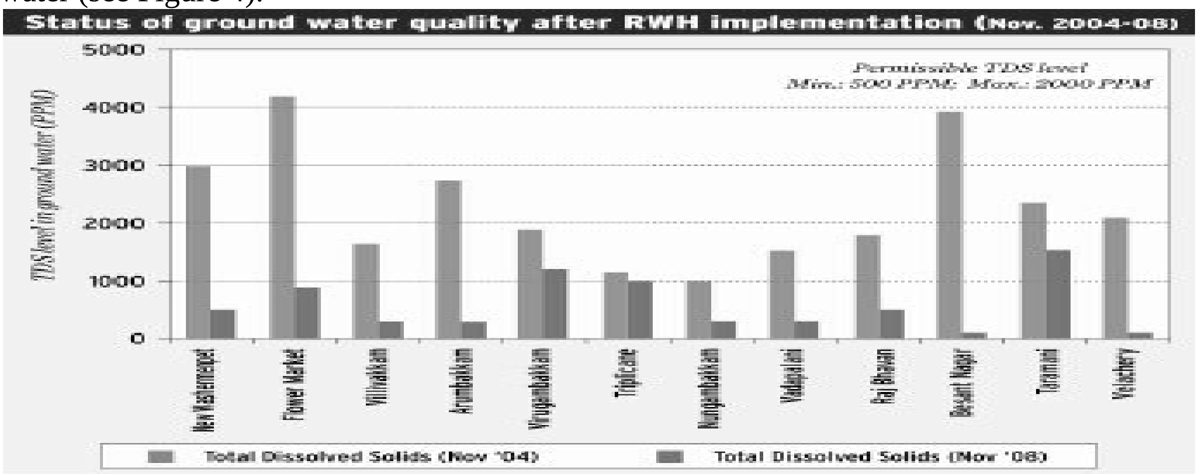

Figure 4[10]

"Before the onset of every monsoon, Metrowater officials conduct a random check of the RWH structures for their maintenance and create awareness about the need to keep these in good shape. Harnessing of rainwater that gets collected in storm water drain network would help reduce the inundation on roads and large volumes of water draining into sea every year….. Unless rainwater runoff in both public and private spaces in the city is harnessed, Chennai may lose out on the precious resource and may end up with water problems during the summer months," note rain-water harvesting experts.

Conclusions

This presentation has tried to show that it takes many years of persistent effort to address a problem in civil society. In Chennai, and indeed the whole of Tamil Nadu, the problem was one of water stress. Research showed that the available rainfall could help people cope but fresh water from the rain was being lost to the sea. Based on this, a proposal was made that ground water recharge was a viable, low-cost solution. This proposal had to be championed. Prof. Vaidyanathan and the then Chairman of CMWSSB, Shanta Sheela Nair, did just that. They showed with great determination and several pilot studies that rain water harvesting would be viable and worthwhile.

They managed to convince the government of this, and RWH became a statutory requirement for all buildings in the state. Monitoring the quantity and quality of the ground water has shown the significant changes this legislation has brought in.

As a side-effect a greater understanding of the need to clean, preserve and secure all types of fresh water bodies has prevailed among the political circles, bureaucracy, NGOs and civil society. The people have also shown great resolve in implementing the solution since it directly affects their lives.

The type of study conducted by MCRC and CSE can be a methodology to assess the water sources, consumption pattern, per capita availability and requirement particularly in developing countries. This way the water supply system can be better planned and implemented to be sustainable.

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A SUSTAINABLE AND ROBUST MEMBRANE WATER TREATMENT UNIT FOR POTABLE WATER PRODUCTION IN REMOTE RURAL AREAS

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Key Words: Rural household water treatment, floods and disaster relief

Abstract

Ingestion of impure water is a major contributor to the downward spiral of poor health and high mortality rates in African and other developing countries Raw water treatment technologies developed for advanced industrialized economies are often not sustainable in developing economies, particularly the remote rural areas, for several reasons. This correspondence reports a successful effort launched in South Africa by Durban University of Technology (South Africa), and Savannah State University (USA) to address the potable water problem in impoverished remote rural communities. A simple water treatment system for remote rural households which overcomes the limitations of existing systems is developed based on a unique and robust microfiltration membrane module developed at DUT using components engineered in Africa. Operation of the system is very simple: Raw water is poured into the feed tank, and the product is withdrawn through an outlet tap. The membranes remove all suspended solids, colloids and most of the pathogens. Independent laboratory trials indicate that system performance is more than adequate for the target application. The System has potential applicability in potable water provision for displaced populations, rural households/ schools and during flood emergencies. This paper describes the system, its economics and applicability in developing economies.

INTRODUCTION

U.N. statistics show that nearly half of all people in the developing world suffer diseases like cholera and diarrhea as a direct result of consuming bad water and that a significant improvement in the quality of drinking water could reduce diarrhea diseases by 90%, [8]. These waterborne diseases are the leading cause of death for children under five, killing more than 2.2 million children each year, on the average [8, 6]. Today contaminated water kills more people than HIV/AIDS, tuberculosis and malaria combined [8]. But portable water could be taken for granted in developed countries. Today, no one in developed economies is subjected to the consumption of raw untreated water. Many advances have been made in effluent and environmental treatment technologies, over the years, albeit developed primarily for “first world” economies.

However, raw water, effluent and environmental treatment technologies developed for advanced industrialized economies are often not sustainable in developing economies due to cost factors, limited skills base, and availability of spare parts. More so, the provision of potable water to rural areas in developing economies poses unique challenges. These impoverished communities are usually off-grid and thus can not use systems powered by conventional electricity. Their homes are also not equipped for running water and thus filtration/purification systems that require pressure from pipe borne water are not applicable. These communities also suffer from severe and chronic skilled manpower shortages, since skilled individuals often tend to migrate to the greener pastures of urban centers. This proposition thus challenges the scientific community to come up with appropriate (indigenous) technologies for portable water provision suitable for developing economies' rural and farm communities with limited expertise and skill base, as well as limited ability to pay high equipment costs.

Several efforts including most recent works by Mikkel Frandsen, Kuennen, Roy W., et al, and James R. Marrusek [7, 2, 4] have been made to address the potable water problem for developing economies and farm/off grid communities. These, however have resulted in water purification systems with certain drawbacks when their application in the communities with the aforementioned attributes are considered. These drawbacks include:
Cost – Many existing systems are simply too expensive for the dollar-a-day income individuals of rural communities. The discouraging high cost compels them to stick to their unhealthy choices.

Flow Rate: Ceramic filters while affordable have shown to be very successful but its agonizingly slow (dripping) flow rate makes it impractical for portable water provision for a household.

Chemical Treatment: This produces good results except that often supply is limited and lack of access to remote villages makes it unreliable. Furthermore, there is the risk of wrong titration and water consumers may prefer the untreated water with latent problems to treated water chemical odor.

Maintenance: Many of the current systems require maintenance which is beyond the skills of the communities that use them.

In developed countries, there has been a major swing towards membrane technology for water treatment. The advantages of membrane technology, particularly microfiltration (MF) and ultra filtration (UF), over conventional chemical treatment methods for the production of potable water from raw waters are well known. A comprehensive review of the applications of membrane technology in water purification with their advantages and limitations has been compiled by S. Mameni [3]. Similarly, an earlier work by Shoichi Kunikane, et al [9] documents a comparative study on the application of membrane technology to public water supply. Also, a more recent work by Catherine Charcosset, [10], presents a review of membrane processes for potable water production.However, until now, it has not been possible to implement these technologies in remote rural regions, due to the challenges identified above.

An effort to address this problem using membrane technology by engineers and scientists from Durban University of Technology, South Africa and Savannah State University, USA has produced a sustainable and robust water treatment system that is affordable and produces high quality drinking water for remote rural households faced with all the constraints alluded to above. This new technology, termed the Remote Rural Water Treatment System (RRWTS) differs in one or more significant ways from any existing technologies, both currently on the shelves, and emerging. Most importantly, the RRWTS described herein is foolproof and designed to mesh with the cultural norms of the targeted communities and would not require any change in the lifestyle of the people, whatsoever. This characteristic is lacking in most other existing systems. This paper describes the development of the RRWTS, its performance, and outlines its various merits in bringing safe drinking water to poor rural communities of developing countries.

Considerations and Choices in the Design and Development of the RRWTS

The issues considered in the development of the design criteria for the water treatment unit are derivatives of the aforementioned obstacles which have made it difficult for existing water treatment systems to penetrate remote rural communities. This system is designed specifically to overcome those obstacles. To achieve this broad objective, the following choices were made to cultivate the design philosophy.

Target Market: Rural communities can broadly be divided into two categories – those with piped water, albeit of poor quality, and those that have to fetch water from a local river or dam. This system is aimed at the latter category, i.e. where users currently fetch water from a local river or dam in 15 L to 20 L containers and carry this back to their households for consumption. The majority of rural Africa and villages in other developing economies fall under this category. Hence, the RRWTS is designed to handle 15 L to 20 L at a time, and should be easily transportable so that it could be used by a single household or shared by a few households.

Required Product Quality: A multi-barrier membrane system guarantees all pathogen removal, but will obviously increase the cost of the system substantially. The question here is, what *minimum* number of units in cascade would give an acceptable water quality to rural users? The RRWTS is designed to produce an adequate water quality for the target market using one compact rig. Water providers have indicated that, irrespective of the water quality produced by a water treatment device, it will still be essential to add a residual disinfectant to cater for contamination of the vessels used for storage, drinking and cooking. In view of this, it is not necessary that the RRWTS produces a top quality product. Instead system optimality should produce a product free of suspended solids, colloids, and most pathogens, and that can be easily disinfected, at low cost.

Scale of operation: The scale of operation is based on the target market. It is assumed that each user will purify 15 L to 20 L at a time. In order to make the treatment unit attractive to the user, to prevent "user fatigue" that may cause reverting to using the untreated raw water, it was decided that this volume should be produced in less than one hour. Hence, the scale of operation is that the unit should nominally produce 20 L/hr, adequate for an average household of 4 per day. Obviously, at the high flow rate of 20L/hr, greater demands can be easily met.

Cleaning and Maintenance: Most membrane systems require periodic chemical cleaning or high pressure back flush. This would obviously be unsustainable in rural environments. Fortunately, the woven fiber micro-filtration (WFMF) system can be cleaned by drying or scrubbing, obviating this problem. Also to be considered is the frequency of cleaning. If a treatment unit has to be cleaned very frequently, this may result in "user fatigue", and the user may consequently revert to drinking raw water rather than using the water treatment unit (WTU). Hence, it was decided that the RRWTS should require cleaning only once a month.

Construction: The construction of the RRWTS must be robust, yet inexpensive. It was also decided that only off-the-shelf components should be used. This would prevent the situation where the technology may be held back because significant capital is required to start production of units. High priority is given to the use of indigenous materials and parts, not only to reduce cost but to ensure availability and easy access.

SYSTEM DESIGN AND FABRICATION

The Water Treatment Unit

The essential features of the RRWTS are the membrane and module. The membrane is a flat-sheet woven fiber micro-filtration fabric produced locally in South Africa (Figure 1). The module consists of three elements: a PVC frame that incorporates a permeate outlet; two sheets of fabric glued to either side of the frame; and a spacer between the sheets of fabric to facilitate fluid flow to permeate outlet. The modules are approximately A4 size (Figure 2). Multiple modules are held together by threaded rods inserted through holes drilled in each module to form a membrane pack of fifteen modules (Figure 2). Below the pack is the permeate collection manifold. The individual modules are connected to the permeate manifold by silicone tubing (Figure 2).

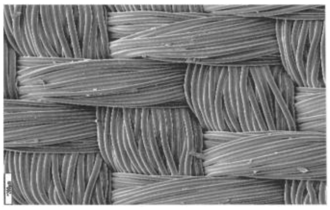

Figure 1: Microfiltration Fabric

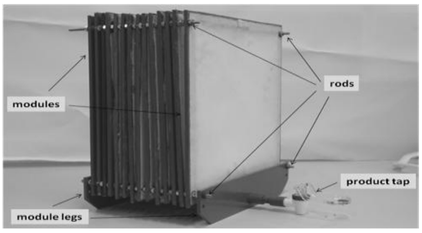

Figure 2: Membrane pack

The water treatment unit consists of a 30 L tank into which the membrane pack (the microfiltration rig) is inserted. The permeate manifold protrudes through the tank wall, via a seal, and has a product tap at the end. The tank is also equipped with a drain valve (Figure 4) for removal of tail products and residue

<u>Operation</u>

Operation of the RRWTS is simple and requires no skills. Raw water is poured into the tank (Figure 3); a few drops of liquid disinfectant are added to a 5 L product container; the product valve is opened and the permeate (treated water) is collected in the product container. Periodically, usually once a week, residue and tail products are flushed out through the drain valve.

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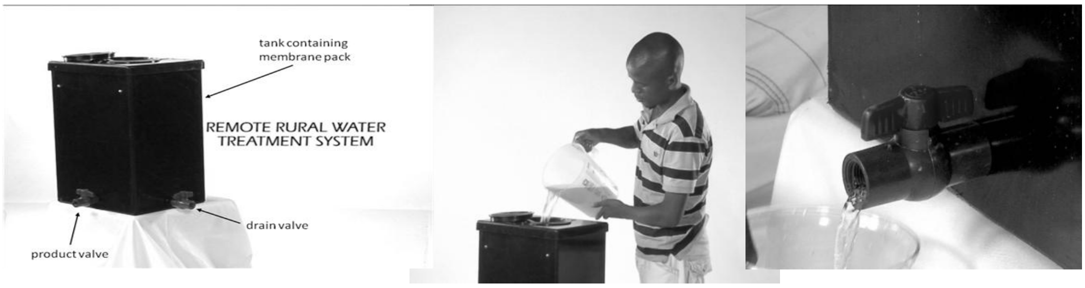

Figure 3: Rural Water Treatment Unit and Its Operation

<u>Maintenance</u>

The only required maintennance is periodic cleaning of the modules and occational flushing of the tank. This routine maintennance requires no skill and can be done *in-situ*, at a frequence which depends on the turbidity of the raw water. Fouled modules are cleaned by simple brushing/scrubing using a bottle brush as shown in Figure 4. The spacing between the modles provide ample pathway for this purpose. Occasionally, the tank is flushed out with clean water via the drain valve. Field tests at target market locations indicate that cleaning the unit once a month produces optimum system performance.

Figure 4: Cleaning the modules by brushing

Performance

The RRWTS has been tested in University laboratories and independent laboratories [1] to determine its performance characteristics. Extensive field tests have shown that it produces portable water of adequate quality for remote rural communities. It is practical and can produce water of very high quality at locations where no other technology is applicable.

Water Quality : In field tests, the RRWTS consistently produced a product of < 1 NTU, for raw feeds ranging from 20 NTU to > 300 NTU. The permeate turbidity was not affected by feed turbidity, runtime, or permeate flux.

The *acid* test of any water treatment system is whether it can consistently remove dangerous bacteria from the raw water. The ability of the RRTWS to remove *E.Coli*, an indicator organism for contamination of water by pathogens, was evaluated by Umgeni Water, and is summarized in Table 1.Typical feed and permeate samples are shown in Figure 5.

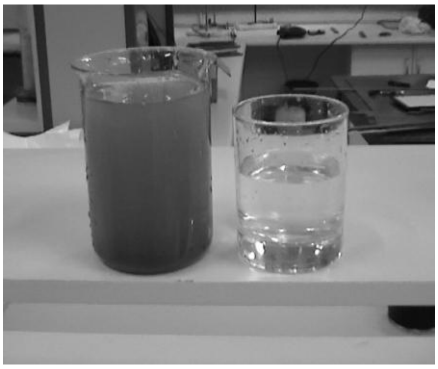

Figure 5: Typical feed and permeate samples

Water Source	**E.Coli in raw water** (counts/100 ml)	**E.Coli in permeate from RRWTS (before exposure to disinfectant)** (counts/100 ml)	**E.Coli in product container** (counts/100 ml)
River 1	4838	980	0
River 2	8160	185	0
River 3	11191	23	0

Table 1: Quality of raw and treated water

The membranes remove about 95 % of the bacteria, and the remaining bacteria are completely destroyed by the disinfectant in the product container. Even for raw waters with very high levels of contamination, the RRWTS produces a final product that is completely safe for human consumption.

Product Flow Rate

A RRWTS unit containing 15 modules can produce 60 Liters per hour (60 l/hr) on the first day of use, and about 15 l/hr after one month of use, if used once a day, without cleaning. The system can therefore provide a household with 30 liters of water each day, for one month without cleaning, depending on the feed turbidity. The above flow rates were obtained using raw water with a turbidity of 60 NTU.

Cleaning Periodicity, Efficency and Regimen

Depending on the raw water quality, the RRWTS will operate effectively for a month before cleaning is required. For the water tested above, a unit used by a single household to provide 30 L per day can operate for up to thirty days before cleaning is required. The system will continue to run but the flow rate progressively decreases if not cleaned, eventually forcing the user to take corrective action. Simply brushing the modules with a bottle brush is all that is required to clean the membranes (Figure 6). No chemical cleaning is required. The modules may also be cleaned by air-drying. This technique however offers no advantage over brush cleaning and may require a skilled technician to disassemble the rig from the tank. When the unit is fouled, the modules can be cleaned by any of the two techniques mentioned above by (i) a roving technician exchanges the fouled unit for a clean unit, and transports the fouled unit to a central service center for cleaning; (ii) the user exchanges the fouled unit for a clean one at a central service center, or (iii) the user cleans the unit by brushing the modules *in-situ* with a bottle brush.

ECONOMICS

If the RRWTS shown in Figure 5 is mass produced, the estimated cost of production would be around USD 30 to USD 50 per unit, depending on scale of production. For a minimum lifespan of five years, and no components that need to be replaced on a regular basis, as would be the case with other systems, e.g. the ceramic cartridges used systems. There is also no maintenance cost. It emerges that the RRWTS can provide sufficient amount of potable water of adequate quality to a rural household for less than USD 10 a year, with an additional USD 0.50 only a week if the family uses the services of a service center to clean its unit at the cost of USD 2 a month.

SYSTEM LIMITATIONS, AND CONCLUSIONS

The RRWTS overcomes several of the limitations of other existing methods for providing potable water to remote rural communities. Though the system produces water of adequate quality for the target communities, its pemeate does not meet international water standards. To attain international standards a disinfection module must be added. The development team is currently investigating various techniques for delivering disinfectants which will neither escalate unit cost nor require user special skills. Several existing technologies, including the recent work by Nguyen, et al [5] are being studied.The development team beleaves that if the unit is equipped with in-line disinfection then the RRWTS would be the ultimate choice since it is cheaper, more robust and user friendly and has substantially higher flow rates than many of the ceramic based systems that are currently aimed at this market.

To arrive at the system design philosophy, the design team has studied a myriad of commonly available water treatment techniques and devices. These include, but not limited to, activated alumina; activated carbon; aeration; anion exchange; chemical precipitation; chlorination; distillation; ion exchange; other mechanical filtration; neutralizing filters; oxidizing filters; ozone treatment; reverse osmosis; and ultraviolet treatment. For the target market, none of these technologies would suffice due to high cost, energy requirement and required expertness. It has also been determined that the cost of existing products which could be easily adapted in the rural environments are not within the reach of the impoverished communities the RRWTS is designed to serve. Furthermore, should these products be deployed in the remote rural areas to be fed with raw waters from ponds and rivers, they would need pre-filtration system in order to survive the environment.

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APPROPRIATE TECHNOLOGY AND WATER: ROLE OF INSTITUTIONS OF HIGHER LEARNING IN FINDING SOLUTIONS FOR A THIRSTY PLANET

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Abstract

Lack of clean water is one of the leading problems resulting in hunger, diseases and high death rate in many developing countries. Over the years Zimbabwe has faced water shortages with cholera outbreak causing high sickness and death rate from 2008-2009. Disputes between Zimbabwe National Water Authority and residents were witnessed in urban areas over water allocation and supply. As an important resource for people's survival and growth, water needs to be guarded jealously. Water education is the key to solve water shortages on our thirsty planet. Policies that aide in reducing water conflicts have to be instituted. This paper therefore seeks to show how Universities as institutions of higher learning can contribute towards finding solutions to the water problems that have rocked the country by facilitating water related education, promoting meaningful research and technological transfer on water related issues. They can transfer knowledge and empower communities on how to develop appropriate technology for sustainable water use. Technical education can be provided on water conservation. Community outreach programmes pertaining affordable and efficient methods of providing clean water even in the most remote parts of the country need to be carried out. Resources mobilization ensures that this comes to fruition.

INTRODUCTION

Clean water resources are getting scarce all over the world. Zimbabwe like any other less developed country is experiencing persistent clean water shortages, while facing the challenge of global climate change. Communities have to be sensitised on how to identify and make use of appropriate technology to access clean water. Such technology will be that which requires fewer resources and is easier to maintain as well as calling for the sustainable use of water resources. The focus is on how education and training programmes can be implemented to achieve sustainable use of water resources. The paper therefore analyses how universities can transfer knowledge and empower communities on how to develop appropriate technologies that are beneficial even to the most remote areas of the country. Universities as transferors of knowledge have a major role to play in finding solutions to a thirsty planet. Technological innovations that can deal with problems of water shortages need to be put in place. The role of Universities in working towards identifying technologies that address the problem will be addressed. Water is life and water education is the key to solve water issues on a thirsty planet.

Background

Water is a ubiquitous resource needed by everyone for "survival, growth and prosperity" (Byron). [1] Though being ubiquitous, different areas have different quantities and quality of the resource due to a number of reasons such as climate change, migration, urbanisation, industrialization, drought and land degradation. The negative impact of agriculture is deforestation which in turn influences the water cycle and patterns of rain received in an area. On the other hand, it appears that urbanisation and migration disturbs the availability of water since the few technological resources that ensure water availability such as pipes are strained. In Zimbabwe it has been observed that industries and mining activities lead to water pollution as companies dump waste materials in water reservoirs since they lack technology to get rid of the waste properly. For instance, it was observed in July 2007 that there was too much raw sewage spilling into Lake Chivero, Harare's main water source. [2]

Thus problems of a thirsty planet call for solutions that appropriately tally with the area of concern. Civic education and awareness campaigns on community participation on water conservation and technological innovations are key solutions. Technological innovations must be spearheaded by the local people who should contribute to the technological process of their area much more than outside experts. [3] In this regard, universities play a critical role in helping local people identify technological innovations necessary to meet their needs. They should come up with strategies and recommendations that can assist people and make the world a better place to stay with clean water resources.

