Proceedings of the Symposium on " Mainstreaming Rainwater Harvesting as a Water Supply Option"

at

International Water Management Institute (IWMI)

5th September 2014,

USAID
FROM THE AMERICAN PEOPLE

IWMI
International Water Management Institute

Lanka Rainwater Harvesting Forum

Symposium on
Mainstreaming Rainwater Harvesting as a Water Supply Option

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11th Symposium on
Mainstreaming Rainwater Harvesting
as a Water Supply Option
September 5th 2014

Panel of Judges of Competition on
Innovative Low Cost Method Technics
for Rainwater Storage

Eng. Devapriya Hapugoda
Dr C.S. Weeraratne
Eng. NUK Ranathunga
Eng. Kokila Ranasinghe

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Mainstreaming Rainwater Harvesting
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Preface

Water is a renewable source as long as the water cycle exists. In mountains and foothill regions deforestation and agriculture activities have lowered the ability of watersheds to retain water in nature, causing a decline in soil moisture and a fall in groundwater levels. In the cities too, water suffers the same fate as rural areas. Many open areas are covered by concrete and rain water falling on them and roofs are carried away by sewers to the nearest streams or canals. Cities, whose locations were once selected for their rich sources of water, now go to extreme lengths to transport water from long distances and purify and at the same time as sluicing away all the rainwater that falls on their own land/ roofs. Predicted effects of climate change will further degrade and deplete our water sources

Rain water harvesting is defined as collection of run-off rainwater for domestic use, agriculture, soil conservation, and environmental management. Roof Water Harvesting' (RWH) techniques is successfully used in rural areas has been supplementing the conventional sources of water supply since it was first introduced in a formal manner by CWSSP (Community Water Supply & Sanitation project) in 1995. Rainwater harvesting has brought much relief during times of droughts, in areas affected by tsunami and for settling communities in the north of Sri Lanka. At present, more than 40,000 domestic rain water harvesting systems are in operation throughout the country.

Lanka Rain Water Harvesting Forum (LRWHF) established in 1996 aim to bring professionals and practitioners together to promote, research and foster rainwater harvesting in the country. During the past few years, the experience gained by LRWHF has made it possible to influence the government and other stakeholders to take on rainwater harvesting as a possible and feasible option for domestic rural water supply. As a result a National Policy on Rain Water Harvesting was passed through parliament in 2005.

11th Symposium of the Lanka Rainwater Harvesting Forum 2014, under the theme "Mainstreaming Rainwater Harvesting as a Water Supply Option" is organized with the support of United States Agency for International Development (USAID and International Water Management Institute (IWMI) to provide open platform to present research and experience in rain water harvesting in Sri Lanka and other countries The papers presented in the following pages under 3 key theme will provide opportunities for learning from renowned researchers, understanding the current state of research and future challenges in the rainwater harvesting and networking with the key players.

We thank the Organizing Committee, the authors, panelist, contributors, key note speaker, our Chief Guest Hon Dinesh Gunawardena, Minister of Water Supply & Drainage Sri Lanka , supporters and invited guest to the symposium for their contribution.

Dr Tanuja Ariyananda
Director ,Lanka Rain Water Harvesting Forum

Message of Hon.Dinesh Gunawardena,

Minister of Water Supply & Drainage

Ambassador of the United States to Sri Lanka Your Excellency Michele Sison, oOur good friend key note speaker, Han Hejinen, Chairman of LRWHF, Dr Mantrhithilaka of IWMI, Dear Friends,

We have heard important aspects of rain water harvesting form our key note speaker who has inspired us right along and seem to inspire us more and more. Firstly I would like to thank your Excellency for taking time off to be part of this event. USAID has contributed heavily, facilitated and give strength to LRWHF as well as others relating to rain water harvesting to pursue in this important area. Thank you once again.

If I may mention in short, water is the most basic resource in the world and is also one of the most essential substances for all living organisms. It was considered a plentiful resource in most areas but with increase in population, urbanization and modernization water requirement has increased considerably. Recent climate change prediction studies (conducted at IWMI and other Institutes) have indicated that Sri Lanka will experience high variability of rain fall. That means wet areas will get wetter and dry areas will be more dry, and intense rain can be expected within a short period. This will cause water scarcity in dry areas and also lead to accelerating of soil erosion process (already 33% of the land area of Sri Lanka is affected by soil erosion) and flooding in other areas. Soil degradation and water quality degradation in many parts of the country also has caused water shortages causing considerable problems to the people inhabiting these areas.

Rain water is the main source of water in Sri Lanka which is bimodal. Sri Lanka gets an annual average rainfall of 2000 mm, ranging from 900 mm to 6000 mm in different regions. However, on average only about 40% of this water is used and the balance goes to the sea as run-off. At this instant I am remaindered of the famous proclamation by King Parakarambahu the Great (1153-1186 AD), ".....let not even a small quantity of water obtained by rain, go to the sea without benefiting man".

Rainwater harvesting saves water which otherwise ends up in sea. It is also a cost saving measure, as water in urban areas has to be paid for. It will also reduce flooding and saves purified water. Rainwater harvesting promotes self-sufficiency and fosters an appreciation for water as a resource. It also promotes water conservation and ground water recharging. Rainwater harvesting also conserves energy as the energy input needed to operate a centralized water system is bypassed. At present we are pumping water from a long distance away from Ambatale. This cost energy and much water is lost from leakages. Both energy and water can be saved if at least portion of the water needs in a household is collected through rain water harvesting at the own premises. Local erosion and flooding in urban areas during heavy rains is lessened as a portion of local rainfall is diverted into collection tanks.

A large number of people in the NCP, Vavuniya, Kurunegala and some of the Mahaweli zones are affected by a kidney disease attributed to pesticides, chemical fertilizers and other toxic compound/compounds in water used by them. Most of them use water obtained from open wells and tube wells. Using rainwater atleast for drinking is important in these areas affected by the kidney disease. My Ministry is promoting rain water harvesting in general and in those areas affected by the kidney disease in particular. It was also found that areas where NWS&DB is supplying water less incidences of kidney disease are being reported. Therefore, NWS&DB has launched a project to distribute clean drinking & cooking water to families through pipe born water and mobile units (bowser supplies) to some of the affected areas

Lanka Rainwater Harvesting Forum (LRWHF) which was established in 1996 promotes this practice in Sri Lanka. In addition to many other activities, this organization has built or have supported to build nearly 42,000 rainwater tanks in many remote areas of Sri Lanka thus bring immense benefits to communities. The 11th symposium on "Mainstreaming Rain Water Harvesting as a Water Supply Option" organized by LRWHF is very timely as it would provide opportunities for learning from renowned researchers, understanding the current state of research and future challenges in rainwater harvesting. Many countries have progressed immensely adopting rain water harvesting practices and rain water harvesting is discussed in many of the international Forums as a viable water supply solution. As we are coming to the end of the Millennium Development goals and future Development agenda is been developed, I strongly recommend that rain water harvesting should be considered in the post development agenda 2015.

I recall as a subject minister Rain water harvesting was made a National Policy in 2005 and UDA regulation also came effect from 2009, making it mandatory to install rain water harvesting system in Municipal and Urban areas in new building above a certain roof area. My ministry has drafted further regulation to offer incentive in the form of reduction in pipe water connections chargers if rain water harvesting is incorporated in the households.

Rain water harvesting has been recognized by the government, private sector and many other institutes. I am happy note that LRWHF has been supported by USAID, Unicef, IWMI, and Malteser International.

As the Minister for Water Supply and Drainage, I wish to express my appreciation to the members of the Lanka Rainwater Harvesting Forum, for organizing this timely symposium and hope that it will lead towards further development of an effective rainwater harvesting systems in the country.

Message of Ms. Sherry F. Carlin
USAID Mission Director toSri Lanka and Maldives

Reviving an ancient technology to ease water woes in Sri Lanka

Water scarcity is a great challenge facing humanity today. As the population and consumption of water increase worldwide along with extreme weather patterns from global climate change, there is greater stress placed on existing water resources.

Given this backdrop, more and more countries are finding rainwater harvesting to be a sustainable method for managing water. The technology is low cost, uncomplicated and user-friendly, making it a viable alternative for present day water issues, particularly in many countries where the United States Agency for International Development (USAID) focuses its efforts

In drought-prone regions around the world, USAID supports long-term solutions to water scarcity in local communities. Partnering with Lanka Rainwater Harvesting Forum (LRWHF) in Sri Lanka, USAID supported awareness-raising on rainwater harvesting techniques and its many benefits, constructed domestic rainwater harvesting tanks bringing clean water to the doorstep of rural families, made water accessible in hospitals and schools and helped restart home gardening. To complement this support, members of households, hospitals and schools also received training on maintaining and operating these tanks.

Having provided a a critical life line for rural communities, this symposium, organized by LRWHF with USAID support, provides a platform for researchers to present their findings, share and discuss best practices, and future challenges related to rainwater harvesting.

This publication consists of research papers presented at the symposium along with USAID program briefs. We invite you to use these findings to strengthen and expand your work in rainwater harvesting.

USAID is proud to partner with LRWHF as we, together, revive ancient technology previously used in Sri Lanka. Our fervent hope is that rainwater harvesting will be replicated in many households and community facilities across the country.

Sherry F. Carlin
USAID Mission Director to Sri Lanka and Maldives

The American people, through the U.S. Agency for International Development, have provided development and humanitarian assistance in developing countries worldwide for nearly 50 years. Since 1956, the U.S. government has invested over $2 billion to benefit the people of Sri Lanka. For more information about USAID's work in Sri Lanka please visit http://www.usaid.gov/sri-lanka

Message of Eng. Deva Hapugoda,
Chairperson of Lanka Rain WaterHarvesting Forum

We at Lanka Rain Water Forum with almost 20 years' experience in rain water harvesting believe that rain water can be used to solve the potable water problem in Sri Lanka. Rain fall is good, can easily be collected as potable water from the available catchments with few improvements.

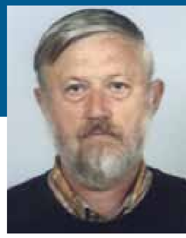
LRWHF has successfully implemented rainwater harvesting systems in household's, schools, temples and institutes in all provinces of the country. We have introduced rain water harvesting for drinking and other domestic need as well as for home gardening and crop production in rural areas. There is much potential to use of rain water for urban areas too. With the legislation changers imposed by the UDA, we hope that many urban buildings especially one with large roof areas, such as hospitals, schools and public building will incorporate rain water harvesting systems to supplement the water supply, thus reducing costs on water treatment, water pumping and water distribution.

Rain Water harvesting is very relevant today to face the reported water shortages, flooding and the problem of Chronic Kidney Problems reported from some part of the country. Much feasibility studies and research remains to be done in the future on these aspects.

We are thankful USAID and International Water Management Institute (IWMI) for supporting us to hold this 11th Symposium of LRWHF titled " Mainstreaming Rain Water Harvesting as a Water Supply Option". This Symposium is aimed to will provide opportunities for learning from renowned researchers, understanding the current state of research, future challenges and networking with the key players in rainwater harvesting. Hope the Symposium will bring out valuable ideas. I wish the symposium the very best .

Profile of Key Note Speaker, Han Heijnen,

Vice-President IRCSA and Water Supply and



Han Heijnen is an environmental health professional currently working with the Ministry of Urban Development as policy analyst at the WASH Sector Efficiency Improvement Unit in Kathmandu. During the last 15 years he undertook assignments in Africa and South-Asia for WHO, UNICEF, USAID, WaterAid, IRC and Rain Foundation in water safety planning, rainwater harvesting, sanitation, cholera, hepatitis E and polio.

During the 1980's he gained his field experience in rural water supply and sanitation with the Ministry of Local Development in Nepal and with the Sarvodaya Rural Technical Services in Sri Lanka. From 1994 to 1998 he managed the consultancy component of the Community Water Supply and Sanitation Programme (CWSSP) of what then was named the Ministry of Housing, Construction and Public Utilities. Through CWSSP the Government of Sri Lanka facilitated a large scale rainwater harvesting capacity development and investment programme and was a co-founder of the Lanka Rainwater Harvesting Forum.

In 1998 Han Heijnen contributed substantially to the formulation of a multi-country European Union grant proposal that furnished LRWHF with funds to undertake several important studies on aspects of rainwater harvesting such as on low-cost storage options with Warwick and Delhi University as partners,.

Han Heijnen is currently vice-president for external relations of the International Rainwater Catchment Systems Organization and a member of the board of the International Rainwater Harvesting Alliance.

Key Note Address by Han Heijnen, Vice-PresidentIRCSA and Water Supply and Sanitation SectorPolicy Analyst, MoUD Nepal

Dignitaries at the dais
Her Excellency Michele Sison, Ambassador of the United States to Sri Lanka
Honorable Minister of Water Supply and Drainage, Mr. Dinesh Gunawardhena
Today's Presenters and Representatives of RWH Stakeholder groups
Ladies and Gentlemen,

I feel honored today to be able to address this august gathering on the occasion of the 11th Symposium of the Lanka Rainwater Harvesting Forum with the theme of "Mainstreaming Rainwater Harvesting as a Water Supply Option". I recognize quite a few good friends and colleagues in the audience many of whom have been travelers on the road to rediscovery of the wider use of rainwater for domestic and livelihood through collection and storage.

It is quite appropriate that the meeting takes place at the International Water Management Institute, an internationally recognized knowledge and research capacity, hosted by the Government of Sri Lanka. When first I came to Sri Lanka in 1986 IWMI was still - under a slightly different name - situated next to the Prima Bakery at Rajagiriya. Both companies appear since to have taken a productive trajectory in their development, undoubtedly because of leadership and a good use of opportunities.

When I returned to Sri Lanka in late 1994 to work with the Community Water Supply and Sanitation Project, CWSSP was faced with the problem that a good number of communities and hamlets could not sustainably be served by traditional water supply solutions. Due to population pressures on available land, young families were forced up to higher elevations beyond the reach of regular water supply services. There was some talk at the time of lifting water to the community, but it quickly became clear that this was financially not sustainable. Thus, CWSSP started work on "Mainstreaming Rainwater Harvesting as a Water Supply Option" as an alternative and complementary source of water.

Clearly this was viewed as rather a poor approach. Hardly anybody was constructing rainwater systems, not the Water Board, or for that matter the Sarvodaya Rural Technical Services, for whom I had worked in the 1980s. Initially there were some doubts about the feasibility of rainwater harvesting. However, in view of the bimodal rainfall pattern in the 3 districts in which CWSSP was working at the time: Matara, Ratnapura and Badulla, it was a good option, that would yield a good service even with a small roof and limited storage of 5 m3. The proof is in the pudding and so Deva Hapugoda, as an engineer with experience in rainwater harvesting from Fiji, was sent out to roam the field in 1995 with the instruction to return only when he had found and tested storage solutions at roughly a rupee a liter. He did come back, and so we could start the remarkable story of establishing rainwater harvesting as an option in CWSSP.

For rainwater harvesting to take off as a suitable rural water supply option in Sri Lanka, three development components were addressed:

- For government or individual households to adopt a rainwater harvesting system, the costing of a system should have to be reasonable. The cost of storage is the most cost-intensive part. Reducing that cost and facilitating decentralized local construction was thus a critical aspect of implementation. The adaptation of the Chinese dome biogas digester tank for underground reservoirs and even more the clever design of the Pumpkin tank of which some thirty thousand have been constructed around the country in the last 17 years, made rainwater harvesting an accepted water supply solution in the CWSSP served districts.

- An inventory of rainwater practices around the island which culminated in the first rainwater harvesting conference at the Open University in early 1996. That conference demonstrated the breadth of current rainwater use by households all over and convinced us of the potential for wider application. The inventory also showed that a good number of households in the wet zone practiced crude rainwater harvesting and storage that could be upgraded with simple technical improvements.
- The establishment of the Lanka Rainwater Harvesting Forum at the beginning of 1996 by a group of representatives from government and non-government institutions interested in further exploring the potential of rainwater harvesting in Sri Lanka provided a home. Physically the home was initially at ITDG, now Practical Action. The contribution by Lahiru and Tanuja in those early days needs to be acknowledged. As we should acknowledge the interest and support by the Ministry, as it was the Minister for National Housing and Public Utilities, Hon. Nimal Siripala de Silva, who formally launched the Lanka Rainwater Harvesting Forum on 19th of March 1997.

The presence and activities of the Lanka Rainwater Harvesting Forum with its representative membership have facilitated the implementation of research and information management to further our understanding of implementation modalities, communication needs with respect to proper use of systems (RCWSSP & Fraser Thomas Ltd., 2006), water quality concerns and adjustments to accommodate rainwater solutions to situations in different climatic zones in the island.

The progress made in Sri Lanka on rainwater harvesting for domestic use is well appreciated in other parts of the world. The research undertaken in collaboration with Warwick and Delhi University in from 1998 – 2001 has created opportunities for developing alternative solutions in storage, technical options for first flush, filters, inlet and outlet to ensure water quality, and to demonstrate applicability of rainwater harvesting solutions through surveys and field studies.

When CWSSP started out with rainwater harvesting, the idea was to provide sustainable services in water supply to those who could otherwise not be served. The concept of water security was coined in which it was assumed that the rainwater systems would provide adequate water for human consumption and domestic chores. Women proved good managers of the water store and prudently used the rainwater collected in their tanks, while taking laundry and a bath at the well down the hill. The reliability that came with the rainwater store offered opportunities for livelihood improvement, raising a few chicken or growing some vegetables.

These days we debate climate change and consider ways how we can adapt to the changes in our climate as these affect our lives. Whereas rainwater tanks cannot be filled with rain during a prolonged drought, it is clear that having a tank next to the home, raises the capacity of a family to survive a longer drought. And when the tank goes empty, there is the chance to fill it again by purchasing a bowser of water, as mentioned in the USAID web-based Frontline Magazine of February 2014 describing rainwater harvesting projects in Vavunya (Gunasekara, 2014).

At the political level the concerns for the future are increasingly taken note of. For instance the Declaration on Partnership for Growth for Our People of the Fifteenth SAARC Summit held in Colombo in August 2008 through its Heads of State expressed "their deep concern at the looming global water crisis, recognized that South Asia must be at the forefront of bringing a new focus to the conservation of water resources. For this purpose they directed initiation of processes of capacity building and the encouragement of research, combining conservation practices such as rain water harvesting and river basin management, in order to ensure sustainability of water resources in South Asia".

In our own way here in Sri Lanka we are cognizant of this message and through national and international conferences and workshops try to advocate for rainwater harvesting practices and promote good practice in domestic water supply. In that respect I have to commend the Hon. Dinesh Gunawardena, who as Minister for Water Supply & Drainage, has been a supporter and advocate of rainwater harvesting not just in Sri Lanka, but also for Nepal and in Bangladesh. His support for the Rain Centre is further proof that the Government of Sri Lanka is keen to raise the profile of rainwater management as part of rural and urban water management, for its own sake, but also in support of development of regional capacity in rainwater promotion and application.

There is still a long way to go, however. For example, on behalf of the International Rainwater Harvesting Alliance, I drafted a statement on rainwater harvesting that was considered at the Budapest Water Summit of October 2013. It indicated that Rainwater is a critical component of every countries water resources that one cannot afford to neglect. In dry areas, because one needs to store the rainwater and use it effectively, and in wet parts because its management in the landscape is critical to reduce flooding and erosion of arable lands. Unfortunately the final declaration only mentioned harvested water, without mentioning rain water!

Currently the 2014 World Water Week in Stockholm is going on, and the Director General of IWMI, Jeremy Bird, is one of the participants. As Concerned Scientists and Experts Declaration on Water, Hunger and Sustainable Development Goals a group of scientists, including Jeremy Bird, drafted and signed a signed a declaration on Managing rain: the key to eradicating poverty and hunger !

It read: "We scientists and experts, joining the 2014 World Water Week in Stockholm, are deeply concerned that sustainable management of rainwater in dry and vulnerable regions is missing in the goals and targets proposed by the UN Open Working Group on Sustainable Development Goals on Poverty, Hunger and Freshwater.

Our concern arises from the failure to recognize the ominous congruence between, on the one hand, poverty, malnutrition, rapid population growth and economic reliance on agriculture, and the water challenges and predicament in semiarid tropical and subtropical climates on the other. These drylands are the most water vulnerable inhabited regions of the world, hosting the world's poorest countries.

Still, globally we see a growing appreciation and respect for rainwater harvesting solutions. I visited Brazil a few weeks ago and gave a mini-course on water security as part of the 9th Simpósio Brasileiro de Captação e Manejo de Água de Chuva, organized by the ABCMAC, the Brazil rainwater harvesting association. Several hundred people attended, from Government, Universities and NGOs. Brazil, with its Amazonas, is viewed as a wet country, but it has great variations in rainfall by year and between years, leading to serious drought conditions in particular in the North East of Brazil. Brazil provides strong government support for rainwater management, for domestic use and for agriculture for survival in tough areas. This year a delegation from East Africa also attended especially to learn more about agricultural techniques that could help mitigate drought problems by increasing rainwater storage in the landscape (UNEP & Delft University of Technology, 2008).

The 11th Symposium of the Lanka Rainwater Harvesting Forum has the theme of "Mainstreaming Rainwater Harvesting as a Water Supply Option". I presume the theme was selected because of doubts about the continued uptake of rainwater harvesting solutions in Sri Lanka and their sustained use (Strand , December 2012).

