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

V L Pillay[1*] and Alex Kalu[2]

[1*]Dept of Chemical Engineering, Durban University of Technology, Durban, pillayvl@dut.ac.za, and [2]Center for Advanced Water Technology & Energy Systems, Savannah State University, Savannah Georgia, USA. kalua@savannahstate.edu

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 Operation of the system is very simple: Raw water is poured into the feed tank, and the product is withdrawn through an outlet tap.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

<u>The Water Treatment Unit</u>

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).

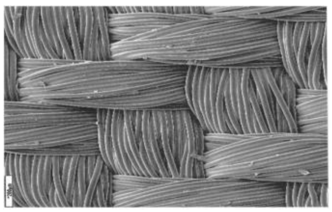

Figure 1: Microfiltration Fabric

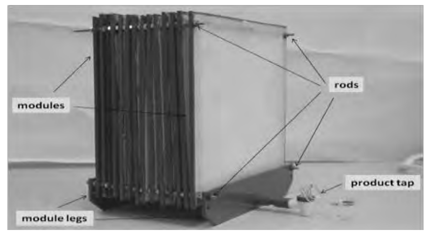

Figure 2: Membrane pack

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.

.

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.

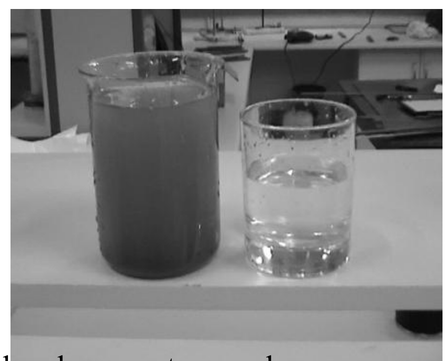

Figure 5: Typical feed and permeate samples

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.

<u>Product Flow Rate</u>

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.

<u>Cleaning Periodicity, Efficency and Regimen</u>

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.

Acknowledgements
Many agencies provided support for this project over the years. Currently and particularly noteworthy are the supports from South African Water Research Commission, Umgeni Water, and NCIIA. The development team is grateful to all our supporters.

REFERENCES

[1] A Report from Umgeni water, A South African Utility Company, June 2009
[2] Kuennen, R. W. et al; Gravity Feed Water Treatment System International Application No.: PCT/US2010/020728; International Filling Date: 12.01.2010 Publication Date: 22.07.2010
[3] Madaeni, S. S., "The application of membrane technology for water disinfection" *Water Research, Vol.33, Issue 2, February 1999, Pages 301-308*
[4] Marusek, J. A. "Gravity Fed Water Treatment System – Mod 1*" http://www.breadandbutterscience.com/GFWTS1.pdf; Accessed January 10, 2008
[5] Nguyen T. P. *et al* « Fabrication of antibacterial water filter by coating silver nanoparticles on flexible polyurethane foams" 2009 *J. Phys.: Conf. Ser.* 187 012079
[6]. Steripen "Global Water Situation," http://www.steripen.com/global-water, Accessed July 30, 2010
[7]. Thangham, C. V. "$3 Water Filter gadget for a year without spare parts, electricity or maintenance" Digital Journal Jun 12, 2007, http://www.digitaljournal.com/article/194901; Accessed July 15, 2007
[8] United Nations; Int'l Decade for Action, A UN Publication Water for Life, 2005 – 2015 http://www.un.org/waterforlifedecade/index.html; Accessed August 1, 2010
[9] Kunikane, S., et al, A comparative study on the application of membrane technology to the public water supply, Journal of Membrane Science Volume 102, Pages 149-154, 15 June 1995
[10] Charcosset, C, A Review of Membrane Processes and Renewable Energies for Desalination, Desalination**,** Volume 245, Issues 1-3, July 2009

Appropriate Technologies for Water and Sanitation

John Tharakan
Department of Chemical Engineering, Howard University
2300 6th Street, NW, LKD 1009, Washington, D.C. 20059, USA
FAX(202)806-4635, E-mail: jtharakan@howard.edu

Keywords: appropriate technology, rain water harvesting, water treatment, water conservation, sanitation, biological waste treatment, biodegradation

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].