The need to educate people on how to solve problems of a thirsty Zimbabwe is very vital. Workable approaches have to be well thought out towards conservation of water resources. Universities have to carry out research as well as establish research links and collaboration on finding appropriate technology to water solutions. Sustainable management of water resources is a major thrust necessary for changing people's mind set and cultivates the culture of sustainability. Universities and research institutions should ensure that policies on water conservation are properly instituted. Participatory research and publications with communities can promote proper implementation by those involved. However this requires finances, technical expertise, and equipment which at times are scarce. Providing water needed to feed a growing population and balancing this with all other demands on water is one of the great challenges of this century. [4] The purpose of this paper therefore is to show how Universities as institutions of higher learning can contribute towards finding solutions to water problems by facilitating water related education, promoting meaningful research and technological transfer.

Zimbabwe water situation – challenges

Over the past years Zimbabwe has been affected by warming. This has been a result of the negative Indian Ocean Dipole (IOD) which has led to changes in rainfall patterns in the country causing incessant droughts and floods, making the demand for clean water high. (Manatsa) [5] This has also resulted in poor harvests in most parts of the country. As a result, there is inadequate food leading to high incidence of malnutrition and deaths. Recently it has been reported that about two million people will require food aid to augment the little harvested food in the country [6]. These shortages have also been caused by poor water management practices.

It appears that population growth, climate change, water pollution and low technological advancement are major sources of lack of clean water in many developing countries. Lack of clean water is one of the leading problems resulting in hunger, diseases and high death rate. Approximately 2.2 million people die of waterborne diseases each year (Mintz, Bartram, Lochery and Wegelin). [6] These waterborne diseases include cholera, diarrhoea and bilhazia. Stagnant, polluted water provides breeding ground for mosquitoes that cause the deadly killer disease, malaria. This implies that clean water is crucial for people's survival and reduction of mortality. Population growth and migration strain existing water and sanitary infrastructure in Zimbabwe’s urban centres.

This scenario is worsened by increasing water pollution in Zimbabwe’s reservoirs especially for urban centres. The country has experienced dwindling water resources such that most water reservoirs have drastically dropped to alarming levels caused by the many competing uses of water. These are being triggered by the pro rata increase in population, urbanization, agricultural and industrial activities. Water is mainly being used for irrigation of agricultural activities taking place in many parts of the country to meet the demands of the growing population. Most industrial activities are polluting water bodies because of the weak enforcement of legislation governing the pollution. This is mainly because the fines for polluting the environment are very low and industrialists choose to pollute and pay the cheap fines.

More so, Winpenny [7] highlighted that water provision in developing countries has led to deadlocks. These deadlocks have been witnessed too in Zimbabwe’s urban centres where residents have failed to reach agreements with Zimbabwe National Water Authority (ZINWA) and Local Municipal Authorities over water provision. Due to water shortages Local Authorities embarked on water rationing which further reduced water allocation and supply to residents in urban areas. This led to disputes between ZINWA and residents. Residents in most towns teamed up and formed Combined Residents Associations aimed at putting pressure to ZINWA, Government and Local Authorities to improve service delivery on water and waste management.

Conflicts have also erupted among residents over water in both urban and rural centres where boreholes that provide clean water are few. A significant part of population in Zimbabwe resides in rural areas where infrastructure is not well developed. Due to the limited numbers of boreholes, women and children both in urban and rural areas travel for long distances to fetch water in nearby streams causing a health hazard since these water sources are unprotected and often susceptible to pollution. Searching for water is a burden for most African women who suffer physically and have psychological stress of having to travel for long distances carrying water, some with children on their backs.

In some residential areas like Zimre Park in Harare there is virtually no water which comes from the taps and the residents rely on boreholes and wells. In other residential areas water pours from the taps in the morning and in the evening for one to two hours only, in each instance. Thus, in the afternoon it is rare to see water flowing from the taps. Local municipalities are struggling to acquire chemicals to treat drinking water, which comes from the highly polluted reservoirs. As a result of this, there was cholera out break which caused high sickness and death rate during the period 2008-2009. Such observations really call for appropriate technology to improve access to clean water as well as proper water preservation methods.

Role of universities in water education

Institutions of higher learning have a responsibility to reach out to the world with the knowledge they possess to enlighten the people on how to access clean water. The need to train staff and community to save water and have mechanisms of sustainability such as water management, waste and disposal management is paramount in developing countries. Universities can join hands and put in place policies for sustainable use of water. For instance they can integrate water sustainability into their curricula making it part of the educational experiences.

The academic world has to create awareness through offering courses and carrying out community outreach on appropriate technology for water conservation and purification. An example of the initiative made by University of Colorado, Boulder can be adopted. It established a Centre for Appropriate and Sustainable Technology (CAST) aimed at developing internationally responsible students who can create sustainable technologies and business solutions applicable to development problems faced by poor communities around the world. [8] This was a step in the right direction through which students have to focus on research and development that bring out new ideas and technologies. Though noble, this is in conflict with Troy's [3] assertion that planners have to involve local people in the early stages of planning for appropriate technology so that those who understand their problems and needs better than anyone else can be in a position to invent the necessary technological innovations to meet their needs. Rubber stamping ideas from outside by outsiders may cause insensitivity to the real problem on the ground as well as resistance from the local people. Universities therefore have to empower the local people with knowledge to identify a problem, finding solutions to the problem and planning the appropriate technology as well as implementing the innovations.

Information gathered from three Universities in Zimbabwe to assess whether water education is being offered is shown in the table below:

Table 1: Institutions offering water education in Zimbabwe

INSTITUTION	DEPARTMENT	Examples of Courses offered
Bindura University of Science Education	Environmental Science	-Water Resources Management - Water Pollution - Watershed Management and Land use planning, etc.
University of Zimbabwe	Environmental Science, Agricultural Engineering	-Environmental Management, Monitoring, principles and methods, Waste management, Sustainable use of Natural Resources, etc
Midlands State University	Land and Water resources management	-soil and water conservation -irrigation engineering theory, methods and applications, etc.

It shows that water education is being offered in a variety of areas and efforts to equip students with information pertaining water resources are being made. It was also observed that very little activities on appropriate technology were being done. Of importance to mention, were the strides taken on water purification where mini water purification projects are being explored at one university. Machines that are less expensive to acquire and cheap to maintain such as hand pumps, bush pumps and bio sand filters are being developed. The same university has a Life Long Learning Centre offering consultancy in relation to water management, rural water supply, sanitation and hygiene (WASH) in the surrounding urban and rural farming Communities. This is a commendable step for Universities in which they are practically orienting the education they provide to meet people's needs.

The United Nation Committee on Economic Social and Cultural Rights under scored that access to clean water is a fundamental right to which Bordhiharma [4] reiterated that the world is currently failing to meet this goal. There is need therefore to ensure that Universities educate society at large in order to achieve better conservation measures and sanitation Universities need to participate in monitoring consistency between national monitoring methodologies and policies as well as resource management decision-making bodies as monitoring of ecological integrity and biodiversity is of great concern. [9] A national template to coordinate monitoring has been suggested where the role of universities is to develop such national templates or guidelines for a set of environmental indicators to be monitored at town, national or regional levels (Ward). [10] These indicators must be capable of showing the relationship between human activity and the effects on natural resources.

Universities play a vital role in promoting the right economic framework which improves the allocative efficiency of water. The economic allocative efficiency can be improved by allocating certain water quotas to certain users as well as formulating strategies for implementing the quotas. [11] The strategy includes the use of taxes, subsidies, regulations, technology changes and also requires coordinated planning involving a number of stakeholders. In Zimbabwe, for instance, the stakeholders include Government Regulatory Authorities like ZINWA, relevant Government Ministries like the Ministry of Health Child and Welfare (MHCW), Ministry of Agriculture (MOA), Ministry of Local Government (MLG), Ministry of Environment and Natural Resources Management (MENRM), other relevant Government Departments and Agencies such as the Environmental Management Agency (EMA), Water Associations, Catchment Councils, Traditional Authorities and Leaders. All these can embark on a multi - disciplinary and integrated approach on appropriate techniques for water management.

Powerful water coalitions among engineers, financiers and politicians are necessary to increase water supply as each stakeholder plays its role effectively. [12] Participatory approaches have to be adopted to ensure that all stakeholders are involved in finding solutions to a thirsty planet. The Universities should make strategic partnerships for educating influential stakeholders on water conservation. Some outreach programmes are being made by lecturers educating farmers on the effects of certain practices that lead to water scarcity such as deforestation and stream bank cultivation so that they implement conservation agriculture. Community can also be taught how to use chemicals, solar disinfection and safe water storage in order to make drinking water safe as well as promote behavioral change through theatre. The need to produce handbooks to ensure that water education trickles down to all concerned people becomes vital. Hence universities have a major role to play in promoting production of the handbooks.

University curricula and methods of training have to be reviewed. There is need for interaction among Universities on how best to develop suitable curriculum. For instance at one university lecturers have attended curriculum review, teaching and learning workshops geared towards improving water education offered at the university. More so, universities can develop partnerships with engineering companies (locally and internationally) to help in skills development, thus promoting sharing of ideas. The writers observed that lecturers were getting the opportunity to further their studies at PhD and Masters as well as attending a variety of short courses, conferences and workshops both locally and abroad.

Universities can advance research on technology that can be used to access clean water. After the research, they can also transfer contemporary and emerging water resources issues to the community. Education and research provide information to people thereby developing capacities of people. A variety of research projects by both students and lecturers were in progress on waste management – reduction of pollutants, conservation agriculture, as well as cheap to buy and maintain water purification methods such as hand pumps, bush pumps and bio sand filters. Public seminars on global climate change were hosted at one university.

Challenges faced by Universities

Universities have challenges in changing perceptions of people especially in developing countries that fetching clean water is a responsibility of women. Therefore there is need to create awareness that appropriate technology is a problem for both genders. There is also a donor dependency syndrome by most communities which usually thwarts the development of an initiative mind among local people.

Planning and construction of water infrastructure is impeded due to lack of finance. Due to poor remuneration, most universities have experienced high turnover of staff in the engineering field, as they move to other countries. This is a major drawback in efforts to educate people on appropriate technology. As a result there is lack of necessary skills to steer ahead technological programmes that may be initiated.

Lack of proper and friendly legislation is also a challenge. For example in Zimbabwe one needs police approval to form a gathering thus affecting outreach programmes. The laws should be flexible to allow efficient outreach programmes. It seems there is lack of law enforcement when it comes to limiting pollution in most developing countries where the main polluters are large industries. These industries pollute the environment because of their ability to pay the cheap fines.

Lack of efficient transport systems among universities has also proved to be a hindrance for community engagements efforts especially in remote areas. Another contributor to this is the fact that some communities are generally ignorant of the importance of conserving water resources such that they can be adamant to change. Hence there is also a great challenge for university personnel in identifying appropriate techniques for imparting knowledge to such communities. As a result one university has started an Environmental Action Awareness Club for the purpose of outreach programmes. In addition all the Universities were hosting Public lectures and Seminars on water related topics to educate communities.

Way forward

The vision of the writers is to see universities on the centre stage of developing appropriate technology for use in finding solutions for a thirsty planet. Their activities in teaching, community service, research and project development, management and implementation should be harnessed towards developing capacities of local people.

The graduants when churned out of the universities should be in possession of appropriate technology skills as clear testimony of the education they have gone through. Hence they should demonstrate the knowledge and skills gained by being in a position to develop appropriate technology using local resources for the local people. Again through community participation, students, lecturers and communities can work hand in hand in identifying water related problems, solutions to the problems as well as planning the interventions to appropriately solve the problems of a thirsty planet. Major input by universities is to provide knowledge and technical support as well as empowering the local people to use their local resources.

The vision also is to see resourceful students, lecturers and communities that are equipped with relevant skills. Such skills may promote team work for solutions to problems facing the country. Hence people may not rely on prescribed solutions that in many cases fail due to lack of involvement of the local people. Awareness campaigns should be carried out by universities to ensure understanding of appropriate technology even by those who have not attended training. This can be done using public media, workshops, theatre and visits to remote areas. These activities can go a long way in enhancing communities with knowledge and skills disseminated in simple terms. Grants from Government or donors to support the initiative to solve water shortages can also make this possible.

Most Universities in Zimbabwe have farms which lecturers and students can use for experiments to test new ideas and innovations on water conservation and issues concerning agriculture and water. Communities must be equipped with knowledge and skills on agricultural methods and crops that need less water. Use of demonstrations for early adopters to new technologies is therefore very essential. However, a lot of funding and personnel with requisite skills are required for demonstrations to be successful.

The Government must ensure that there is water conservation both at household and institutional levels and that there are strict laws to control water pollution. Waste water reclamation and recycling programmes can be implemented. In addition, ground water mining in form of boreholes and rain water harvesting in form of gutters and infiltration tanks can be encouraged.

Conclusion

Education on environmental conservation is crucial for long term and short term solutions to water shortages on our thirsty planet**.** Through research universities can come up with fundamental concepts for managing and monitoring water use and preservation. Curriculum on water education has to be adopted by all universities. This may enable technological advancement among graduands who are the future community. Capacity building is therefore a collective proposal for further development. There is need for knowledge sharing among universities so that communities have maximum benefit on water conservation and management. It is important to note that "the water we pollute today maybe the very water for our future requirements", [13] Hence the need for collective efforts by all concerned to ensure that environmentally friendly measures that allow proper usage and saving of the scarce resource are put in place.

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AN APPROPRIATE TECHNOLOGY CHECKLIST

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Abstract
The protocol for the International Network on Appropriate Technology (INAT) defines the objectives and methods of globally sustainable and equitable technology. This essay provides a checklist for INAT members to use in assessing the merits of proposed technologies. Checklist items serve as reminders of steps to be taken while engaged in life-critical measures. The checklist focuses on three aspects of proposed projects: their rationality, ethicality, and compatibility with key features of appropriate technology. Justification for the first two sets of checklist items flows from the origins of rationality and ethicality in evolutionary processes. The rationale for the last set evolves from historical applications of appropriate technology.

INTRODUCTION

The protocol for the International Network on Appropriate Technology (INAT) defines the objectives and methods of globally sustainable and equitable technology. This essay provides a checklist for INAT members to use in assessing the merits of proposed technologies.

The checklist model derives historically from aviation [1] and more recently from hospital practice [2, 3]. Checklist items serve as reminders of steps to be taken while engaged in life-critical measures. Two points are key in using checklists. First, careful use of the checklist does not always guarantee successful outcomes. The items must be applied in the context of collective professional practices. Second, correct use of the checklist items is a matter for professional judgment rather than algorithmic rule application.

In the context of the INAT protocol, not only scientists and engineers but also social scientists, ethicists and members of the communities in which appropriate technologies are to be deployed should use the checklist for collective decisions. Where practical, social science professionals should include economists, political scientists, psychologists, anthropologists, sociologists, and social workers. Physical science specializations will vary according to the nature and environmental context of potential projects, but at the very least biologists, chemists, physicists, and environmental (including earth and atmosphere) scientists should be on call. Participation of ethicists with field experience is critical.

The checklist focuses on three aspects of proposed projects: their rationality, ethicality, and compatibility with key features of appropriate technology. Justification for the first two sets of checklist items flows from the origins of rationality and ethicality in evolutionary processes. The rationale for the last set evolves from historical applications of appropriate technology.

RATIONALITY

Defining *rationality* is the first step in constructing a checklist. Rationality is our capacity to select and carry out our goals. Before rationality became self-conscious or reflexive, goal selection and execution were automated processes. Goals unencumbered by humanity's capacity to construct mythical goals were survival and flourishing, set within the limits of the environment. Humans share these goals with other organisms.

Because our large brains have given us the capacity for massive abstraction and imagination, we can now change the environment to suit our goals in ways that other animals do not. Our rationality now includes not only goal selection but the capacity to alter "naturally ordained" goals through rationality's reflexive function.

Like language [4] and morality [5], rationality is both genetically and culturally endowed. As humans are capable of speech and moral behavior, so they are also capable of expressing rationality in the form of science. Here I use *science* in the sense of abstracting from experience to form guiding generalizations. (*Experience* includes mental as well as sensory phenomena—even the most theoretical mathematics is, after all, an experience.) As those generalizations begin to conform more precisely to the constraints of rationality itself, science begins to take on its modern mathematical form.

Rationality's constraints follow from its evolutionary function. The complex brain and its capacity for imagination and abstract thought augment our capacity for survival. A brain mapping and basing its behavior on selected patterns in its environment has a better chance of survival than an organism that reacts "blindly" to its circumstances through chemical signals or purely automated stimulus-response mechanisms.

Humans are gifted with the ability to externalize their mapping functions through the use of symbols. Symbols express their own survival capacities by triggering emotional responses that move us to replicate them—the memetic process. Symbols have emotional as well as semantic and syntactic meaning. We select symbol sets, theories, in part by reason of their capacity accurately to reflect our experience. Culture, education, and other experiences shape our rationality.

RATIONALITY CHECKLIST

Item 1: Semantic And Emotive Meaningfulness

We are prompted to ensure the emotive, semantic, and syntactic force of the symbols we use to "re-present" experience (the first presentation was through the senses). Symbols used to present candidates for appropriate technology must in their net effect be emotionally compelling. Their semantic meanings, the networks of relations that tie them to experience, must be clearly understood. The ambiguity of symbols flows from their very etymology: "symbols" are literally "throwings together." Symbols acquire their meanings through (initial) acts of choice. The nature and limits of choices of symbols must be continually reviewed.

Item 2: Correspondence Between A Technology's Theoretical Aspects And Its Tested Results

Every proposal for an appropriate technology is conveyed through symbols, whether they are elements of ordinary spoken language or graphic representations such as blueprints. Those symbolic representations of a technology and its predicted consequences must be carefully mapped onto experience. The correlation of symbolic representation and experience is enshrined in what is called the correspondence theory of truth. One of the primary functions of the brain is to establish correlations between its states and those of the environment.

Item 3: Non-Contradictory Character Of A Technology's Theoretical ElementsA third prompting insists that theoretical proposals for appropriate technology cannot offer contradictory representations of experience. The primary instrument of rationality is reason. Reasoning most simply defined is the process of connecting experiences by means of abstract patterns. It would be "irrational" to claim that a thing "x" is connected to something else "y," and at the same time in the same way is not connected. This "law" of non-contradiction is so important in the history of thought that it serves as the foundation of the coherence theory of truth.

Item 4: Practicality or Effectiveness Of A Technology
A technology that cannot execute the purposes for which it is designed is an unacceptable project. Thinking itself has evolved by reason of its practical nature. The practicality of proposed projects is enshrined in the pragmatic theory of truth. This theory holds that it is never possible to know the truth in any absolute way. The best we can achieve is to hold beliefs that yield the consequences we aim to achieve.

Item 5: Widest Possible Application Of A Technology
A fifth prompting demands that proposals for appropriate technology have the widest possible application. A technology that can perform multiple functions is to be favored over one that can execute a single function, other things being equal. This prompting follows from the conviction that our theories or technical proposals should cover the widest possible range of experience. The evolution of computers from calculating machines to multi-tasking devices is an example of this principle in action.

Item 6: Simplicity Or Economy Of A Technology: "Doing The Most With The Least"
A sixth prompting is the truest test of the intellectual power of a technology proposal: KISS, or Keep It Simple, Solomon. An engineer who can streamline a device so its every part is indispensable to its function is simply a genius. Thinking is itself the art of abstraction. Abstraction in its original sense is literally a "pulling apart" of a pattern from an experience. The simpler the pattern, the higher its degree of abstraction. The test of a pattern's simplicity is the number of symbols required for its representation. The fewer symbols required for a proposal's representation of experience, the more abstract the proposal.

Item 7: A Technology's Capacity To Stimulate Reexamination
The seventh and final prompting springs from the conviction that no matter how good a technology is, there must be some way to improve on it. Technologies that by their very nature induce us to rethink the ways we think exemplify this checklist item.

APPLYING THE CHECKLIST: RULES NOT INCLUDED!
None of the seven items on the rationality checklist are "make or break" items Compliance with checklist items cannot guarantee a technology's "perfect" rationality. For example, the theories underpinning a technology may be false, even if the technology itself works perfectly well. A proposal to drain a swamp to stop malaria's spread might follow from the hypothesis that "bad air" (the roots of the term *mal-aria*) is the cause of the disease. If the swamp is in fact the exclusive breeding ground of the anopheles mosquito, the technology would be practical. But the underlying theory would be false.

Rationality is a function of connectivity. The rationality of a technology can be measured by the numbers and kinds of connections that issue from its guiding principles. A technology may fit several items on the checklist and fail utterly on others. The items are intended as reminders rather than as strict rules for a technology's compliance. Particular evaluation metrics may not be pertinent in some cultural contexts and applications [6].

ETHICALITY

Ethicality first requires its own definition. *Ethics* has acquired the sense of a field distinct from morals. *Morals* refers to behavior that is customary or acceptable in a given society. *Ethics* means the study of morals and more deeply the study of value itself. What is valuable is what is desired or, more strictly, what is desirable given some set of fundamental assumptions.

At its most basic level, ethics considers appropriate mechanisms for choosing principles or values to guide our lives. Rationality and ethicality are analogous in the sense that both are complex phenomena that cannot be given a single-factor analysis. Both are indispensable for choosing the directions of our lives. We draw an analogy between tests for rationality and ethicality. Just as rationality cannot have a single defining criterion, so ethicality is expressed through a basket of values.

Philosophers like Plato, Aristotle, and Kant have exaggerated rationality's importance, declaring it to be the primary human value. However, rationality itself depends on our survival for its exercise. Pleasure also drives us toward survival, as do love, caring, and community bonding in our lives. Freedom, happiness, and meditation as well are close allies of survival. Nevertheless, survival cannot be given a role as the preeminent value because many humans whom we respect and cherish over the ages have sacrificed their own survival for the sake of values they deemed more important than survival—love in the case of Christ, duty for Socrates, *satyagraha* for Gandhi.

Item 1: Survival

Does the proposed technology promote the survival of those for whom it is intended? Over the past five thousand years of recorded human experience, no debate has been more contentious than the question of an ultimate value: does some single value serve as the foundation for all other values? The most brilliant philosophers have proposed a wide range of answers to that question. One fact overrides all ethical controversy: to be good is first of all to be. Unless we exist, unless we survive, all reflection on value is impossible.

Item 2: Flourishing Or Happiness

Does the proposed technology promote the flourishing of those for whom it is intended? The concept of "flourishing" takes its meaning from biology. We speak of organisms as flourishing if their basic needs beyond mere survival are met. The conditions for basic human survival are air, temperature control, hydration, nutrition, health care, and education. Given the prospect of global climate change, we must deploy technologies that are additive with respect to the environment (cf. the cradle to cradle configuration of industrial ecology, McDonough and Braungart [7])

Item 3: Rationality

Does the proposed technology execute the seven checklist items for rationality in the most appropriate ways? From the vantage point of evolution, rationality is the instrument that has driven the human population from a handful 200,000 years ago to nearly 7 billion strong today.