The 2012 report of the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation shows that 1.3% of the world's population uses rainwater as its main source of domestic water. In developing countries, 2.4 % of the rural population or over 76 million people worldwide are reported to depend on rainwater, and many homes will be using it for drinking as well (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2012). The use of rainwater is not limited to developing countries only. Texas, Hawaii and other water stressed areas in the US, Australia and New Zealand are noted examples of countries where rainwater is harnessed at the household level for reasons of conservation, gardening and domestic use including for drinking water.

The Australian Bureau of Statistics in 2010 reported that households living in a dwelling suitable for a rainwater tank, have further increased rainwater system installation, from 24% in 2007 to 32% in 2010. Almost half (49%) of South Australian households used a rainwater tank, followed by Queensland (36%) and Victoria (30%) (Australian Bureau of Statistics, 2010).

Overall, the JMP report indicates that rainwater collection has become significantly more important as a source for domestic water supply since 1990, with 89% more households depending on it in 2010.

In our region, JMP data indicate that 2.8% of the rural population and 0.6% of the urban population is using rainwater. I belong to the 0.6% as Kathmandu water supply is limited to about 1 hour every 1.5 weeks. In my compound 2 families depend fully on rainwater collected and stored on my plot. With conservation and reuse of bathing water we manage throughout the year.

Rainwater use in the WHO South Asia region has increased in the rural areas from 2% in 1990 to 2.8% in 2010, while urban rainwater use has fallen a little by 0.2% in the same period. My estimates for Sri Lanka would amount to some 0.8% of the population currently being served by rainwater.

Nepal has reached around 85% coverage in water supply. The remaining communities and households to be served are remote and in places where groundwater or surface water is not easily available. We expect that some 7 to 8 % of the population could benefit from rainwater solutions, for drinking and to raise their livelihood prospects. The challenge is to develop a system for the cost-effective delivery of rainwater harvesting systems to deserving households using a subsidy scheme that is fair and reflects the subsidy the government gives to towns and villages that receive support for piped schemes.

The objective of the symposium is to provide open platform to present research findings related to the mainstreaming theme and to provide opportunities for learning. I am afraid I have not done real research on the issues that determine whether rainwater harvesting can play a more important role in providing water supply at household level. I am sure that some presenters will have interesting observations later today, and I will be happy to listen and learn.

Still, I suppose I should share a few of my thoughts on the subject, based on my experience and perceptions.

1. "Experts" are the greatest hurdles in adopting new ways of delivering water supply. Rightly, they need to be convinced of the capacity of the rainwater solution to serve the purpose intended. Promotors and advocates need to demonstrate that in most conditions rainwater harvesting works, that it does not do harm, and offers a good service level. And collected rainwater for human consumption should meet water quality standards or after boiling, solar disinfection or other household treatment do so.

2. Champions or good examples of rainwater harvesting applications should be identified and their publicity value used to raise appreciation for rainwater harvesting for domestic water supply, for small scale agriculture and ecosystem services.

3. Government through policies, acts and financing strategies should create support for rainwater harvesting applications. This will be relevant where absence of water supply or the risk of flooding makes interventions in rainwater harvesting beneficial.

4. Linkage with the private sector for advisory and system development services is necessary. The private sector will be interested if there is market volume and the opportunity to make profit on for instance PVC filter appliances.

5. Packaging may be necessary to promote rainwater harvesting systems for 10 or 20 households in one go, with some 5 or 10% rebate on the costs charged by the private entrepreneur or NGO.

6. Through advocacy and promotion, Government or NGOs can appeal to the 'green' or ecosystem and sustainability concern regarding resource use, especially with respect to water. This is a long shot, but may well encourage some households to adopt more ecological practices. This changed behavior is a 'soft' target that can be toughened up when there are longer-term cost benefits. For instance by highlighting cost savings due to reduced billing for water. A sustained IEC effort would be needed to mold the willingness of households and users to tailor their water use to (seasonal) availability. This will require extensive public education, social marketing and persistent communication about effects of climate change and water security (Heijnen, 2012).

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Session I

Technical, Social and Economic Aspect of RWH

Paper 01

An Open Source Hardware & Software Online Raingauge for Real-Time Monitoring of Rainwater Harvesting in Sri Lanka

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Abstract

The rainwater harvesting network is in need of volumetric estimation of rainfall-runoff contributed to recharge of the aquifers. Regular reporting of high quality rainfall events and intensity is still a challenge to be addressed in Sri Lanka.

A combination of Open Source Hardware (OSHW) and Free & Open Source Software (FOSS) is being used to created a royalty-free, cheap raingauge design, with full control of on-board data collection and statistics.

Actual state-of-development has gone through the generic weather station prototype delivery to Irrigation Department for tank management and is in testing phase. A local manufacturer has delivered an all-in-one integrated board based on the prototype provided. Local manufacture of the sensors (tipping-bucket and other wind sensors) is under experimentation.

Introduction

Sri Lanka has already displayed its share of signs of climate change with global temperature warming over past century. Many researchers have concluded that no significant systematic trend of annual rainfall is evident in Sri Lanka but the pattern of the rainfall has been changed (De Costa, 2008 ;Basnayake, 2011 ; Chandrapala, 1996 ; Jayatillake et. al, 2005 ; Domroes, 1996 ; Manawadu and Fernando, 2008). During the last decade, Sri Lanka has experienced a number of extreme rainfall events and severe droughts in crop growing periods. Farmers are continuously complaining to planners about the uncertainty and inadequacy of rainfall. The country has seen flash floods, ponding, landslides and urban floods due to frequent high intensity rainfalls. Also, some provinces have faced considerable difficulties in managing erratic and insufficient rainfall for agriculture. The impact of the rainfall event depends on how it unfolds as much as on the final rainfall tally. 40mm of rainfall in 24 hours in an urban area (city) may not become a disaster, and is beneficial to rural areas as it permits proper infiltration to the crops root zone. But if the same rainfall falls within an hour it can change the entire economic environment of that city, or in agricultural areas, it could be lost to runoff.

Open design is the development of physical products, machines and systems through use of publicly shared design information (https://en.wikipedia.org/wiki/Open_Design). Open Source HardWare (OSHW) is a direct consequence of the Open Design philosophy (Pearce, 2013a). It permits to share blueprints of open designs in formats ready for circuitry manufacturing tools. Such is the Arduino micro-controler. As the makers of Arduino describe it: "Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists and anyone interested in creating interactive objects or environments" (www.arduino.cc). Recently, a Sri Lankan version of Arduino was created under the name of "Lakduino" (Fig. 1 ;www.lakduino.com), which is manufactured and distributed in Sri Lanka.

In the same line, many add-on boards have been open designed to plug on Arduino and provide specialized functionalities. These add-on boards are called "shields" in the Arduino jargon. Shields may provide sensors, GPS radio or communication devices, and are stackable. They can be plugged on top of each other to provide the required types of combination of eg; sensors, location services and online reporting.

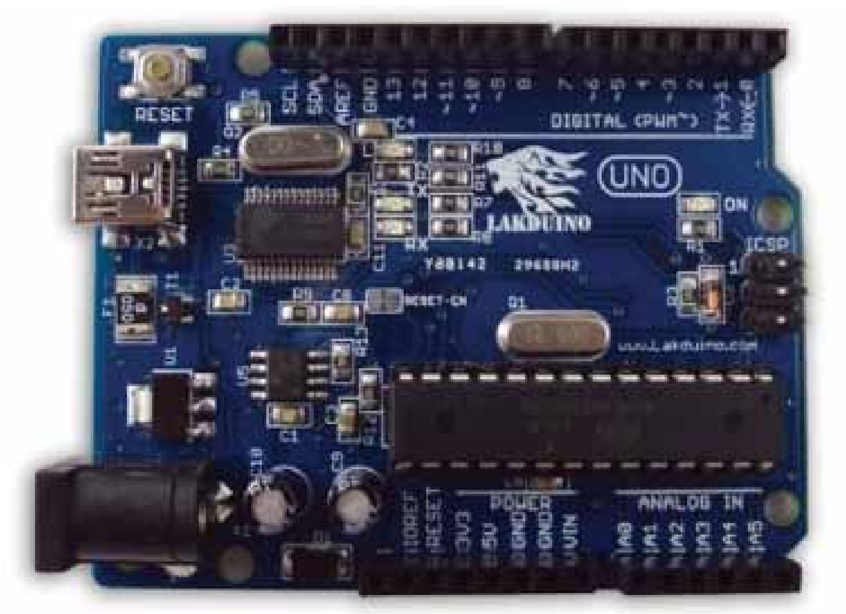


Figure 1: Sri Lanka's Arduino: The Lakduino

Since Arduino systems are open source software programmable, they belong to the owner to generate the actual program that will process the Arduinostack. This is a strong advantage, as it makes it possible to custom-build a generic tool, then customize it to conditions, environments or experiment. It has now become more prominent in several fields of science to design your own experiment to know/control more uncertainties using OSHW & FOSS (Pearce, 2013b ; Pearce, 2014).

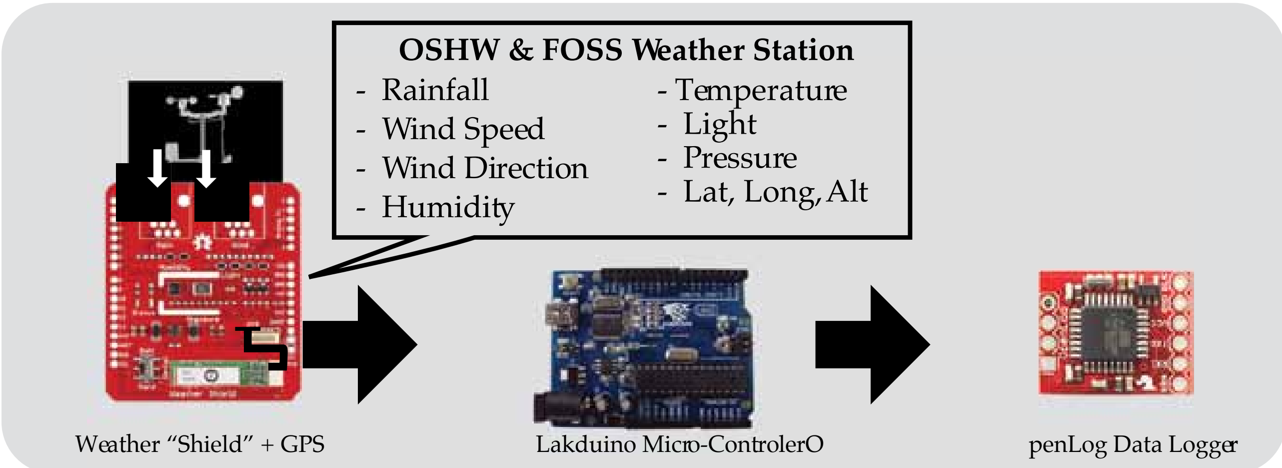
This research explores the creation of a fully customized meteorological station with a rain-gauge, based on the open design, open hardware, open source software corner stones. It has the benefits of being replicable royalty-free, customizable in terms of sensors and data logging analysis & on-board statistics. The aim of this study is to assess the Commodity Of The Shelf (COTS) possibilities to create a Mini Weather Station (MWS) that can be cost effective and customizable under the Open philosophy.

Methodology

The following flow-chart brings together the required elements for an effective sensing and data logging system of weather information (generic basis). After designing this generic version, the targeted design as a rain gauge was a subset to be identified and implemented.

The various components of this generic design were found in various online micro electronic stores in Sri Lanka and abroad. The lakduino (http://lakduino.com) website provides the basic information and an online store (in LKR) with postal delivery, along with the certification of full compatibility with the original Arduino design (http://www.arduino.cc), which we tested positively. The lakduino micro-controler is programmable with 32Kb ROM storage, which is compiled and uploaded through the Arduino IDE (http://arduino.cc/en/Main/Software). All software already online is following the Open Source Software philosophy, and thus is copylefted (https://en.wikipedia.org/wiki/Copyleft).

Three main components were used to build the weather station circuitry stack, the first one is the "Weather Shield", the second is the GPS, and finally the data logger.



The "Weather Shield" is an add-on board to the Arduino, and plugs directly on top of it. It is manufactured and distributed by Sparkfun (http://www.sparkfun.com), an online store of small electronics. On the board are temperature, humidity, light and atmospheric pressure sensors. Two additional plugs provide connectivity to a wind/rain weather kit (also from the same online store). The set once soldered, and mounted, can be programmed through the Arduino board to return the data from all sensors to the session terminal. The data is returned to the terminal in Comma Separated Values form (CSV ; file extension *.csv ; https://en.wikipedia.org/wiki/Comma-separated_values).

The GPS is a small form factor radio geo-location system, also from the same online store as the "Weather Shield" and the weather kit. It plugs directly on the "Weather Shield" through a small cable connector. Programming is simple through a specialized library that can be downloaded from a url in the same online site. Besides providing an accurate GMT time for each weather sensor's reading, the GPS permits to geo-locate the readings, without the need of an external GPS at each installation. This is useful when using the rain gauge station on a rotation experience to cover more sampling areas or evaluating the best grid network with less number of stations.

The data logger is an OpenLog Design (https://github.com/sparkfun/OpenLog/wiki) and receives a micro SD card, tested with up to 16Gb. Internally, it is using a fat16/fat32 file manipulation library for Arduino from Bill Greiman (https://code.google.com/p/sdfatlib/). The data coming from the Arduino program is printed to the terminal screen, and this same print of data is recorded as text files in the micro SD, without any configuration required.

Results

A generic meteorological weather station was designed and prototyped to fit several research and monitoring requirements within Sri Lanka. The first prototype is shown in Figure 3 and was delivered to Irrigation Department in Anuradhapura for testing in June 2014 after a first trial run and discussion with them where specific rainfall statistics were identified.

Figure 3: Left side: circuits (red circle) & power. Right side: wind sensors &rain-gauge

Specialized programming for the requirement of surface water flow from the irrigation department has been done in the form of 5 minute-statistics of rainfall intensity, with a detection flag for rainfall event detection and duration (Figure 4). The aim of the required customized analysis is to corner the rainfall types and their influence on the runoff pattern for improving tank management. Such programming is now available as a basis for the rain-gauge development for high intensity evaluation and monitoring of rainfall-runoff events and modeling.

The rain-gauge data programmed is analyzed below (Figure 5). There is a rain detection flag (RainFlag, values are 0 or 1) operating on a 5 minute time interval. Three statistical aggregations of Rainfall are computed, 5 minutes (Rain5 ; not shown), hourly (RainH) and daily (RainD ; not shown).

```
//Interrupt routines (these are called by the hardware interrupts, not by the main code)//-=-=-
=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=
void rainIRQ()
//Count rain gauge bucket tips as they occur
//Activated by the magnet and reed switch in the rain gauge, attached to input D2
{
        raintime = millis(); // grab current time
        raininterval = raintime - rainlast; // calculate interval between this and last event
        if (raininterval> 10) // ignore switch-bounce glitches less than 10mS after initial
        {
              dailyrainin += 0.011*25.4; //Each dump is 0.011" of water
              rainHour[minutes] += 0.011*25.4; //Increase this minute's amount
              rain5m[minutes_5m] +=0.011*25.4; // increase this 5 mntsamout
              rainlast = raintime; // set up for next event
        }
        //Rain or not (1 or 0)
        if(rainin_5m >0)
{
              Rainindi=1;//RainFlag is ON
        }

        if(rainin_5m == 0)
        {
              Rainindi=0;//RainFlag is OFF
        }
}
```

Figure 4: Example of a specifically designed rainfall event code

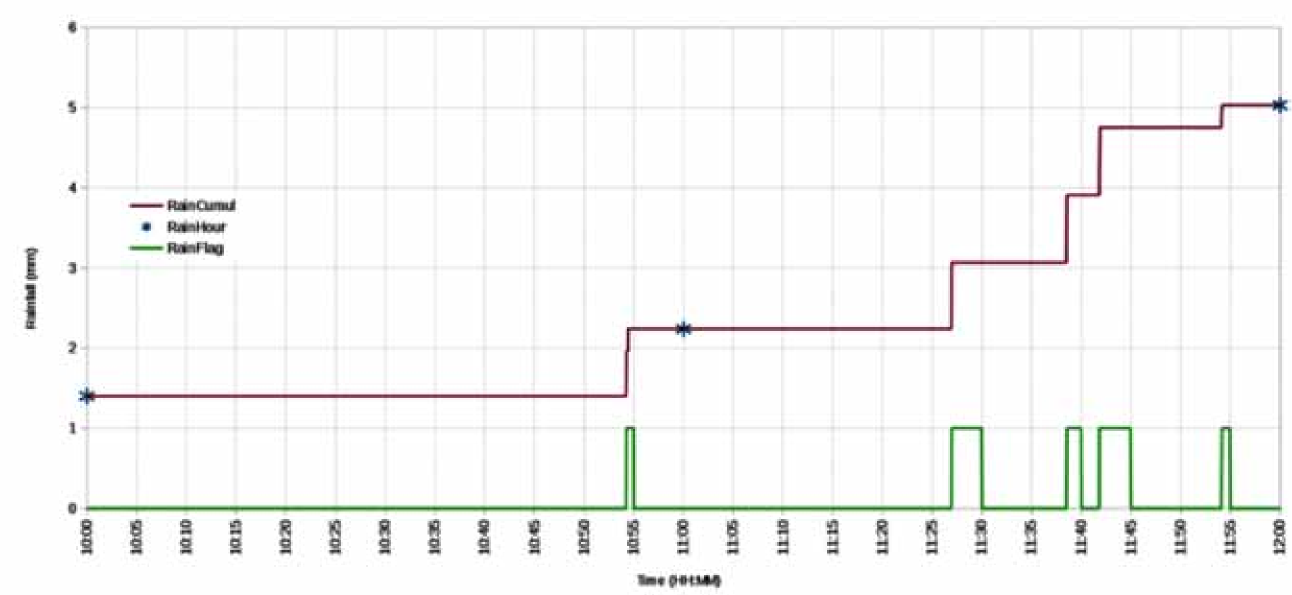


Figure 5: Raingauge Data Analysis

Discussion

Climatic monitoring observations of Sri Lanka use daily rain gauge accumulation, not rainfall intensity of duration. As a result authorized institutions are weak in predicting upcoming issues and building up awareness. Daily accumulations are not enough to capture the rate of individual intensity of rainfall because high accumulation can result from a short period of high intensity rainfall, a higher frequency of lower rainfall or combination of these two. There is an arising need for a higher frequency data, to improve statistics for research and accelerate the accumulation of knowledge on extreme weather events. The edge of the interval of data recording is below 30 minutes: 10 minutes or 5 minutes.

Rainwater harvesting depends upon the frequency and quantity of rainfall. Therefore detailed statistics of rainfall are essential in the initial stages of the rainwater harvesting system. For instance, the annual rainfall and monthly rainfall is not enough in sizing (storage capacity) a rainfall harvesting system especially with the extreme rainfall pattern due to climate change. The size of the rainwater harvesting system should vary from area to area depending on the rainfall pattern, intensity and frequency pertaining to the specific locations.

For several weeks, data was re-evaluated and feed-back converted into structural and software changes. Among the structural changes required is the shape of the rain-gauge cup, not designed for heavy rainfall, and prone to splashing, reducing the total rainfall recorded. We are in contact with a local manufacturer of micro-electronics to address those changes and increase the percentage of the weather station being made in Sri Lanka.

The requirement is to have an efficient monitoring system of rainwater harvesting, reporting to a central repository, preferably open to the public. It turns out that on-going development of the circuits include tests with GSM modules. Online upload of rain data could be done 4 times per day, with each upload reporting hourly rainfall in an ftp site, ready to be used for GIS preparation and modeling, offline or online too.

Conclusion

This research endeavours to demonstrate that Open Design, Open Source Hardware and Free & Open Source Software can be used to tailor-make a rain-gauge meteorological station, with Commodity Off The Shelf elements. The advantages are multiple, the cost is several times less than market options, it records what is of interest to the user only, and prepares analysis on-the-fly as programmed. Availability of parts of the COTS elements is now increasing locally. Complete local manufacture of the whole rain-gauge is underway, along with an online reporting capability in testing phase.

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Paper 02

Brief Analysis on Rainwater Storage and Regulation in Municipal Drainage System

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Abstract

Rainwater plays an important role in improving drainage performance while the drainage network structure and capacity remains unchanged. Based on comparison of rainwater storage performance in project rainwater drainage systems, the table work on comparison in this article shows rainwater storage facilities based on current rainfall intensity computing formulation improves drainage systems. This study proves that decentralized rainwater drainage network in municipal drainage helps to reduce the design rainfall intensity capacity in draining network design, thus an effect can be created equal to increased rainfall duration in the rainwater drainage network design. So, the rainwater storage facilities in decentralized networks are to optimize rainwater drainage network in community rainwater drainage design. It reduces capacity of the drainage network and improves safety of the municipal rainwater drainage in residential areas.

Key words: urban water-logging; rainwater regulation and storage; rainstorm intensity; rainstorm return period

Introduction

Rainwater runoff is the main rainwater source of the storm-water drains for most built up residential districts. Rainwater drainage is an important infrastructure in the urban construction. It is one of the major infrastructures to be constructed in the early stage of urban development construction which will become a permanent underground construction after project completion[1]. Therefore, it is impossible to immediately improve urban storm sewers when the urban water-logging becomes severe. The effective measure to relieve the pressure of urban storm sewer is to reduce the water displacement from the residential district and delay rainwater entering the urban storm sewer.