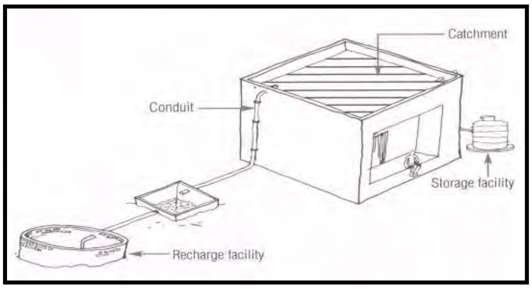

Figure 1: Basic elements of a rainwater harvesting system. From [12]

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.

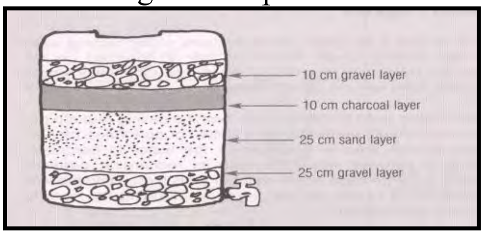

Figure 2: Basic elements of a sand-charcoal filter configuration, from [11].

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 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

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

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.

REFERERENCES

[1]Solon, Pablo, Bolivian United Nations Ambassador, *Personal Communication,* October 22, 2010.
[2] 'Nagpur **ragpickers** out, machines in', Down To Earth, September 15-30 2009.
[3] J.Tharakan, "Appropriate Technologies for Water Use and Conservation in Public Health," *Proc.2nd Intl.Conf.Appropriate Technology, July 2006*, National University of Science and Technology, Bulawayo, Zimbabwe, pp 87 – 92 (2006).
[4]Rybcynzski, W, *Paper Heroes; Appropriate Technology: panacea or Pipedream*, Penguin, USA (1991).
[5]Darrow and Saxenian, *Appropriate Technology Sourcebook*, Volunteers in Asia, Stanford, CA (1986).
[6]Tharakan, J., "Appropriate Technology and Water Availability and Use: Impact on and Implications for Land Reform," *Proc.1st Intl. Conf. Appropriate Technology, July 2004*, pp. 97 – 104, National University of Science and Technology Press, Bulawayo, Zimbabwe (2004).
[7]Agarwal, A., S. narain and I. Khurana, *Making Water Everybody's Business,* Center for Science and Environment, New Delhi, India (2001).
[8]Ibid, 2003
[9]Ibid, 2005

[10]Keller, K., *Rainwater Harvesting for Domestic Water Supply in Developing Countries: A literature Survey*, U.S. Agency for International Development, Arlington, VA (Undated).
[11]Center for Science and Environment, *A Water Harvesting Manual for Urban Areas: Case Studies from Delhi and Mumbai,* p. 3, CSE, New Delhi, 2003.
[12]*Ibid.,* p. 5 (2003).
[13]Van Dijk, J.C., and J.H.C.M.Oomen, *Slow Sand Filtration for Community Water Supply in Developing Countries: A design and Construction Manual,* Technical Paper No. 11, IRC Press, London (1978).
[14] SODIS ®, http://www.sodis.ch/index_EN; Accessed Nov 1, 2010.
[16]Jagadeesh, A, "Drinking Water for All", Center for Energy and Sustainable Resources, R.M.K.Engineering College, Kavaraipettai, India (2006); http://www.ewb-international.org/pdf/WaterForAllJagadeesh.pdf , Accessed May 2006.
[17] Tharakan, J. (ed), *Proceedings of Symposium on Biological Methods of Waste Treatment and Management in South India,* The New College, Chennai, February 2007.
[18]McDonough, W., and M. Braungart, *Cradle to Cradle – Remaking the Way We Make Things,* North Point Press, New York, 2002.
[19]Parr, J., and R. Shaw, "Choosing an Appropriate Technology," http://www.lboro.ac.uk/departments/cv/wedc/, Accessed June 2006.

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

[1]Gate T, [2]Karambakuwa RT and [3]Chigunwe G
Bindura University of Science Education, Human Resources Department and Department of Economics, Bindura, ZIMBABWE
Zimbabwe Open University, Faculty of Social Sciences, Bindura, ZIMBABWE
Email: gatetsitsi@yahoo.co.uk

Key Words: Appropriate Technology, Universities, Water Education, Clean Water

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.