Item 4: Community Solidarity

Does the proposed technology promote community solidarity in the best possible ways? Philosophers like Mo-Ti and Christ in East and West Asia have claimed that love or the bonding power of any community whether large or small is the primary human objective. From an evolutionary viewpoint, humans are incapable of surviving without community support.

Item 5: Freedom Or Creativity

Does a proposed technology enhance the freedom of the communities in which it is to be deployed? Here we use the term *freedom* to mean "freedom of choice." We have choices because of our rationality, our power to abstract from unique experiences to form generalizations. Generalizations allow us to predict and thereby control the future. From an evolutionary point of view, freedom as the ability to create variation in our lives is a primary guarantee of our survival.

Item 6: Pleasure

Does a proposed technology enhance the pleasure of the communities in which it is to be deployed? We can give an evolutionary explanation of pleasure by saying it is the driving mechanism that points us in the direction of the behaviors necessary for the survival of the species.

Item 7: Meditation Or Contemplation

Does a proposed technology enhance the capacity of its users to think about their thinking? Central and East Asian cultures affirm that meditation is a primary value. Meditation is perhaps best defined as the control of the attention by the attention. Our survival depends on paying attention to the right thing at the right time. Organisms that can control their attention through rational reflection can exert some measure of control over their survival

APPLYING THE CHECKLIST: CAN ETHICAL VALUES BE RANKED?

The separate checklist values have their champions in the history of philosophy. Each great philosophical tradition makes a case for a single value's having overriding status. Can these disparate values be ranked or does each hold an independent status, as is the case with the basket of values comprising rationality? Survival may under certain circumstances trump all other values—particularly for communities or for the whole earth population when survival is at risk

APPROPRIATE TECHNOLOGY EVALUATION AND IMPACT ASSESSMENT

Appropriate technology has been a contentious issue since Schumaker [8] decried mega-projects as the only route to improving the quality of life in the "third" worlds of the sixties. Developing the concept that "small is beautiful," he focused on community level needs. He proposed small scale, affordable technologies that would have an immediate impact on improving the health and well being of under-developed communities. Rybczynski [9] and others have debated appropriate technologies' contributions to sustainable development. While appropriate technology is not a panacea, it has demonstrated its potential to improve the quality of life when developed with community members as key players throughout the process.

In this community development context, it is important to frame a set of questions that help evaluate the effects of a proposed technology. These questions should set a standard comparable to the environmental impact assessments that are now *de rigueur* for the implementation of any project. The questions must not be restricted to any particular set of issues. This open-ended approach will ensure that all issues that may be important in any given application context will be considered. Table 1 lists a sample set of questions.

TABLE 1
Checklist for Appropriate Technology Evaluation and Impact Assessment

1. **Does the project require small or large amounts of capital?**
2. **Does the project emphasize the use of locally available materials?**
3. **Is the project going to be relatively labor intensive or is it going to be capital intensive?**
4. **What is the scale and affordability of the project/technology? Can individual families in the community afford it?**
5. **Does the context of the project require a scale that is local or global?**
6. **Is the project/technology understandable without high levels of training? Can it be controlled and maintained by local community members without specialized education?**
7. **Can the technology be produced in villages and/or small shops?**
8. **Will the project contribute to community members working together to improve the quality of life/standard of living?**
9. **Does the technology/project process include local communities in technology/project innovation, modification and implementation?**
10. **Is the technology adaptable and flexible? Can it be adapted to different places and changing circumstances?**
11. **Will the technology/project have an adverse impact on the environment?**
12. **Is the technology/project sustainable, both with respect to the environment and to technology repair and replacement when and if skilled professional support is no longer available?**
13. **Does the project/technology offer the opportunity and have the potential to enhance local, national, and global justice and equality?**

The rationale for appropriate technology assessment springs from several perspectives. First and foremost, appropriate technology permits local needs to be met more effectively as community members become involved in identifying and addressing local community needs. Appropriate technology also implies that tools are developed to extend human labor and skills within the community, not to replace or eliminate them.

Furthermore, appropriate technology, relying on local materials and skills, represents a scale of activity that is comprehensible and controllable at the community level. Appropriate technology permits a more economical technology development and implementation process by eliminating long-distance transportation costs. In the same vein, it makes expensive, and sometimes unavailable, financial, transportation, education, advertising, management, and energy services unnecessary.

With its emphasis on empowering local communities, appropriate technology helps establish a self-sustaining and expanding reservoir of skills within the community it seeks to serve, thus lessening economic, social and political dependency.

Appropriate technology is always situation-specific, depending on local community desires, geography, culture, location, availability of materials and other factors. Economic considerations are also critical. Judging appropriateness must reflect overall costs and benefits, including beneficiaries and payees.

However, non-economic criteria must play a large role in choosing appropriate technologies. The empowerment specified in the INAT protocol demands that technological choice be localized. And caution must be exercised with respect to institutional prejudices influencing technology choices.

*Portions of paper adapted from Verharen 2008, 2006.

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Placer Mining and the Guyana Environment

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Key words: placer, sluicing, tailings, solid waste and sanitation, process, reclamation.

Abstract
This paper is prepared by a Director on the Board of the Guyana Geology and Mines Commission (GGMC) based on his visits to gold and diamond mining operations in rivers and riversides in Guyana. Gold mining is an important source of income for small and medium scale producers and the nation. The paper gives an overview of gold mining operations, challenges and the approach to solutions to these challenges. This includes a discussion of tailings management; solid waste management and sanitation; process improvement; reclamation. The international call to desist from the use of mercury gives rise to the need for greater consideration of all factors that lead to sustainability. Greater collaboration between West African and Guyanese miners is recommended based on shared geological history when millions of years ago the Precambrian Shield of Guiana and south West Africa was one land mass.

INTRODUCTION
One of the most striking physical features of Guyana which occupies the North Central corner of South American is its rivers. Most of Guyana's main rivers either flow East such as the Potaro, Mazaruni and Cuyuni rivers; or they flow North such as the Essequibo, Demerara and Berbice rivers. Geologically, Guyana is on the northern province of the Amazon Craton or land mass.

Gold is a heavy mineral with a specific gravity of 19.3. It occurs in all of Guyana's rivers that flow east from the Pakarima Mountain range to the Essequibo River - notably the Potaro and Mazaruni rivers and their tributaries. Placer deposits are observed on most of the main rivers draining the greenstone terrain which hosts the majority of the primary gold. Lode gold is frequently found in Precambrian terrains [1]. The Precambrian rocks are meta-volcanic and meta-sedimentary. A compilation of 135 types of deposits worked and observed in Guyana by Bernard (1990) showed that within the major gold occurrences in parts of Guyana (Barama-Mazaruni terrain):

40% of the mineralised area lodes are within greenstones and meta-sediments
30% of the in-situ deposits are near granite-greenstone contact zone
20% of the placer deposits occur over greenstone regions
10% are in other deposits including alluvial deposits and lodes in granitic and gneiss rock [2].

Guyana's rivers became waterways for gold-seeking 'pork-knockers' (small scale operators working cooperatively) immediately on Emancipation of African slavery in 1838. Hassan Arero, Curator, Africa, Oceania and the Americas Collection, British Museum mentions how highly gold is esteemed by Africans not only for status and wealth but also as a symbol of mental, physical and spiritual protection. Guyanese esteem gold similarly – protection, wealth, status, power, and bonding of the genders [3].

Guyana has six mining districts. W. T. Dalgety was appointed on February 26, 2004 to be a Director on the Board of Directors of the Guyana Geology and Mines Commission (GGMC). He then began visiting gold and diamond works of native miners. He has visited operations at Frenchman Creek, Mahdia and Omai in Potaro Mining District #2, Puruni, Oranapi and Aruwai in Mazaruni Mining District #3, Groete River and Aurora in Cuyuni Mining District #4, and Purple Heart Gold Mine in Arakaka in North West Mining District #5.

This paper presents an overview of gold mining in Guyana, some challenges caused by mining operations and the numerous ways these challenges are being addressed. This includes a discussion of tailings management; solid waste management and sanitation; process improvement; reclamation. The basis for establishing relations with West African gold miners is also discussed.

OVERVIEW of GOLD MINING IN GUYANA

Figure 1, Cutterhead

ile)

In Guyana, gold is mined by two methods: river dredging and land dredging. River dredging technology is described as cutterhead, suction, and missile. All three employ the force of suction to transport gravel from river bed to the surface for processing. Cutterhead is a mechanical cutter used to disintegrate compacted gravel before it is sucked to the surface (figure 1). Suction dredging involves a diver on the river bed with flexible hose to suck up loose gravel, sand and mud. Missile dredging uses a diver-less nozzle to suck up unconsolidated gold bearing gravel (figure 2). Land dredging technology is subdivided into a) hydraulicking (or jetting), b) dry mining. Dredge sizes range from 3 inch to 14 inch and this represents the diameter of the gravel pump feeding the ore to a sluice box. The popular size is the 6 inch. The process technology used to recover gold by either river or land dredging is called sluicing.

River Dredging:
A river dredge is a floating gold processing plant. First, a pontoon is constructed of wood, empty oil drums, or steel. The pontoon supports equipment. The essential equipment is a 6-cylinder engine, an impeller pump, cutterhead, suction nozzle, or missile nozzle, a sluice box fitted with fur mat, expanding metal and magic mat, a lavador, a battel, a gold retort, a gold scale and mercury. Nearly all river dredges are designed and fabricated in Guyana. In addition to the essential equipment, the pontoon supports kitchen and living space for workers.

In river dredging, the 'tailings' is deposited into the river. However, direct discharge of tailings into a river or creek without the permission of the Commissioner of the GGMC is an offence because this redistribution of tailings can cause navigational problems if not adequately managed. The critical turbidity of a river in Guyana is 30 NTU (Nephelometric turbidity Unit). However, "operators shall ensure that discharge from a tailings pond or a dredge into any river or creek shall not exceed 100 mg/L or 50 NTU," Reg.240 (3)(b)(i) and (ii)/2005 [4].

Land dredging:
Hydraulicking (or jetting) operation: The essential equipment in hydraulic mining (jetting) is two 6-cylinder diesel engines, a gravel pump, a pressure pump, hoses, a sluice box fitted with fur mat, expanding metal, and magic mat, a lavador, a gold scale, a battel, a gold retort, and mercury [5].

Two engines are used in this method of mining. One engine is used to pump water from a river, creek or stream to the mining site and the other engine is used to suck ore from a sump called the "marack hole" to the sluice box. With one engine, high pressure water jets are directed to the gold bearing earth. These jets disintegrate loose material like sand, loam, clay and gravel making it "slurry". This slurry is channelled into the "marack hole". From there, the second engine with the gravel pump "sucks up" the slurry onto the Sluice Box where the gold is trapped. The washing cycle called "wash down" follows.

Dry mining operation: Dry mining equipment includes excavators, bulldozers and loaders. Excavators and bulldozers are used to transport the gold bearing earth towards

	Surface Grading (Gold)
1.2m	Grading Gravel (Gold)
1.8m	Sandy Gravel (Gold)
2.7m	Formation of fine Stringers (Gold)
6.1m	Large Stringer Formation mixed with a Black rock that has gold. The stringer stones are good for crusher.
12.2m	Large Brown & white reef stones (very wide) - these are the ones broken with sledge hammers for the mill.
18m	Below 18m there is a yellow rock which is the real pay (3-4 dwt per battel)
30m	Presently Purple Heart (May) is about 30 meters deep. At this dept GGMC says it`s too dangerous for hydraulicking (Jetting).

Figure 3, Profile of the claim "May" (Purple Heart)

the "marack hole". This mining method allows for several choices because not only loose material is mined but also indurate cemented material. A profile of the Purple Heart mine which includes "hard rock" dredge mining is shown in figure 3. The Higgins family who own Purple Heart Mine in Arakaka, Mining District #5, has overcome several challenges since 1983 when the mine began production. There, gold was recovered from within the first two feet of the ground, then in the sand, gravel, saprolite, and indurate cemented rock. Stone was broken by men using sledge hammers. A hammer mill is employed to crush stones and extract gold from them.

In other dry mining processes different from Purple Heart, the pay gravel is generally stockpiled and washed into the "marack hole" via a washing plant. Washing plants are vibrating screens fitted with transverse jets or jetted manually by miners. A back hoe feeds the screen with pay gravel. The washing plant is normally very near the "marack hole". After this stage is the sluicing operation.

Sluice Box Processing i.e. "wash down": Since the 1850s, sluicing has been the preferred method of capturing gold in Guyana. According to Karen Livan, "The sluice box is essentially an open section of a box with a sloping channel and some form of riffling or matting to collect the concentrate. Sluice boxes are of low capital cost and require low operating costs and simple to construct. The gold is trapped on the matting at the bottom of the sluice box. A pre-concentrate from the sluice box is gained by washing the mats in water and collecting the concentrate in a container. The pre-concentrate from the sluice box is further upgraded using a battle or gold pan" [6]. The concentrate from the gold pan / battel is upgraded by amalgamation with mercury. The final concentrate which is amalgamated gold (amalgam) is then transferred to a cotton cloth. The cloth is squeezed to recover excess mercury leaving the amalgam. The squeezed amalgam is transferred to a retort and heated to recover gold as a residue.

CHALLENGES and DISCUSSION OF APPROPRIATE SOLUTIONS

In land dredging where ancient river beds are mined with water in a tropical rainforest environment there are many challenges. Karen Livan wrote, "In a small scale operation alone, a single land dredge in Guyana moves about 130 tons of material daily. At about 1000 operating dredges in the country, about 130 million tons of alluvial is moved daily during the mining of gold and diamonds. At most of these operations, often there are no adequate tailings management plans and hence much of the fine particles from the materials moved by the dredges end up in the creeks, streams, and rivers".

The challenges caused by handling and processing such large quantities of mud, sand and stone for gold include siltation of rivers, turbidity of waterways, navigational problems and mercury contamination of potable water. These may result in depletion of fish stock and diseases. The responses to these challenges are proper tailings management, proper solid waste management with enforceable sanitation regulations, improved processing and retorting, and reclamation. Urgently, sustainability has to be the watchword to ensure livelihoods are sustained while wealth is pursued.

GGMC is working towards sustainable mining. GGMC describes sustainable mining as "present mine development that does not compromise the resources that are available to present and future generations" [7]. GGMC identifies elements of sustainable mining to include: exploration, feasibility study or assessment, environment and social impact assessment for large scale mining operations, environmental management systems for large and medium scale operations, mine planning, environmental management planning, mining with environmental management, mine site reclamation and closure".

The mineral licence holder in Guyana sets up operation to make money. Unless he/she is made aware and convinced of the short and long term social and environmental dangers based on traditional practices, and made to consider them, he/she would cut corners for an extra dollar. Licence holders need to be persuaded to want to change. The regular science and legal staff of GGMC cannot systematically monitor practises at all locations. In 2002 there were about 1000 operating dredges but by the end of 2009 the number had increased to about 2400. Visits made by W. T. Dalgety reveal the need for improvements in tailings management, solid waste management and sanitation, processing and retort technology and reclamation.

Tailings Management: Tailings discharges for more than 2000 operating dredges places an environmental stress on Guyana's waterways. In 2008 a mining manual was prepared and distributed by Guyana Environmental Capacity Development (GENCAPD) giving a guide to water management, pond development and design features, self-monitoring and guidance on how to make and use a simple turbidity tube for water quality testing [8]. The Mining (Amendment) Regulations 2005 spell out requirements for managing tailings, turbidity including daily monitoring of turbidity of tailings discharge. Tailings should not be directly released into streams, creeks and rivers unless the Total Suspended Solids (TSS) is below 100mg/l. Suspended solids absorb heat from sunlight making the waterways warmer – thus reducing the oxygen available for living things. Suspended solids can also destroy the habitats of spawning fish and pose severe hardships for communities that live down river from mining communities. Many Small and Medium Scale miners must be commended for the innovative ways to successfully contain and clarify tailings and recycle tailings water. This includes use of sand bags, setting up silt fences and planting on the silt fences. Some recommendations of the 2008 manual have been used at Gloria Creek in Potaro Mining District#2 and have caused a reduction of pollution levels by approximately 40%.

Solid Waste Management and Sanitation: Lack of solid waste management and inadequate sanitary facilities exposes miners and visitors to an unhealthy camp environment. Many camps do not have sanitation facilities or solid waste disposal pits. There is need for community mass education to allow all the population to understand the dangers of poor sanitation. Many young persons leave the cities and villages to get quick money in the mines. They rarely stay beyond a few months. One assumes that if sanitary conditions were better, family members could visit camps thus causing greater stability of the work force. Better waste management could also release space for games and recreation.

On June 30, 2010 W. T. Dalgety wrote the Hon. Prime Minister of Guyana Samuel A. Hinds who has responsibility for GGMC and the mining sector. The letter describes conditions concerning water and sanitation observed at two miners' camps in Groete River on the 22nd June 2010. Dalgety wrote, "I walked around two camps. The water for both locations was pumped from Groete River. The sanitary conditions at the camps were unacceptable. Toilet facilities are non-existent. Garbage is strewn in the surrounding space. This space is adequate for recreation after work if solid waste management is employed. Dalgety noted that there was an abundance of water but little was directed towards recreation and sanitation. We must insist and regulate mining camps to be fit for grandmothers in the march of progress".

The letter also went on to state that "it should not cost a licence holder G$100,000.00 (US$500.00) to install a modern toilet that can be moved from one camp site to another" and it ended by stating that "many licence holders visit their properties but consider it unimportant to improve conditions under which their male miners work. It is our concern in the peopling of our country"[9].

The Prime Minister fully supported the thrust of the letter. His response was that "camps can and ought to be improved – visits of family members of workers in the camps should be facilitated". He was "100% in agreement" that modern toilets should be installed at camp sites to accommodate significant females. Improved sanitation in mine camps was addressed by a GENCAPD draft proposal in early 2010. The design of GENCAPD toilets for adaptation by miners (Figure 4) was recently posted at main mining locations. These toilets could be erected at an estimated cost of about G$125,000.00 (US$625.00) [10].

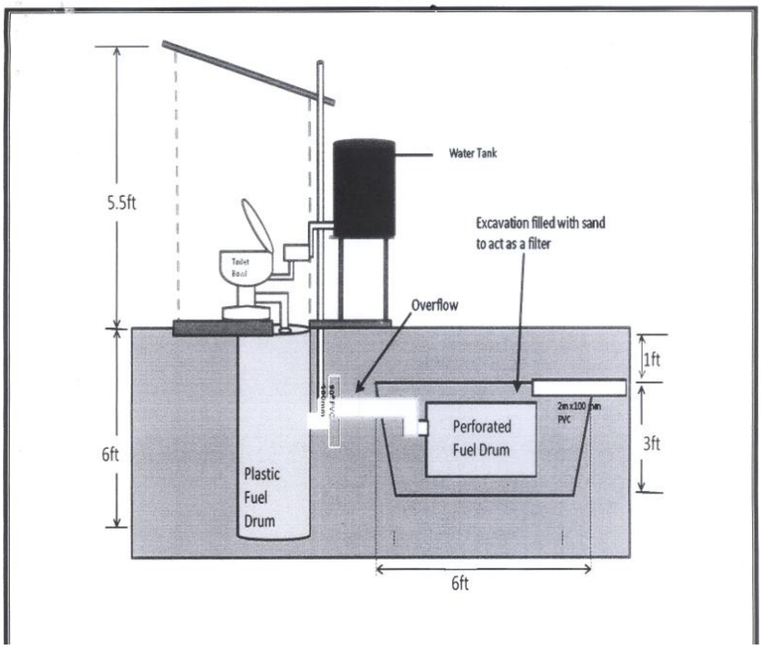

Figure 4, Flush Toilet Design for Miners

Process Technology: Improvements in process technology will help to reduce waste and the level of contaminants entering the environment. The Shaking Table fed by a Vibrating Screen process to optimize gold recovery without mercury use is being demonstrated in mining districts throughout Guyana. Other equipment beyond the sluice box used to increase recovery of gold includes the pinched sluice (called "warrior" locally), centrifugal concentrators, and jigs. Although these technologies are in use by some miners they are not in widespread use. A closed retort system should be the norm. In this system mercury vapour is captured during the final processing stage and recycled. This ensures that mercury is not being released to the environment.

Reclamation: GGMC recognises that successful reclamation of mined out areas provides the best legacy the gold mining industry can leave for future generations of Guyanese. Reclamation was successfully demonstrated at some mined out areas where pastures for small ruminants, lime, acacia and fast growing Paulownia trees were established. The Paulownia could be harvested for timber, energy, paper pulp and forage as a second career for ex-miners. Reforestation of mined out sites is consistent with Guyana's Low Carbon Development Strategy (LCDS) as it increases standing forest while rehabilitating sites disturbed by mining. GGMC has a plant nursery at Mahdia, Potaro mining district #2, providing seedlings for mine site reclamation.

GUIANA and WEST AFRICAN MINERS COLLABORATION

Written in the GGMC 'The Mining Sector In Guyana 2010' report is the following: "Guyana lies within the Amazonian Craton. The Amazonian Craton is subdivided into two geographic shields, the Guiana Shield in the north (in which Guyana is situated) and the Central Brazil (Guapore) Shield in the south. The Amazon Craton shows striking similarities to the West African Shield. Both connected and formed part of a larger continent, prior to the opening of the Atlantic during the Mesozoic period".

With this similar geology, figure 8 shows a number of gold mines and gold occurrences in Venezuela, Guyana, Surinam, French Guiana, Ghana, Guinea, Mali, Burkino Faso, Ivory Coast, Liberia, and Nigeria [11]. Small and Medium Scale miners of all these countries should associate and take advantage of their endowment. The heritage of courage and motive to search for gold needs accelerated action to be more affective and beneficial to the African Diasporas in gold mining. A congress jointly organised by Guyana and West African mining associations should be held as soon as possible to address this goal.