Various measures have been taken by related municipal management authorities in many cities to install unequal-sized rainwater storage pools around different locations and drainage paths. The purpose is to regulate rainwater through the peak shifting discharge method of storm-water runoff, and finally realize alleviation on pressure of urban drainage and water-logging. Yet, on our visits to municipal management authorities we have discovered that the construction of related facilities do not match the local rainfall intensity which may lead to unsatisfactory functioning of the storage facilities.

Based on professional views on water supply and drainage, combining prevailing specifications, this study puts forward that rainwater regulation and storage plays an important role in alleviating municipal drainage pressure in the neighborhoods construction, and this study has also summarized the construction standard of rainwater storage facilities for the reference of design engineers in the field.

1 Analysis on reasons causing urban water-logging

The reasons for urban water-logging varies according to different conditions and we can summarize them as follows:

1) Failure of surface water being guided to underground;

2) Failure of underground water to be drained off in a timely fashion.

In our opinion, urban water-logging is generally caused by improper operation during one or more in the three phases of design, construction and management in which design is the most important. Urban storm sewers applied very low design standard since the establishment of People's Republic of China[2], i.e., a low standard and a low flow calculation method is used in designing the recurrence interval of rainstorm, and low value is applied to safety coefficient in computing method of flow calculation.

2 The Function of Rainwater Regulation and Storage in Computational Formula of Prevailing Regulation

2.1 Water flow computational formula in prevailing regulation

Krakow, the expert of the former Soviet Union, first brought forward the calculation concept of rainwater drainage in which pipeline volume is used to regulate and store rainwater .The theoretical basis is that the runoff of different design sections inside storm sewer does not reach their maximum flow volume at the same time. As for pipelines designed according to the maximum volume of runoff, its cross section of passage way will produce void volume inside the ditch. This calculation concept of using pipeline volume to regulate and store rainwater can help to reduce the designed flow. Krakow[3] took storm formula as the basis and supposed the probability of raining from heavy to light and from light to heavy is a half-and-half balance. Then he took a calculation method based on full pipeline filling time to reduce the design flow and he brought forward the following formula:

$Q=(A/t^n)F\Psi=AF\Psi/(t_1+mt_2)^n$

Where Q is the designed discharge capacity of rainwater (L/s); F is the catchment area, hm2; Ψ is the flow runoff coefficient; t1 is the ground (roof) catchment time min, it varies on length, topographic slope and ground surface condition. Normally, the catchment time will be from 5 to 10 min for outdoor ground, and 5 min for building roof. When the roof slope is larger and short time ponding will cause hazardous events, the value of actual catchment time should be used. When the calculation condition cannot be met, correction factor should be used for simplification; m is the coefficient of delay, normally m=2; t_2 is rainwater flow time in pipe and ditch; A, n are the local rainfall parameters[1].

It was introduced to China's Code for design of outdoor wastewater engineering in 1963 which is still in use[2]. Now in the calculation formula of Building Water Supply and Drainage Design Manuals[4]

$$Q=167kA(1+clgP)F\Psi/(t_1+mt_2+b)^n$$

where k is the correction factor, normally k =1. When the roof slope is so steep that short time ponding will cause hazardous events (for instance, roof gutter overflow entering indoor space), the factor will be 1.5. P is the designed recurrence interval. A, b, c ,n are the local rainfall parameters[2,4].

2.2 Rainwater regulation and storage

The rainwater runoff calculation formula in existing rules uses ditch volume flood regulation method which reduces the design flow by increasing the calculation time of pipe flow (change t2 to mt2)[4]; and therefore for secondary development district, it can effectively increase the calculation time of pipe flow and reduce the design flow of municipal storm sewers by setting up rainwater regulation and storage facilities before connecting the rainwater pipelines with municipal storm sewers within the district.

Methodology

Storm Formula	P=1			P=3			P=5			P=10			P=20			P=100		
	V=0	V=200	V=500	V=0	V=200	V=500	V=0	V=200	V=500	V=0	V=200	V=500	V=0	V=200	V=500	V=0	V=200	V=500
Beijing 2001（1+0.811lgP）/（t+8）$^{0.711}$	187.2	131.9	95.2	259.6	198.5	150.9	293.3	230.2	178.3	339.0	273.7	216.6	384.7	317.6	256.0	490.9	420.6	350.4
Shanghai 2969（1+0.823lgP）/（t+10.472）$^{0.796}$	195.6	137.4	97.5	272.4	208.2	156.7	308.2	242.0	185.9	356.6	288.2	226.7	405.1	334.9	268.7	517.6	444.4	369.3
Guangzhou 2424.17（1+0.533lgP）/（t+11）$^{0.688}$	228.3	175.1	133.7	286.4	230.0	181.6	313.4	255.8	204.6	350.0	291.1	236.5	386.6	326.6	268.9	471.7	409.5	345.8
Chengdu 3360（1+0.663lgP）/（t+18.768）$^{0.784}$	191.0	142.7	105.7	251.4	199.6	154.9	279.5	226.5	178.7	317.6	263.2	211.8	355.7	300.2	245.6	444.2	386.7	326.0
Wuhan 983（1+0.65lgP）/（t+4）$^{0.56}$	165.8	117.9	88.1	217.2	164.7	127.3	241.2	186.9	146.3	273.6	217.4	172.9	306.0	248.2	200.2	381.4	320.5	265.4
Taiyuan 1446.22（1+0.867lgP）/（t+5）$^{0.796}$	111.6	59.7	37.1	157.7	96.8	63.9	179.2	115.1	77.6	208.3	140.5	97.3	237.4	166.5	118.1	305.0	228.5	169.4
Changchun 1600（1+0.8lgP）/（t+5）$^{0.76}$	138.6	83.0	54.6	191.5	128.1	89.0	216.1	149.9	106.3	249.4	180.1	130.9	282.8	210.9	156.5	360.3	283.6	219.0

Tab.1 Relationship between rainwater regulation & storage facilities and their role of improving drainage capacity in different cities

Note：*V* is the effective volume of storage facilities,m^3; $F=10000m^2$;$\psi=1$; $t_1=10min$; $t_2=10min$.

Tab.1 reveals that in secondary development zones of 1ha and according to storm formula for different districts, rainwater regulation and storage facilities can be set before connecting the rainwater pipelines to municipal storm sewers within this district, and then can be calculated the flow entering the municipal storm sewers. The following conclusions can be drawn through Tab.1:

1) The designed flow of municipal rainwater drainage pipes can be effectively reduced by setting rainwater regulation and storage facilities before connecting the rainwater drainage pipelines to municipal storm water sewers within the secondary development district.

2) For same district, the higher standard of rainwater regulation and storage facilities is, the better it works in alleviating the municipal drainage pressure.

3) For same rainwater storage, the smaller the intensity of storm is, the better it works in alleviating the municipal drainage pressure.

Results

In most cases, the rainwater drainage design standard for the secondary development zone and the planning design standard for the municipal rainwater pipe network are two independent systems. Rainwater drainage design standard of two-year or three-year recurrence interval will often be applied to the drainage design of the secondary development zones located in planned drainage standard of one-year recurrence interval zone. Therefore rainwater regulation and storage facilities shall be constructed in addition to improving the safety coefficient of rainwater drainage for projects inside the rainwater planned district of low design standard[6]. Take Beijing for example: the municipal storm sewer network with one-year recurrence interval can accommodate drainage storm runoff for constructed project with three-year recurrence interval and regulation and storage for 20 mm rainfall capacity , and it can accommodate drainage storm runoff for the project with five-year recurrence interval and regulation and storage for 50 mm rainfall capacity. The municipal storm sewer network with three-year recurrence interval can accommodate drainage storm runoff for constructed project with five-year recurrence interval and regulation and storage for 20 mm rainfall capacity, and it can accommodate drainage storm runoff for constructed project with twenty-year recurrence interval and regulation and storage for 50 mm rainfall capacity. The municipal storm sewer network with ten-year recurrence interval can accommodate drainage storm runoff for constructed project with twenty-year recurrence interval and regulation and storage for 20 mm rainfall capacity, and it can accommodate drainage storm runoff for constructed project with a hundred-year recurrence interval and regulation and storage for 50 mm rainfall capacity.

Discussion

We have applied the above-mentioned method to optimize the drainage system in hot spring area of Beichuan new county district, Minyang city, Sichuan province of China. The scale of construction of rainwater discharge system has been reduced by 1/3, and its systemic function meets the requirement and design expectation in all major heavy rain ever since 2010, the function featuring rainwater regulation and storage facilities alleviating the drainage pressure has been proofed in this case.

Moreover, rainwater regulation and storage facilities have now been introduced to many cities to address grim situation of urban waterlogging [7-11].

Conclusion

Rainwater regulation and storage ponds in the secondary construction projects play a positive role in alleviating municipal storm sewers drainage pressure. It is also applicable to rainwater storage ponds which are built between upstream and downstream rainwater pipelines inside secondary constructed projects and it can reduce the scale of downstream rainwater drainage pipelines. The way has been effectively proved in the construction of hot spring area of Beichuan new county district, Mianyang city, Sichuan province of China. It has not only reduced the construction scale of pipelines but also improved the safety coefficient of municipal pipelines. It is effective in controlling rainwater.

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Paper 03

Effective Used of Bio-Cement Jar(Bio-Sand Filter) in Rainwater Harvesting System

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Abstract

Approximately, 1.1 billion rural and semi- urban communities of developing countries do not have access to safe drinking water. The mortality from diarrheal-related diseases amount to 2.2 million each year from consumption of unsafe water.

Rainwater harvesting systems are simple to construct from inexpensive local materials, and are potentially successful in most habitable locations. Roof rainwater can be of good quality and may not require treatment before consumption in normal situations. However most of the villagers at deltas and coastal areas in Myanmar are compelled to live in houses with thatched roofs according to their income levels. A feasible option to transform the rainwater they harvest into safe drinking water would be the use of a locally appropriate design of the Bio Cement jar (adaptation of Bio Sand filter) in combination with the rainwater harvesting system.

The Bio-Cement jar is an adaptation of Bio-Sand Filter, which uses sand and gravel as filtering medias. It is a cheap and easy to use filter primarily intended for household use. The main difference between the traditional jar and Bio cement jar is whereas the traditional jar is just a water storage container the Bio Cement jar is a household water treatment and safe storage (HWTS) system.

Traditional cement jar (Thai Jar) (for only storage)

Bio-Cement jar (for Household water treatment)

Introduction

Clean and safe water is very important for day to day life of human beings. Safe water should be colourless, odourless and free from pathogens. There have been many attempts to solve this problem of making safe potable water available to people, which have encountered problems such as high costs, accessibilities, fabrication technology, production mould costs, etc. Therefore the community is dependent on the outside world for funding and materials. The Bio Cement jar (adaptation of Bio-Sand filter) design in this report will attempt to address these issues through practical application of appropriate low cost technology, using locally available materials and utilizing participatory approaches and getting the village jar makers to offer their services voluntarily.

Bio-Cement jar, is the adaptation of bio-Sand filter, designed by the IRC Myanmar's Environmental health team. Already (since 2013) there are 50 Bio- cement jar pilot test units in the field in Myanmar. The first Bio-sand filter was invented by Dr. Menz in 1990. It is an intermitted slow sand filter design, more than 80,000 units of which are in operation at present. This design can be made with locally available materials; it can be adapted to suit any country. Since 2010, Myanmar developed a number of prototype designs of the Bio Sand filter. In 2012, the first successful Bio-cement jar designs were launched in Myanmar. According to this design in 2013, June to December, pilot project (50) units already tested in the fields trial, villages in Myanmar. In some cases, rainwater may be the only available, or economical, water source.

The filter consists of fine and coarse sand and gravel mesh in three sizes,3/4inch Dia: PVC pipes. The design of filter is simple, and it can be constructed by the village jar makers. Pathogens and suspended materials are removed from the water through a combination of biological and physical processes. These occur both in the biolayer and within the sand bed. These processes include: mechanical trapping, adsorption/attraction, predation and natural death. All the materials are easily available in rural areas. These filters can be maintained easily.

What is a bio sand filter?

The bio sand filter is a modified form of the traditional slow sand filter in such a way that the filters can be built on a smaller scale and can be operated intermittently. These modifications make the bio sand filter suitable for household or small group use. The bio sand filter can be produced locally anywhere in the world using materials that are readily available. The bio sand filter should be used as part of a multi-barrier approach which is the best way to reduce the health risk of drinking unsafe water. Barriers which protect water from pathogens can occur in each of the following steps:

Step 1 – Protecting the water source

Step 2 – Sedimentation

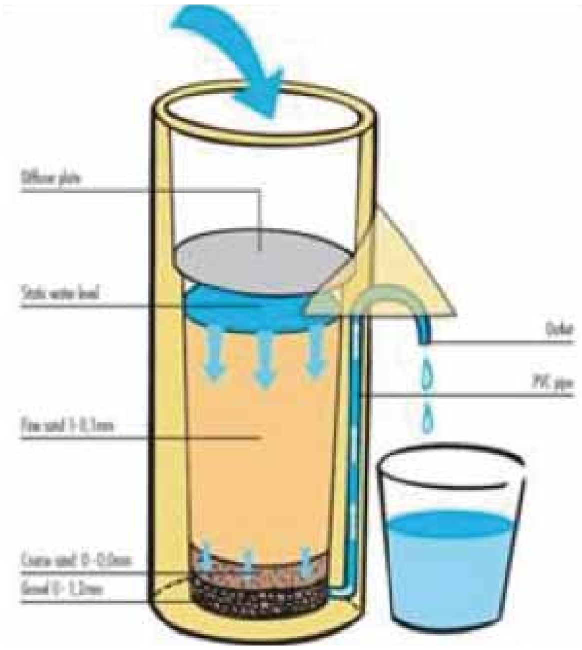
Step 3 – Filtration (e.g. bio sand filter)

Step 4 – Disinfection

Step 5 – Safely storing water after treatment

The bio sand filter is a 'point of use' or household treatment device. Water can be obtained from the closest water supply point, whether that is a river, a stream or a well, and used immediately after filtering. The water supply, treatment, and distribution are all within the control of the individual householder.

Overview of the Bio Sand filter



The main Difference between the Bio Cement jar and other Bio Sand filters around the world

- 100% done in the field level, no need to carry from place to place, for Bio Cement jar.
- Apply skills learnt from village jar makers, for fabrication of Bio Cement jar. In other words technology is transferred from village jar makers to other villagers so that they can do it themselves, and do maintenance on the long run.
- No special iron mould for fabrication, and no need for investing in fabrication workshops.
- Actually, Bio Cement jars are adaptations of appropriate Myanmar design of CAWST (Canadian design) and Nadi (Indian design) (see more detail in PowerPoint presentation as well as Manual booklet).

High User Acceptability

The bio sand filter is easy to use and it improves the appearance and taste of water. Also the filter takes up very little space and can easily fit into most rooms. In fact, previous experience has shown that the filter normally occupies a place of significance in the living room because it is so important to the individual household.

BioSand Water Filters are Capable of Removing:

- Helminthes (eggs and worms) 100%
- Parasites (Guardia, Amoeba, Schistosomiasis, and Cryptospordia) 100%
- Bacteria 90 – 99% (may be sub-infectious)
- Viruses 90 – 99% (may be sub-infectious).
- Spores 100%
- Sand, silt and other suspended solids including algae (turbidity less than 1 NTU)
- Oxidized iron – almost 100%.
- Arsenic (up to 100% depending on organic complexing)
- Organic and inorganic toxins (reduced)

BioSand Water Filter Based Treatment Systems Can Treat:

- Water from ponds, lakes, cisterns, reservoirs, rivers, streams
- Water from shallow and deep wells
- Rainwater
- Spring water
- Unsafe water from piped systems
- Unsafe delivered water
- Grey water

Positive Impacts

- Reduce health care costs
- Better productivity for users
- Improved quality of life
- Affordability
- Sustainability
- In-country manufacturing
- Potentially large employer
- Opens up new markets within a developing country
- Measurable performance
- Meets an unfulfilled basic need

Methodology

Using a very simple methodology our trained staff would show how to do this. Village jar makers also would assist. After such a practical demonstration the villagers themselves would be able to make them. Participatory approaches and methodologies would be applied. Most of the village jar makers are women.

Advantages	Disadvantages/limitations
- Removes over 98.5% bacteria, 100% bacteria, turbidity, some iron, manganese, arsenic. Quality of water improves with time. - Simple to operate and maintain - Cheap to operate and maintain - Operates under a range of temperature, pH and turbidity - Operates best under intermittent use More suitable for household use than the slow sand filter - Cheap, no on-going costs - High flow rate – up to 36 liters per hour. - Water appears and tastes good. - Maintenance is easy - Cement can be easily acquired in most developing countries. - Household labour or volunteer labour can be utilized in the manufacturing process - The concrete container is durable and robust. It does not need to be replaced as often as a plastic container - The spout piping is located inside the filter. Consequently, it is less prone to damage than a plastic filter, which has piping on its exterior - Fabricated from local materials. Plastic fabrication usually requires the importation of raw material or the finished product. Depending on your views of international trade, this can be an advantage or disadvantage. - The life expectancy of a plastic model is substantially less than a concrete model. The ultimate disposal of plastic is a concern for the environment - Encouraging and empowering local people to completely manage their own project increases local sustainability and motivates others to take action for safer water. This process can only be facilitated if the product supply is managed locally. In most cases, if a plastic model is used, there will always be a dependence on outside manufacturers and distributors to supply filters at a higher cost.	- Biological layer takes 3 weeks to develop to maturity - High turbidity (> 100 NTU) will cause filter to clog and require more maintenance - Requires that the filter be used periodically on a regular basis - Cannot remove color or dissolved compounds (same as all other filters) - Can be difficult to move (weigh 170 lbs / 77 kgs) - Cannot ensure pathogen free water - Cannot guarantee bacteria free water (lab testing has shown a 97-99.7% reduction and field testing a 90-97% reduction) - Does not remove color, organic chemicals or dissolved compounds from the water

How does it Work?

A biosand filter is a concrete or plastic box that is filled with layers of sand and gravel. Water is simply poured into the top of the filter and collected in a safe storage container. Pathogens and turbidity are removed by physical and biological processes in the filter sand.

Technical Specification

The concrete BSF typically uses a box about 0.9 m tall by 0.3 m square, or about 0.3 m in diameter. The filter box is fabricated by cement jar method with pre-fabricated PVC pipe. The container is filled with layers of sieved and washed sand and gravel (also referred to as filter media). There is a standing water height of 5 cm above the sand layer. The different layers trap and eliminate sediments, pathogens and other impurities from the water. Similar to in slow sand filters, a biological layer of microorganisms (also known as the biolayer or schmutzedecke) develops at the sand surface, which contributes to the water treatment. This biological layer matures over one to three weeks, depending on volume of water put through the filter and the amount of nutrients and micro-organisms in the water.

A perforated diffuser plate or basin is used to protect the biolayer from disturbance when water is poured into the filter.

Operation

Contaminated water is poured into the top of the filter on an intermittent basis. The water slowly passes through the diffuser, which dissipates the initial force of the water, and percolates down through the biolayer, sand and gravel. Treated water collects in a pipe at the base of the filter and is propelled through plastic piping encased in the concrete exterior and out of the filter for the user to collect in a safe water container.

The biolayer is the key pathogen removing component of the filter. Without it, the filter is significantly less effective. It may take up to 30 days to establish the biolayer depending on inlet water quality and frequency of use. The water from the filter can be used during the first few weeks while the biolayer is being established, but disinfection is recommended during this time, as during regular on-going use.

The biolayer requires oxygen to survive. When water is flowing through the filter, dissolved oxygen in the water is supplied to the biolayer. During pause times, when the water is not flowing, the oxygen is obtained by diffusion from the air. Correct installation and operation of the biosand filter has a water level of approximately 5 cm above the sand during the pause period. It is this design feature that distinguishes the Biosand filter from other slow sand filters, allowing for small scale construction and intermittent use. The layer of water is shallow enough for oxygen to diffuse through, providing the biological layer with enough oxygen to develop. A water depth greater than 5 cm results in lower oxygen diffusion to the biolayer. A water depth less than 5 cm may evaporate quickly in hot climates and cause the biolayer to dry out.

A pause period is needed between uses to allow time for the microorganisms in the biolayer to consume pathogens in the water. The recommended pause period is 6 to 12 hours with a minimum of 1 hour and maximum of 48 hours.

The biosand filter has been designed to allow for a filter loading rate (flow rate per square meter of filter area) which has proven to be effective in laboratory and field tests. This filter loading rate has been determined to be not more than 600 liters/hour/square meter.

Results

Our Bio Cement jar is successfully used in the field level. It can be produced at field level using participatory methodologies. In 2008 we started a low cost project to produce jars of 200 liter capacity. Villagers and jar makers in most of the villages in the delta and coastal areas of Myanmar were involved. In 2013, 50 units of Bio Cement jars (Bio sand filters) were successfully field-tested in Myanmar. It is really efficient as the future BSF design for the world. We have already done water quality testing by PathoScreen as well as Membrane Filtration tests in the field. (Please see Annex-A for water quality test results).

Effectiveness

Quality: Very effective in removing turbidity and pathogens.

Quantity: Can filter 12-18 liters each batch; recommended to use at least once a day to ensure effective pathogen removal.

Local water: Can be used with any water source, may need to sediment water before filtering

Appropriateness

Local availability: Concrete filters can be constructed anywhere in the world.

Time: Concrete filter flow rate is 0.6 liters/minute; plastic filter flow rate is 0.8 liters/minute

Operation and maintenance: Simple maintenance to clean sand when the flow rate slows down.