Acknowledgements
We would like to acknowledge with heartfelt gratitude Conference organisers, Mrs. L Mujuru, Ms. E Madungwe (Bindura University of Science Education), Mr. M Shumba (Midlands State University) and Mrs P Gandidzanwa (University of Zimbabwe) for their advice, support and valuable suggestions that made this paper possible. Our deepest gratitude also goes to our families and to God who made all things possible.

REFERENCES

[1] Byron, J (2007). **Water Wars: The Need for a National Water Policy**. http://handle.dtic.mil/100.2/ADA469088. Accessed 11 June 2010

[2] Herald 31 July (2007) Kwidini, T. The Herald July 31, 2007 **Water Shortages in Capital Leave Residents Desperate**

[3] Troy, S. **What is Appropriate Technology?** Jade Mountain Inc. http://www.gdrc.org/techtran/appr-tech.html. Accessed 8 July 2010

[4] Bordhiharma 6th Century (2006**) All know the way, but few actually walk it.** http://www.unesco.org/water/wwap/wwdr/wwdr2/pdf/wwdr2_ch_15.pdf Accessed 15 June 2010

[5] Manatsa D (2009) Seasonal Forecasts:-Decoupling Of The Primary Predictors From Regional Rainfall In The Recent Decade, **Unpublished Paper** presented at a Land Use Science Workshop at Bindura University of Science Education on 2-4 November 2009

[6] Mintz E, Bartram J, Lochery P and Wegelin M (2001). **Not just a drop in the bucket: Expanding access to Point-of-Use Water Treatment Systems.** www.guardian.co.uk/news/datblog/2009/mar.../access-water

[7] Winpenny, J.T. (2002), **Powerless and thirsty? The out look for energy and water in developing countries.** Utilities Policy, Volume 2, Issue 4, pp290-295

[8]**University of Colorado at Boulder- Creating Appropriate Technologies for Developing World.** nciia.org/node/917 Accessed 10 June 2010

[9] Bryman, A. and Cramer, D. (2000) **Qualitative Data Analysis for Social Scientists**. London Routledge

[10] Ward, J.C. (2002) **Environmental Indicators for State of the Environment Reporting, Information Paper No. 21, Centre for Resource Management**, Lincoln University Canterbury NZ

[11] Mohamed, AS and Savenije, HHG. (2000) **Water demand management; Positive incentives, negative incentives or quota regulation?** Physics and chemistry of the Earth Part B Hydrology, Oceans and Atmosphere. Volume 25 Issue 3, pages 251-258

[12] Gumbo, B. and Van Der Zaag, P. (2002), **Water Losses and the Political Constraints to Demand Management**: The Case of the City of Mutare, Zimbabwe

[13] Kanda A (2009) **Land use Science and Water Resources, Unpublished Paper** presented at a Land Use Science Workshop at Bindura University of Science Education on 2-4 November 2009

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

Joseph Thomas,
Chief Technology Officer, Villgro, Chennai, Tamil Nadu, INDIA
E-mail: joseph@villgro.org

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.

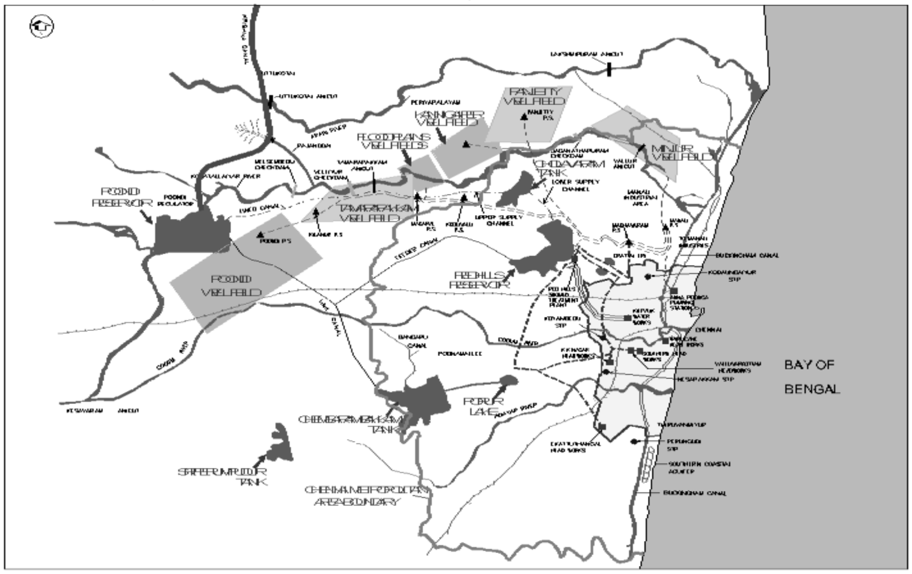

Figure 1.