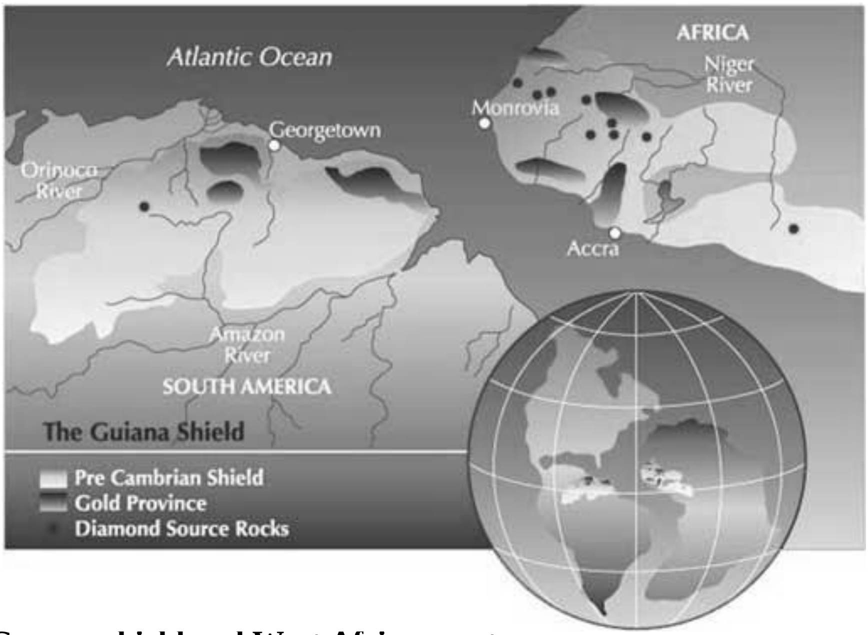

Figure 8, Guyana shield and West African craton

CONCLUSIONS and RECOMMENDATIONS

1. GGMC is moving generally in the right direction in terms of tailings management; solid waste management and sanitation; improved processing and retorting; and reclamation.
   Academically capable Guyanese should perceive a career as miners. Two-thirds of gold mining is done by persons with little secondary education and technical training. This needs to change. A lot more has to be done in the education of miners. In addition to mining manuals other means should be made to educate miners in the basics of tailings management, solid waste management and sanitation, processing including retorting and reclamation.
2. A lot more has to be done with respect to collaboration among West African gold miners and African gold miners in the Diasporas – in Guiana and Guyana particularly.
3. A West Africans in the Western Hemisphere conference in mines management should be held as soon as possible.

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HOUSEHOLD WILLINGNESS TO PAY FOR IMPROVED SOLID WASTE MANAGEMENT IN OSUN STATE, NIGERIA

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Key words:
willingness to pay, solid waste, improved service, Osogbo metropolis

Abstract
Environmental quality value can be estimated from what people are willing to pay (WTP) to improve or to restore their environment, using valuation techniques which measure peoples' preferences. The study examined the general features of the existing solid waste management, household willingness potential for improved waste disposal, identified the socio economic variables and other factors influencing WTP for improved waste disposal services. Primary data collected from 120 households in Osogbo metropolis, was analysed using descriptive statistics and logit regression model. The result reveals that 65 percent of the respondents are male while 67 percent are married with an average household size of 4 members. Majority of the respondents are in their active age with mean age of 42 years. Most of the respondents have formal education, the average years of education is 5 years. Fifty-three percent of the respondents are engaged in the civil service as their primary occupation. About 37 percent of the households dispose their solid waste through burning, while 60 percent claim to dispose off their waste on a weekly basis. Irrespective of non-reliability of waste vendors, 52.5 percent of the respondents paid between ₦400- ₦600 monthly to dispose waste. Majority of the households (87 percent) are willing to pay for improved waste services while most of the respondents will be willing to pay less than 5 percent of their monthly income on waste management services. The logit result reveals that sex, household expenditure and years of education are statistically significant at 10, 5 and 1 percents respectively while other factors are insignificant statistically. It was recommended that programmes that will facilitate investors (private sector) in waste disposing be initiated while payment for this service should be made affordable to encourage those households that are willing to pay.

INTRODUCTION

Solid wastes by definition include refuse from households, non-hazardous solid waste from industrial and commercial establishments, refuse from institutions market waste, yard waste, and street sweepings [7 and 4]. Broadly, Household wastes otherwise known as residential or domestic wastes are made up of wastes that are consequences of household activities. These according to [6] include food preparation, sweeping, cleaning, fuel burning and gardening wastes old clothing, old furnishings retired appliances, packaging and reading materials, and where diapers or bucket latrines are used, household waste include faecal material.

In Nigeria, many metropolises are faced with the problems of rapid expansion due to population increase and this, no doubt, brought increasing strain on urban infrastructure facilities. One area in which this strain has become obvious is in waste management where the existing system appears to be incapable of coping with the heap of waste generated on daily basis. The urban centers are experiencing an increased rate of environmental deterioration, with refuse dumped along drainage channels. Most cities in Nigeria are faced with waste management problems, and Osogbo is not exempted.

Attempts have been made by scholars, researchers, consultants and government to determine the actual amount of waste being generated in Nigeria in general [3]. In a survey carried out by [6] on waste generation in Nigeria. The study shows that the volume of wastes generated by all the states increased over the period between 1994 and 1996. It was estimated that by the year 2010, Nigeria will generate about 3.53 million tonnes of solid waste, based on a per capita solid waste generation of 20kg per year [3].

Nigerian cities have been described as some of the dirtiest, the most unsanitary and the least aesthetically pleasing in the world [4]. This is because some individuals are dirty, this evidence can be seen everyday by way of indiscriminate discharge of garbage into drains and the highways. About 75 percent of solid waste collected in most Nigerian cities is disposed in open dumpsites. This method which is rampant is improper as it is not aligned to the sanitary landfill recommended. It marginalizes the urban environment as a result of the negative externalities it generates [17 and 2]. In corroborating this assertion, [6], stated that the decomposition of wastes on dumping grounds emit intolerable smells and attract potential diseases. The dumpsites, which are poorly maintained, are also a source of pollution and a cause of poor urban aesthetic [6].

The economic importance of waste management on the quality of life cannot be over-emphasised. Wastes that are not well managed can affect the environment in terms of the contamination of the atmosphere, soil and water. This can cause severe problems for humans and animals population. It can also affect human health in particular by causing convulsion, dermatitis, irritation of nose/throat, anaemia, skin burns, chest pains, blood disorders, stomach aches, vomiting diarrhoea and lung cancer which may lead to death [4]. It is worthy to note that it breed flies (which carry germs on their bodies), mosquitoes, and rats which aids salmonella, leptospirosis and other diseases they cause by biting and spoiling millions of tons of food. Lastly, is the social effect where flood may occur as a result of dumping of refuse in drainage especially during the raining season; an example of this is the recent flood which happened in late July 2010 in Osogbo metropolis. Lives and properties worth millions of naira were lost in this July flood [10].

Problem Statement.

Collection of waste used to be the responsibility of municipal authorities in the past [9], hence, waste collection is a service for which local government is responsible [7]. In short, waste collection is the constitutional responsibility of the local government. This responsibility is not mutually exclusive, because, there is no local government area in Nigeria that can afford the huge financial, technical, administrative and human resource requirements to effectively carry out this constitutional responsibility [4]. The collection of solid wastes in many Nigerian cities has always until very recently, been dominated by government agencies; it has been concluded that it is the responsibility of government to solve the waste collection problems, as part of government obligations to the citizens.

An explanation for the inability of the government to manage solid waste collection effectively arose perhaps from the misconception of this task as a public good. Irrespective of the fact that government gave waste collection a priority in their development objectives, their ability to curtail the problems of waste collection deteriorates with time, due to rising capital costs for plant and equipment, increasing operation and maintenance costs. Considering the rapid spatial and population growth of most urban areas with decreasing coverage levels, and with increase in level of waste generated, confronted by increasing public demand for improved services [12 and 13], the need arises for the involvement of the private sector and the civil society in the provision of municipal solids waste service. It should be noted, however, that it is only in the large urban centres of Nigeria e.g. Lagos, Ibadan, Warri, Suleja amongst others that the activities of formal private sector are recorded [4]. In majority of the secondary cities such as Osogbo, they are neither totally absent or being substituted with the informal refuse collectors such as cart pushers. This therefore gives rise to the need to evaluate the household willingness to pay for improved solid waste disposal services in the study area. Specifically the study examined the general features of the existing solid waste management, household willingness potential to pay for improved waste disposal, identified the socio economic variables and determine the factors influencing WTP for improved waste disposal services.

Methodology

Data collection and sampling technique: The study was carried out in Osogbo metropolis. Osogbo is the capital city of Osun State, Nigeria. It is therefore a centre of administration. Two major local government areas (LGAs) are located in Osogbo namely Olorunda LGA and Osogbo LGA. The third, however, is Egbedore LGA having about two-fifth of its land coverage within the Osogbo metropolis. Osogbo metropolis has a population of approximately 350,000 people according to the 2006 National population census. It lies on the tropical rainforest with both favourable rainfall and adequate soil. It has an annual rainfall of about 1130mm covering a period of 200-220 days each year. The study area was selected because it is the centre of administration of Osun state and by this status has experienced expansion due to population increase.

The study used primary data. The data were collected with the use of structured questionnaires. A two stage sampling technique was used to select households used for the study. The first stage involves stratifying the entire study area into new and old areas. The study covers three locations in each of the two areas. The locations covered in the new area include Agunbelewo, Odekale and Ataoja Estate while locations covered in the old area are Oke-onitea, Jaleyemi and Dada Estate. Twenty households were randomly selected from each of the locations and this forms the second stage. A total of 120 households were sampled from both areas, i.e. sixty households from the old area and sixty households from the newly developed area.

Descriptive statistics such as frequency distribution tables, mean and standard deviation were used to analyze the socioeconomic characteristics of the respondents. The logit model was used to determine the mean willingness to pay for improved waste disposal service by households. The logit model which is based on the cumulative probability function was adopted because of its ability to deal with a dichotomous dependent variable on a well established theoretical background. Logistic regression, according to [11] is a uni/multivariate technique which allows for estimating the probability that an event will occur or not through prediction of a binary dependent outcome from a set of independent variables. The model specified by [8 and 15] was adopted for this study as used by [5] in a study on willingness to pay for improved conservation of environmental species in the USA and [17] on willingness to pay for improved household solid waste management in Ibadan North Local Government Area, Oyo State.

Willingness to pay(WTP) of the households for improved waste disposal services

The logit regression model specified below was used to obtain the willingness to pay of the households for an improved water supply. The coefficient estimates obtained were then used to calculate the mean willingness to pay of the households as used by [1].

$$P_i = E(Y = 1/X_i) = \frac{1}{1+e^{-(\beta_0+\beta_1 X_i)}} \qquad ---1$$

Where P_i is a probability that $Yi = 1$

X_i is a set of independent variables

Y is dependent variable

$ß_0$ is the intercept which is constant

$ß_1$ is the coefficient of the price that the households are willing to pay for improved water supply

Mean willingness to pay for improved waste disposal by households was calculated using the formula derived by [3] and given as:

$$MeanWTP = 1 * In\ \frac{(1+\exp^{\beta_0})}{/\beta_1/} \qquad ---2$$

where $ß_0$ and $ß_1$ are absolute coefficient estimates from the logistic regression and the *Mean WTP* is the mean for the improved waste disposal by households.

Factors influencing willingness to pay by household: To identify the factors influencing willingness to pay for improved waste disposal by households, the household responses to the WTP question was regressed against the households WTP potential and other socioeconomic characteristics of the household. The regression logit model is specified as:

$$Y = \frac{1}{1+\exp^{z}} \qquad ---3$$

Where Y = responses of household WTP which is either 1 for Yes and 0 for No

$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 .... + \beta_7 X_7$

$Z = ß_0 + ß_1 X_1 + ß_2 X_2 + \ldots\ldots\ldots\ldots\ldots + ß_7 X_7$

X_1= Sex (Dummy: Male=1, Female= 0)

X_2 = Age (yrs)

X_3 = Educational level (number of years spent in the school)

X_4 = Marital status. Dummy variable (married =1, single=0)

X_5 = Household size (number)

X_6 = Percentage WTP from income (number)

X_7 = Household expenditure (₦)

The pseudo-*R* square and the chi-square were used to measure the goodness of fit of the model and the significance of the model used.

Discussion of the Results

The socio economic characteristics of the respondents are presented in table1. The male accounted for 65 percent while 35 percent were female. The high percentage of the male is as a result of sampling of the household heads. The proportion of the married in the study area is 67 percent which may therefore encourage the willingness to pay for improved solid waste considering the volume of waste from members of the household. The household size distribution showed that 70 percent of the respondents have between 1-5 household members while only 5 percent represent those that have above 10 members. The mean household size of the respondents is 4 members. The age range with the highest frequency is 41 – 50 years which accounted for 35 percent of the respondents while those above 60 years accounted for 3.3 percent. The average age in the study area is 42 years. This implies that respondents are in their active age and therefore can work to earn, more income which can affect their decision to pay for improved waste services.

About 10 percent of the respondents represent those without formal education while only 5.8 percent of the respondents had post graduate education. The mean years of education in the study area is 5years. This revealed that a typical household in the study area had at least 5 years of formal education. Education helps to enlighten the respondents on the need to keep our environment clean, free from germs and healthy for all. The primary occupation of the respondents revealed that 54.2 and 20 percents engaged in civil service and trading respectively while only about 7.5 percent were involved in other income activities such as transportation, attendants in eatery, fuel stations etc .

Household expenditure on food and non-food was used as a proxy for income s most respondents would otherwise not divulge the real value of their monthly income [1]. The level of household expenditure is generally low, about 51.7 percent of the respondents spent on a monthly basis about ₦20,000 or less as household monthly expenditure while about 12.5 percent spent over ₦60,000 as monthly expenditure. The average household expenditure was about ₦26,655, with the lowest and the highest being ₦6,800 and ₦108,500/month/household respectively. The result reveals the level of earnings of respondents as they are not likely to spend above their income. As the level of income increases, the probability that households would adopt improved waste disposal services will also increase.

Table I: Socio economic characteristics distribution of the respondents

Socio economic		**Frequency**	**Percentage**	**Mean value**
Sex	Male	78	65.0	
	Female	42	35.0	
Marital Status	Married	81	67.5	
	Single	39	32.5	
Household Size	1-5	84	70.0	**4**
	6-10	30	25.0	
	Above 10	6	5.0	
Age (yrs)	≤ 30	24	20.0	**42**
	31- 40	40	33.3	
	41 -50	42	35.0	
	51- 60	10	8.3	
	above 60	4	3.3	
Education (yrs)	None	12	10.0	**5**
	1-6	54	45.0	
	7-12	27	22.5	
	13- 18	20	16.7	
	>18	7	5.8	
Pry Occupation	Civil service	65	54.2	
	Farming	10	8.3	
	Trading	24	20.0	
	Artisans	12	10.0	
	Others	9	7.5	
Monthly expenditure	<20,000	62	51.7	₦26,655
	20,001- 40,000	25	20.8	
	40,001- 60,000	18	15.0	
	Above 60,000	15	12.5	

The general method of disposing waste, its reliability as well as the frequency of waste disposal is presented in Table II. The result revealed that 37.5 percent of the respondents claimed to dispose their waste through burning which helps to keep the environment clean. On the reliability of use of this method, 80 percent attested that it is a reliable means of disposing their waste. On another hand, 35 percent of the respondents dispose their waste by dumping it on the roadside, at a dump site, or a nearby bush. However, 54.8 percent of this category indicated that it was not a reliable means of disposing their waste. Twenty five percent of the respondents used waste vendor (waste collector) by paying a token to dispose their refuse, but 63 percent of this category also claimed that was not a reliable means of disposing waste because of the limited number of waste vendor. Lastly, only 2.5 percent of the respondents bury their waste in the soil and they all claimed that the method is reliable to dispose their household waste.

The frequency of disposing waste showed that while 14 percent dispose waste daily, about 60 percent of the respondents dispose their waste on a weekly basis and only 2.5 disposed occasionally. With the knowledge that keeping household waste in the house for a week long has its health implication because it can harbour germs, breed rats, mosquitoes, cause air pollution amongst others. Given this result, households may be encouraged to pay for improved, prompt and regular waste disposal through the private sector.

Table II: Method of Solid waste disposal, reliability of methods and frequency of disposal

Variable	Frequency	Percentage
Method Burning	45	37.5
Use Of Waste Vendor	30	25.0
Dump Nearby	42	35.0
Bury In The Soil	3	2.5
Total	**120**	**100**
Reliability Of Method (Yes=1)		
Burning	36 (9)	80 (20)
Use Of Waste Vendor	11 (19)	36.7 (63.3)
Dump Nearby	19 (23)	45.2 (54.8)
Bury in The Soil **Frequency**	3 (0)	100 (0)
Of Disposal		
Daily	17	14.2
Weekly	72	60.0
Bi-weekly	12	10.0
Monthly	16	13.3
Occasionally	3	2.5
Total	**120**	**100**

Figures in parenthesis represent the claim that the methods are unreliable and the corresponding percentage

Table III present the distribution of the current expenditure on waste disposal and the willingness to pay potential of the household. The result revealed that 52.5 of the respondents spend between ₦400- ₦600 on waste disposal per month. While 7.5 percent claimed to dispose waste at no cost, only 3.3 percent spent above ₦ 800 on waste disposal. This is an indication that majority of the respondents are already expending money on solid waste disposal and therefore may be WTP for improved services. A binary response to household willingness to pay for improved services showed that 87.5 percent are willing to pay. However, 71.4 percent of this category of respondents are willing to pay only less than 5 percent of their monthly income to waste collectors while only 3.8 will be WTP above 10 percent of their income if the need arise. The mean value of the percentage of income the respondents are WTP is 3 percent. Given the advantages of improved services, most households in the study are WTP a proportion of their income, to sanitise their immediate environment.

Table III: Household Current and Proposed Expenditure on Waste Disposal

Expenditure (₦)		Frequency	Percentage
Current	None	9	7.5
	<400	29	24.2
	401- 600	63	52.5
	601- 800	15	12.5
	above 800	4	3.3
	Total	**120**	**100**
Household WTP	Yes	105	87.5
	No	15	12.5
	Total	**120**	**100**
WTP Potential	< 5%	75	71.4
	5-7.5%	21	20.0
	7.5- 10%	5	4.8
	above 10%	4	3.8
	Total	**105**	**100**

Determinants of WTP for improved waste disposal services: Table 4 presents the logit analysis of the factors that determine the willingness to pay for improved waste disposal services. The results showed that respondents' age, marital status, household size and percentage household WTP potential do not significantly influence the willingness to pay for improved waste disposal. However, sex, educational status, and monthly expenditure of households are statistically significant at $P < 0.10$, $P < 0.1$ and $P < 0.05$ respectively. Educational level is positively related to WTP for improved waste disposal services. This indicates that as level of education increases the tendencies to adopt and pay for improved disposal services will also increase. The coefficient of household expenditure, a proxy for income is also positive, an indication that increase in income will increase the probability that households would be willing to pay for improved disposal services. This is confirmed by [14 and 16], The result reveals that the marginal effect on probability of households paying for the service with respect to household monthly expenditure is 0.46776. This implies that for every ₦1 increase in household monthly expenditure, the likelihood of paying for improved refuse collection and disposal increases by 0.46776.

Table IV: Multivariate Logit Regression.

	Marginal effect on probability of willingness to pay		
Variable	Coefficients	Standard Error	Z-statistics
Constant	8.18259	1.510	0.3112
Sex	-2.25270	-1.827	0.0677*
Age	-9.82100	-1.159	0.2463
Educational level	0.33107	3.105	0.0019***
Marital status	0.96002	0.924	0.3554
Household size	0.53208	1.782	0.0747
WTP Potential	0.18453	1. 245	0.2133
Expenditure	0.46776	2.185	0.0289**

***	Statistically significant at 1%	Chi-squared (LR statistic)	22.36494
**	Statistically significant at 5%	Degree of freedom	7
*	Statistically significant at 10%	Significance level	0.00000
	Log likelihood -20.84719	Restricted Log likelihood	-32.03139

Conclusion and recommendations

The study revealed that payment for waste disposal is not a new idea in the study area, however, majority of the respondents were willing to pay for an alternative waste disposal services, particularly when it is going to be an improvement on the existing means of services. Sex, education and household expenditure were discovered to be determinants of household WTP for improved disposal services in the study area. It is recommended that programmes facilitating investors in waste disposing be initiated while payment for this service should be made affordable to encourage those households that are willing to pay. In addition, public enlightenment campaign through mass media could also be adopted in order to properly inform the citizens on the need to patronize the solid waste disposal investors.

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WASTEWATER MINIMISATION IN THE PRODUCTION OF KENKEY (A TRADITIONAL GHANAIAN CORN MEAL PRODUCT)

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Key words: Water Minimisation, Reuse, Recycle, Waste Management, Corn Steeping

Abstract

Kenkey is a traditional Ghanaian corn meal product produced on a micro to small scale in a process that includes corn steeping, with the spent steep water generally being discarded without treatment. The increasing number and scale of Kenkey producers, implies that the environmental impact of this wastewater discharge cannot be ignored. There are however major economic and technical obstacles to the traditional solutions of either requiring the Kenkey producer to treat the waste, or central collection and wastewater treatment. The reuse of spent steep water in Kenkey production was investigated as an alternative approach to handling this wastewater problem. Potential modifications to the traditional steeping process were considered, including the addition of SO_2 to the steep water. Samples of products from reuse were subjected to physical, sensory and microbiological analysis to determine the impact of the reuse. Results obtained indicate that under certain conditions, spent steep water can be reused in the steeping process to yield Kenkey that is acceptable to consumers and not significantly different from traditional Kenkey.

INTRODUCTION

Kenkey is a traditional corn meal product native to the coastal region of Ghana including the capital, Accra. It is produced primarily on a micro to small scale in a process that includes corn steeping, with the spent steep water generally being discarded without treatment. This practice of discharging waste without treatment is common to almost all traditional food production in Ghana, with varying severity of impact on the environment.

With the dramatic increase in the population of Accra over the last decade, the number and scale of artisanal production is reaching a point where the pollution they create is no longer insignificant. There are however major economic and technical obstacles to the classic solutions of either requiring the producers to treat their waste prior to discharge, or to the municipal authorities collecting the wastewater and treating it centrally. Municipal authorities are focussed on dealing with the growing crisis related to the collection, treatment and disposal of solid domestic waste, and Kenkey producers do not generally have the financial or technical foundation to treat their waste prior to discharge. Thus, whilst central treatment of this liquid waste may be the long term solution, it is not a viable short or medium term solution.

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As an alternative to the classic solutions to waste management, this research sought to determine the extent to which principles of water reuse and recycle could be employed to significantly reduce or even eliminate the wastewater produced. The objective of the study was therefore to identify modifications of the the Kenkey production process that would reduce or eliminate the production of wastewater whilst maintaining a product acceptable to consumers, without compromising on product safety.

PROCESS ANALYSIS

Sources and Sinks

The first stage of the study was to identify opportunities for water reuse and recycle, as a means of reducing water usage and wastewater generation. Water Pinch techniques [9] were adapted for this task to identify the water using steps (i.e. water sinks) and water generating or rejecting steps (i.e. water sources) of the process. The process for Kenkey production [4] is illustrated in Figure 1, showing where water is used and discarded within the process.

