RAIN WATER HARVESTING FOR WATER EFFICIENCY AND MANAGEMENT

[1]Ariyananda T, [2]Wickramasuriya S S, [3]Wijeyesekera D S

[1]Director, Lanka Rain Water Harvesting Forum, 28/3a, Subadrarama Lane, Nugegoda, Sri Lanka.
[1]E-mail: tanuja@sltnet.lk

[2]Department of Civil Engineering, University of Moratuwa.
Department of Civil Engineering, University of Moratuwa. Katubedda, Moratuwa, Sri Lanka.
[2]E-mail:sunilw@civil.mrt.ac.lk

[3]former Vice Chancellor, University of Moratuwa, former Vice Chancellor, Open University of Sri Lanka, Former Chairman, Institute of Construction Training and Development, Past President, Institution of Engineers, Sri Lanka. No. 7, Barnes Avenue, Mount Lavinia, Sri Lanka.
[3]Tel: +94 777312238, Fax: +94 112735596 ; E-mail: dayantha@sltnet.lk

Abstract: Water being one of the world's basic resources and one of the most essential needs to life, could be considered the nature's precious gift to the living being. Although this resource was available in plenty till recently, due to urbanization, increase in population, industrialization and for large scale enterprises the shortage of water in the world has become evident. Furthermore, due to implications of climate change on rainfall patterns, with extremities of weather giving rise to floods and droughts there is growing concern globally about appropriate strategies to be adopted as far as the built environment is concerned for proper management and harvesting of rain water. Thus globally a Millennium Development Goal has also been set and rain water harvesting has emerged as an important issue in the international scenario. It has been highlighted at the third World Water Forum held in Kyoto, Japan, in the context of Millennium Development Goals and the issue of sustainability, at the Global Ministerial Environmental Forum in Korea, which has led to formulation of many networks and policies.

The famous proclamation by King Parakramabahu the Great in (1153-1186 AD) could be considered as one of earliest policy statements, on water resources development and management in Sri Lanka, which highlights rain water harvesting. "Let not allow a single drop of water falling as rain flow into the sea without being used for the benefit of mankind". This shows the wisdom and commitment of ancient kings and people to conserve and efficiently manage water resources by building tanks specially in the dry zone and the design and construction of complex water collection and distribution systems such as in the Sigiriya rock fortress.

The Government of Sri Lanka in June 2005 accepted a "National Policy on Rain Water Harvesting & Strategies". Sri Lanka has used rain water for both domestic and agricultural purposes for many centuries and the institutionalized rain water harvesting became a practice in Sri Lanka in 1995, under the World Bank funded Community Water Supply and Sanitation Project. This project initiated the emergence of the Lanka Rain Water Harvesting Forum (LRWHF).

A major challenge is the need to have a delivery of the stored rain water, for which gravity flow and hand/manual pumping has been the economic option the use of Solar Energy is being promoted specially in rural areas where there is no main grid power available. Another challenge is the public Health concern due to the comparatively stagnant nature of rain water harvesting.

There has been a significant increase in the use of rain water harvesting in Sri Lanka, which has proved to be a boon to rural people, particularly for domestic water supplies in water scarce situations. An estimated thirty thousand systems are presently in operation, scattered over a large number of districts. Interestingly, several large scale projects have also been implemented in the urban context, and this too is likely to increase in the future. With a National policy on Rain Water Harvesting and other legislation in effect, Sri Lanka stands to benefit significantly by the appropriate use of this technology.

Keywords: *Water efficiency and management*

Abbreviations[12]:

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ADRA	-	Adventist Development & Relief Agency Sri Lanka
Asia Onlus	-	ASIA ONLUS
BLIA	-	Buddha's Light International Association
CI	-	Care International
CWSSP	-	Community Water Supply & Sanitation Project (under the Ministry of Urban Development and Water Supply (www.urbanlanka.lk/Agencies.htm#cwwsp)
EC	-	Ekamuthu Cultivators
GTZ	-	GTZ
HKLM	-	HKL Menike
IOM	-	International Organization for Migration
ITDG	-	Intermediate Technology Development Group (Practical Action)
KOPBMO	-	Kala Oya River Basin Management Office
LRWHF	-	Lanka Rain Water Harvesting Forum
NCC	-	National Christian Council
NGOWSSDS	-	GO Water Supply and Sanitation Decade Service
NWS&DB	-	National Water Supply & Drainage Board (under the Ministry of Urban Development and Water Supply) (www.waterboard.lk)
ORDE	-	Organization for Resource Development and Environment
OXFAM	-	OXFAM
PALM	-	PALM Foundation
Plan	-	Plan Sri Lanka
PRDA	-	People’s Rural Development Association
Sarvodaya	-	Lanka Jathika Sarvodaya Shramadana Sangamaya
SDA	-	Southern Development Authority
USIP	-	Urban settlement Improvement Project
WV	-	World Vision