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).

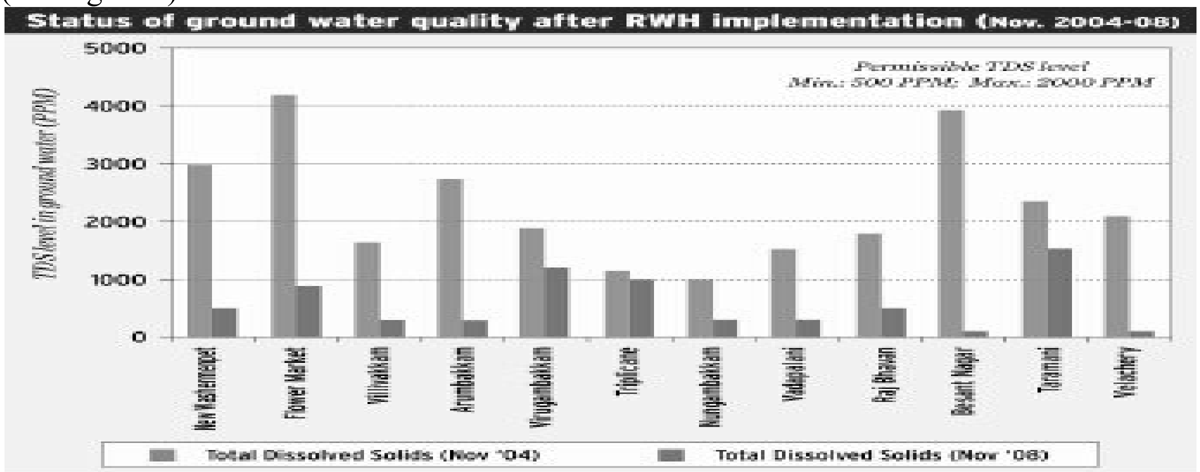

Figure 4[10]

–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.

REFERENCES

[1]http://www.rainwaterharvesting.org/Crisis/Urbanwater-scenario.htm

[2]Balakrishnan, T., Technical Report Series District Groundwater Brochure, Chennai District, Tamil Nadu. Central Ground Water Board, South East Coastal Region, Chennai, Ministry of Water Resources, Government of India, November 2008. Published by Regional Director, CGWB, SECR, E-1, Rajaji Bhavan, Besant Nagar, Chennai -600090, Tel:+9144 24912941/24914494, Fax +9144 24914334 Web: www.cgwb.gov.in email rdsecr-cgwb@nic.in

[3]Thomas, Joseph, Sustainable Fresh Water Supply for Madras (now Chennai) City, India (Contract No.S$P/95/0042) Final report submitted to UNICEF, 73, Lodi Estate , New Delhi 110 003, Printed by Shri AMM Murugappa Chettiar Research Centre, Tharamani, Madras (now Chennai), Tamil Nadu, India 600 113, May 1997.

[4]A. Vaidyanathan & J. Saravanan, Chennai's Water Supply Problems and Prospects (A background paper) National Water Harvestors Network –Tamil Nadu Unit, Centre for Science and Environment. (undated circa 2000)

[5]http://www.manage.gov.in/managelib/extdig/Jul99Water.htm

[6]Vaidyanathan, A. with Saravanan, J. ‗The Urban Water Scene: A Case Study -Water Situation in Chennai City' in A. Vaidyanathan, India's Water Resources: Contemporary Issues on Irrigation. New Delhi, Oxford University Press, 209-247 (2006).

[7]http://www.business-standard.com/india/news/tn-govt-to-takers-1400-cr-flood-control-project/397769/

[8]http://www.cmdachennai.gov.in/pdfs/SeminarOnWaterways/1.pdf

[9]http://www.chennaicorporation.gov.in/departments/storm-water-drain/introduction.htm

[10]http://www.hindu.com/pp/2009/01/31/stories/2009013150010100.htm