A key step in water pinch analysis is to determine the quality constraints for water usage within the process, as well as identify the quality characteristics of all the water that is discarded within the process. This is used to identify and eliminate infeasible reuse options, reducing the number of options for further consideration. The Kenkey process does not however have defined quality constraint for water usage, and as such all options had to be considered.

The sources and sinks identified in Kenkey production are shown in Table 1.

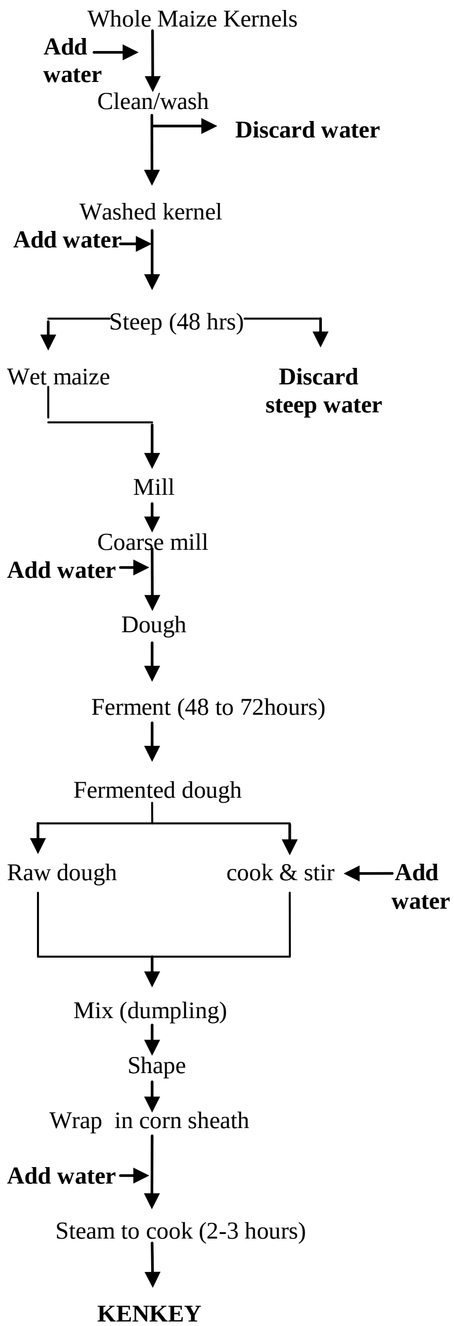

Figure 1: The Kenkey Production Process

Sinks	Sources
Corn washing	Wash water
Corn Steeping	Spent steep water
Dough making	
Cooking dough portion (aflata)	
Kenkey cooking (steaming)	

Table 1: Water Sources and Sinks in the Kenkey Production Process

Although there is some water left over from the cooking process, this water can be considered to be a by-product of the Kenkey production process and was not therefore considered for reuse.

Identification and Screening of Reuse Options

The initial list of reuse options is generated by matching all sources with all sinks, as shown in Table 2, followed by screening to eliminate infeasible or undesirable options.

Source of water	Sink (reuse target)
Wash Water	Corn washing
	Corn Steeping
	Dough making
	Cooking dough portion (aflata preparation)
	Kenkey cooking (steaming)
Spent Steep Water	Corn washing
	Corn Steeping
	Dough making
	Cooking dough portion (aflata preparation)
	Kenkey cooking (steaming)

Table 2: Reuse and recycle possibilities in the Kenkey production process

The wash water was considered unfit for reuse for any purpose other than washing, because by definition it would contain dirt and other substances deemed to be undesirable in the final product. The reuse of the wash water in any subsequent processing steps would re-introduce this dirt into the product. Elimination of the wash water from consideration leaves the reuse options listed in Table 3.

Source of water	Sink (reuse target)
Wash Water	Corn washing
Spent Steep Water	Corn washing
	Corn Steeping
	Dough making
	Cooking dough portion (aflata preparation)
	Kenkey cooking (steaming)

Table 3: Screened reuse and recycle possibilities

EVALUATION OF STEEPWATER REUSE OPTIONS

The screened opportunities for reuse and recycle thus identified were subjected to further analysis to determine their viability. As this is a food product, a number of laboratory experiments were required to determine the impact of the proposed reuse options on both the final Kenkey product as well as some intermediate products in terms of physical, chemical, microbiological and sensory properties. Due to the large number of experiments required, the only options covered in this paper are the reuse of the spent steep water for corn steeping and for dough making. These steps in the process have been demonstrated by previous researchers [5,6,7] to have a significant impact on the quality and properties of the resulting product.

Evaluation Procedure

100g of washed maize was steeped at a constant steeping time of 24 hours. The spent steep water from this first batch of corn was reused to steep two further batches of 100g of washed maize, so as to produce three types of steeped grain as follows:

Fresh – **corn steeped with fresh water.**
First generation – **corn steeped with steep water from fresh sample.**
Second generation – **corn steeped with steep water from first generation sample**

An additional variable included was the use of 0.2% SO_2 in the steep water as a means of inhibiting the growth of undesirable microorganisms – a practice long employed for steeping in the corn wet-milling industry [3].

Each of the steeped corn samples was then milled and made into dough, using both fresh water (the normal process), and spent steep water from a batch of corn steeped with fresh water. The dough was then left to ferment for 24 and 48 hours.

Various properties of the resulting fermented dough were measured, including pH, total titrable acidity and pasting characteristics, to determine if there was any discernible impact from the reuse of steep water. Finally, each of the 24 hour fermented dough samples was mixed and stir cooked into aflata using fresh water, and then used in the preparation of Kenkey for consumer acceptability tests. To reduce variability in the product, an experienced commercial Kenkey processor prepared the aflata and Kenkey after the dough had been produced in the laboratory.

Sensory analysis was conducted using untrained consumers randomly recruited from the University of Ghana campus. Criteria for recruitment were that panellists were regular consumers of Kenkey and were familiar with the characteristics of Kenkey.

Results and discussion

A detailed presentation and discussion of the results of the experiments is presented elsewhere [1], and only the highlights are provided here.

Impact on Steep Water

The water discharged from the steeping of unwashed grain was measured to have a BOD^5 ranging between 300 and 340 mg/l, which is significantly above the Ghana Environmental Protective Agency discharge limit of 50mg/l.

It was observed that with the addition of SO_2, the steep water was cleaner in appearance compared to steep water without SO_2 which appeared cloudy after second generation steeping. Steep water without SO_2 tended to develop a foul odour during and after second generation steeping, however with the addition SO_2, this foul odour development was significantly reduced. This indicates that water without SO_2 can be reused for steeping other batches of maize only up to first generation steeping. Based on this finding, second generation steep water without SO_2 was eliminated from further consideration, leaving a total of ten different process options (including the control consisting of the traditional Kenkey product) to be analysed.

Effects on corn dough quality

The pH and titratable acidity of dough prepared from each of the water reuse treatments followed the same trend as the control:- pH decreased with increasing fermentation time, with a corresponding increase in titratable acidity for all the samples. These results (especially those from corn dough prepared from steep water containing SO_2) indicate that the fermentation proceeded as in normal corn dough, and that SO_2 had little or no adverse effect on the desired activities of the microbial flora of the dough.

The effect of the different dough treatments on pasting characteristics (i.e. pasting temperature, peak viscosity and setback viscosity) were also determined to provide a measure of the performance of the dough [8]. Pasting temperatures did not vary significantly with the steeping treatment or the type of water used in the preparation of the dough. Pasting temperatures observed ranged between 79^{o}C and 83^{o}C, with the control sample having a pasting temperature of about 80^{o}C. Peak viscosity was not significantly affected by water reuse, but rather by the presence of $SO_{2.}$ Peak and setback viscosities increased whenever steeping of the maize kernels was done in the presence of SO_2. This may be due to the action of SO_2 in releasing the starch granules during the steeping process [2]. Peak and setback viscosities however decreased when steep water without SO_2 was used in the preparation of dough. This could be due to the activities of microorganisms that were already present in the steep water added during the preparation of the dough.

The results above demonstrate that the use of steep water in dough preparation does not adversely affect the quality of the dough in terms of pH, titratable acidity and pasting characteristics, provided SO_2 is added to the steep water. Without SO_2 addition however, reuse lowers peak and setback viscosities.

Effect on Kenkey Product

The level of preference in terms of taste, smell, colour, texture and overall acceptability of Kenkey produced from each of the 24-hour fermented corn dough as well as traditionally prepared Kenkey was analysed. A selection of the rank sums indicating the degree of preference are shown in Table 4.

	Sample	Sum of Ranks	Order of Ranks
1	Control (traditional process)	116.7	1st
2	First Generation Steepwater	121.8	2nd
3	First Generation Steepwater + SO2	129.0	3rd
4	Fresh with steepwater reuse for dough	152.5	4th
5	Second Generation +SO2 and reuse for dough	221.1	10th

Table 4: Selection of Friedman sensory ranking scores for overall preference of Kenkey samples

With respect to taste, samples 2, 3 and 4 in Table 2 were not significantly different from the control (sample 1 – traditional process). Texture, was the attribute that varied the least among the samples and this implies that the different treatments given to the maize and dough did not significantly influence the texture of the resulting product.

Smell, colour and overall acceptability of the different Kenkey samples were however significantly affected by the treatments given to the maize and dough. This suggests that the primary concern in steepwater reuse would be the development of undesirable odour or aroma in the Kenkey product. It is important to note however that the development of such undesirable odour is a significant risk in the preparation of the traditional Kenkey product itself.

CONCLUSIONS

The feasibility of reuse of spent steep water for steeping and for dough preparation in Kenkey production has been demonstrated. The primary obstacle to the reuse of steep water appears to come from the foul odour that develops with time due to activity of bacteria in the steep water. The development of foul odour can however be mitigated by the introduction of SO_2 in the water used for steeping, and this does not prevent the activity of the lactic acid bacteria required for subsequent fermentation.90

The presence of SO_2 during steeping and the reuse of steep water for steeping other batches of maize did not affect the quality of dough and the consumer acceptability of Kenkey produced. Kenkey prepared using dough made from maize that had been steeped in reused steep water had sensory attributes not significantly different from traditionally produced Kenkey. The use of steep water in dough preparation for Kenkey was however not acceptable to consumers. Results obtained from sensory analysis indicate that spent steepwater can be reused for steeping a second batch of corn with or without the addition of SO_2 to the water, and the resulting Kenkey produced is acceptable to consumers.

This study demonstrates a potential approach to mitigating the environmental impact of traditional artisanal food production in developing countries, until suitable municipal waste management is effectively implemented.

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Potentialities of contemporary earth construction addressing urban housing crisis in Africa – A lesson from Zimbabwe

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Key words: housing crisis, earth construction, appropriate technology, urban.

Abstract

Several studies have shown that contemporary earth construction has the potentials to address the urban housing crisis in the developing countries. On the other hand there is a wrong perception among the users and the professionals that, 'earth houses are only used by the poor people'. In this regard political support would help to overcome people's wrong perception, citing the example of existing earth houses in Africa. This paper identifies and discusses the potentialities of contemporary earth construction to address urban housing crisis in Africa in the light of the successful examples.

Introduction

Hundreds of millions of people in the world today live in poor housing under adverse climatic conditions that stress their undernourished bodies toward the limits of human endurance and occasionally beyond (Shearer, 1986). There is an urban housing crisis in most of the developing countries and this is largely attributed by the rapid urbanisation (Dwyer et al, 1981, 33). According to Kamete (2006), the housing crisis is often sold and pushed onto the agenda in pre-dominantly quantitative terms and the mismatch between supply and demand is perhaps the scariest indicator used by proponents of increased housing delivery. The majority of the urban local authorities and central governments did and do not have a tradition of providing shelter to a large permanent population; there has been a lag of supply to demand of urban housing (Zami and Lee, 2007). According to UN Habitat (1996), housing shortage in African cities ranges from 33% to 90%. To meet housing needs, many people have resorted to renting backyard shacks and squatting on illegal land. According to the South African census report of 1996, 1,049,686 households lived in informal dwellings. People reside in squatter settlements, where there are no provisions for social services and utilities. UN Habitat (1996) also estimates that approximately 60% of the African population resides in shantytowns, slums and uncontrolled settlements. The unprecedented boom in the construction industry since independence resulted in the high demand of building materials that superseded the production capacity of the manufacturing sector in most of the African countries (Zami and Lee, 2008). A house is composed of several materials such as brick, cement, timber, window frames and several other building materials and the use of bricks as a standard building material began in the early 1900s in most of the African countries. Brick, cement, sand and timber are the major construction materials in Africa up to date which is unaffordable nowadays and an appropriate building material and construction technique needs to devise to solve the urban housing crisis. For example, 'earth' can be used as an appropriate construction material in Africa. The aim of this paper is to evaluate earth as an affordable alternative material to housing in such a way, that if compared to established materials, it should prove to be an ideal alternative. The experiences and example of practice of using the earth construction will be borrowed from other societies and countries and demonstrate the dynamism of the material and construction in Africa.

Historical background of earth as a construction material in Africa

It is essential to look at historical evidence of the success of earth construction. It is currently estimated that over one third (Dethier, 1981) to over one half (Smith and Austin, 1989) of the world's population lives in some type of earthen dwelling. The history of earth building lacks documentation, because it has not been highly regarded compared to stone and wood (Houben and Guillaud, 1989, p8). There are cities built of raw earth, such as: - Catal Hunyuk in Turkey; Harappa and Mohenjo-Daro in Pakistan; Akhlet-Aton in Egypt; Babylon in Iraq; (Easton, 1998, p3). "*30% of the world's population, or nearly 1,500,000,000 people, live in a home built in unbaked earth. Roughly 50% of the population of developing countries, the majority of rural populations, and at least 20% of urban and suburban populations live in earth homes*" (Houben and Guillaud, 1989, p6). Figure 1 illustrates the world geographic locations of where earth structures are used and Figure 2 shows the spread of different kinds of earth structure being used by different regions of the world.

Figure 1
Geographic locations of earth structure.
Source: Houben and Guillaud, 1989, p6.

Figure 2
Different forms of earth structure being used by different region of the world.
Source: Houben and Guillaud, 1989, p12.

In Africa, the Egyptian civilisation provides abundant evidence of the use of earth in building as found in the early human settlements at the Merimd and Fayum sites in the Nile delta, which dates from the fifth millennia before Christ. The dominance of the Egyptian dynasty promoted buildings of prestigious structures made of brick from the Nile clay, desert sand and straw from the grain fields. These bricks were made by hand and dried in the sun before the development of the mould. The excavation at Saggarah and Bbydos show the use of bricks which were covered by stone. The art of brick vaulting was also developed in the lower Nubia, between Luxor and Aswan (Rastorfer, 1985, 32).

The Egyptian architect, Hassan Fathy devoted himself to housing the poor in developing nations. According to Iskander (2005), Fathy aimed to create affordable and liveable spaces suitable to the surrounding environment, thus improving the economy and the standard of living in rural areas. His buildings were surprisingly inexpensive. He encouraged local materials and saw a more appropriate method of building in the Vernacular Architecture of the Nubians (region of southern Egypt). Nubian craftsmen were masters at constructing domed and vaulted roofs of mud brick which they also used for the walls. While implementing the Nubian building techniques, he aimed to train Egyptian craftsmen to build their houses using mud brick or Adobe, which was ideally suited to the local conditions of Upper Egypt (Serageldin et al, 1985). In eastern Africa, movements by the Indian Ocean, the migrating Kushites and the influence of the Axum Kingdom (3rd to 8th BC) from Nubia as far back as Kenya have spread the use of sun dried bricks. As a result there was a great change in the architecture of the surroundings with the introduction of mosques. These were mainly built of earth using local expertise. In Zimbabwe, building in earth dates back as far as the 12th century when Great Zimbabwe was built and earth has been used progressively mainly in the rural areas (Mubaiwa, 2002, p10). Existing urban structures of earth can be seen mainly in the houses of the Crainbone suburb of Harare and in Bulawayo's Sourcetown suburb.

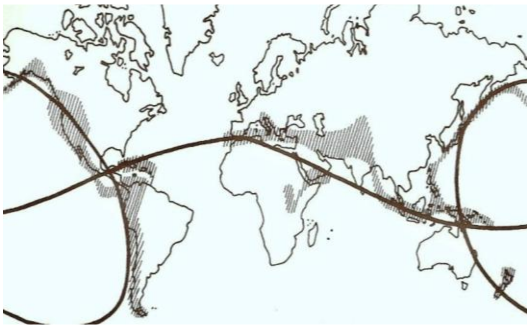

Figure 3
Seismic regions of the world.
Source: Houben and Guillaud, 1989, 306.

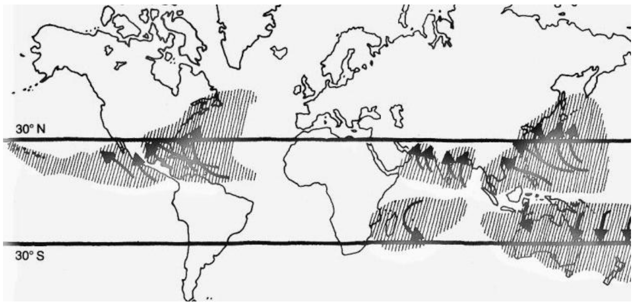

Figure 4
Storm regions of the world.
Source: Houben and Guillaud, 1989, 320.

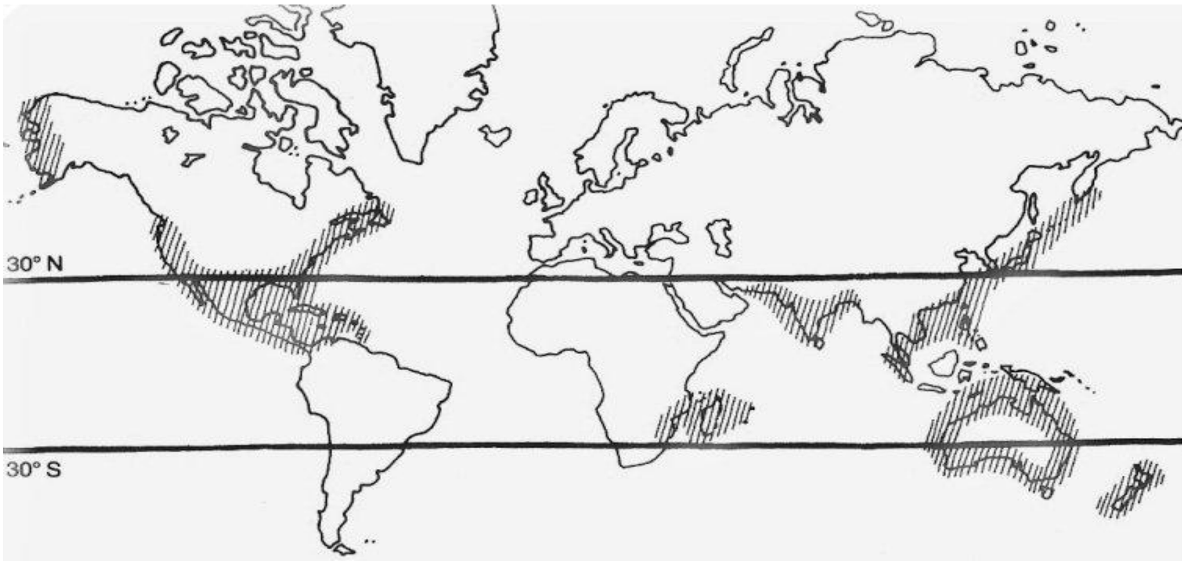

Figure 5
Flood regions of the world. Source: Houben and Guillaud, 1989, 324.

According to Denyer (1978), *"earth architecture should not of course be considered a miraculous solution to neither all our housing problems, nor one which can be applied successfully anywhere, everywhere."* Before any building is constructed with earth, it is essential to identify the soil to be used. The identification process involves various tests, which need the use of a laboratory. Apart from the laboratory identification process, local knowledge of the soil and traditional skills are necessary. In Africa, suitable soil is found in most of the countries. According to Houben and Guillaud (1989, p305), in 1976 alone seismic activity in the Philippines, Indonesia, Turkey, Italy and China caused the loss of more than 500,000 lives. Figure 3 shows the seismic areas of the world; most of the countries in Africa are not within seismic area. Figure 4 shows storm regions of the world and the whole of Africa is almost out of storm area except Madagascar. Flood is another form of natural disaster which causes many deaths. Figure 5 shows the flood areas of the world in which it is very clear that Africa is less affected by flood. So, from the above discussion it can be posit that earth construction is safe in terms of natural disasters in majority countries in Africa.

The benefits of earth construction

The advantages of a mastery of earth construction are multiple and complementary and are as follows summarized in Table 1: -

Benefits	Author
1. Earth construction is economically beneficial.	Lal, 1995; Easton, 1998; Minke, 2006; Zami and Lee, 2007; Morton, 2007; Kateregga et al, 1983; Cassell, 1993; Walker et al, 2005; Hadjri et al, 2007; Morris and Booysen, 2000; Adam and Agib, 2001, p11; Maini, 2005;
2. It requires simple tools and less skilled labour.	Kateregga, 1983; Easton, 1998; Minke, 2006, p15; Hadjri et al, 2007; Morris and Booysen, 2000; Adam and Agib, 2001, p11; Maini, 2005;
3. It encourages self-help construction.	Kateregga, 1983; Minke, 2006, p15;
4. Suitable for very strong and secured structure.	Lal, 1995, p119; Houben & Guillaud, 1989; Walker et al, 2005;
5. It saves energy (low embodied energy).	Morton, 2007; Lal, 1995, p119; Minke, 2006; Hadjri et al, 2007; Adam and Agib, 2001, p11; Maini, 2005;
6. It balances and improves indoor air humidity and temperature.	Cassell, 1993; Howieson, 2005; Alphonse et al, 1985; Minke, 2006; Kateregga et al, 1983; Lal (1995, p119); Walker et al, 2005; Hadjri et al, 2007; Adam and Agib, 2001, p11;
7. Earth is very good in fire resistance.	Alphonse et al, 1985; Walker et al, 2005, p43; Hadjri et al, 2007; Adam and Agib, 2001, p11;
8. Earth construction is regarded as a job creation opportunity.	Adam and Agib, 2001, p11;
9. Earth construction is environmentally sustainable.	Minke, 2006; Easton, 1998; Walker et al, 2005; Hadjri et al, 2007; Adam and Agib, 2001, p11; Maini, 2005; Ngowai, 2000.
10. Loam preserves timber and other organic materials.	Minke, 2006, p15.
11. Earth walls (loam) absorb pollutants.	Cassell, 1993; Minke, 2006;
12. Easy to design with and high aesthetical value.	Morton, 2007; Houben and Guillaud, 1989; Walker et al, 2005; Hadjri et al, 2007.
13. Earth buildings provide better noise control.	Kateregga, 1983; Alphonse et al, 1985; Hadjri et al, 2007;
14. Earth construction promotes local culture, heritage, and material.	Frescura, 1981.
15. Earth is available in large quantities in most regions.	Adam and Agib, 2001, p11; Easton, 1998; Lal, 1995; Hadjri et al, 2007; Morris and Booysen, 2000; Adam and Agib, 2001, p11;

Table 1

Bnefits of earth construction. Source: compiled by author, 2009.