Lifespan: Concrete filters 30+ years; plastic filters 10+ years; lids and diffusers may need to be replaced.

Acceptability

Taste, smell, color: Usually improved.

Ease of use: Easy for adults; may be difficult for small children to pour water into the filter .

Cost

Initial purchase cost: US$12-30 for concrete filters; US$ 45 for plastic filters.

Operating cost: None.

Discussion

One of the major water sources in the delta and coastal areas in Myanmar is rainwater harvesting, because sinking of wells in these areas is not possible as intrusion of saline water is a problem. The communities rely on rainwater sources. People in flat areas store rainwater in ponds to be used during the dry season. Harvesting rainwater is an old and traditional practice. Rainwater harvesting is done at household and community level. Cement jar making is done as a collective activity. The Bio-cement jar is a good option to meet the need of a Household Treatment and safe Storages System (HWTS) of water in future world.

Conclusion

Many developing countries in the world are faced with issues relating to potable water. The Cement jar (adaptation of Bio-Sand filter) design, can provide the means of using rainwater for drinking purposes specially for those poor people living in thatched houses. As such it can be called the "filter for the poor". The materials, fabrication methodology and maintenance are very simple, and common, doing 100% in the field level with local available materials, doing with skills transfer technology and participatory approach by themselves. The other factors such as its marketability significantly increase the opportunities of creating sustainable small businesses. Furthermore, other features such as its minimum maintenance, which could be performed by villagers themselves makes it acceptable to villagers.

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Paper 04

A Study on Bamboo as a Reinforcing Material to Replace Steel in Rainwater Harvesting Tank Construction

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Abstract

Rainwater Harvesting (RWH) is a good alternative source of water but the main issue faced is the high installation cost of the tank. Consideration on various material to replace usual material types such as cement, steel, bricks etc. is very important. This research reviews the possibility of using bamboo as a reinforcing material to replace steel in tank construction in RWH systems. It can be concluded that bamboo is a promising material to replace steel in tank construction for RWH systems which is a sustainable solution to the existing issue.

Introduction

Cement, steel, bricks and blocks have become the basic materials that are used to make water tanks and the other common type of tanks used is plastic tanks which are readily available but costs a considerable amount for each tank depending on its capacity. Even though cement, steel, bricks, blocks and plastic are used to make tanks these materials do have an impact on the environment as well as the cost. The main material cost is high when compared with bamboo since bamboo can be obtained naturally with minimum cost if bamboo is planted and harvested in an environmental friendly manner. Steel is considered a sustainable material for construction since it does not produce CO2 after construction but in the manufacturing process one ton of steel produces 1.8 tons of carbon dioxide as well other harmful gases (Worldsteel, 2014). But on the other hand bamboo is a gift from nature where one tree produces nearly 0.13 tons of oxygen per year. On an average a bamboo plant will produce up to 65 tons of oxygen per year. Energy needed to produce 1 kilogram of steel from recycled steel is 6 – 15 MJ, and energy required to produce 1 kilogram of steel out of iron is 20 – 50 MJ. The aim of this investigation is to review the use of bamboo as a reinforcing material, mainly for tank construction, by replacing the traditional material that are used currently, since this may help to reduce the total material cost needed to build storage tanks which is the main cost element in rainwater harvesting systems as well as a good solution as a sustainable material.

Literature Review

According to Janssen (2000) Bamboo is a tree which consists of a hollow inner area, horizontal partitions called diaphragms and these partitions are denoted by a ring around the culm and the diaphragm and the ring outside together makes the node and the part between two nodes are known as internodes and the inside of the internodes is empty. Bamboo has 40% fibers, 10% vessels and 50% parenchyma approximately. The cellulose acts as a reinforcement similar to the steel reinforcement used in concrete. These fibers are usually concentrated on the outside. Research indicates that there are 45 groups and 750 species recorded and out of these 45 groups

and 750 species of bamboo 7 groups and 14 species have been recorded in Sri – Lanka according to Senaratne (1956) but according to Soderstorm (1998) there are 12 species in 6 groups of bamboos in Sri – Lanka.
According to Kariyawasam (n.d.) Bambus multiplex grows in rural areas, Bambusa vulgaris in the wet zone, common on river banks, Dendrocalamusasper grows in the intermediate zone, Dendrocalamusgigenteus in the wet zone, common on river banks and home gardens, Dendrocalamusmembranaceus grows in the intermediate hills and Dendrocalamusmembranaceus in the dry zone. As per De Soyza (1991), the bamboo species that can be used as structural elements and reinforcing material are Bambusabambos, Bambusa vulgaris, Dendrocalamusasper, D. giganteus, D. membranaceus, D. strictus and Thyrsostachyssiamensis.

Harvesting Bamboo

According to Schröder (2014) the main concern when harvesting bamboo is the starch content of the tree. If there is a large amount of starch present in the bamboo tree then there is a huge possibility for the tree to be affected by fungi and parasites. If the bamboo tree has less carbohydrates there is a huge chance that the plant will resist parasites and fungi naturally. Further to this it mentions that the best time to harvest bamboo is the end of rainy season and the beginning of the dry season.
According to Satish Kumar (1994) the natural durability of bamboo is usually between 4 to 7 years but the durability of the bamboo changes with the species of bamboo and climatic conditions. Also, in order to preserve bamboo, it should be dried and treated with chemical preservatives in an effective manner to increase the durability of bamboo. Usually the drying takes 6 – 12 weeks.

Mechanical Properties of Bamboo

According to Xiao (2008) it seems that different types of bamboo have different tensile strengths, modulus of elasticity, compressive strengths and that these mechanical properties also change with the bottom, middle and the top parts of the bamboo plant as shown by Xiao (2008). Bambusa vulgaris has the maximum tensile strength which is 14.56 MPa, Dendrocallamusgiganteus has the beat modulus of elasticity which is 14380 MPa and the best compressive strength which is 58.66 MPa. Also it has also been shown that the strength also increses with the age of the bamboo (Li, 2004). The mechanical properties of bamboo are indicated in Table 01

Table 01: General mechanical properties of bamboo (Rush, 1966;Chandra. Sabnani, n.d.;Iyer, 2002)

Mechanical Property (on average)	Value (psi)	Value (MPa)
Ultimate compressive strength	8,000	55
Allowable compressive stress	4,000	28
Ultimate tensile strength	18,000	124
Allowable tensile stress	4,000	28
Allowable bond stress	50	0.4
Modulus of elasticity	2.5x106	17237

Discussion

It can be seen that using bamboo as a construction material for rainwater collecting tanks can be very effective if proper cultivation practices have been used, and proper chemicals have been used to preserve bamboo for a long time. Bamboo can be used to build water tanks due to their mechanical properties which are much closer to some of the mechanical property values of steel. The traditional method of constructing rainwater tanks uses Ferro cement, chicken mesh and steel rods as a temporary skeleton for the tank. If bamboo is used as a construction material in rainwater harvesting tanks it is important to use proper water proofing techniques from the inside as well as outside of the tank since water can create a breeding ground for bacteria and fungi and if this happens water will be contaminated and the mechanical properties of the bamboo will decrease. The most important mechanical properties when dealing with water tanks are the compressive strength and the tensile strength. To increase the strength of the water tank bamboo strips should be installed horizontally, vertically and diagonally and each bamboo strip should be connected using binding wire to keep all the bamboo strips in place. If bamboo is obtained as a free material from nature the cost of the tank will be limited to the foundation, preservation chemicals, mortar, water proofing coat and for binding wires which will be a small cost compared to constructing a tank using Ferro – cement, steel and chicken mesh.

Conclusion

Bamboo as a construction material for rainwater harvesting tanks would be energy efficient, sustainable, cheap and technically suitable since the bamboo plant has proper mechanical properties that would be suitable for constructing rainwater harvesting tanks. Most suitable types of bamboo to be used in Sri Lanka for constructing would be Bambusa vulgaris, aged between 4 – 5 years. The most effective and cheap method of treatment for bamboo would be using borax, boric acid and water in the correct ratio, for example 1kg borax : 1kg boric acid : 100 liters of water.

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Paper 05

Rainwater Harvesting and Nile Delta Groundwater Aquifer Recharge between Matruh – Alexandria Area, Northern Nile Delta, Egypt

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Abstract

Studied area is located on northern part of Nile Delta from Matruh Gov. in west to Alexandria Gov. in east. Studied area is considered as one of the most populated regions which has environmentally complicated risks on water and soil, in addition to suffering from water management problems. The problem of surface and groundwater quality deterioration, sea water intrusion, land salinization and degradation, and water use malpractices are environmental hazards that should be focused on and deeply investigated. The socio-economic and health impacts are the other sides of the problem which call for sustainable water management options.

Water scarcity and contamination of available water by sea water intrusion are major problems that will be studied as core issues that threaten the ambitious developmental planning of Nile Delta. Sustainable groundwater management will depend on the Rainwater Harvesting and Groundwater Recharge. The project will be a good source for historical and up-to-date databases and as a core strategic adaptation and solution for sea water intrusion and water scarcity, which could be used effectively by the decision makers, researchers, executive authorities, planners, and related governorates. The project will be presented by simulated models to display that rainwater could be harvested and to show how it could be injected to fresh groundwater in order to evaluate studied area water resources and planning the optimal development and allocation of water supplies to promote sustainable development depending on water risk analysis, assessment and management. Natives as main end users and essential players will be a major target of the project. The project objectives will assist in poverty alleviation, accelerating agricultural development, improved agricultural and food production, combating desertification, unemployment problems and raising individual incomes.

Introduction

According to international standards, the state is below the water scarcity line. Its citizens' right to water availability is about 1000 m3 per year. Citizen's right of water availability in Egypt in 1986 was about 1138 m3 per year and was reduced to 860 m3 in 2003 and to 759 m3 in 2007 and is expected to fall further to 582 m3 per year in 2025. Total renewable water resources in Egypt in 2006 reached 64 billion m3 of water while it was supposed to be 68.6 billion m3 and expected to reach the total available water resources in Egypt to nearly 71.4 billion m3 in 2017 but it is supposed to be 86.2 billion m3. The Nile River is the primary source of water in Egypt which supplies the country 55.5 billion m3, representing 86.7 percent of the total water resources. It is expected that the contribution of the river will be reduced to 80.5 percent in 2017 and in turn It is expected to increase Egypt's dependence on groundwater which will serve 18.4 percent of the total renewable water resources in Egypt in 2017. The agricultural sector was the dominant consumer of water, using up large quantities of water resources in 2007 - 2008 by 83.3 percent versus 11.8 percent for household usage, 1.7 percent in industry and 0.3 percent for River navigation while the evaporated water from the Nile and canals reached 2.9 percent.

Water risk is nowadays one of the most crucial environmental problems world-wide. Pollution in aquifers and surface waters takes place, apart from local sources discharging wastewaters, mainly from diffuse sources, scattered within the entire river basin and aquifers. The problem which must be dealt with is the prediction in space and time of the concentration of a pollutant substance introduced in the water body. The analysis of this problem with mathematical or physical models may assist in the optimal design of wastewater treatment plants, the positioning of wastewater outfalls and the determination of the flow rate and composition of effluents at the discharge outlet.

Location

Studied area is located on northern west side of Nile Delta which consists of oolitic limestone, sabkhas, and quaternary sediments. The lithological succession of the studied area causes environmental hazards affecting the water resources and quality in studied area. Problems associated with sabkha soil shows that when fresh water reaches the sabkha soil, precipitated salt will dissolve leading to a soil with high void ratio and an open structure with high tendency to collapse upon loading. Also they stated that absorption of moisture from the atmosphere may reduce the strength of stable surfaces. The impact of rising of ground water levels in reducing the bearing capacity and the stiffness and increasing the compressibility should be taken into consideration.

Climate

The investigated area is characterized by a long dry summer and a short temperate winter with a rainfall period from October to March. The normal climatic data of concerned meteorological stations within and around the area under study pertaining to a 52year period have been collected in order to simulate the meteorological model to assess the climatic changes. Statistical analysis of variances in monthly means of weather elements classified the climate of Alexandria and Matruh into cool and warm seasons. The cool season starts from October to March with mean air temperature of 16°C, higher atmospheric pressure, lower relative humidity, more clouds with chance to precipitation, lower horizontal visibility due to occurrences of fog and mist and prevailing wind direction from north northwest and north northeast with 17% of gale winds more than 21 knots among all hours. The warm season starts from April to September with mean air temperature of 25°C, lower atmospheric pressure, higher relative humidity, clear skies with no chance of precipitation, better horizontal visibility and prevailing wind direction from north northwest and north with 7% of gale winds of speeds higher than 21 knots.

Objectives:

The project aims to provide a sustainable water risk management for rural communities through a number of innovative strategies designed to promote traditional water use technologies. The project proposal specifically aims to:

- Provide a sustainable source of clean drinking water.
- Provide water for agriculture to guarantee reliable locally produced food.
- Improved community health (by reducing the level of waterborne diseases).
- Improve industry (stimulate sustainable economic growth through a revival of the water-dependant agricultural industries).
- Improve local environment. (Reforestation, soil conservation, groundwater recharge, protection of biodiversity, etc.).

- Combating desertification and drought.

In order to achieve the project objectives the following points should be covered:

1) To use Landsat TM/EgyptSat-1 images (SPOT 4), Radar images and others for mapping purposes and production of important essential maps.
2) To prepare a series of Rainwater harvesting points merged with surface/groundwater resource maps to evaluate surface/groundwater evaluation maps.
3) To evaluate surface/groundwater resources for the sustainable development, urban allocation and hazard protection.
4) To propose optimum levels of water resource protection to people and property and suggest the water control works to optimize the use of surface and groundwater resources and minimize their economic and environmental hazards.
5) To plan for water resources sustainable management.
6) To provide digital GIS infrastructure data, plans and related information as required for structural and non-structural (planning) investigation related to water resources development.
7) Water management from socio-economical point of view and establishing many expected scenarios.
8) Data base for water risk causes in order to establish a base of studying risk analysis/assessment to reach the finalized purpose which is water management
9) Training for all who are concerned in water risk (hydrologists, engineers, scientists, geographer, medical scientists, …..etc).

Methodology

Stage1:

1. Preparation of infrastructure database and documentation.
2. Digital conversion and preparation of data.
3. Field trips and in situ meetings with the concerned authorities and communities.
4. Official and public presentations for explaining the project's objectives to raise public awareness about the SGM.
5. Performing socio-economic investigations.
6. Data inventory about surface and/or groundwater and soil profiling (testing land capabilities).
7. GPS recording for wells, water points, land points proposed for rainwater harvesting techniques.

Stage2:

1. Performing and running the watershed model to assess the water resources and land use pattern.
2. Construction of rainwater harvesting point's potentiality map using RS and GIS.
3. Soil and land capability map.
4. Water use map
5. Sustainable groundwater management (SGM) planning.
6. Water hazard protection maps.
7. Examining the strength and weakness of Farmers Associations work in the project research area with the view of closing gaps on water planning and management.
8. Initiate a code of conduct of uses and management of water resources, especially in ground water and surface water.
9. Integrate women in all aspects of water planning and aspects of management according.

Stage 3:

1. Studying the water risk sources
2. Water risk analysis
3. Water risk assessment
4. Water risk management scenarios and strategies
5. Rainwater Harvesting sustainable management as water resources core in Nile Delta

3- Results:

In the following the compiled sheet for the objectives and results of the project :

Obj. No.	Objective	Expected Results
01	To provide digital GIS database about climatic records	Data bases documentation and refining to be ready for inputting in the planned GIS system
02	To use Landsat TM/EgyptSat-1 Spot-4 images, Radar images and others for mapping purposes and production of important essential maps.	Base maps construction, geological map, geo-morphological map, Drainage net map, buried channels map, present-day water/ land use pattern, etc.
03	To prepare a series of water resources maps to evaluate water potentialities.	Surface/groundwater capability maps
04	To formulate water resources development master plan by SGM	Surface water /groundwater Development Master Plan by SGM
05	To evaluate surface water resources for the sustainable development, urban allocation and hazard protection	water use map and water/land use map
06	To propose the optimum levels of water resources protection to people and property and suggest the water control works to optimize the use of SGM and minimize economic and environmental hazards	Water resources hazard mitigation planning, mitigation measures, surface water controlling structures and their localization
07	To perform Watershed Management	Land Management Master Plan

Obj. No.	Objective	Expected Results
08	To present some of the socio-economic design elements of micro-catchments SGM	RWH technology transfer and local society training programming.
09	To document project output through digital GIS-ready data bases, maps, drawings, photos and printed reports	GIS-ready data bases, digital maps, photos, illustrations, digital and printed 5 half annual reports. One Final report in both digital and printed formats
10	To present project's outputs through presentations and workshops Socio-economic and environmental results versus objectives could be added from here	Annual meetings to discuss project progress with one final workshop to present project outputs

Conclusion:

1-Preliminary results for the hydrological simulation for the large-scale (Northern west Nile Delta aquifer) were presented in order to assess the current situation of water scarcity in the studied area.

2-The hydrological model and GIS maps illustrates the contour map for the pizometric head, flow velocity and flow direction in the aquifers, also calibration of the model and water balance in the aquifer were presented were presented.

3-The results of studying the hydrological model, GIS maps and lithological succession would establish a core base map for Rainwater Harvesting catchment points.

4- The project, as a simulated model should be studied and discussed with the concerned organizations and sectors.

5- It is recommended to establish an climatic simulation merged with the rainwater harvested and their effect on water resources in the studied area

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Paper 06

The Tube Recharge

Rainwater Storage at a Cost of 1 US$ per Cubic Meter

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Abstract

The natural storage for rainwater is the groundwater layer (aquifer). If the depth of the aquifer is 35 meters or less and if it is possible to make low cost wells, storing rainwater in the aquifer can become a very cost-effective and sustainable storage option. The following example comes from a family in Njombe, Tanzania. The total cost of an 18 meter deep hand dug well, a hand pump and a ground water Tube recharge system installed in 2011 was US$ 600. Each year over 100 cubic meters of rainwater is infiltrated and "stored" around the well. Each year over 60 cubic meters is pumped up for domestic use and garden irrigation. This system now has been working for 3 years and the well did not dry up. In former years, this well did dry up during 3 months every year. In a period of 10 years, the cost of this storage averages to US$1 / cubic meter. This is 10 to 30 times less than the cheapest water storage tank of plastic or cement. More investigation of the functioning of this combination is needed.

However, where technically possible this recharge technology can add a low cost storage option and increase access to water for domestic use and irrigation. It could be disseminated via examples and training of families, communities and local private sector.

Keywords: Rainwater Harvesting, Groundwater Recharge, Low-Cost Technologies, Rural water supply, Food security

Introduction

To increase access to water the combination of low cost wells, hand pumps and groundwater recharge has a good and yet untapped potential. For instance, there are an estimated 3 to 5 million hand dug wells in Africa of which many dry up by the end of the dry season. Reasons for this include over extraction, lack of rainwater infiltration due to compact top soils or changing rain patterns due to climate change. (Ref. 3). One solution is to increase infiltration of rainwater around wells that dry up with options such as; small dams, cultivation on contour or planting trees and plants like Vetiver. Another new option is the so called Tube recharge. The principle of this option is based on recharge pits as used in India but it is simpler, cheaper and it includes a sand and cloth filter to avoid clogging of the pit. After a short training, local well diggers or families themselves can construct it. The cost of materials for a Tube recharge is around US$10 and the volumes that can be recharged can be 100 to 500 cubic meters per rainy season.

Methodology/ Technical Description

The Tube recharge is part of a range of technologies as promoted by the SHIPO and Mzuzu SMART Centre (Ref 4) and in general it is targeted at family level for reasons of ownership and maintenance. The system consists of a pit of 1 to 10 cubic meters (size depends on the rain pattern), and is installed nearby a hand dug or drilled well that dries up in the dry season. Inside the pit a recharge hole (diameter of 6 to 10 cm) is made with a Soil punch. The depth of this recharge hole is 3-6 meters or more. The logic is that it passes through the top compact (clay) layer and enters a soil layer that can retain water. A PVC pipe of 3 meters, with filter slots at both ends, made with a hacksaw, is placed in the hole. The hole is filled with gravel or small stones and has a sand filter at the top. A cloth filter is placed on top of the sand filter and can be taken out and cleaned after each rain or whenever needed. The recharge hole does not go into the aquifer. This is to avoid infiltration of, possibly contaminated, surface water into the aquifer. If water is used for drinking, the Tube recharge system should be combined with Household water treatment like boiling, chlorinating or a household water filter which in Tanzania and Malawi are available at a cost of around US$20.

When it rains, water that otherwise would run off, is "injected" to the ground via the cloth, sand filter and the recharge hole and eventually reach the first aquifer. In this way each time it rains 1 to 10 cubic meters is infiltrated to the ground. Part of the water will flow away in the aquifer but a part will stay around the well, thus increasing the water volume that can be pumped up. Depending on the conditions, this extra water volume would be enough to provide water throughout the dry season. Where SHIPO installs these systems, the well is combined with a locally produced rope pump costing US$ 80. Another hand pump option is an EMAS pump that cost around US$50.

Target groups for a Tube recharge system are:

1) Families or communities in rural areas with (hand dug) wells that dry up, and who live in areas where rainwater runs off because of compact top soils or other reasons.

2) Families in urban or peri-urban areas where it is a legal requirement.. For instance, in some states in India, the law requires that each house or building has a water storage and recharge system.