1. Introduction

Many water problems in the world can be attributed to the uneven distribution of rainfall in time and space. Extremities of weather give rise to floods and droughts, often causing considerable damage to life and property. Countries subject to monsoonal weather patterns such as Sri Lanka, can experience flooding after a prolonged dry spell or a period of drought. There is also a growing concern globally about the implications of climate change on rainfall patterns, and about appropriate strategies to be adopted as far as infrastructure is concerned for proper management of rain water. In addition, globally a Millennium Development Goal has also been set, which aims to halve the number of people who do not have access to safe drinking water by the year 2015. Thus rain water harvesting has emerged as an important issue in the international scenario and was highlighted at the third World Water Forum held in Kyoto, Japan in 2003. In the context of Millennium Development Goals and the issue of sustainability, the following conclusions are noteworthy:

- Harvested rain water is a major water supply option , as important as surface and groundwater
- That decentralized water utilization and resource management uses rain water harvesting for the sake of the people and the Earth

Furthermore, at the Global Ministerial Environmental Forum held in Korea in 2004, it was concluded that alternative and cost effective technologies, such as rain water harvesting, should be explored and promoted and the transfer of appropriate technology increased. Suggesting rain water harvesting as a new paradigm, Han (2004) suggests the building of a worldwide network to promote rain water harvesting.

2. Rain Water Harvesting Policy & Legislative Support

One of the earliest policy statements on water resources development and management in Sri Lanka, mentions rain water harvesting. The famous proclamation by King Parakrambahu the Great (1153-1186 AD), "......let not even a small quantity of water obtained by rain, go to the sea without benefiting man" (Arumugam, 1969, quoted from Mahawansa), shows the wisdom and commitment of ancient kings and people to conserve and efficiently manage water resources. The ancient tanks of the dry zone and the complex water collection and distribution system of the Sigiriya rock fortress bear ample testimony to this fact.

In June 2005, the government of Sri Lanka accepted a "National Policy on Rain Water Harvesting & Strategies" presented to the Parliament by Minister for Urban Development and Water Supply. The policy objective is aimed at encouraging communities to control water near its source by harvesting rain water. This results in, minimizing the use of treated water for secondary purposes, reduction of flooding, improving soil conservation and groundwater recharge, providing water for domestic use with adequate treatment, agricultural benefits and reduce energy consumption.

3. Rain Water Harvesting – Current Situation

Sri Lanka has used rain water for both domestic and agricultural purposes for many centuries. However, institutionalized rain water harvesting became a practice in Sri Lanka in 1995, under the World Bank funded Community Water Supply and Sanitation Project (CWSSP) which introduced rain water harvesting as a water supply option in two districts Badulla and Matara. (Heijnen and Mansur (1998).

This project initiated the emergence of the Lanka Rain Water Harvesting Forum (LRWHF), which is an NGO actively engaged in promoting rain water harvesting in the country. Since the CWSSP, a number of other organizations and institutions have adopted rain water harvesting as a means of supplying water to water scarce households in both the wet and dry zones. Some of the noteworthy contributions in rain water harvesting for domestic use have been made by , the Southern

Development Authority, the Dry Zone Development Project funded by IFAD (International Fund for Agricultural Development), Kandy, by National Water Supply and Drainage Board, 3rd and 4th ADB Water and Sanitation projects and the 2nd CWSSP project. During the last 13 years, LRWHF has actively promoted the concept of rain water harvesting in all districts through demonstration projects, awareness programs, training, research and development, and networking.

Presently, there are more than 30,000 domestic rain water harvesting systems recorded in 25 districts (Table 1). Most of these rain water harvesting systems are in rural areas and have been implemented through government projects or by NGO's.