The drawbacks of earth construction

The following are drawbacks of earth (un-stabilised) in building construction: -

Drawbacks	Authors
1. Less durable as a construction material compared to conventional materials.	Kateregga, 1983; Lal, 1995, p119; Cassell, 1993; Blondet & Aguilar, 2007; Maini, 2005; Morris and Booysen, 2000; Hadjri et al, 2007; Adam and Agib, 2001, p11; Minke, 2006; Walker et al, 2005, p13;
2. Earth construction is labour intensive.	Lal, 1995, p119; Cassell, 1993;
3. Mud houses behave poorly in the event of earthquakes.	Blondet and Aguilar, 2007;
4. Structural limitations.	Maini, 2005; Hadjri et al, 2007;
5. Need high maintenance.	Hadjri et al, 2007;
6. Professionals make less money from earth building projects.	Robinson, 1939.
7. Special skills needed for plastering.	Hadjri, et al, 2007
8. Loam is not a standardised building material.	Minke, 2006.
9. Need higher wall thickness.	Walker et al, 2005.
10. Suitable only for in situ construction.	Walker et al, 2005.

Table 2

Drawbacks of earth construction. Source: compiled by author, 2009.

Success of contemporary earth construction in Zimbabwe – a lesson for Africa

Initially Zimbabwean professionals did not recognise the use of earth for construction of 'descent' shelter for the urban environment (Mubaiwa, 2002; Kannemeyer, 2006; Zami and Lee, 2007). The recognition of stabilised earth construction was expedited by the adoption of Zimbabwe Standard Code of Practice for RE structures which was first published in 1996 (Kannemeyer, 2006) and included in the Zimbabwe Model Building Bylaws in 2004. The In-situ Rammed Earth Company (ISREC) founded by Mr. Rowland Keable who has over 15 years' experience working with RE in Africa, Australia and the UK, initiated the request to the Standards Association of Zimbabwe (SAZ) and was seconded by the then newly formed Scientific and Industrial Research and Development Council (SIRDC). Mr. Rowland Keable pioneered many RE projects in Zimbabwe; among them some of the first officially recognised in Zimbabwe since the country's independence and worked largely in conjunction with the SIRDC in the late 90s to revive RE construction in Zimbabwe.

The performance of experimental RE and CSEB construction in Zimbabwe is a great success to date (Mubaiwa, 2002; Kannemeyer, 2006). One of the first stabilised earth projects was the British government's Overseas Development Administration (ODA) funded, the DfID School block at the SIRDC centre, Hatcliffe, Harare, Zimbabwe. This project was mainly constructed to demonstrate that RE could successfully support a roof span of 8m whilst at the same time being a test bed for the publication of RE Structures: A Code of Practice. The building was inexpensive, and showed that wide span roofs are possible with the technology, important for classrooms and clinics. In the Hatcliffe building, concrete was used for the foundations. This house/classroom block built on SIRDC premises attests to the versatility of RE construction. The construction cost of this block was 60% cheaper than the traditional concrete brick and blocks construction. The ISREC also carried out a number of RE projects in the country among some of them were a private house in Bonda, Manicaland commissioned by pioneering passive solar architect Mick Pearce in 1997, Office and housing in Chimanda on the North East border with Mozambique (Zami, 2010).

SIRDC built a RE teacher's house at Rukanda Secondary School in Mutoko. The house's appearance is impressive. Costs incurred in building the two roomed Rukanda teacher's house shows that construction using RE and roofing with MCR (micro-concrete roofing) tiles resulted in a low cost of 18 million Zimbabwe dollars compared to $45 million when using conventional technologies. An important point to note is that a good part of the $18 million was used for peripheral expenses such as transport, accommodation and allowances of SIRDC technical staff who supervised the project. Besides making housing affordable to the majority of the population, these two SIRDC initiatives have the added advantage of employment creation amongst young people (the same as the Mutoko project).

The use of CSEB construction is fairly new in Zimbabwe (Zami, 2010). The Chitungwiza House is one of the few known buildings made of CSEB. This was a deviation from fired bricks or cement bricks/ blocks and asbestos roof used for most of the low income houses in Zimbabwe. This pilot project by the Intermediate Technology Group (ITG) was implemented with the participation of the Chitungwiza municipality in 1993 as a low income house. The aim of this project was to evaluate the response of the people towards earth structure and the performance of low tech and sustainable materials used in the construction of low cost housing. The use of local labour and the absence of imported materials sent a message to the local communities that the solution of affordable sustainable and low cost housing is possible. Until now this structure stands as a success to all participants working in the housing industry in Zimbabwe. Therefore, all the experimented low cost stabilised earth construction housing projects have been a success. Surprisingly stabilised earth construction technology has not been adopted to address the low cost housing crisis in Zimbabwe despite the fact that the experimental projects are successful (Zami, 2010). Therefore, it is essential to investigate the factors influencing the widespread adoption of contemporary stabilised earth construction.

Conclusions

Earth is affordable and available and would be appropriate in the case of low cost house construction in Zimbabwe and as well as in many African countries. This paper has argued the promotion and implementation of earth as an alternative material is worthwhile. It is possible to use un-stabilised raw earth as rammed earth or compressed earth blocks; but the stabilised form is more suitable for the African situation in terms of by-laws and housing standards. The only challenge that prevents earth becoming the preferred choice of building material amongst the general population is the acceptability of this material by that same population. An awareness and understanding by people to environmental issues such as air pollution, deforestation, land degradation and energy conservation would help them change their attitudes and views towards earth building. The flexibility and simplicity in technology incorporated in earth building affords adaptability and easy transfer of knowledge between different stakeholders in the building industry. Individuals and community as a whole can easily participate in building their own homes in affordable ways.

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THE ROLE OF ADVANCED CONSTRUCTION TECHNOLOGIES IN PROMOTING SUSTAINABLE SHELTER, WATER AND DEVELOPMENT IN SOUTH AFRICA

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Key words:
Advanced Construction Technologies, Next generation materials, Modular houses, Housing and Shelter, Water, Sanitation, Development, South Africa

Abstract
This paper presents a brief overview of the role and contribution of advanced construction technologies (hereafter ACTs) in promoting the provision of sustainable shelter, water and development in South Africa. South Africa faces acute shelter, water and sanitation challenges as a result of partly rural-to-urban migration, legacy of apartheid, geography and climatic zone. This paper traces the origin and development of ACTs, which is largely attributable to advances in material science, building components production and assembly technologies. In the process, issues are highlighted while potential solutions are discussed. The paper is evidence based making use of primary and secondary data/information examples of shelter and sanitation backlogs and challenges in areas such as Western Cape (Cape Town); Mpumalanga (Mbombela formerly Nelspruit), Province of the Eastern Cape (Buffalo city) and Limpopo Province (Capricorn & Vhembe District Municipality). The evidence is analyzed with ACT indicators taking into account the sustainable shelter and water sector requirements. The analysis is further situated within the overall context of desiring to promote sustainable and productive housing settlements that are a pleasure in which to live, recreate and produce in. The paper further argues and confirms that ongoing commercialization of ACTs technologies in the shelter and water sector will lead to a significant improvement in building performance, reduce environmental impact and provide a better framework for guiding the growth and development of sustainable human settlements. The next-generation of construction materials will most probably be mainly led by polymeric-fiber based products, light-metals alloys, with high performance with qualities such high tensile and compressive strengths.

INTRODUCTION AND BACKGROUND
About one billion people in the developing world (40 - 50 percent of the total world urban population) dwell in shacks or squatter camps. These settlements are generally defined as informal settlements or slums. In the Southern African Development Community (SADC) region alone, South Africa (SA) has an estimated informal settlement population of 4.5 million [4][7]. The South African government’s housing statistics backlog is estimated at

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approximately 3 million [3][5][8]. As an example, the Eastern Cape Province (one of the ten provinces constituting South Africa) has an estimated backlog of about 800 000 units. In Cape Town (SA) informal settlements are growing at an estimated rate of approximately 10% each year [15].Contemporary water supply and sanitation in South Africa is still characterized by both achievements and challenges since the advent of democracy in 1994. In 1994, about 15 million people were estimated to be without access to safe drinking water and at least 20 million were without adequate sanitation services [8]. South Africa is one of the few countries in the world that formally recognize water as a human right. The country has established a national water and sanitation program, which is undergirded by the following principles and values, namely rights based water supply and provision philosophy, basic needs provision and delivery of sanitation services pathway approach and public-private partnerships in South Africa . While encouraging evaluations that point to improvements in housing, water and sanitation in South Africa since 1994 exist, the major headline issue remains the backlogs and service gaps that still need attention [8, 18].

Purpose of the Paper

This paper presents a brief overview of the role and contribution of advanced construction technologies (ACTs) in promoting the provision of sustainable shelter, water and development in South Africa. The paper's departure point is that the demand for innovative and appropriate construction technologies for shelter, sanitation and development places great responsibility on alternative shelter, water construction, service delivery and deployment technologies.

Linking Water and Sanitation Gaps with Housing Challenges

Sustainability challenges exists in present day SA regarding not only water and sanitation but also housing delivery, which are driven by economic, social and environmental factors as will be discussed in sections that follow.

Housing Backlog in South Africa

Housing backlog can be said to be higher than official count of 2.2 million due to increased inter-regional migration from neighboring Zimbabwe, Botswana, Angola, Mozambique, Zambia up to Nigeria, Kenya, India, Ethiopia and Somalia. Inadequate supply of low cost Reconstruction Development Programme (RDP) housing accompanied by poor service delivery is largely credited to the xenophobic attacks on foreign nationals experienced during the early periods of the year 2008. This resulted in huge internal population displacement of foreigners and long term effects much of which is still felt today.

Electricity Supply and Demand

Currently, SA and SADC regional countries have a huge energy supply side deficit in terms of electricity generation. In 2008 Electricity Supply (ESKOM) the SA power utility supply company introduced electricity load-shedding. Statistics for SA reveal that the country needs 41 539 mega watts (MW) of electricity by 2013. Renewable energy supply projections are estimated to provide 1 667 MW (4%) by 2013. About 44% of SA households do not use electricity for cooking but fossil fuels such as wood and about 20% of SA households do not use electricity for lighting [15].

Water Supply and Demand in South Africa (water stress)

South Africa is also experiencing water stress. The following quote illustrates this:

"Up to 1000 people from informal settlements in South Africa are estimated to be using contaminated water for domestic purposes. Greenbelts, dams, wetlands and a canal that hundreds of people in informal settlement use for washing, have been identified as radioactive or toxic, especially those located within 100 kilometers of South Africa's biggest cities such as Johannesburg, Tshwane (Pretoria), eThekwini (Durban) and Cape Town. Fifteen sites close to Johannesburg have been named in a 210-page report as being toxic. Some of these sites register a radiation levels above 200 times the legal limit. Long-term exposure to toxic chemicals and radioactivity has serious health side effects and may cause cancer (Source). However, the pollution could be far worse than the report suggests, and perhaps the document should be used as a basis for further studies." This is according to The Sunday Times, South Africa, 19 July, 2009 [8,18].

Global Warming Impacts on South Africa

Climate change causes less precipitation generally in some parts of SA but also increased rainfall with flash flood in some. Informal settlements especially along the coast e.g. in Cape Town suffer perennial flooding and destructions of their shacks. Other factors such as land distribution, legislation, standards and norms and political and economical instability in form of war, famine and flooding affect sustainability [12].

Table 1: Sample of Low Cost Technologies in Zimbabwe and SADC Region

SYSTEM	COMPOSITION	DIS/ADVANTAGES
1. Frametech	Gypsum panel boards	**Standards / Easy, fast construction**
2. Frametech	Concrete / Wire Mesh (durawall)	**Standards / Easy, fast construction**
3. Frametech	Wood panels	**Standards / Easy, fast construction**
4. Wood Cabins	Wood planks / boards	**Standards / Easy, fast construction**
5. SSB / CB	Earth cement / Earth	**Quality of product**
6. SFB	Earth, Agric waste, (Saw Dust, Bagasse, cement, Pozzolana)	**Quality / Easy, fast construction**
7. Rammed Earth	Earth / Cement	**Quality / Easy fast construction**
8. MCR Tiles	Cement, Sand, BFS	**Quality, Cheap**
9. Earth Domes / Vaults	Earth Bricks	**Quality, Climate Stability**
10. Reinforced Earth	Grass, Bamboo, Wood, Earth	**Standards, Easy, fast construction**
11. Concrete Blocks	**Cement, Sand, PFA**	**Quality / Easy, fast construction**

Source:[9][11][12]

Current ACTs Delivery Methodologies and Technologies

There are basically three different ways to classify building of houses including Toilets, namely: Conventional, Elemental or panel prefabrication, and Modular also known as volumetric units prefabrication. Table 1 that follows summarizes existing technologies in the SADC region with particular referencing to South Africa, which have to date, for a number of reasons have failed to adequately achieve desired housing delivery. These are mostly a mixture of the conventional/traditional and elemental prefabricated technologies. Industrial product driven technologies are less applied relative to distances from the cities or reliable trunk road networks.

Appropriate Sanitation Technologies

A range of toilet technology types are currently used in South Africa, including: buckets, chemical toilets, simple pit toilets, ventilated improved pit toilets – with the possible addition of micro-organisms to reduce cleaning frequency. On average VIP's are unsuitable in most parts of the major cities in South Africa due to the prevalence of generally high water tables. Consequently dehydrating and composting toilets, vacuum technology toilet systems, anaerobic toilets, aqua-privies, flush toilets with septic tanks, flush toilets with conservancy tanks, flush toilets with small bore solids free sewers, and flush toilets with full waterborne and central treatment works are the more popular option. Table 2 presents levels of service for sanitation, Mbombela (formerly Nelspruit).

Table 2: Levels of Service for Sanitation, Mbombela (Nelspruit) South Africa.

Sanitation Types	2004	2009
Connected to sewer	21,935	24,329
Septic Tank	500	500
VIP		2,325
Other, bucket	30,127	46,446

Source:[2]

It is however important to point out that the choice of technology is influenced by many factors, including the following criteria:

1. ***Affordability*** to the household.
2. ***Operation and maintenance*** (O&M) requirements. High service levels, such as flush toilets, have onerous and costly O&M requirements. Local community members can readily undertake maintenance of on-site toilets.
3. ***Sustainability***: The system should be manageable making use of the local community and be sustainable over the long-term. "The sustainability of a sanitation system is usually the most important consideration when selecting a specific technology option for a community. Sustainability not only refers to measures to minimize breakdowns and costs in the operation of a scheme, but also to measures taken to maximize its positive social impact while minimizing any negative environmental impacts."[8]
4. ***Anchoring healthy and sustainable communities*** in terms of overall improvements to health of community members in particular and the community health in general.
5. ***Sustainable environmental development and exploitation of resources.*** This can be measured in terms of the level of compliance with existing environmental protection regulations.
6. ***Inclusive small contractor empowerment and development programs***. This relates to the ability of community based contractors to implement water, sanitation and housing technology interventions for example. (Table 3 presents sanitation service levels for the city of Cape Town)

Table 3: Sanitation Service Level Categories for the City of Cape Town

Service Level Hierarchy	Observation and Comment
Inadequate	• No or limited access to sanitation • Residents share sanitation facilities with other residents, supplied at a basic or full level of supply • Residents self-provision of sanitation facilities – often through unhygienic means. • In many instances Residents are being serviced by the CCT through the weekly removal of 20 litres open stercus “black bucket” containers, a service to be replaced.
Essential	• Partial access to sanitation (more than 5 households per toilet), as dictated by site-specific constraints (e.g., high dwelling densities)
Basic	• The provision of a shared toilet (at a ratio of not more than 5 families per toilet) which is safe, reliable, environmentally sound, easy to keep clean, provides privacy and protection against the weather, well ventilated, keeps smells to a minimum and prevents the entry and exit of flies and other disease-carrying pests; and • The provision of appropriate health and hygiene education.
Full	• On-site Waterborne, Conservancy Tank or Suitable Waterless Technology

Source:[6]

STRUCTURE AND ORGANIZATION OF PAPER

The paper is organized in four sections. ***Section one*** has provided the introduction and problem setting. ***Section two*** explains the research methodology. ***Section three*** discusses the major issues regarding water and sanitation and advanced construction technology interventions interface. ***Section four*** is dedicated to the conclusion and recommendations emanating from this article.

RESEARCH METHODOLOGY

This paper draws heavily on creative secondary analysis of existing literature regarding water and sanitation, housing and advanced construction technology interventions in South Africa. In addition the authors draw from over fifty years experience shared working in the water, sanitation, and housing and construction industry in Europe, Asia, Latin America and Africa for different research and development institutions, universities, consultancies and engineering firms.

FINDINGS AND RESULTS OF SUSTAINABLE SHELTER, WATER AND DEVELOPMENT IN SOUTH AFRICA

The CSIR study spot check assessment report for the Department of Water Affairs and Forestry [8]carried out in the year 2007/8 compared study results with those of the pilot study in 2006/7. The rationale behind spot checks is that they are carried out randomly thereby assisting in validating and verifying existing programme /project data in order to promote lesson learning and assist in the identification of challenges and problem areas so as to provide timeous solutions and corrective measures and/or interventions. Some of the results and findings are summarized as follows.

Household water projects

The completed rural household water projects that were assessed are generally non-compliant to the water and sanitation programme specifications. A number of problem areas should be addressed to ensure higher compliance levels with technical design standards. These include water metering, leakages, the non-existence of tap mechanisms, poor piping, poor tap stands, and the many households that have not received any training in good water use or in the operation and maintenance of their taps. Using a scorecard scale rating scale technique with **A** being compliant and **F** being non-compliant, a **C** scorecard rating was achieved for this category. This evaluation technique is applied throughout the analysis of section 3.1 to 3.4 of this article. A positive finding is the lack of vandalism counter-balanced however, by a worrisome indicator in terms of the number of illegal connections that have been identified, perhaps evidence of the inadequate water and sanitation delivery in rural households. The incomplete rural household water projects that were assessed are generally partially noncompliant mainly due to problems with tanks, water meters and taps. Illegal connections are prevalent at 7% of projects even before the project has been completed and commissioned.

Bulk sanitation projects

Completed rural bulk sanitation projects that were assessed are generally partially noncompliant. Attention should be focused on a variety of aspects to improve the daily functioning and operation of treatment works, also ensuring the safety of personnel. A **B** scorecard rating category was attained. The incomplete rural bulk sanitation projects that were assessed are generally non-compliant. Though nearly a third of the projects were compliant in terms of health and safety, about a fifth is extremely non-compliant (**F**), suggesting urgent rehabilitation. All three types of treatment works scored low compliance ratings on their technical design standards, a major indication that intervention and restoration are needed, before projects are commissioned, to ensure future sustainability.

Household sanitation projects

The results highlight a range of components that are problematic (therefore the **C** rating of non-compliant) for the completed rural household sanitation projects that were assessed. Most critical is the lack of communication with the communities and beneficiaries on sanitation, hygiene and the operation and maintenance of their newly built toilets. A worrisome observation is the non-availability and non-use of hand washing facilities (soap and water) and also problems identified on technical design standards regarding the safety aspects of walls, roofs and floors, the accessibility of pits for cleaning purposes, the condition of vent pipes of VIP toilets, the installation of proper sewer systems and the maintenance of cisterns for flush toilets. The incomplete rural household sanitation projects that were assessed obtaining non-compliant **C** ratings mainly due to problems with the floors being lower than the surrounding ground, roofs with holes and not secured well, walls that are not durable, doors that are broken, damaged or cannot lock, poor quality pedestals and inadequate sewer systems for Flush toilet projects, as well as the pit lining and collar, the pedestals and the vent pipes of VIP toilets. Intervention, restoration and rehabilitation are widely needed to ensure the future sustainability and the physical safety of the beneficiaries before these projects are handed over to them.

Comparison of MIG-funded Water supply and Sanitation Projects

The Overall Compliance ratings for the MIG-funded rural water supply and sanitation projects that were assessed show no difference between the ratings for 2006/07 and 2007/08 when all MIG funded water and sanitation projects are grouped together - these projects generally remained within the partially non-compliant category (**B**) for both years [7].

CONCLUSION

This paper has confirmed that ACT has a role to play in improving housing, water and sanitation infrastructure and services especially with special emphasis in rural areas, peri-urban areas, and informal settlements. However for the full potential of ACT to be realized it is essential that research and development (R and D) support and funding be channeled in this important area.

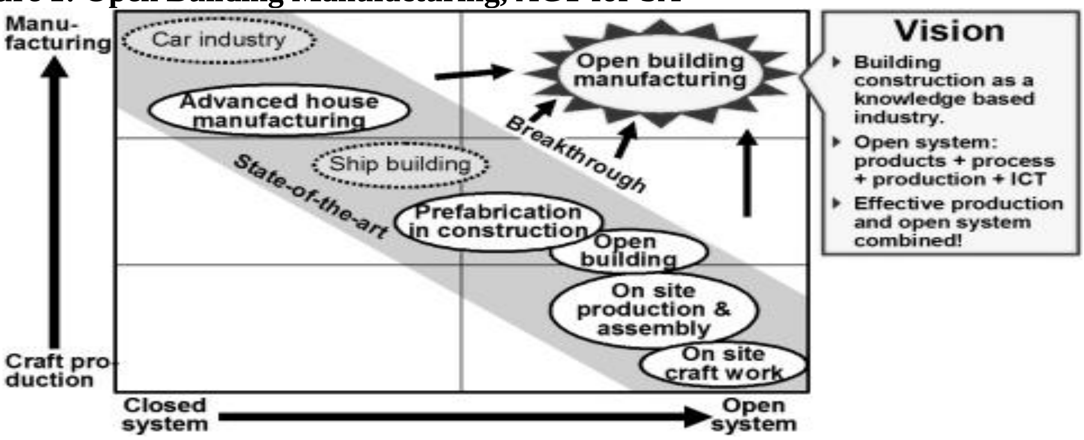
Recommendations on contribution and application of ACTs: Some perspectives

Emanating from this review, the major recommendations regarding tackling the headline issues in the water, sanitation, and housing and construction industry include some of the under-listed.

Simulation and prospecting on the next-generation of construction materials that can be used in addressing the water, sanitation and housing infrastructure backlogs in South Africa point in the direction that this will most probably be mainly led by polymeric-fiber based products, light-metals alloys, with high performance with qualities such as high tensile and compressive strengths.