Results and Cost

There are approximately 70 Tube recharge systems installed. A few in Northern Ghana in 2007, some 50 in Malawi and Zambia in 2009 and 15 in Tanzania in 2011 and 2013

Many of these system were not installed and maintained correctly but of those who were, wells now have water all year round whereas before these wells were dry for one to three months every year.

The cost of a system as promoted by SHIPO is;

Hand dug well 15 meters. Cost depends on geology Range US$200-500. Average	US$350
Rope pump, family model	US$80
Renting a Soil punch (Total cost Soil punch of 6 meters is some 80US$)	US$20
Material cost Tube recharge. (PVC pipe, sand, gravel, cloth filter, rope)	US$10
In case of labor for a Tube recharge, 4 man days at US$10	US$40
Total cost of a well, hand pump and a ground water recharge	**US$600**

Construction can be carried out with local materials and, after due training, with local skills.

Discussion

Although technologies like a rope pump and a tube recharge are simple, experience is "simple is not easy". Many details can go wrong. If not done right, the pump guide box breaks, the rope slips, the tube recharge clogs up etc. In general in technology "the devil is in the detail". To guarantee good quality and to avoid re-inventing the wheel, a 1 to 3 year follow up period is needed on quality control and training the local private sector via structural training. Examples of such training is realized in the so called SHIPO SMART Centre in Tanzania, and Mzuzu SMART Centre in Malawi. They train the local private sector to guarantee there is a "profit based sustainability" so activities could go on after the project funds stop. Another condition to scale up dissemination is to create a critical mass of good examples in a certain area. Once 5% of families in an area have well-functioning systems and see the benefits, neighbors and others are likely to follow.

Conclusion

More investigation is needed to indicate in which situation the Tube recharge will work. However, where technically possible, the combination of a well, a low cost hand pump and a recharge system is a cost- effective option, 10 to 30 times cheaper than rainwater harvesting tanks. This technology is fit for areas with ground water levels of 35 meters or less where geology permits to make low cost wells. The idea of the Tube recharge fits in the so called 3R concept (Retention, Recharge, Reuse) as promoted by organizations like MetaMeta.(Ref 3). The Tube recharge therefore deserves investment and further investigation and demonstration. A wide-scale application of this innovative technology could increase water access for millions of people and so result in improved health, increased incomes and more food security.

References

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4 SMART stands for; Simple, Market based, Affordable, Repairable Technologies

Info on you tube; https://www.youtube.com/watch?v=lho2oNqJN7U

Acknowledgement

The above developments are possible thanks to the activities of the SHIPO SMART Centre in Tanzania and the Mzuzu SMART Centre in Malawi.

Tube Recharge and Rope Pump

Here a pit of 5 m3. A recharge hole is made with a Soil punch. This hole passes the top compact clay layer and in this case is 6 meters deep

The sand filter pit (25 cm deep, 60cm diameter) is made and the recharge hole is half (3m) filled with coarse sand or gravel.

A common ¾"PVC pipe 3 m long with filter slots at both ends(see manual Tube recharge) is placed in the recharge hole. The top of the pipe is 10 cm under the sand. The hole is filled with gravel and the sand filter pit is filled with sand.

The sand is covered with a cloth filter folded around a metal ring made of round bar 10 mm. Bricks are placed on top to avoid the cloth from floating. A rope is attached to enable the filter to be taken out for cleaning

The pit fills up during the rain. After some time the water seeps to the ground via the cloth and sand filter. This is repeated every time it rains

The cloth filter has to be cleaned when clogged. Material cost of this Tube recharge is US$5-10

A Tube recharge system installed for a family in Njombe in Tanzania in 2011

The water from the roof and run off water from the area around the house is led to the pit.

Whenever it rains the pit fills up and water infiltrates to the ground via a cloth filter and a sand filter

When the cloth filter is dirty it is cleaned by lifting and shaking it. Before the Tube recharge, this well dried up for 2 months every year. Since 2011 the well has water all year round. The water is used for 1 cow, a family of 6 persons and irrigation of a garden of 300 m2

Paper 07

Innovative Low Cost Technology for Rain Water Storage through Dug Well Recharge

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Abstract

To harvest the full potential of a catchment (say the roof), conveyed through pipes, stored in containers of appropriate sizes, (so that a reasonable percentage of the daily household requirement is met) and to make the cost per household as minimum as possible. This paper presents a new approach to overcome the limitations of storing limited rainwater quantities in tanks, as compared to the enormous quantities which could be harvested.

Key Words: Rainwater Harvesting, dug wells, storage, infiltration, Water security

Introduction

The development of Rainwater Harvesting in the country has been focused mainly on provision of 5 and 8 m3 storage tanks. According to tank sizing curves, the former works out to a supply of 45 l/day in Mannar, to 375 l/day in Pelawatta, throughout the year, from a 100 m2 roof. This shows the ability to supply the minimum drinking water requirement for a family, throughout the year. However the greater part of the harvested water, in reality, overflows and goes waste, contributing to flooding downstream.

The smaller the capacity of the tanks, the higher the cost per unit storage. Therefore this hurdle can be overcome by considering the womb of the Earth as the medium of storage, which can easily be achieved by conveyance of the roof water, using dug wells for both storage and infiltration. There are over 2.6 million numbers of such wells used for drinking alone, currently readily available countrywide (2012 Census).

Such an approach would ensure that the full potential of a roof, be stored in the vicinity of the well it would discharge to, which is in fact a compensatory act for the water forced to travel on ground (rather than underground) due to roads, buildings and other hard paved areas. The speed of a drop of water reduces by several thousand-fold, immediately it enters the earth when compared to that of an impervious drain.

Since several roof discharges can be connected to a common manifold, running by gravity, feeding several wells in the vicinity, the rainwater falling in the area would be stored in the same area, making the Water table higher, thereby enhancing the quantity, and improving the quality too by the action of dilution. Reducing the flooding problem and its related economic woes, would be an added bonus.

Method

Design and use of appropriate construction techniques-

A wide spectrum of techniques are in vogue to recharge ground water aquifers. Similar to the variations in hydro-geological framework, the artificial recharge techniques too vary widely, and can be broadly categorized into

1. Direct Surface Techniques
2. Direct subsurface techniques
3. Combination surface-subsurface techniques
4. Indirect Techniques

What is considered in this paper is dug well recharge, using Roof top Rainwater Harvesting, which is one of the options under the Direct subsurface Techniques (See Figure 1). This is seen as the easiest, and least cost technique which brings quick improvements with one cycle of rain. Observations by the Lanka Rainwater Harvesting Forum in the well recharging done in the Ayurvedic Hospital, Vavuniya in 2013 bears testimony to this.

Bill of Quantities and Cost

Since this is a system where individual tank storage is only desired and not essential, the cost is in the pipe laying , which in turn will depend on Pipe diameters, length per household and laying .

Assuming a 90 mm PVC pipe laid free of charge by the community , and a length of 50 m pipe per Household, the cost = Rs. 400 per m of pipe x 50m =Rs. 20,000 per Household.

As the Earth has almost unlimited storage capacity to store the infiltrated water, the Mansur Curves can be used to show that if a community of 100 households, each having 100 m2 of interconnected discharges, could increase the daily safe supply to well over 90 l/day in Mannar, compared to 45 l/day from individual household discharges to storage of 5m3 each.

The cost of a 5m3 Ferro cement tank is currently app.=Rs. 40,000

Thus an interconnected system would double the reliability of water of that of an independent system, while halving the cost.

Total cost of an interconnected project for 100 households= 100x 20000= 2 Million RS. (without contingencies, price escalation, gutters and downpipes, and community doing the pipe laying work, backfilling and road reinstatement.)

The benefits increase in the higher rainfall Districts. This shows that the water security per Household could be increased at lesser cost than providing individual storages.

Observation, Measurement and Monitoring of Results

The monitoring of water levels and water quality, both inside and outside of the areas of direct influence, is of prime importance in the artificial recharge of groundwater. The data to be monitored would speak for the efficacy of the structures constructed, and would help in effective measures for groundwater management on improved scientific lines, in the pertaining area

Discussion

Since a rain drop has “ Watergy” (Water and energy) embedded in it, this energy could be more efficiently utilized, the higher it is harvested. The small amount of “ safe” water required for drinking could easily be achieved by running the stored water through a simple household san/clay filter to eliminate pathogens, if any.

The rain water thus collected and stored underground can be pumped back using the same pipe line used to collect it. The system could be best adopted in a semi rural area/ housing complex with gently sloping terrain.

Social acceptance of this concept needs field testing due to its novelty. The environmental footprint would be very positive as it recharges the ground with no new intrusions. Technically it is simple.

It may be of interest to know that this concept harmonizes with

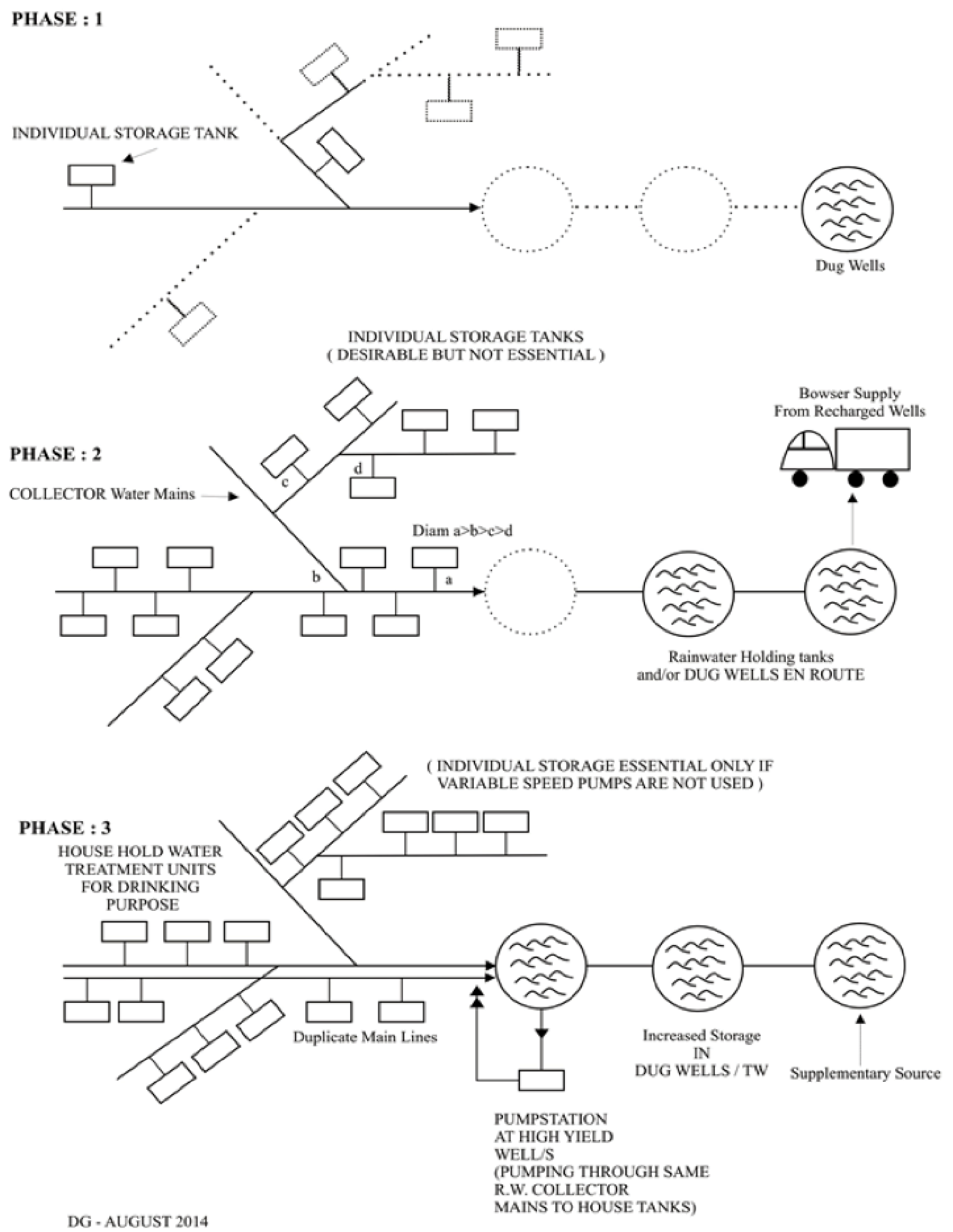
a) Owners of wells being the “custodians “of the harvested water to be used for the community (as stated in the National Policy of RW in Sri Lanka- 2005 June)

b)The Communist motto of “From Each according to his ability- To each according to his needs”. (Individuals contributing

REFERENCE

Guide on Artificial Recharge to Groundwater- Central Groundwater Board, Ministry of Water Resources, New Delhi

FIGURE
INNOVATIVE LOW COST TECHNIQUE FOR RAINWATER STORAGE



Paper 08

To Assess the Socio Economic Impacts of the Rain Water Harvesting Project Implemented in Vavuniya District

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Abstract

Increasing population enhances demand for quality drinking water which often leads to pollute the natural water resources. On the other hand ground water naturally contains calcium, fluoride and some other ions due to geological reasons and indiscriminate use of agro chemicals and fertilizers, which are affecting the quality of water. In this situation we have to find a proper solution for drinking water. Rainwater is the only freely available quality water source so we can use that as drinking water. This study was carried out in Vavuniya district under the project of "Water security for resettlement areas in the northern province of Sri Lanka through rainwater harvesting". In the project area people utilize various water sources and the main source is the common well and at the same time 46% of them are not using any purifying methods. By having a rainwater harvesting system 36% beneficiaries are able save time for their family welfare. Up to 25% of the people use rainwater for drinking and cooking purposes during both dry and wet seasons.

Keywords: Rainwater Harvesting, Vavuniya, Water sources

Introduction

Water is essential to sustain life. People get water from various sources such as rivers, reservoirs, dug wells, tube wells and pipe water systems provided by National Water Supply and Drainage Board. Some of these sources can be polluted due to human and natural influences. Rainwater is a natural and pure water source. The harvesting of rainwater is a low cost method of obtaining pure water. Sri Lanka is divided into three zones according to rainfall. They are the dry zone, intermediate zone and the wet zone. The project is located in the Vavuniya District which is in the dry zone and it has a shallow regolith aquifer on the hard rock. Therefore the water storage capacity is very low and as a result the ground water level is low. This leads to flooding in rainy season and drought in dry season. That's why shallow domestic wells are low yielding and quickly filled during rainy season and disappear in dry season which results in a water scarcity in this region during drought months. Ground water also has a high content of minerals, and therefore it is known as hard water. Rainwater harvesting is the best way to solve the drinking water problem in the district. Besides, it is an environmental friendly method.

The main objective of this project was to improve the health of the community by making uncontaminated water available for drinking and at the same time to enhance food security of the resettled community by providing irrigation water to develop their home gardens. The target of the project was to build 750 rainwater harvesting (RWH) systems in resettlement households, 9 rainwater harvesting systems in schools and hospitals and 10 plant nursery centers to support home gardening in the households. The period of the project is eighteen months starting from February 2012 to July 2013. This survey was carried out to monitor and evaluate the project impact at household level.

Materials and Methods

Household Survey

Household surveys are one of the main access routes to socioeconomic data for researchers. They provide indicators to measures specific economic and social issues. They also provide information which makes it possible to know and explain the causal factors underlying the behavior of such issues.

Study Area

Vavuniya district has a more acute water problem because of the aquifer type. There are four Divisional Secretariats. The community is made up of Tamil, Muslim and Sinhala ethnic groups. All ethnic groups are served under this project. The major water sources of these communities are dug wells, tube wells, piped water supply of the National Water Supply and Drainage Board, reservoirs and bottled water.

This project was conducted in Vavuniya district because of:

- Large number of resettled families
- Ground water contaminated with agro chemicals
- High concentration of ions (calcium, fluoride)
- No water available during dry season

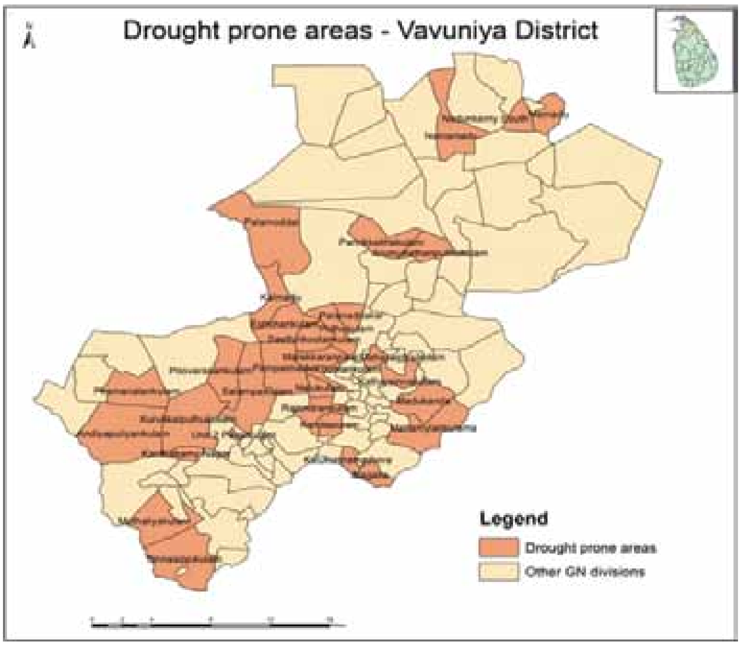

Figure I: Map of the study area

Sampling Procedure

A total of 89 beneficiary families were randomly selected from 350 beneficiary families. Direct interview method was conducted to collect data for the survey. Data was entered in excel sheets and descriptive and tabular analysis was conducted.

Data Collection

A structured questionnaire was designed and pre-tested to see whether it's applicable to the people. The questionnaire covers the socio economic and water usage before and after the implementation of the project. Three investigators were selected and provided with a day's training by the project team. Data were collected between the periods of January to February 2013.

Results and Discussion

Before implementing the project, people used the common well as the main water source. It was the major drinking water source in both dry and wet seasons. Figure 2 illustrates the details.

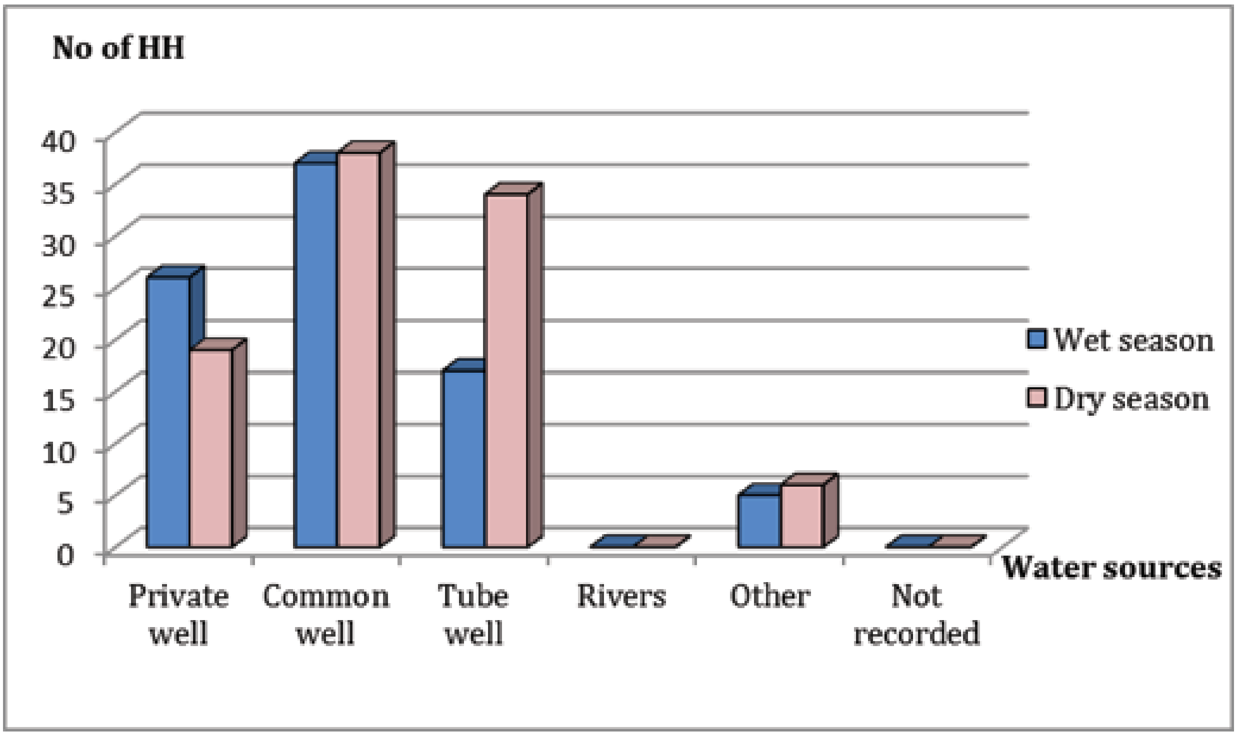

Figure II: Major Drinking Water Sources before the Project

Distance Travelled to Bring Water

Distance travelled to bring water from other sources varies between 50 – 2000m. Majority of people travel less than 500 m to bring water during both seasons.

Table I: Distances travelled to bring water

Wet season (M)	No. of HH	Dry season (M)	No. of HH
< 500	68	< 500	66
500<1000	7	500<1000	11
1000<	2	1000<	2

Water Treatment Methods Before the Project

People used different kinds of water treatment methods. However, half of them were not using any treatment methods.

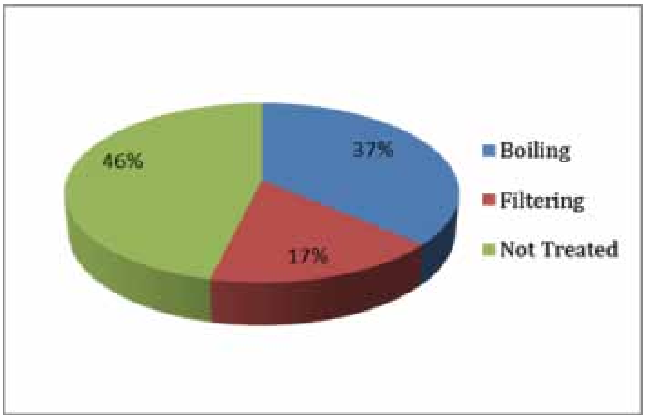

Figure III: Adopted Water Treatment Methods before the Project

Reasons for Requesting a Rain Water Harvesting System

The existing water source does not have enough water throughout the year. Even those having enough water had a high concentration of ions and therefore not suitable for drinking. Since most of the people depended on the common well, they did not have a reliable water source. Figure IV shows the reason for requesting an RWH system.

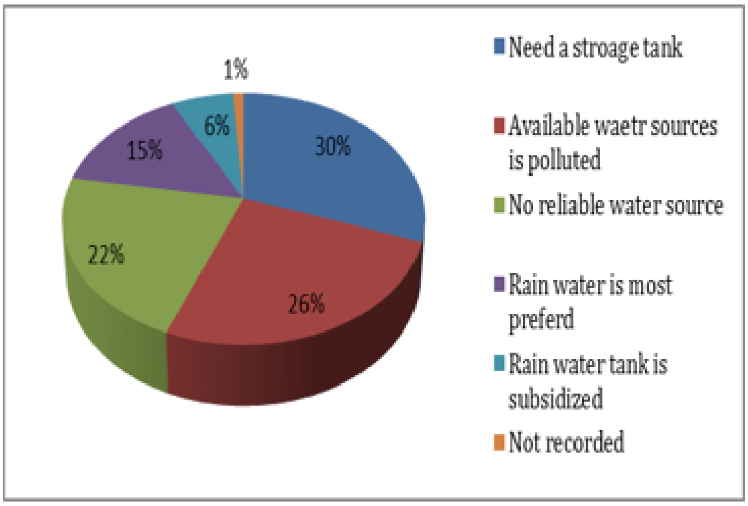

Figure IV: Reasons for requesting a RWH System

Utilization of Rainwater Harvesting Systems

People use the system with different sources of water. Approximately half of them utilize the RWH system with rainwater. Figure V shows the percentage of tanks filled with different sources.

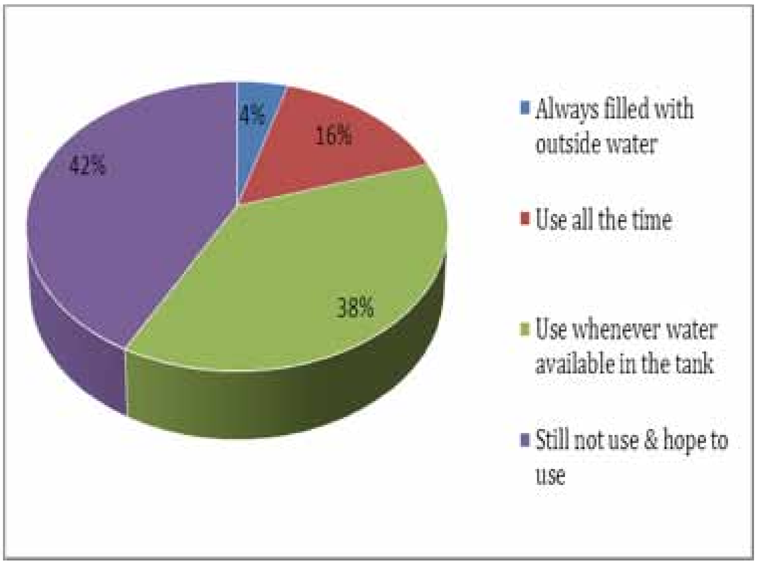

Figure V: Use of RWH System

Rainwater Usage for Different Purposes

Even people who utilize the RWH system, they use it for various purposes. Majority of the people use rain water for cooking and drinking purposes. Figure VI shows different usages of rainwater.

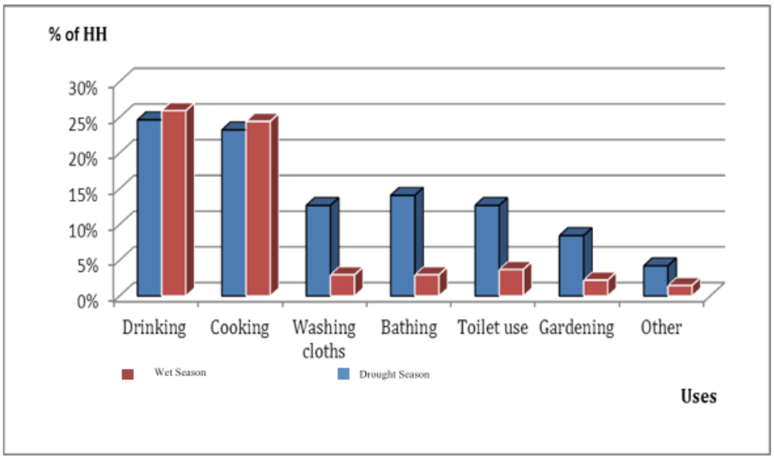

Figure VI: Rain Water Usages

Methods of Treating Rainwater for Drinking

Most of the people use rain water for drinking without any purifing method.

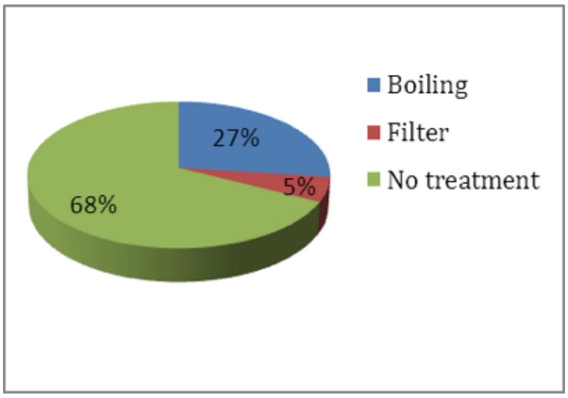

Figure VII: Treatment methods of rain water for drinking

Social and Economic Benefits of the Project

Some people used to transport water for drinking purpose from far away, but after construction of the RWH tank they have good drinking water sources at their premises. Their expenditure of transporting water is reduced by having the RWH system. They also save time by not having to go to get water form distance sources. They use the saved time mostly for family welfare and leisure as shown in the figure VIII.

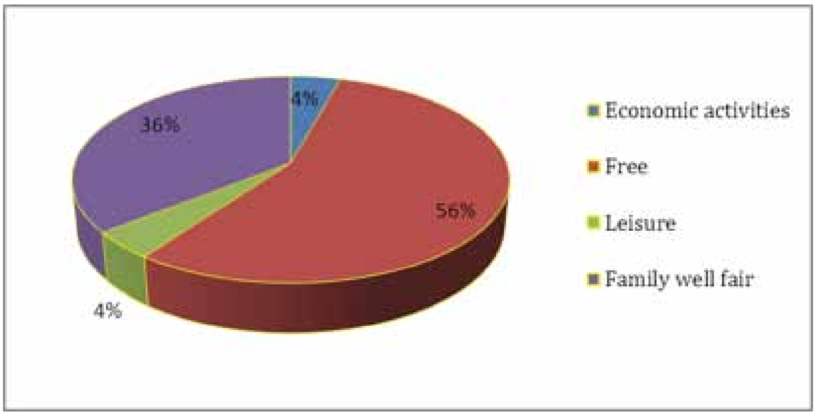

Figure VIII: Percentage use of time saved by having a RWH system

Water Usage After the Project

Before implementing the project people used a variety of water sources for all purposes. But after the project constructed the RWH system, rain water is also included as a main water source for their daily needs. Figure IX shows the percentage of water usage for different purposes from different sources after the construction of rainwater harvesting system both in the dry and wet seasons. It indicates that rainwater is a main source of drinking water during dry season.

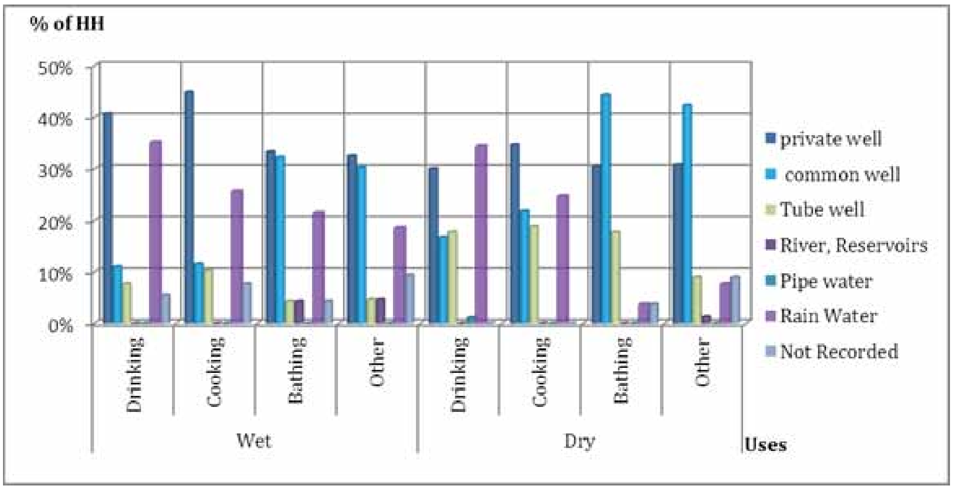

Figure IX: Water usage after the RWH system developed

Consumer Preference on Rain Water Vs Other Water Sources

According to figure X people prefer rain water to other water sources due to 3 main reasons, viz, because they like to use rain water (25%), because it is easy access (20%) and because there is no expense involved (18%).

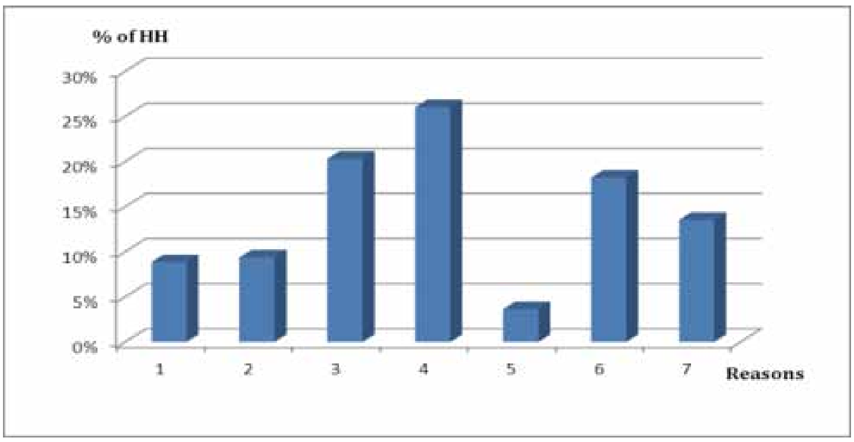

Figure X: Preference on Rain water VS.other Water Source

1. There is no other water source
2. Other sources go dry in dry season
3. Easy access
4. Like to use rain water
5. There is nobody to bring water from outside
6. There is no expense
7. The quality of other sources are not good

Conclusion and Recommendations

Most of the people use rain water for drinking and cooking during the dry season and during rainy season they use rainwater for all purposes. There is no ill health effects recorded due to drinking rainwater. By having a RWH system people have many advantages.

- They save time and money as they do not have to spend time for fetching water and money for buying water
- Have water at their premises
- Obtain pure water free of cost
- The have more time to spend with their families

Most people do home gardening during the rainy season. Only a few people are doing home gardening by using water from RWH system because they want to save the stored water for drinking and cooking purposes. They informed that they are going to collect overflow water for their home gardening purposes.

It is recommended to do monitoring and evaluation three or four times per year to encourage the people to use rainwater

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Paper 09

Domestic Rainwater Harvesting Interventions in Sri Lanka: Some Lessons Learnt

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Abstract

The lack of accessibility to safe drinking water is one of the primary constraints affecting rural livelihoods, especially in the Dry Zone of Sri Lanka. This situation affects the poor more than the rich people in the community. Rainwater harvesting systems (RWHS) were implemented using the roof as the catchment at household level under subsidized schemes, which was a measure to minimize water and sanitation issues. The harvested rainwater was intended to be used for drinking and other domestic purposes with or without treatment.

Assessment of the current status of RWHS in the country shows that there is a high correlation between the lack of some of the essential components of RWHS and non-use of the system. All the systems that were not being used lacked one or more of the essential components of a typical RWHS, such as gutters, tank lid, filter and first flush device. Due to the subsidized scheme, part of the system was provided by the beneficiaries in order to get ownership. Economic reasons and the willingness to use rainwater delayed providing the expected contribution to the beneficiary. With time, the system never became fully functional. There were some who made use of the system and maintained it fully, but this was around 50% of the original number of beneficiaries. Awareness also plays an important role in adoption of the system.

As expected, almost all the beneficiaries who had undertaken routine maintenance of RWHS used the harvested rainwater for drinking purposes. Abandonment of systems takes place when the system provided is incomplete or if it lacks one or more of the essential components.

Keywords: Rainwater, filter, gutter. Tank lid, first flush, tank abandonments

Introduction

Sri Lanka has the traditional wisdom of harvesting and utilizing rainwater. However, an institutionalized rainwater harvesting system was introduced around 1995 under the World Bank-funded Community Water Supply and Sanitation Project (CWSSP). The project promoted rooftop rainwater harvesting as an option for domestic water supplies. After this project ended, various other government and non-governmental organizations, and funded projects supported the development of rainwater harvesting systems at household and community levels.

Realizing the importance of rainwater harvesting and the growing scarcity of high-quality water, the Government of Sri Lanka adopted a national policy on rainwater harvesting in 2005. According to the Lanka Rainwater Harvesting Forum, the estimated number of domestic rainwater harvesting systems constructed all over the country was over 31,000 by 2009. Despite the development efforts, recent studies have shown that a substantial number of rainwater tanks constructed under various projects are abandoned or the water collected is not used for drinking purposes (Ariyabandu, 1998; Ariyabandu and Aheeyar, 2000; Gunasekara and Thiruchchelvam, 2002). Therefore, it is vital to identify the reasons and concerns of the beneficiaries for the abandonment of RWHS and underutilization of the harvested rainwater.

The most expensive item in the installation of a RWHS is construction of the storage tank, which was mostly subsidized by the projects. However, the availability of a tank alone is not sufficient for the proper functioning of a RWHS. The complete system requires 'other' essential components, such as roof gutters, sand filter, properly closing tank lid and first flush device, to collect and store clean water. The 'other' essential components were mostly not funded by the projects, and the beneficiaries were requested to install these components at their own cost. These 'other' essential components required periodic replacement and/or routine maintenance, but this was not very expensive.

Objectives

The main objective of this paper is to assess the current status of RWHS provided for domestic use, and identify the reasons behind abandonment of the system and for not using the rainwater for the intended purpose. Based on the results, recommendations will be made for future interventions.

Methodology

The data necessary for the study was collected from a sample survey conducted throughout the country. Multistage random sampling technique was adopted for the questionnaire survey. In the first stage, two districts were selected from each province purposively. The districts which had the highest number of rainwater harvesting systems were selected. The districts selected were Vavuniya, Mannar, Ampara, Batticaloa, Anuradhapura, Polonnaruwa, Kurunegala, Puttalam, Matale, Kandy, Gampaha, Kalutara, Matara, Hambantota, Ratnapura, Kegalle, Moneragala and Badulla. In the second stage, two villages that have the highest number of rainwater harvesting systems were purposively selected from each district. Finally, sample households were randomly selected from the selected villages for the survey. The total sample size was 500, which was 8.3% of the total number of beneficiaries in the selected areas. The sample was selected from the RWHS that were constructed during the period 2000-2008. Key informant discussions were also conducted to verify and validate the survey findings.

Salient Features of the Rainwater Harvesting Tanks in the Study Areas

The findings show that 46% of the total RWHS constructed during the period of 2000-2008 were implemented after the Tsunami at the end of 2005 (Figure 1). There are mainly three sizes of tanks available in the areas, i.e., 5,000, 7,500 and 8,000 liters. However, about 65% of the total tanks are of 5,000-liter capacity. All the tanks of 8,000-liter capacity are available in Batticaloa, Vavuniya and Trincomalee districts, but there are no 5,000-liter tanks in Vavuniya and Batticaloa districts. About 40% of the total number of tanks is constructed with financial support from the Asian Development Bank, followed by the CWSSP. One of the major reasons behind the construction of RWHS as perceived by majority of the beneficiaries was the involvement of subsidies.

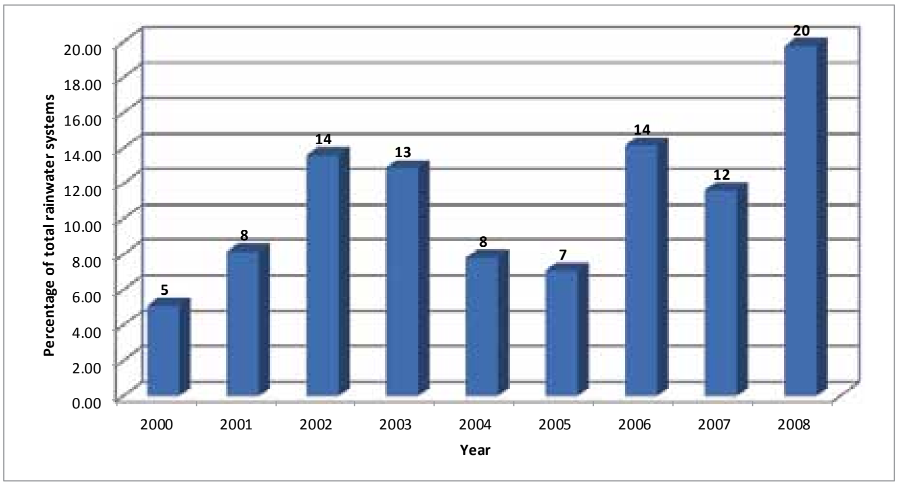

Figure 1:
Construction of rainwater harvesting tanks during the period 2000-2008
(percentage of total tanks constructed during the period).

Current Status of the Rainwater Harvesting System and the Use of Rainwater

Rainwater harvesting systems were introduced and promoted as an alternative option to ensure household water security, especially to provide safe drinking water. According to the findings of the survey (Figure 2), about 50% of the RWHS provided are currently used. The remaining amount is abandoned (23%) or used as a stock tank to store water collected from other sources (27%). The use of RWHS for storage of water from other sources is prominent in Hambantota and Moneragala districts. Figure 3 illustrates that non-use of a large number of tanks is common in all the districts, irrespective of the wet and dry zones.

About 80% of the people in the selected areas were dependent on groundwater sources (private wells, common wells and tube wells) for drinking and cooking purposes. The primary reasons for the choice of RWHS selected by majority of the sample beneficiaries (over 55%) were related to water quantity issues, such as lack of alternative water sources in an accessible distance and drying up of available water sources during dry seasons or in some parts of the year. The poor quality of available water was an issue for only 10% of the beneficiaries. The perceptions of beneficiaries on the use of RWHS indicate that abandonment of systems has mainly taken place due to technical reasons, such as the system provided being incomplete or absence of other essential components and faults in the storage system as a result of poor construction (55% of the non-users). Another reason for the non-use of harvested rainwater for drinking purposes or household needs is linked with poor quality (color, smell and turbidity) of the water collected (16% of the nonusers). The quality of water collected from an RWHS is by and large determined by the availability of the filter and first flush device, and routine maintenance of the RWHS. Heijnen and Mansur (1998) also reported high turbidity and color in the water collected in rainwater systems that had not utilized first flush devices.

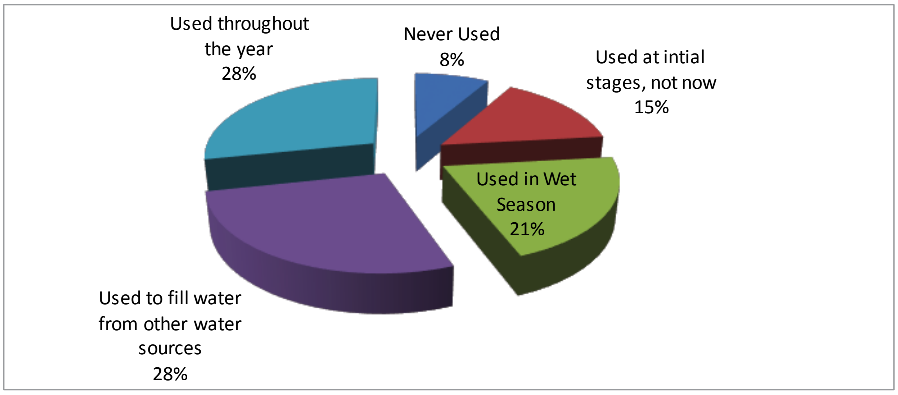

Figure 2: Level of utilization of RWHS.