The learning outcomes of the demonstration projects and trial houses at test sites in South Africa such as the CSIR should be keenly investigated with a view to incorporating the outcomes for rolling out of the successful ACT model in the country. The existing ACTs Strategy for SA leans on the ECT (European Construction Technology) and is carried under the ACTP (European Construction Technology Platform) a national project under CSIR since 2007. Various technologies are conceptualized, adopted and tests within the ACTP laboratory are shown in Figure 1.

Figure 1: Open Building Manufacturing, ACT for SA



Sources: [1][15][16]

The spirit and purpose of the ACT Vision should be continuously promoted and perhaps seriously jealously guarded if greater impact and influence is to be realised from this discipline for enhanced construction outcomes. This vision is reconfirmed because of its importance in the wider debate of alternative building materials and technologies to address the construction industry challenges. The vision is to create "A future where customers will be able to purchase high quality manufactured buildings having a high degree of design flexibility and at low cost compared to today" Current Material Research Areas being carried out focus on advanced light metals, thin concrete and fibre composites using advanced production technologies, logistics, LCA and ICT. Funding and support for the continuous development and improvement of these areas remains a continuing challenge and lasting requirement.

This paper's review has further confirmed and corroborated results of surveys, assessments by many organizations in SA which have indicated that the current approach or methodology is insufficient to remove the housing, water and sanitation backlog, leading to sustainable development. Current methods of construction of both entities until now are not conceptualized in such ways as to ensure quality, safety and rigid structures which will be easy to maintain. Commercialization of ACT technologies for shelter and water offer not only a missing link but is perhaps the ultimate solution, albeit under current conditions.

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Enhancing Crop Production in Zimbabwe Through the use of Information and Communication Technology

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Key words:
Agriculture, crop, production information system, competency

Abstract

Agriculture forms the backbone of Zimbabwe's economy and accounts for 17% of the GDP. Agricultural production is ideally considered to be the gate-pass to food security .The National Information and Communications policy encourages the adoption and use of Information and communications Technologies as a way of contributing directly to food security at national and household levels. In this paper we demonstrate how crop production can be enhanced through the use of Information and communication using a prototype web based crop information system which implores internet web technologies to deliver information and services to users. The web based information system empowers the resource poor farmers with up to date knowledge and information on crops and their varieties to be produced in each of the five farming regions by farmers. The system also provides information about agricultural technologies for crop improvement, pest control, soil and climatic requirements, best practices, markets, sources of finance and related inputs. The system thus improves the competency of the farmer by speeding up the circulation of agricultural information, affording easy access to systems of technology by the farmer, production efficiency resulting in a quality crop as well as access to national and international markets. The system is easily affordable to both the large and small scale farmer

Introduction

Agriculture forms the backbone of Zimbabwe's economy and accounts for 17% of the GDP [7].A major challenge to the farmers both commercial and small holders is that of lack resources when it comes to the production of food crops[4]. The government has through the National Information and Communications policy [15][17] encouraged the adoption and use of information and communications technologies as a way of contributing directly to food security at national and household levels. In this paper we demonstrate how crop production can be enhanced through the use of Information and communication technology using web based crop information system[16] which implores internet web technologies to deliver information and services to users. The web based information system provides information about technologies for crop improvement, pest control, soil and climatic requirements, best practices, markets, sources of finance. The system is serves also serves as a decision support tool for the farmers. The rest of the paper is follows section 2 gives an overview of the theoretical background of crop production in Zimbabwe, section 3 deals with the methodology and section 4 presents the design of the web based crop information system, section 5 shows the implementation and finally section is a Discussion.

Background

Agricultural production is ideally considered to be the gate-pass to food security [2], but this has not been the case due to a series of challenges such as low produce, pre-harvest losses, climate changes, disasters and poor information and knowledge links [11]. The Food and Agricultural organisation sites have used ICTS by installing agricultural information systems such as Food security statistics [9], Famine early warning systems [8], Global information and early warning system [10], Agricultural knowledge and information systems for rural development [1], farmer information and network for agricultural and rural development [3]. In Zimbabwe agricultural information has been made available through the Agricultural research extension services (AREX) which falls under the Ministry of Agriculture, Mechanisation and Irrigation Development[14][13] .Arex provides professional agricultural services, research, extension and farmer training, advisory and technical support to farmers. Arex is also involved in agricultural information production, analysis and promotion. The shortage of manpower, transport and a constrained budget has been the main challenges that have hampered Arex. The government of the day has tried to go round this challenge by trying to provide the bulk of agricultural information through print and electronic media. This has had its own pitfalls as it has proved difficult to reach the majority of rural farmers who have no access to both radio and television transmission.

The government of Zimbabwe has also embarked on some ICT driven projects to promote agriculture such as Zarnet [12] which is an initiative of the research council of Zimbabwe. A local company has developed a software package e-Hurudza [6] to help support government's agrarian reform. This software package provides agricultural information for all regions, tutorial on how to grow crops, planting methods, information on inputs, farm equipment and is also concerned with livestock.

Methodology

The incremental model was adopted because of its advantages such as report back facility, resource management and early functionality. For the documentation and representation of the system the unified modelling language was used. The proposed system is then developed using PHP which is a server-side scripting language that can be used on a host of web platforms and HTML.A database server is developed using MySQL and Apache is used for the web server. The data used to design the information system was obtained through interviews granted by the Ministry of Agriculture, Mechanisation and Irrigation and staff at the Matopo research centre. The questionnaire contained information such as farm locations, sources of information and crops grown.

Design

We propose a web based crop information system which comprises of the following basic elements, a database, and a user interface. We begin our design process by presenting a sequence diagram of the overall web based crop information system in figure 1 followed by that of a Database which is the heart of the system in figure 2.(Application software, Database, hardware). The sequence diagram of the proposed information system is a kind of interaction diagram that shows how processes operate with one another and in what order.

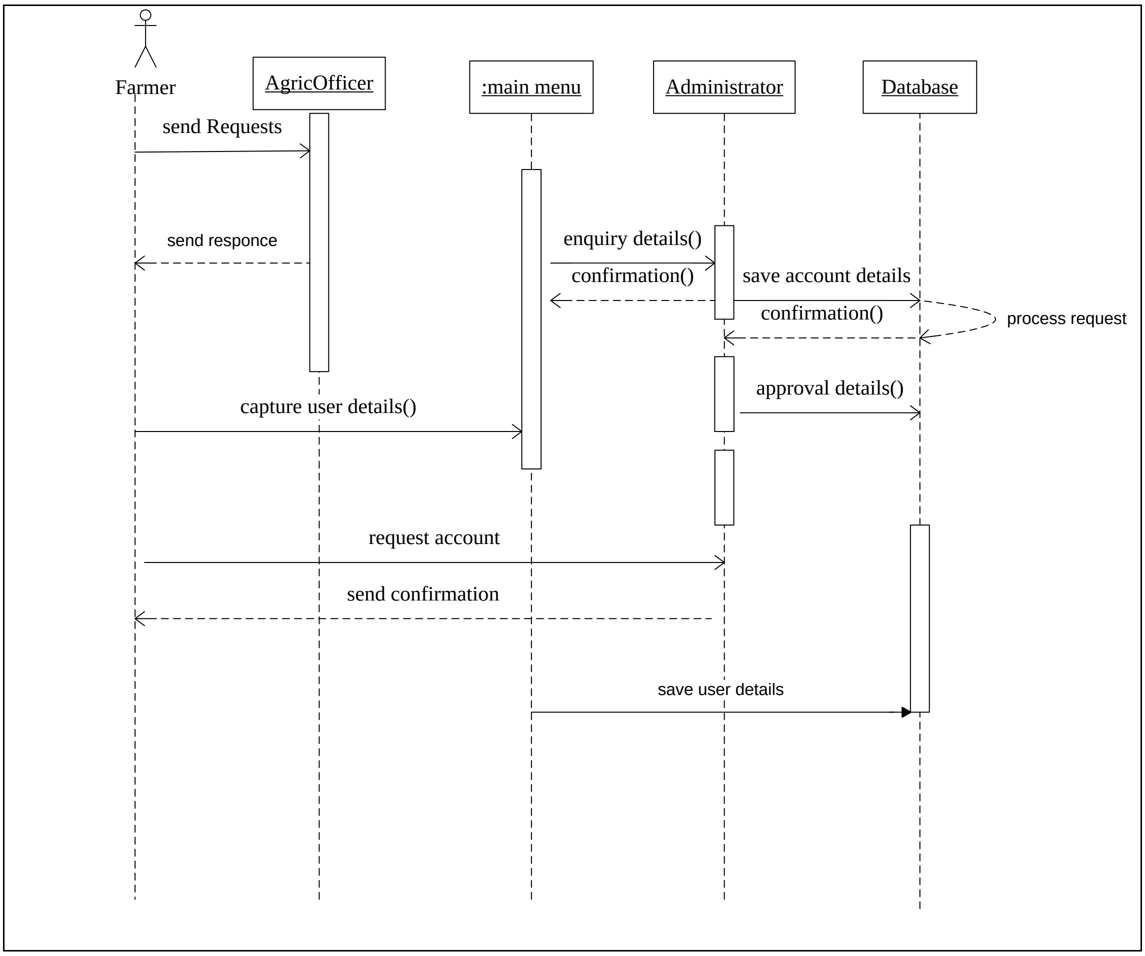

Figure 1: Proposed Information System

It also shows how the system is triggered and what iniates activity in the system, the type of processing and the changes that occur as well as the outputs produced at the end of the system. The system comprises the farmer who is the targeted user, the main menu which is also the user interface that allows the user to interact with the system database. The system database is depicted in figure 2 and contains the following tables

- **Login table-** holds details about the system users, their username and passwords and access level. This table is accessed every time a user logs or attempts to log on. All this information is encrypted.
- **Details table** contains the detailed information about the system users, who happen to be the farmers and agric officers
- **Crops table** contains crop information and their characteristics, regions where they are grown, their pests and their diseases.
- **Crop variety table** records all the crop varieties of the selected crops and their characteristics, soil type and region names
- **Region table** holds details about all the regions in Zimbabwe and their characteristics, cities, provinces and farming systems found in each region

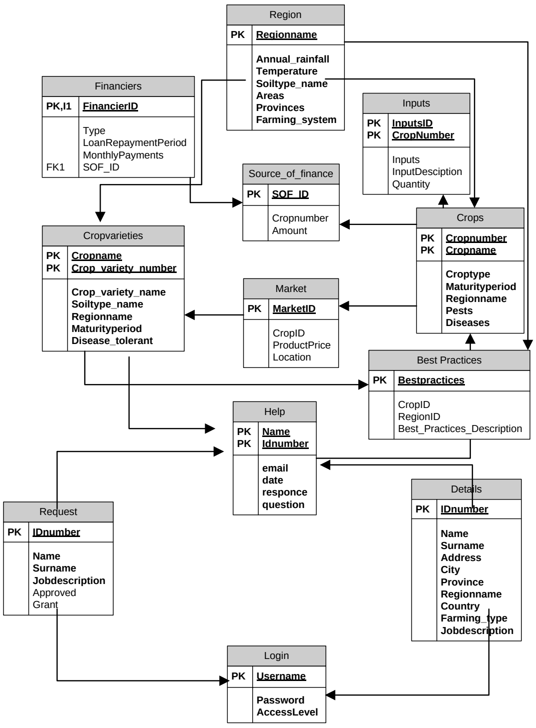

Figure 2: Proposed Database

Implementation

The prototype system has been designed and is ready for implementation. The following are presented as case scenarios in the testing of the system.

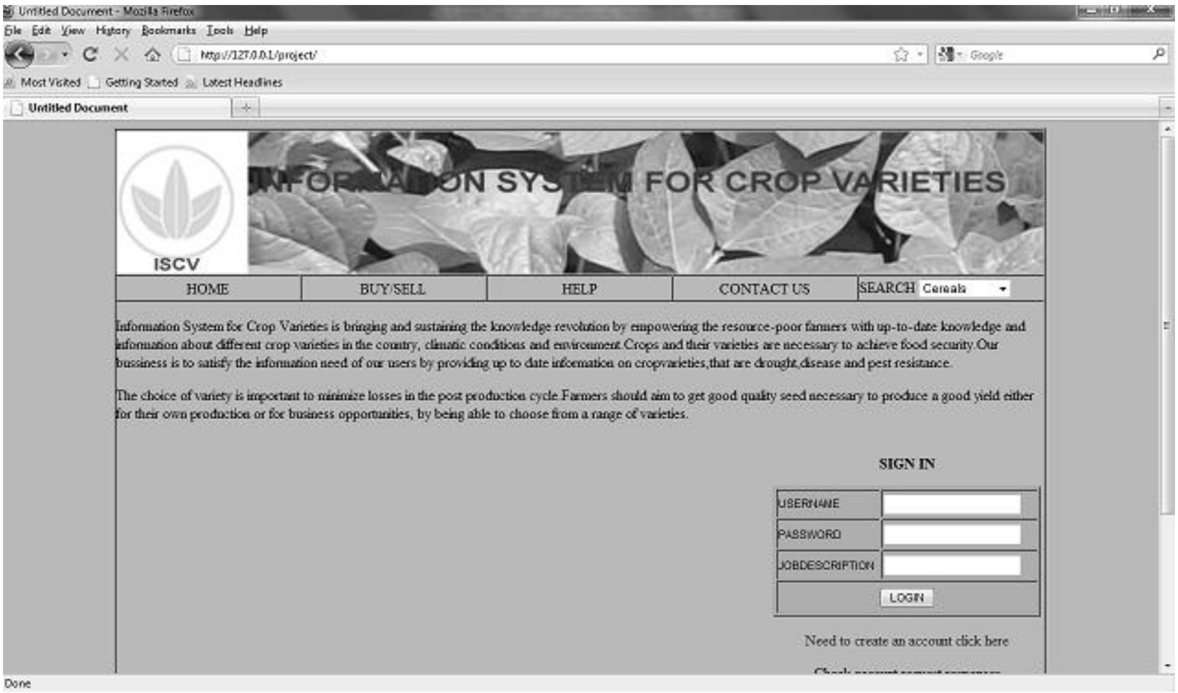

Figure 3: Home page

Figure 2 shows the screen shot for the home page of the web based crop information system. A registered user can sign in. The user is at this stage able to view information on where they can either buy or sell the produce and inputs. They are also a search facility for searching other related information. The system also provides information on crops which have been classified as cereals, legumes, oilseed and others. Particular choices of crop will advice the user on the best area in terms of the region to grow the crop as well as the associated conditions in that particular region.

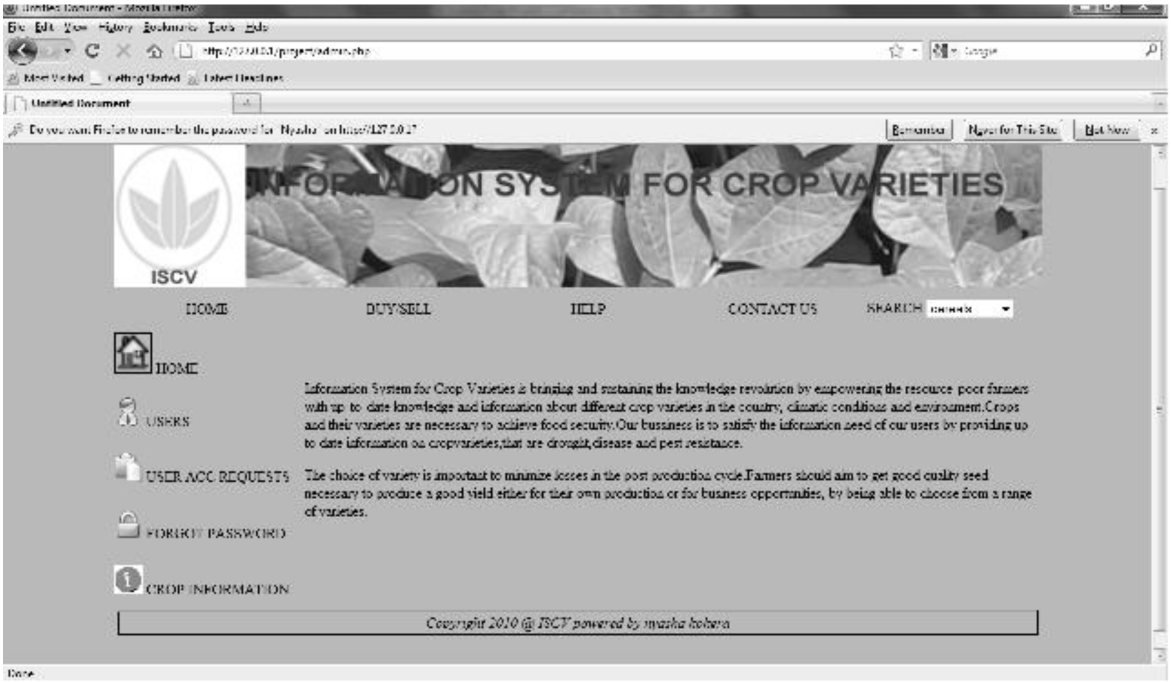

Figure 4: screen shot for farmer’s home page

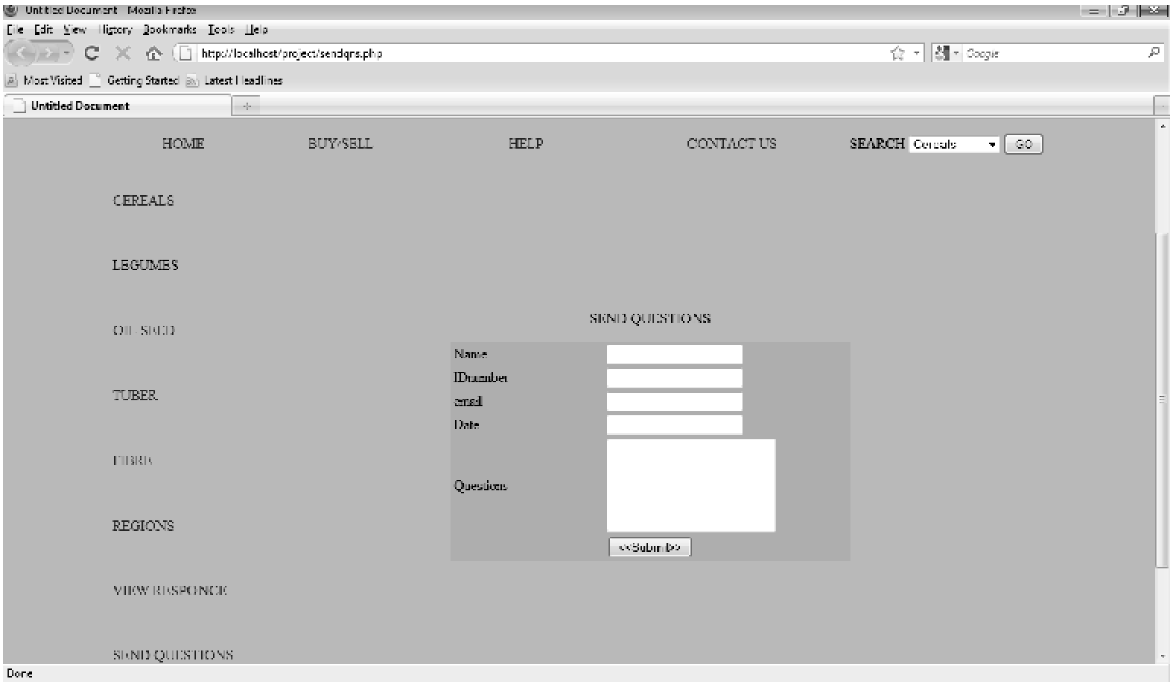

Figure 5: Interactive page (posting questions)

The system is also interactive meaning farmers are able to post questions on the web as shown in figure 5.

Conclusion

The use of Information and communications technology in farming improves the competency of the farmer by speeding up the circulation of agricultural information especially with the deployment web based crop information system. The availability and exchange of information also leads to increased production efficiency as farmers are exposed to information on the high yielding varieties, sources of inputs, finance improved management practices, pest management crop health, crop diversification and adoption of integrated crop production technologies. The system also exposes and gives the farmer access to national and international markets as well as easy access to the systems of technology. The web based crop variety information system is also easily affordable to the both the large and small scale farmer as it is not expensive to access the web. Crop production is challenged by factors such as lack of infrastructure and power supply in some remote parts, population growth and land scarcity, Global warming and sea level rise which may still threaten food security

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BUSINESS SOLUTIONS FOR SMALL SCALE IRRIGATION TECHNOLOGIES: MEDA'S EXPERIENCE IN ZAMBIA

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Key words:
Smallholder farmers, irrigation technologies, water utilization, smart subsidies, market development model, Zambia

Abstract
In developing countries, access to water during the dry season presents a viable solution for increased farm enterprise income and cash smoothening for smallholder farmers who often rely on rain-fed agriculture. However, smallholder farmers typically do not have access to appropriate and affordable irrigation technologies and rely on ineffective irrigation techniques. To address this, a number of non-governmental organizations have introduced irrigation technologies to smallholder farmers through free or highly subsidized distribution. With this approach, outreach is limited and issues around quality and limited after-sales service often arise. Mennonite Economic Development Associates (MEDA) in Zambia took an alternative approach of developing the supply chain for appropriate irrigation technologies. Using a demand stimulant and building the capacity of irrigation technology suppliers on marketing and distribution, MEDA's experience highlights successful market development strategies. Evidently, farmers have shifted from ineffective irrigation practices to more labour saving, water saving, effective and efficient irrigation technologies. Smallholder farmers can be direct, paying costumers of appropriate irrigation technologies and likely to maintain a technology they have paid for. The paper argues that addressing poverty and improving rural livelihoods requires business solutions that create sustainable access to irrigation technologies that leads to increased productivity and improved water utilization.

Introduction
In many developing countries, low income households often do not have access to reliable sources of water for either household consumption or productive purposes, such as farming. In rural areas, the situation is exacerbated for those who do not live near natural water sources such as lakes, rivers or favourable water tables. Since agriculture is major source of income for most rural households, a number of investments have been made in promoting small scale irrigation schemes. Common interventions are community or collective ownership of irrigation schemes or provision of small scale irrigation technologies through grants or free distribution. The result is typically limited in scale and outreach; impact is further diminished due to failed irrigation schemes owing to challenges of collective ownership and management.