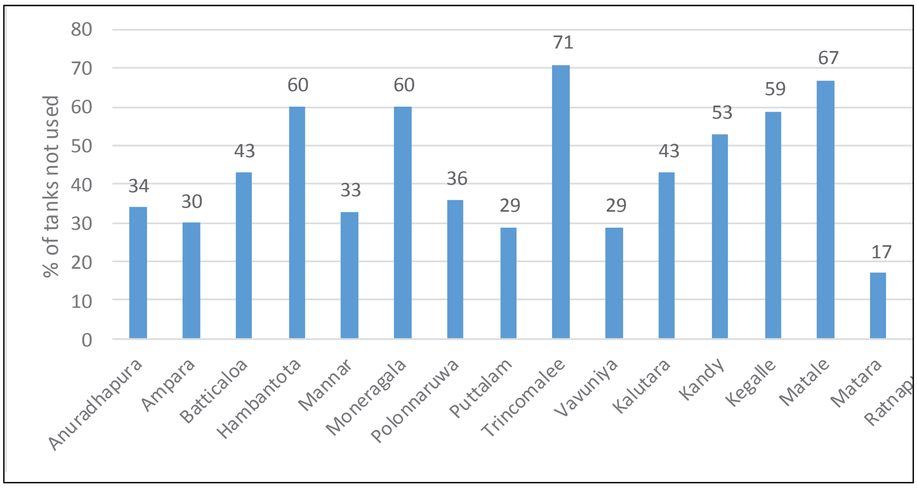

Figure 3: Number of systems not utilized for rainwater harvesting.

Availability of 'Other' Essential Components and Non-use of Rainwater Harvesting Systems

Most of the subsidized rainwater harvesting projects expected beneficiaries to contribute to the establishment of 'other' essential components, such as roof gutters, sand filter, properly closing tank lid and first flush device, to collect and store clean water. However, there was a time lag in installing such components depending on the economic situation of the beneficiary, and also their real need and willingness to collect rainwater. For example, the people who intended to use the tank to store water collected from other sources do not need these 'other' essential components, except for the tank lid.

Figure 4 shows the availability of different 'other' essential components among the selected households, indicating that almost half of the people do not have filters and gutters. The first flush device is available only among 15% of the beneficiaries.

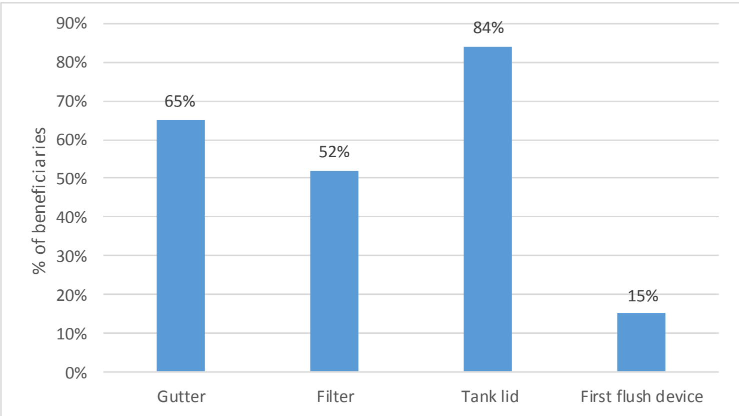

Figure 4: Availability of 'other' essential components by 2011.

There are 279 RWHS out of 543 which are currently not used to harvest rainwater. Table 1 shows the high correlation between the lack of 'other' essential components of a RWHS and non-use of the system. All the non-use systems are lacking one or more of the 'other' essential components, such as gutters, tank lids, filters and first flush devices. Filters and first flush devices are important to collect clean water, and tank lids that close properly are necessary to ensure the safety of stored water by preventing the entry of external polluting materials. Although tank lids are available among 85% of the beneficiaries, they are not used by most of them. Tank lids introduced by the projects were made out of concrete and they are fairly heavy. The beneficiaries found it difficult to manipulate these lids during cleaning of the tanks, and most of the time they were kept open. Therefore, the situation permitted the entry of pollutants, especially the breeding of mosquitoes.

Table 1: Relationship between non-availability of 'other' essential components and non-use of RWHS.

'Other' essential component	Number of RWHS that lack an essential component (N= 543)	Number of non-used systems
Gutter	156	156
Filter	156	156
Lids	49	49
First flush device	231	231
Lack of one or more of the above	279	279

Source: Authors' survey data, 2011.

It was also found that around 25% of the beneficiaries who are currently using the systems to harvest rainwater were using the harvested water for drinking purposes during at least some parts of the year, with the highest percentage of such users coming from Anuradhapura followed by Puttalam District. Almost all the beneficiaries who used the rainwater for drinking purposes were cleaning the storage tank, roof catchment and gutter system routinely, and had installed first flush devices into the RWHS. All the functioning inadequately equipped or incomplete systems are used to collect rainwater for purposes other than drinking and cooking, and are used to store water collected from other sources during wet seasons.

Concluding Remarks

Majority of the beneficiaries in all the areas are not convinced that RWHS is the best option to solve their water problems. This may be due to lack of awareness or poor targeting of the beneficiaries or lack of own experience in using such water. Although most people think that rainwater is a clean water source, they lack confidence on the system they use to collect and store good quality water. Therefore, beneficiaries should be educated on the quality parameters, and their short- and long-term health impacts, of rainwater and other alternative water sources, as the quality of rainwater collected properly has been proven to be good quality potable water (Ariyananda, 1999, 2000, 2001; Weragoda et al., 2013).

A complete rainwater harvesting system is vital for collecting clean water. Therefore, measures are necessary to install all the recommended components of the system during the construction process, as there are high linkages between the perceptions of beneficiaries on water quality and availability of 'other' essential components. The installment of 'other' essential components such as gutters, filters, tank lids and first flush devices should be assured before completion of the project.

Appropriate and easy-to-manipulate tank lids with proper sealing should be introduced, in order to facilitate trouble-free cleaning of tanks and to protect them from becoming mosquito breeding sites, especially for dengue mosquitos. Entry of different fauna into the tank also creates a negative perception on water quality.

Acknowledgments

This paper is based on the research project supported by the Water Supply and Sanitation Collaborative Council and the National Water Supply and Drainage Board. The authors wish to acknowledge financial support provided by these organizations.

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Session II

Rainwater Harvesting as a Climate Change Adaptation Measure

Paper 01

Rainwater Harvesting As an Adaptation Measure for the Impact of Climate Change on Water Resources in Central Hills of Sri Lanka

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Abstract

Climatic changes have severely affected Sri Lankan economic, social, and agricultural sectors owing to high dependency on water for power generation, irrigation for agriculture, domestic and human consumption. The frequency of floods, landslides and drought situations are increased drastically in the Central Hills of the country and there is an urgent need to study the impacts of climate change on future water resources. Therefore climate change impacts for 2050s have been studied for Sri Lanka using climate change projections of HadCM3- a General Circulation Model of UK Hadley Centre for Climate Prediction and Research, UK. These predictions were then applied to the IPCC-Emission Scenario A2 (worst impact scenario). Simple water balance methods and runoff coefficients were used to estimate the potential soil moisture deficit and runoff. For this study three locations in Central Hills were used namely Nuwara Eliya, Ratnapura and Kandy. Results of HadCM3 for 2050s - A2 scenario were compared with 1961-1990 data as baseline and recent past decade data (1999-2008) of the Meteorology Department, Colombo.

According to the results of HadCM3 for 2050s-A2 scenario prediction, the southwest monsoon has increased by 57%, 43% and 20% for Nuwara Eliya, Ratnapura and Kandy respectively. However during the recent past decade (1999-2008) the south west monsoon has increased by 10% for example in Nuwara Eliya. Due to the increase in rainfall during southwest monsoon the surface runoff which causes excessive runoff / floods are also increased significantly in central hills. Therefore during southwest monsoon period floods and landslides are prominent.

In contrast during the north east and first inter monsoon period there is a drastic decrease in rainfall. According to HadCM3 for 2050-A2 scenario prediction there will be 31%, 34% and 29 % decrease in rainfall in Nuwara Eliya, Ratnapura and Kandy respectively. However during the recent past decade (1999-2008) northeast, first and second inter monsoon rains in Nuwara Eliya has decreased by 11% , 16 % and 14% respectively. It shows that the decreasing trend in northeast and first inter monsoon are proportionally high in the prediction in 2050s compared to the baseline. Consequently the soil moisture deficit has increased almost 100% in all three locations. This decreasing trend will pose severe drought problems in the central hill country. Further this situation will create severe water shortages and the communities will face difficulties to meet domestic and drinking water requirements. In addition up-country vegetable cultivation too will be affected due to severe water shortages.

According to the results, heavy rains during five months cause tremendous damage to the people and properties. Therefore the simple solution in this case is to increase the retention of water that is received during the rainy periods to be used during the non rainy periods. It could be done best by following the approach adopted in history which was to construct reservoirs and to develop canals for distribution of water thus retained, to other areas. By doing this groundwater recharge also could be improved and the groundwater could be used for domestic purposes. Further, rainwater harvesting will be a good option for communities facing water shortages during non rain period. Maintaining a good balance of forest cover also is very important, to reduce the adverse effect of excessive runoff and floods. Forest cover is important because it plays a very useful role in controlling and retaining water, reducing erosion and softening the aggressive rain fall which increases soil erosion.

Key Words: Climate change, drought, water harvesting

Introduction

The plantation sector in Sri Lanka has a long history of over 150 years which contributed to a considerable amount of total foreign exchange earnings. Lack of water and occurrence of drought are causing lower yields and less work for the community. Estate sector faces inadequate supply of safe drinking water, lack of proper housing and toilet facilities. Because they are generally not educated, they are less aware of minimum requirements for health. Safe water supply has been not only seen as a basic need of people, but also essential for a healthy life. Unsafe water has becomes a significant vehicle for water borne diseases, being the major cause for illnesses in the communities in the central hills. Although about 65 percent of estate people obtain their water requirements from pipe borne water supply, scarcity of water, traveling long distance to fetch water and pollution of water are major water related problems.

In contrast, flood damages are almost an annual feature during the major rainy seasons in the river basins. Ratnapura city is situated in the wet lowlands of Sri Lanka and the town is located beside the Kalu Ganga. Kaluganga is the third longest river in Sri Lanka. Further it discharges the largest volume of water to the sea. Flooding of Ratnapura town has been a frequent occurrence. Most of the Ratnapura district including the Ratnapura town is subject to floods when river level rises up to 18m.msl. Urban area spreads over 20 square kilometers with a population of 46300. The inhabitants of the city face natural hazards like periodic flooding, land instability and number of other environmental problems created by their activities. During high rainfall periods, more than 20% of the urban area is flooded as approximately 273 square kilometers of drainage basin accumulates around the city. In 2003 floods, estimated damage to the Ratnapura area was Rs. 1,140 Mn and 122 people died. Therefore appropriate development planning is necessary. In addition, the lowlands of Nuwara Eliya and Kandy too experience heavy floods and land slides during southwest monsoon season. With the climate change impacts the situation will be aggravated in future.

Rationale and Objective

The frequency of floods, landslides and drought situations are increased drastically in the central hills of the country and there is an urgent need to study the impacts of climate change on future water resources in the central hills of the country. Therefore this paper intends to analyse the climate change impacts based on HadCM3 model prediction on water resources in central hills and possible adaptation measures.

Methodology

There are few Global Circulation Models (GCMs) developed by various countries and these models predict the future climate change in climatic variables such as rainfall, temperature, wind speed, relative humidity based on the green house gases, sea level rise and other related parameters for the whole world except Antarctic regions for 2020s, 2050s and 2080s (Hulmeet al, 1998). Therefore the results are in larger pixel points such as 300km x 300km to cover the whole world. It creates problem for small countries like Sri Lanka which could use only two or three pixel points to extract the results of the global circulation models. It doesn't mean that the Global Circulation Model results cannot be used to Sri Lanka or not reliable for Sri Lanka. There are scientifically and internationally accepted downscaling procedures available to down scale the 300km x 300km pixel results of climate change predicted by global circulation models to the 10km x 10km pixel used by Sri Lanka for baseline data from 1961-1990 (New et al, 2002). Therefore global Circulation model results on climate change could be scientifically used to predict the rainfall and temperature changes in Sri Lanka in 2020's, 2050's and 2080s.

Therefore the climate change predictions for 2050s have been studied for Sri Lanka using climate change projections of HadCM3- a General Circulation Model of UK Hadley Centre for Climate Prediction and Research, UK. These predictions were then applied to the IPCC-Emission Scenario A2 (Worst case) (IPCC, 2007). Simple water balance methods and runoff coefficient were used to estimate the potential soil moisture deficit, runoff and potential groundwater recharge. For this study three locations in Central Hills were used namely Nuwara Eliya, Ratnapura and Kandy. Results of HadCM3 for 2050s - A2 scenario were compared with 1961-1990 data as baseline and recent past decade data (1999-2008) of the Meteorological Department.

Results and Discussion

The annual average rainfall is predicted to increase in Ratnapura, Nuwara Eliya and Kandy by 12% in 2050 (A2) scenario compared to the baseline (1961-1990). This is mainly due to the increase predicted during the southwest monsoon rainfall across the country by 38% (A2) and 16% (B2) in 2050s. The predicted increase in rainfall during southwest monsoon period (May to September) in Ratnapura, Nuwara Eliya and Kandy are 43%, 56% and 20% respectively in 2050 (A2) compared to the base line (1961-1990). This prediction agrees with the recent past decade (1999-2008) data of Meteorological Department on south west monsoon rainfall as it has increased by 10% in Nuwara Eliya for example.

Further, among the wet zone areas the annual runoff in Ratnapura, Nuwara Eliya and Kandy are predicted to increase and the predicted increase in Kandy is almost 100% compared to the baseline (1961-1990). Due to the increase in the surface runoff, floods and land slides would also increase significantly in central hills. It shows that during the 5 months of southwest monsoon season (May to September) the central hills are predicted to receive a tremendous amount of rainfall which causes excess runoff / floods and land slides in these areas (De Silva et al, 2007).

Table 01: Predicted increase in runoff in percentage compared to the base line (1961-1990) in Kandy/Katugastota

Year	Kandy/Katugastota
2010	33.2
2020	49.8
2030	66.4
2040	83.0
2050	100

In contrast northeast monsoon rains during December to February is predicted to decrease by 31%, 34% and 29% respectively in Ratnapura, Nuwara Eliya and Kandy in 2050 compared to the baseline (1961-1990). Further the second inter monsoon (October to November) too is predicted to decrease in rainfall. Therefore the rainfall during October to February (northeast monsoon) is predicted to decrease in Ratnapura, Nuwara Eliya and Kandy by 6%, 10% and 5% respectively in 2050, A2 scenario compared to the baseline (1961-1990). For example in Nuwara Eliya the rainfall during the recent past decade (1999-2008) has already decreased by 11%, 16% and 14% during northeast monsoon, first and second inter monsoon respectively (Figure 01). Therefore the decreasing trend observed in recent past decade (1999-2008) agrees with the decreasing trend predicted by the HadCM3 for 2050. Therefore for 7 months from January to May and October to December there is a predicted decrease in rainfall.

Further the annual average temperature is predicted to increase in Ratnapura, Nuwara Eliya and Kandy by 1.7ºC, 1.1ºC and 1.5 ºC respectively in 2050 (A2) compared to the baseline. Because of this temperature increase the maximum soil moisture deficit is predicted to increase by almost 100% in all these stations in central hills which will pose a severe impact on available water for up country vegetable cultivation and it may need additional irrigation water for sustainability. However the potential groundwater recharge is predicted to increase by 74%, 23% and 33% in Kandy, Nuwara Eliya and Ratnapura respectively in 2050 (A2) scenario compared to the baseline Figure 02).

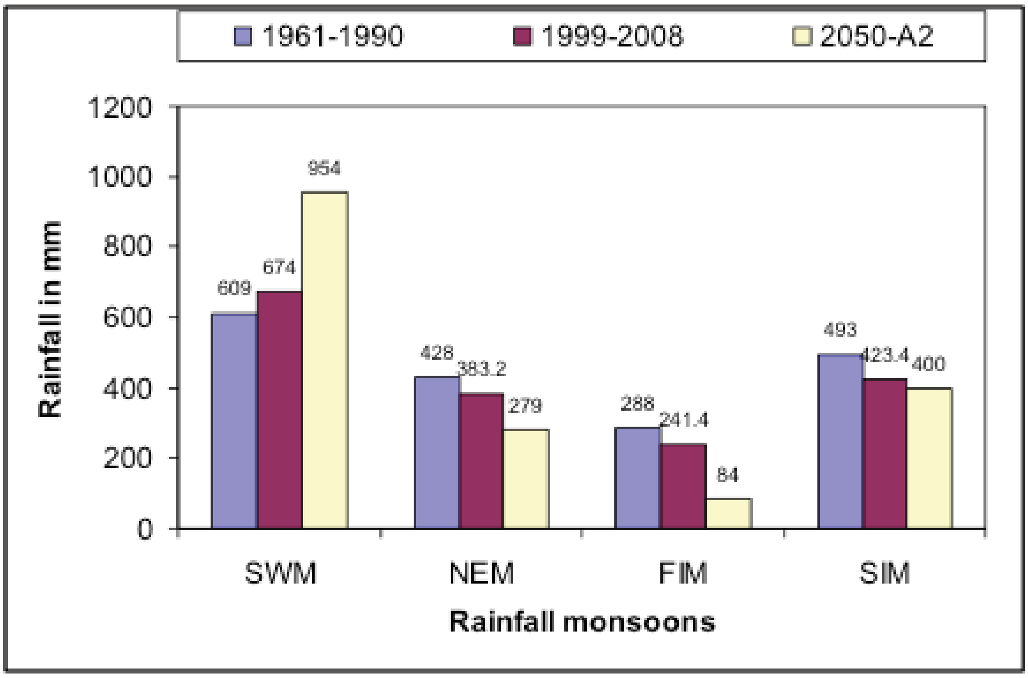

Figure 01 Rainfall in Nuwara Eliya during Southwest- monsoon (SWM), Northeast-monsoon (NEM), first inter-monsoon (FIM) and second inter-monsoon (SIM) in mm for periods from 1961-1990, 1999-2008 and HadCM3 prediction for 2050.

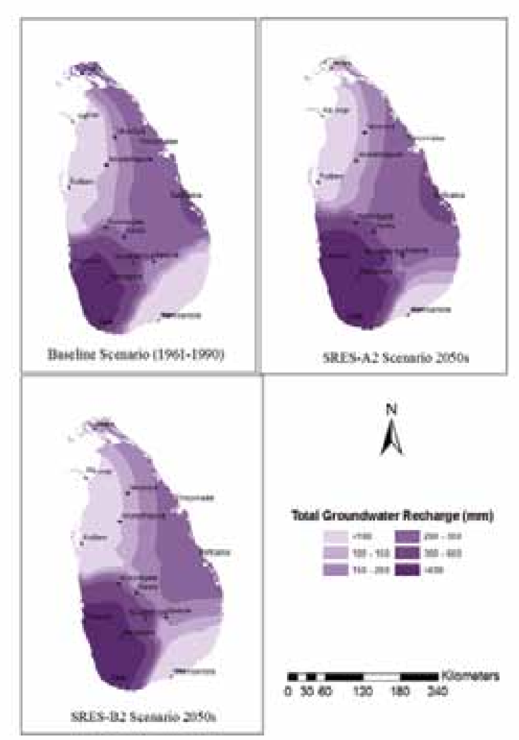

Figure 02. Spatial variations in total potential groundwater recharge in mm, for baseline (1961-1990) and SRES A2 and B2 scenarios for the 2050s by HadCM3

Conclusions

According to the HadCM3 prediction for 2050 and the recent past decade (1999-2008) results on rainfall there is an increase in rainfall for 5 months during southwest monsoon period. This will cause flash floods and landslides. But for 7 months during first, second inter monsoon and northeast monsoon the rainfall is predicted to decrease in central hills which will pose severe water deficit for up country vegetable cultivation. Further it will affect the availability of water for drinking and domestic purposes.

Adaptation Measures

Adaptation measures should be mainly focused on rainwater harvesting in various ways. It should be designed to store the excess runoff water when the demand for water is low in central hills during southwest monsoon for other months when there is no rainfall and demand for water is high.

During the southwest monsoon period the excess runoff water must be retained in runoff collection or surface ponds or small reservoirs or surface tanks whereever possible in the direction of water flow. Further series of water retention dams and structures could be erected in the downstream of each reservoir so that the spillway water could be retained rather than letting go waste. In the dry zone of Sri Lanka there is a cascade system where the excess water flows to the tanks one after one in the downstream and the water is not lost. In the present system, there are no means between major reservoirs to store the spillway water for water retention. Therefore the system similar to the dry zone should be developed in the central hills wherever possible. When the slope is steep there should be mechanical structures constructed to reduce the velocity of the water and divert to the surface ponds and surface tanks. By careful employment of water retention and water management techniques the excess water during southwest monsoon period could be retained for future agricultural and other uses. This may be done mainly by government based organizations such as the Irrigation Department through proper policy decisions and implementation.

Figure 03 Runoff collection tank to store excess runoff

Similarly community based projects also should be encouraged through proper awareness programmes to collect and store the excess runoff by runoff collection tanks for home gardening and other purposes (Figure 03). For drinking purposes each household should maintain a rainwater harvesting system to collect roof water during the rainy season (Figure 04). This should be encouraged as community based projects so that the community could be responsible to store water for drinking purposes when there is rainfall.

In contrast during the northeast, first and second inter monsoon periods there will be decrease in rainfall and high evapo-transpiration due to increased temperature. Therefore the available water must be used efficiently for sustainable agricultural activities. Drip and Sprinkler irrigation systems will increase the water use efficiency. Further, cultivation in protected houses/poly tunnels and green houses will reduce the impact of adverse climate. But the farmers involved in small scale farming can practice mulching and water retention methods such as ridge and furrows. Further the farmers could consider crops which need less water. However, for drinking purposes the groundwater could be used as the potential groundwater recharge is predicted to increase. But the use of groundwater should be done very carefully to make sure that there is no over exploitation of groundwater resources and sustainability should be ensured.

Figure 04 Roof rain water harvesting system for drinking water purposes

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Paper 02

An Analysis of Rainwater Harvesting as a Climate Change Adaptation Method for Dry Zone, Sri Lanka

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Abstract

Sri Lanka faces many issues due to lack of access to safe water mainly in the dry zone. Rainwater harvesting may be a suitable option to solve this issue, but it depends on the availability of rainwater (RW) and also the demand for drinking water. This study analyzed the rainfall pattern in 9 districts in dry zone, Sri Lanka with the drinking water demand for a usual family when considering the mixing possibility with groundwater (GW) in 1: 2 ratio (RW:GW). According to the evaluation, rainwater harvesting for drinking water shall be a promising technology for all the districts considered when mixed with groundwater in 1: 2 ratio, and used with 5 m3 tanks from a 25m2roof top attachment. Effectiveness can be enhanced if the rooftop catchment can be improved, by use of impermeable roofing material, proper maintenance of catchment area, gutter system and the first flush system, and appropriate maintenance of the tank system.

Introduction

Rainwater harvesting is defined as "the gathering and storage of water running off surfaces on which rain has directly fallen" (Pacey & Cullis, 1986). Rainwater harvesting is sustainable and is inexpensive. Also, rainwater harvesting can reduce salt accumulation in the soil which can be harmful to root growth (WaterfallL.P.H, 2004). Another advantage is that the collected rainwater can be used for many different purposes around the home. Sri Lanka faces many issues due to lack of access to safe water mainly in dry zone. This research aimed at evaluating the possibility of using rainwater harvesting as a drinking & cooking water supply source for nine districts in dry zone in Sri Lanka.

Methodology

An analysis was done comparing the rainfall pattern of each district, by considering the drinking and cooking water requirement of 3 member and 5 member families for an year, to evaluate the possibility of using 5 m3 tank, to be used mixing with groundwater in 1:2 (Rainwater: Groundwater) ratio by considering 30% wastage and also a 25m2 roof area. Further to this the evaluation was done considering the minimum rainfall required only in a month per year, and also a month rainfall requirement within 7 months gap to fulfill the above requirement since usual rainfall pattern shows that at least 100 mm rainfall has occurred with less than a 7 month gap.

In this study rainfall data of nine districts in the dry zone have been obtained from the main stations of each district; they are Anuradhapura, Polonnaruwa, Puttlam, Mannar, Jaffna, Hambantota, Trincomalee, Vavuniya and Kurunegala Districts from the Department of Meteorology, Colombo. The monthly rainfall of the above districts were analyzed for the last five years in order to understand the effective application of a rainwater harvesting system. Mainly monthly rainfall, highest monthly rainfall, and the rainfall variation throughout the year have been considered as main factors. Table 01 and Figure 01 illustrate the data for Anuradhapura, and similar data have been considered for other 8 districts as well.

Literature Review

The climate in Sri Lanka is defined as tropical. The warm and humid climate of the country has an annual temperature between 25°C and 32 °C in the coastal areas and the dry zones in North and North-East and the temperature ranges from a low of 15 °C to 18°C in the Central Highlands. Typically Sri Lanka has only two seasons which is the Wet season and the Dry season. The Rainfall of Sri Lanka depends on the two Monsoons. The first Monsoon is from May to October which brings rain to the island's south-western half, while the dry season lasts from December to March. The Second monsoon blows from October to January, bringing rain to the North and East, while the dry season is from May to September. There is also an inter-monsoonal period in October and November when rain can occur in many parts of the island.

Why Select Rainwater Harvesting for the Dry Zone?

The major reason for selecting rainwater harvesting for the Dry zone is that the majority of the communities in dry zone, Sri Lanka, uses groundwater as the drinking water source which has high hardness and fluoride, which causes health hazards and also is a nuisance when used. A suitable replacement as drinking & cooking water source is very important for the current situation.

Rainwater Harvesting Method and Application

Usually rainwater (RW) has low quantities of essential minerals, and long term use of low mineral water can cause many health complications. Hence, the most suitable suggestion would be to mix the rainwater with another source, mainly the groundwater (GW), which may not only lower the fluoride and hardness concentrations in groundwater, but on the other hand it adds essential minerals to rainwater. It is required to install a simple purification system in order to filter out the impurities (bird droppings, dust etc.) that are collected in the harvested rainwater. The consumer should take the responsibility of the secondary filtering/ purifying of the water in the form of boiling, making certain that there is no presence of harmful bacteria.

Results and Discussion

A periodic fluctuation may be observed in the Anuradhapura district and similar variations are present in other districts as well. Here is a proposition for rainwater harvesting for day to day usage. According to W.H.O. (Freedrinkingwater.com, 2014) records and based on an approximate calculations, an average person uses 227.1litres of water for drinking and cooking per month. Therefore an average three member family uses 8176 litres of drinking and cooking water per year. In the case of a five member family the usage of drinking and cooking water per year is around 13627 litres. The suggested water tank to be used for the purpose of harvesting rainwater should be capable of holding approximately 5000 litres of water, as the cost and land requirement is quite high if a higher capacity tank is installed. The mixing will be done in the ratio of 1:2 (RW: GW).

Table 01: Rainfall data for Anuradhapura District (Department of Meteorology, Colombo)

Year	Average Annual Rainfall	Highest Monthly Rainfall
2009	89.59mm	307.7mm
2010	138.78mm	376.5mm
2011	159.65mm	382.5mm
2012	156.5mm	683.9mm
2013	99.49mm	232.6mm

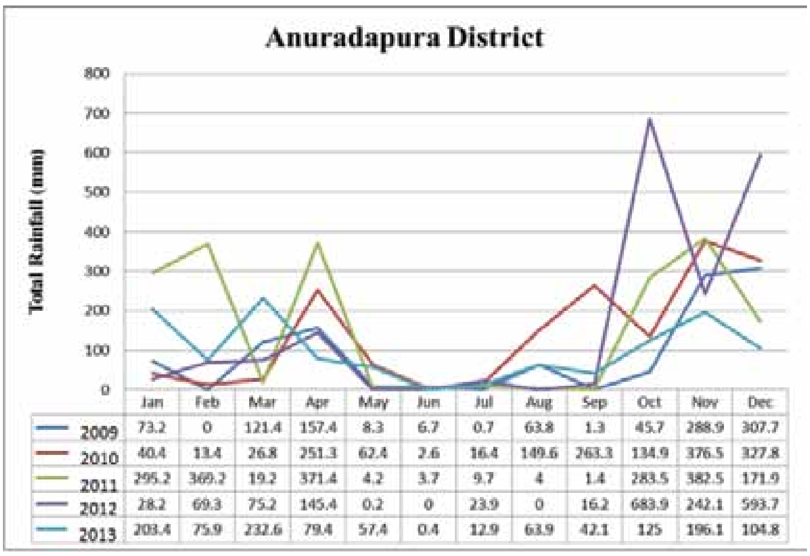

Figure 01: Rainfall Variation throughout the Year

It is important to evaluate whether it is applicable to use 5000 litres tank, for rainwater harvesting with the available rainfall during the year. Considering a five member family, the required amount of water for a period of 12 months is 4542 litres. The harvested rainwater will be mixed in 1:2 proportion with groundwater. According to the calculations, to acquire this amount of water, there should be an approximate rainfall of 236 mm at least in one month a year allowing 30% wastage and also 25m2 roof area. When considering the rain fall of Anuradhapura district, which is the most vulnerable district for health hazards, it can be seen that almost all the years the rainfall in a month has exceeded this requirement within the last five years. The minimum highest monthly rainfall data recorded is 232 mm and the maximum value is 684 mm. Also it is clear with illustration in figure 01 that the maximum gap between 100mm monthly rainfall has been recorded as less than 7 months. Hence, if 7 month water storage requirement is considered, it is very clear that all the highest monthly rainfall data exceeds the requirement of 138 mm, which is the monthly rainfall requirement for sufficient water storage for 7 months use.

Conclusion

Rainwater harvesting for drinking purposes shall be a promising option for all the districts considered when mixed with groundwater in 1: 2 ratio (RW: GW), and used with 5 m3 tank from a 25m2 roof top catchment. Effectiveness can be enhanced if the rooftop catchment can be improved, by use of impermeable roofing material, proper maintenance of catchment area, gutter system and the first flush system, and appropriate maintenance of the tank system. Further to this, the initial cost of the system can be lowered by using a low-cost alternative material for tank construction.

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Session III

Health Benefits and Issues Related to Rainwater Harvesting and Use

Paper 01

A Review on Health Benefits and Issues of Using Rainwater as a Drinking Water Source

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Abstract

Rainwater Harvesting (RW) is considered a good answer to water scarcity in the world. But the quality of water has a direct impact on human health. This study reviews the rainwater quality and health effects when RW is used as a drinking water source. It was found that that RW is a good solution for areas affected with water scarcity as well as areas with groundwater quality issues. Unavailability of potable water affects the life style of the people as well. Many studies have shown that the physical and chemical standards of rainwater are within the acceptable limits. Due to bad maintenance practices of rainwater harvesting systems, heavy metals and other substances can cause issues to human health. Also there's a risk of long-term use of RW as a drinking water source as it may cause health hazards due low mineral composition of RW. Therefore if rainwater is consumed for a considerable period of time, it is recommended that minerals are consumed via food or medicines. Also mixing with groundwater shall be a good option when RW is used as a primary source of drinking water.

Introduction

Generally, in Sri Lanka, people have access to different sources of water such as piped water, public taps, borehole or pump, well water, spring water or rainwater. The National Policy on Drinking Water (2009) states that, before the year 1980, 50% and 56% of the urban and rural population in Sri Lanka respectively had access to potable water. By the year 1990 and 2002, these percentages have increased from 50% to 91% - 99% in the urban areas and 56% to 62% - 72% in the rural areas. It is identified that still Sri Lanka has a great need for clean water. The same source states that limitations that Sri Lanka has to face when it comes to water resources are that it is very limited, the demand is ever increasing and contamination of water resources has become a major issue. While efficient management of water is one method of distributing water to the whole community, improving rainwater harvesting can also effectively cater to the water needs of the community.

Unavailability of clean water has affected household activities, increase of water borne diseases, indirect effects of rising of burden on women and the impact on the education of children (Bartram et.al, 2005). Mainly the community in dry zone depends on the groundwater as the main source of drinking water, most of the time without any treatment. Dental and skeletal fluorosis is a wide spread disease in dry zone, and currently a Chronic Kidney Disease due to unknown etiology is prevailing in dry zone, which is suggested to have a strong linkage with the groundwater quality in dry zone (Weragoda et. al., 2013). Rainwater harvesting is a good alternative for regions suffering from groundwater quality issues. Hence this research is focused at understanding the possibility of using rainwater as a drinking water source. It further reflects on the issues that could occur due to consuming rainwater for a longer period.

Literature Review

About 1.1 billion of the population of the world do not have access to potable water. This has increased the number of deaths that occur every year due to unclean water. Most countries do not have access to clean water therefore they consume unclean water which leads to a lot of water related diseases. Acceptable physical and chemical characteristics should be present in water to be used as a source of drinking water (WHO, 2011).

Composition of Rainwater

According to Ariyananda & Aheeyer (2011), the main issue identified in water collected in rainwater harvesting systems in Sri Lanka is dissolved contaminants and micro-organisms. The pH, Color, turbidity and conductivity values are found to be within the recommended standards of WHO. Leaves, droppings of animals and insects may cause contamination in rainwater and this may have an impact on the quality of rainwater. But these contaminations are considered to be minor and can be minimized by following a few cleaning procedures. A well designed and maintained RWH system can cause low health risks and high improvement in the health of humans (Ariyananda, 2005). The composition of water can be categorized as having physical & chemical properties. The physical properties permissible for drinking water are shown in table 01.

Table 01: The Physical standards for potable water is as follows (SLS 614:1985 part 1)

Serial No.	Characteristics	Maximum Desirable Level	Maximum Permissible Level
1	Colour	5 Units	30 Units
2	Odor	Unobjectionable	Unobjectionable
3	Taste	Unobjectionable	Unobjectionable
4	Turbidity	2 Jackson Turbidity Units	8 Jackson Turbidity Units

Even though the given characteristics in Table 01 shows that certain parameters of rainwater are within the acceptable limit or is unobjectionable, for those who are used to consuming mineral water may reject same due to these reasons (eg. Taste). Table 02 shows the desirable levels that are expected in rainwater and the maximum permissible levels of chemicals according to the SLS 614:1985 part 1.

Table 02: The Chemical Standards for potable water is as follows (SLS 614:1985 part 1)

Serial No.	Substance of Characteristics	Maximum Desirable Level	Maximum Permissible Level
1	pH range	7.0 – 8.5	6.5 – 9.0
2	Electrical Conductivity	750 μs / cm	3500 μs / cm
3	Chloride	200 mg/l	1200 mg/l
4	Fluoride	0.6 mg/l	1.5 mg/l
5	Total Hardness	250 mg/l	600 mg/l
6	Sulphate	200 mg/l	400 mg/l

The above table shows that most characteristics are within the acceptable limits. It further provides evidence that the amount of minerals in rainwater is at a much lower level than the acceptable amount. Therefore it is identified that rainwater has low minerals in it and same can cause many issues to human health if consumed for a longer period.

Some of the commonly found contaminants in rainwater are, E Coli (is quite common in samples of rainwater collected shortly after a rainfall. Pathogens such as, Cryptosporidium, Giardia, Vibrio, Salmonella, and Pseudomonas have been found in rainwater. Even though this is so, it states that the occurrence of pathogens is generally lower in rainwater than in other unprotected surface waters. In the first flush of rainwater the concentration of contaminants is high. This amount reduces as rain continues to fall. It is recommended to collect rainwater especially during rainy seasons. It further states that rainwater is slightly acidic and therefore it is aggressive to a certain extent. (Rainwater Harvesting, online).

Hence it has been recommended that consuming of rainwater should be done after it undergoes a simple cleaning process and after it is boiled. If not, it can be directly used for purposes such as, cleaning, gardening and washing. The quality of rainwater depends on the atmospheric conditions, harvesting methods and how the collected water is stored. Therefore if good practices are adopted for RWH, rainwater can be used as a main water source in Sri Lanka.

High amounts of zinc and lead have been reported in areas such as the Northern Province of Sri Lanka. This can lead to chronic kidney diseases, which has become a major issue in Sri Lanka at present (Jayasumana, et al. 2014).

But this could be due to bad maintenance of rainwater harvesting systems and also can be due to metallic roofs and storage tanks and also due to traces of contaminants found in the atmosphere. Many studies have reported that there is no large risk in drinking rainwater when compared to drinking treated pipe water. Lack of certain minerals such as, calcium, magnesium, iron and fluoride which is essential to human health up to a certain level has been reported. These minerals are important where dental health is considered. Lack of certain minerals may cause a different taste in water which may be a factor causing some people to reject using rainwater as a primary source of drinking water.

1. Consequences of Consuming Rain Water for a Longer Period

Kozisek (nd) states that there are a lot of specific standards that should be in water that is consumed by humans. It further describes the effects that humans may have due to consuming such water for a longer period. Rainwater does not consist some of the essential minerals that should be present in drinking water.

Effects of consuming low mineral water (Kozisek ,nd)

- Direct effects on the intestinal mucous membrane, metabolism and mineral homeostasis or any other body functions
- Low intake of essential elements required for the human body (e.g. Calcium, Magnesium, etc.)
- Chances of in-taking toxic metals to the body
- Bacterial contamination of low mineral water

Very little studies have been done on the effects of drinking water with fewer minerals. It is recommended that minimum mineral levels in water should be met before consumption. Minerals such as calcium, magnesium, iron and fluoride are considered important to human health. Therefore if rainwater is consumed for a longer period the intake of these minerals through food or certain tablets or medicines should be ensured. Low mineral water also causes a difference in taste for those who are used to drinking high mineral water. Due to lack of such minerals in rainwater there had been a few instances where consuming rainwater for a longer period has caused health effects to humans (Weragoda, 2014). Hence it is usually recommended to use rainwater by mixing with another source such as groundwater.

Conclusion

RW can be used as a good alternative source for drinking water if proper procedures are adopted for collection and treatment. Long-term use of RW may cause health hazards due to long term consumption of low mineral water, hence mixing with groundwater is recommended, when using RW as drinking water. Hence it is recommended to add minerals to meals, if RW is used as drinking water for a longer time.

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Paper 02

Use of Rainwater to Control Chronic Kidney Disease of Unknown Etiology

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Abstract

Chronic Kidney Disease of unknown etiology (CKDu), also called Chronic Renal Failure (CRF) has been reported to occur in several areas of Sri Lanka, mostly in the North Central Province (NCP). A large number from Badulla and Kurunegala districts are also affected by CKDu. According to Ministry of Health, in 2010 there were around 30,000 CKDu affected persons.

According to the results of studies carried out by a number of Sri Lankan scientists, CKDu is thought to be caused by toxic element/s or compound/s in drinking water. Among these toxic compounds are aluminum, arsenic, cadmium, fluoride, toxins released by Blue Green Algae, pesticides etc. Although the specific cause for the CKD is unknown, it is likely to be multi-factorial and due to a combination of chemicals or toxins in water.

Rainwater is relatively the most pure form of water. Water that falls on a roof of 1000 sq m in an area where the average annual rainfall is 1,000 mm, would be around 1,000 cubic meters (ie. 1 million liters) Water thus collected would be free of toxic substances and could be used for numerous domestic purposes including drinking by those affected by CKDu.

Introduction

Chronic Kidney Disease of unknown etiology (CKDu) also called Chronic Renal Failure (CRF) has been reported to occur in several Divisional Secretary Divisional areas of Sri Lanka, mostly in the North Central Province (NCP). A large number from Badulla and Kurunegala districts are also affected by CKDu. (World Health Organization,2013) According to Ministry of Health in 2010 there were around 30,000 CKDu affected persons. It is likely that at present this number is around 40,000.

The geographic distribution of CKDu patients in Sri Lanka as in 2010 is given in Table 1. CKDu has affected economically and socially, thousands of families in the areas indicated.

Table 1.
Geographic Distribution of CKDU

District	No. of CKDu affected people
Anuradhapura	8044
Polonnaruwa	2563
Kurrunegala	1251
Ampara	977
Badulla	4656
Trincomalee	1285
Vavuniya	393

Source: Report on "Indiscriminate use of chemical fertilizer and agrochemicals with special reference to Chronic Kidney Disease of unidentified etiology" submitted by the officials committee appointed under the Cabinet decision dated 1812.2012

Discussion

Several studies have been conducted by a number of Sri Lankan scientists as reported by Andrew Noble et al (2014). Results of these studies indicate that CKDu is likely to be multi-factorial and attributed to a combination of chemicals or toxins in water Among these toxic compounds are aluminum and fluoride (Ileperuma, O.A, 2011) cadmium (Bandaraet al 2008) toxins released by Blue Green Algae (C.B. Dissanayaka, 2005) , some pesticides (World Health Organization, 2013) and many other factors (. DhammikaMenikeDissanaya, et al, 2003). A study conducted in six CKDu affected areas in Anuradhapura, Polonnaruwa and Kurnegala districts indicate that severity of CKDu is reduced by consuming water from Reverse Osmosis (RO) plants (Weeraratna, C.S). A number of RO plants have been installed in the affected districts. These plants cost around Rs. 1 million and are managed by the Community Based Organizations in the respective areas.

Water purified by RO plants are sold at Rs. 1.50-3.00 per liter (ChamindaPrithikumara, 2014). The amount of water a person needs a day is about 4 liters. Hence, a considerable amount of money has to be spent by those who are affected by CKDu. Further, RO plants are expensive and are not available at all the places affected by CKDu. Hence, it is necessary that alternate sources of pure water be found.

Rainwater is the most pure form of water. Ariyananda (2011) reported that good quality rain water can be collected and stored if the rain water harvesting system is managed and operated efficiently. That is if the roof is kept clean, first flush device and filters are used and the tank is kept closed to prevent sunlight entering which promotes algal growth and mosquito breeding. According to Pathakand Heijnen (2004) the physico-chemical quality of rain water in terms of colour, odour and taste, pH, total dissolved solids (TDS) and total hardness (TH), meet the prescribed World health Organization standards.

Most of the areas affected by CKDu get heavy rains during some months of the year. In such areas a considerable portion of the rainwater can be collected in appropriate tanks in the premises themselves. Water that falls on a roof of 1000 sq m in an area where the average annual rainfall is 1,000 mm, would be around 1000 cubic meters (i.e 1 million liters). Water thus collected would be free of toxic substances and could be used for drinking by those affected by CKDu and also for numerous domestic purposes.

Conclusions:

There is an urgent need to take appropriate action to control CKDu which has a devastating effect on thousands of people in a number of districts of Sri Lanka. However, the causal factor/s of CKDu are not known but it is considered to be due to drinking polluted water. Rainwater is the most pure form of water and incidence of CKDu and its severity can be reduced if patients affected by this disease consume rainwater instead of well water.

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