This paper presents Mennonite Economic Development Associates (MEDA)'s alternative approach of promoting a commercial solution of building a sustainable supply chain of

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affordable and appropriate irrigation technologies for small scale technologies in Zambia. The paper starts by providing a background context on the situation in Zambia. A brief description of the technologies promoted is offered, with the factors that influenced the choice of technology including cost, durability, effectiveness, performance and environmental concerns. The paper then proceeds to provide an overview of MEDA's approach to accelerate supply and demand for selected technologies. The paper concludes with a discussion of the results and project challenges, including competition from NGOs facilitating free distribution and slow responsiveness by private sector. The paper highlights that it is possible to pursue and implement solutions that lead to both economically and environmentally sustainable access to water for rural populations. The typical assumption is that the poor cannot pay for technologies means that organizations turn to strategies which involve free distribution and collective ownership; yet these approaches are not sustainable. Alternatively, commercial responses have greater potential of creating sustainable solutions; however challenges arise due to interventions by donors, governments and development practitioners with contrary approaches.

Background and Country Context

Zambia is a landlocked sub-Saharan country with a total surface area of 743,390 square km, thus ranking among the smaller countries in South Central Africa (World Bank). The population of Zambia at the end of 2008 was estimated at 12.6 million (World Bank). On the Human Development Rankings, Zambia ranks 164 out of 182 countries (UNDP, 2009). On crucial socio-economic indicators, the 2006 census showed that overall poverty is at 64% (CSO 2006). Formal employment only absorbs 18.3% of Zambia's working population. Forty percent (40%) of the working population is engaged in the informal economy, with the balance either unemployed (primarily in urban areas) or involved with subsistence agriculture (CSO 2000).

The Food and Agriculture Organization (FAO) estimates that only 6.4% of the arable land in Saharan Africa is irrigated (Frenken, 2005). This is far lower than Asia which has 35% of irrigated land. Zambia is one of the Sub-Saharan African countries blessed with abundant natural sources of waters. However, small scale farmers, even those that live near these natural sources of water still struggle with means to access water with one of the major challenges the availability of water technologies. MEDA's assessment (MEDA 2007) indicated that most of rural households in Zambia were not aware of affordable microirrigation technologies. Further, those who had accessed them through free distribution were not using them, often due to frequent breakdowns. Acquisition did not include access to spare parts and after-sale service support, as they were received for free, farmers did not appear to care about continued functionality.

Micro irrigation technologies; Access, Appropriateness and Affordability Considerations

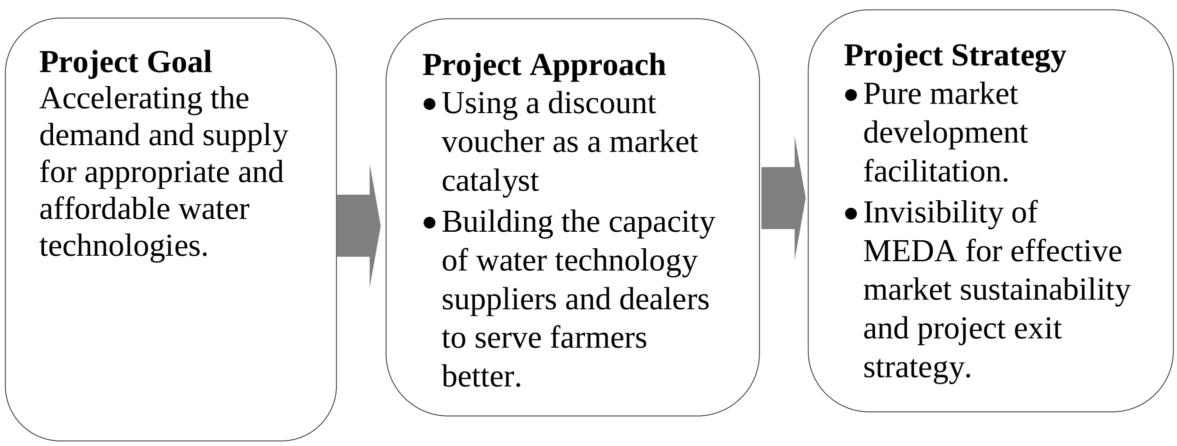
Generally, conventionally available irrigation technologies and methods are expensive and often far out of reach of the poorest smallholders. The majority of Zambian farmers therefore resort to traditional irrigation techniques such as bucket irrigation which is cheap but labour-intensive; this often limits cultivation area size and yields, resulting in continued low production. Other conventional irrigation systems, such as channel irrigation and wild flooding are inefficient, leading to high levels of water loss and soil erosion.

Around the world, low-cost irrigation technologies such as treadle pumps and drip irrigation systems are proving to be effective water solutions for small scale farmers and rural households with increased access and usage of these technologies one way to address poverty. According to the FAO, small scale irrigation can increase yields for most crops by 100 to 400% (FAO, 2006). Irrigation enables small scale farmers to smoothen their cash flow. A typical farmer normally focuses on rain-fed agriculture; income is therefore only received at one time during the year. With appropriate irrigation technologies, farmers generate income year round and can switch from subsistence production to market-oriented production, with higher yielding and higher-value crops.

In the search for appropriate irrigation technologies, MEDA looked at other possible irrigation technologies. MEDA's decision was to promote irrigation technologies that provide a strong return on investment and are environmental friendly, specifically treadle pumps and drip irrigation systems. Drip irrigation systems are a series of pipes with a water storage device or reservoir that facilitate direct watering of plants; emitters allow for water to be dispersed at the root of the plant thereby reducing water wastage and improving yields. Treadle pumps are manual pumps that allow farmers to manually draw water from shallow water tables or rivers and streams; these technologies are less-labour and resource intensive and are effective in drawing water with minimum wastage. Research on these technologies indicates through the adoption of these technologies farmers, on average; earn an additional $100 in net income per annum (Frausto, 2000). The main question was how to create a sustainable solution to improve availability of these technologies for millions of farmers in rural areas of Zambia.

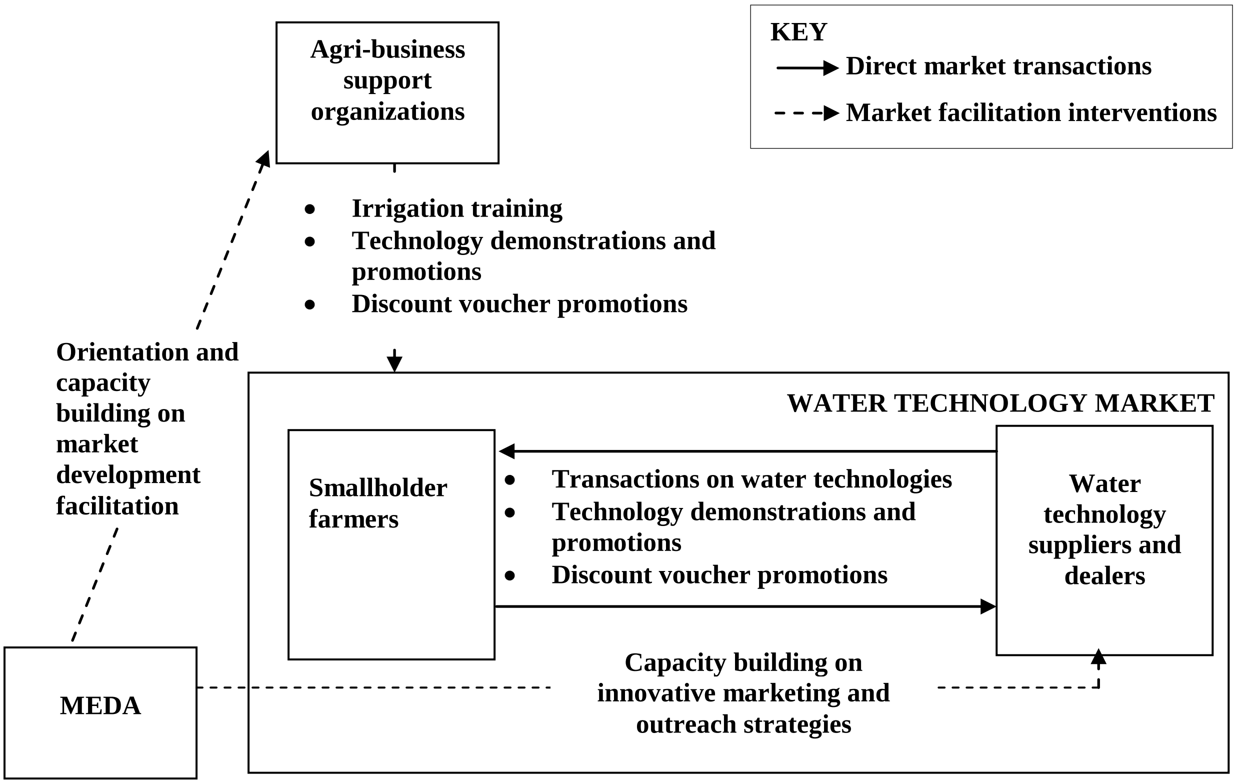
The experiment: Accelerating the supply chain for affordable and appropriate water technologies in Zambia
In response to the need of appropriate and affordable water technologies, MEDA designed and implemented a market development program to accelerate supply and demand for these water technologies without dependency while strengthening local businesses to ensure their long term viability and sustainable reach to underserved rural populations in Zambia. The water technologies promoted, namely treadle pumps, hip pumps and drip irrigation systems were not new technologies in Zambia. Distribution, however, was focused on sales to NGOs who then provided the technologies to farmers for free or highly subsidized basis. Unlike the common response by NGOs for free distribution, MEDA experimented with commercially driven model using a discount promotion strategy through technology suppliers. The project goal, approach and strategy are summarized in Figure 1.

***Figure 1:** Project goal, approach and strategy*



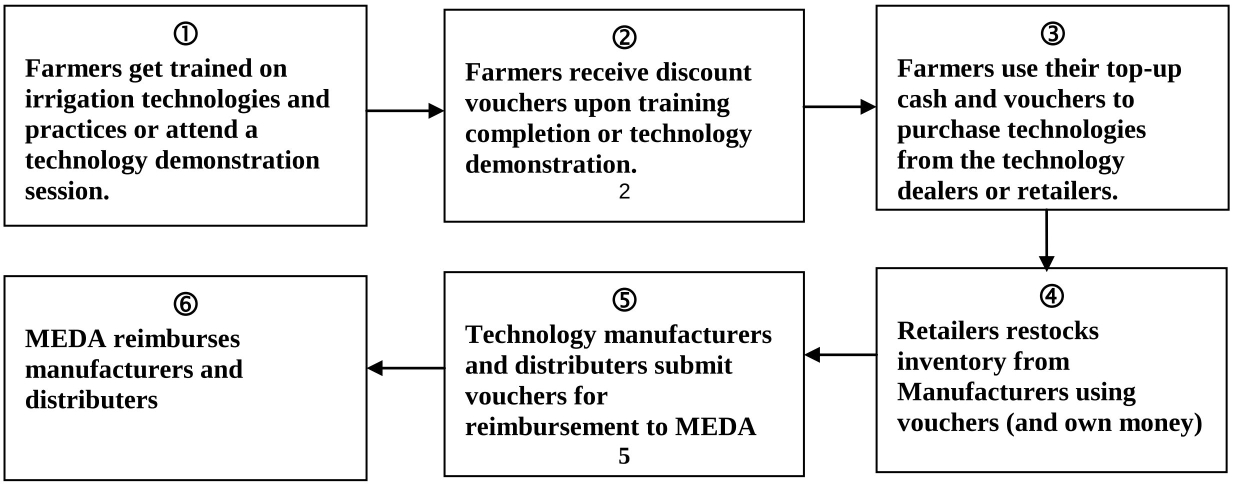
Based on a market facilitation strategy, MEDA employed a model which included both supply and demand side interventions, as outlined in Figure 2. MEDA focused its activities on implementing a voucher program and training suppliers while working with partners to ensure farmers were trained on appropriate techniques.

Figure 2: *Voucher Program Market Development Model*



Central to the project was the introduction of a voucher scheme, offering farmers a promotional discount off the price of the technology. MEDA worked with suppliers to promote direct sales to farmers through technology demonstrations and irrigation best practices promotion with training sessions, agricultural fairs and other information sessions. These sessions were organized by technology suppliers and MEDA's NGO partners. Farmers received a discount voucher in the form of an irrigation training certificate upon completion of a training or attendance at a technology demonstration. The discount vouchers were assigned a unique random number from a mobile phone 'short messaging service' (SMS) application which provide real-time monitoring of voucher issuance and redemption. Farmers would then present the discount voucher and required top-up cash to purchase technologies from the registered retail outlets. Retailers would redeem the discount vouchers, again using SMS technology to verify the vouchers while working out their profit margin. All voucher transactions are therefore conducted electronically and conveniently through a mobile phone application. Figure 3 outlines the process.

Figure 3 *Market Stimulation Model*



The program commenced in 2008; at project launch the discount voucher value was set at a fixed amount of USD50, regardless of the price of the water technology the small scale farmers chose. To acquire a water technology, the average and highest top-up amounts were USD 85 and USD140 respectively. In the second year, the discount promotion was changed to a variable voucher with a discount of 40%; this was subsequently reduced to 30% and 20% in the third year as part of the project's exit strategy. To arrive at the discount value, MEDA worked with suppliers to look at the market conditions, indicative willingness-to-pay, and incentive structure that would stimulate demand. However, flexibility was applied to ensure that promotion responded to the market changes. In the final year, the discount amount is cost shared between water technology suppliers and MEDA as part of the exit strategy.

Results, Outcomes and Challenges

Contrary to expectations by most NGOs who opt for free distribution, the discount promotion for water technologies in Zambia has enabled over 1,400 small scale farmers to acquire water technologies. Discount vouchers served as an incentive to reduce risk aversion among farmers, investing in a new technology. Technology demonstration led to increased sales as most farmers saw firsthand the environmental and financial benefits of the owing these technologies. The vouchers also served as an incentive to draw irrigation suppliers into the rural areas.

The discount voucher approach used by MEDA as an alternative to the handout approach has revealed a number of lessons for commercially driven strategies aimed at stimulating input supply or technology markets. Table 1 presents some comparisons between commercial model and handout model for introducing irrigation technologies to small scale farmers.

Table 1: *Comparisons between Commercial model and Handout model*

Lens	**Commercial Model**	**Handout Model**
Product Demonstration	Product demonstration is conducted by technology suppliers; good start of supplier-buyer interactions.	Product demonstration is usually provided by the NGO.
Access	Provide equal and wide access to farmers who would like to acquire the technologies.	Access limited to the provider's target group, normally selected by an NGO.
Ownership	Promotes individual ownership and responsibility.	Technologies mainly provided under collective ownership and hence do not promote individual ownership and responsibility.
Promoting Economic Choice	Farmers are able to select technology based on needs and preferences.	NGO selects technology and provides to farmers.
Entrepreneurial Spirit	Strengthens entrepreneurial spirit among technology buyers	Does not promote entrepreneurial spirit as there is no financial commitment of the technology recipients.
After-sales service support and access to spare parts	Farmers more concerned about after-sales service support and availability of spare parts.	Farmers usually do not know where they can obtain after-sales service support or purchase spare parts as acquisition is not directly through the technology supplier or dealer
Supplier-buyer linkage	Good prospects of ongoing interactions between suppliers and farmers.	Farmers normally have no direct linkage to suppliers.
Supply Chain Development	Good prospects of developing a sustainable supply chain.	There is often objective of developing supply chain; often disruptive to efforts to build a commercial supply chain.

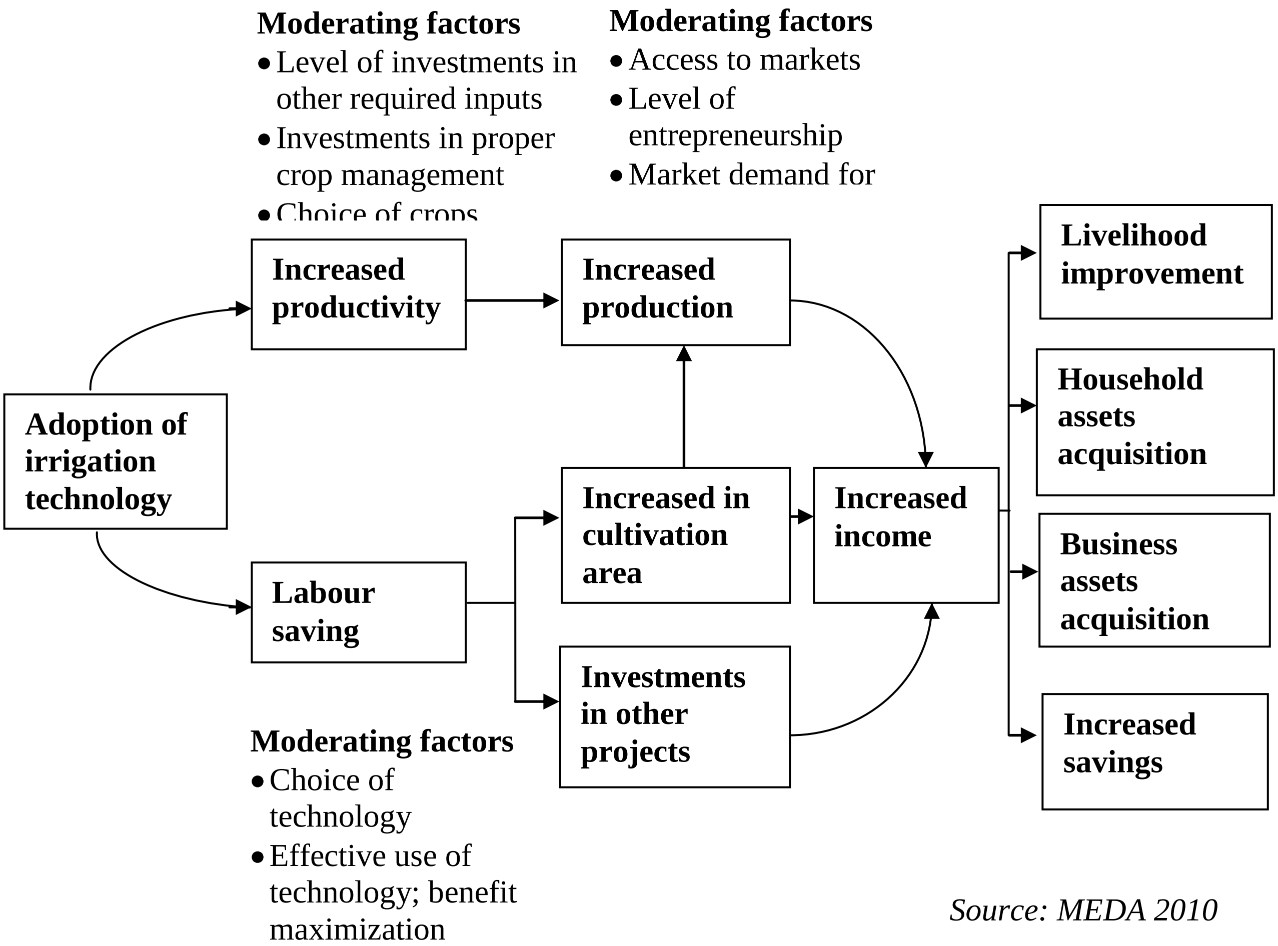
The monitoring and evaluation surveys conducted by MEDA has also revealed that while the vouchers are effective in stimulating demand, in a very weak supply market, complementary activities, such as training of suppliers on marketing, support for farmers to access new markets, and financial services linkages are critical in developing a sustainable and dynamic supply chain. As the demand for the technologies grows, suppliers often fail to service the effective demand. From a pure market development approach, supply-side capacity building interventions should be restricted to business demonstration of what works in terms of retail supply network development. In Zambia, the proactive and entrepreneurial suppliers have invested in lead-farmer agent networks in order to bring water technologies closer to the farmers. MEDA's experience in Zambia shows the benefits of using a market catalyst in form of a smart subsidy to develop a very weak supply chain. Box 1 summarises the lessons learned in stimulating the irrigation technology supply chain using a discount voucher as a smart subsidy.

Box 1: Lessons from stimulating markets using vouchers as smart subsidies

- Vouchers do not hide the real cost of the technology. Farmers are aware that the discount provided is in fact a price reduction (which is viewed as being offered by the suppliers).
- The voucher is offered as a clear one-time cost reduction. This is not an ongoing price subsidy but rather a promotion to allow farmers to try the technology. Each farmer has six months in which to redeem their voucher, after which the voucher expires.
- Research has shown that farmers are more likely to apply and use technologies when purchased as opposed to being provided for free. As such, they also serve to automatically direct the limited subsidy to farmers who are most likely to use the voucher efficiently.
- Farmers are still required to pay for the majority of the technology cost. As farmers are rational consumers, it can therefore be expected that only those who want to enhance their production under irrigation will take up the offer.
- Vouchers create demand that draws a commercial network into rural areas, increases the capacity of retailers to invest in inventory, and strengthens the technology market for future clients.
- By enticing suppliers to enter the market, after-sales service is now available for technology users. This was not the case when technologies were distributed for free as maintenance services and spare parts markets were not developed.

Source: Snelgrove and Manje 2009

Figure 4: *Impact causal effects from adoption of irrigation technologies*



Source: MEDA 2010

MEDA's impact evaluations show that use of appropriate water technologies can substantially increase the income of a rural household. However, there are a number of moderating factors which include quality of technology, proper usage and maintenance, family involvement, choice of crops and access to markets. Figure 4 summarizes the multiple impact causal effect relationships that have emerged from the MEDA project in Zambia.

Private sector responsiveness proved to be one of the major challenges for this program. MEDA's program design required private sector water technology suppliers to be proactive in direct marketing and selling of the water technologies. This entailed investments in technology promotions, marketing campaigns and retail networks closer to farmers. After the first year, it was clear that water technology suppliers needed to invest in dynamic retail networks that reach farmers even in the remote rural areas. Since most of the suppliers were used to NGO sales which did not require them to directly interact with farmers, jumping at this opportunity and innovatively implementing marketing and sales strategies was challenging. For this reason, water technology sales were low in the first year; only 500 water technologies were sold directly to farmers under the discount voucher promotion. However, with additional coaching and by seeing the ability of farmers to purchase technologies, suppliers eventually started investing in marketing and by the second year over 1,300 sales had been made.

It is important to note that vouchers were used as a short-term strategy to kick start the market for irrigation technologies. Suppliers and buyers in weak markets are not likely to respond to new market opportunities independently. The vouchers acted as a short-term incentive to catalyse the market while complementary, longer term solutions, such as access to financing, were developed.

Conclusions

MEDA's experience in Zambia presents evidence that it is possible to stimulate sustainable access of agricultural inputs and technologies; in this case, it has been possible to accelerate the supply and demand of improved and efficient water technologies for small scale farmers and rural households. Sometimes, assumptions made of poor rural households are untrue. Rural households are not homogenous; most of the households are willing to invest in a technology that breaks them out of the poverty cycle. Commercially driven or business solutions can create sustainable access of desired technologies and inputs for farmers in rural communities. Free distribution or handout often creates a dependency syndrome that presents challenges of successfully implementing a commercial model and indeed developing sustainable solutions to developmental problems.

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