Table 1: *Distribution of Rain Water Harvesting Systems in Sri Lanka*

Province	**District**	**No. of total rain water tanks**		
		By LRWHF	**By other organizations**	
			No. of tanks	**Organizations**
Central Province	Kandy	10	2663	CWSSP
	Matale		994	CWSSP
	Nuwara Eliya	5	964	CWSSP, PALM
Eastern Province	Ampara	652	31	CI
	Baticoloa	11	36	Asia Onlus
	Trincomalee	19	-	-
North Central Province	Anuradhapura	13	3483	Plan, KOPBMO, ITDG, BLIA, NWS&DB
	Polonnaruwa	-	1096	NWS&DB, NCC
North Western Province	Kurunegala	51	577	GTZ, NWS&DB, Sarvodaya, Plan
	Puttalam	14	1652	ORDE, PRDA, NWS&DB
Northern Province	Jaffna	14	-	-
	Kilinochchi	09	-	-
	Mannar	11	98	IOM
	Mulathivu	03	-	-
	Vavunia	48	66	WV, IOM
Sabaragamuwa Province	Rathnapura	-	111	EC, HKLM
	Kegalle	8	1664	NWS&DB
Southern Province	Galle	1397	-	-
	Hambanthota	1107	2811	Sarvodaya, WV, ADRA, OXFAM, NWS&DB, ITDG, SDA
	Matara	629	1089	CWSSP
Uva Province	Badulla	1	5488	CWSSP
	Moneragala	40	1904	Sarvodaya, NWSDB, SDA, ITDG
Western Province	Colombo	5	41	USIP
	Gampaha	1	23	EC, CWSSP
	Kalutara	-	1443	NGOWSSDS, Asia Onlus, NWS&DB
Total		4048	26234	
Grand total			30282	

4. Water Quality Issues

Rain water is one of the purest sources of water available as it does not come into contact with many of the pollutants often discharged into local surface waters. It comes free and can be used to supply potable (drinkable) water and non-potable water. If collected properly, it can be used for all domestic purposes including drinking.

Rain water from well managed roof catchment sources is generally safe to drink without treatment. Except in heavily urbanized and industrialized areas or regions adjacent to the volcanoes, atmospheric rain water is pure. Any contamination of the water usually occurs after contact with the catchment system (roof). Regular cleaning and inspection of the catchment area and gutters are important to ensure good quality water (Heijnen and Pathak, 2006). Further treatment through boiling, exposure to sunlight and chlorination can be undertaken if there are concerns about the water quality. Insects breeding inside the tank can be prevented, by keeping the storage tanks and other openings sealed. Awareness and education are the two most important strategies to prevent water pollution.

5. Rain Water Harvesting in Urban Buildings

Households in urban areas use pipe borne water not only for drinking and cooking, but also for gardening, car washing and also other all activities. A close examination of Table 2 shows that apart from drinking and cooking, there is immense potential to utilize rain water to supplement household water supply for non-potable requirements, thereby reducing the use of treated pipe borne water. Thus authorities will be able to supply pipe borne water to more households.

In view of the existing constraints faced by the authorities in meeting the increasing demand for water, it is vital that rain water harvesting be used as a new source of water in urban areas in which pipe borne water consumption is very high.

A study indicates that on average in low income households in Sri Lanka, if **30%** of the monthly water requirement was met by rain water then a **34%** reduction in water bills can be obtained (Ariyananda & Gunasekara, 2004). In middle income households, if **30%** of the monthly water requirement is met by rain water, then the monthly water bill can be reduced by **61%** at the present water rates.

The potential of rain water harvesting for large housing projects as a supplementary source and the required structural measures to be adopted have been studied and presented by Jayasinghe (2004).

Table 2: *Average amount of water used per family per day (Ariyananda & Gunasekara, 2004)*

Water use Activities	Low Income		High Income	
	Ave. Liters per day per family	%	Ave. Liters per day per family	%
Drinking	24	4	20	2
Cooking and Washing pans	90	15	100	11
Washing clothes	127	21	147	17
Toilet use	140	23	150	17
Bathing and Washing face	163	26	257	29
Gardening	43	7	117	13
Other	30	5	90	10
Total	**617**	**100**	**880**	**100**

Rain water harvesting in urban areas has many functions. It can supplement pipe borne water for non-drinking purposes thus conserving pipe borne water; reduce energy cost of pumping, and also reduce flooding. Rain water collection in commercial and public buildings has particular advantages resulting from large roof areas.

Various technical problems faced were overcome with the assistance of the University of Moratuwa and the Institute for Construction Training and Development (ICTAD).

6. Rain Water for Drought Mitigation and Recharging Groundwater

6.1 Domestic Use

Rain water harvesting has brought much relief to people during times of drought, water scarcity and recently to those affected by the devastating tsunami of 2004.

Even though Sri Lanka has a relatively high rainfall, it varies both temporally and spatially. Some areas can experience extreme dry spells between monsoons or on occasions a total failure of the monsoons. Several dry zone districts of Sri Lanka experience prolonged drought, causing tremendous hardships to people. Rain water harvesting systems constructed in Hambantota, Moneragala and Anuradhapura were able to use rain water stored in the tanks for as long as 5 -6 months during this period. (Ariyanbandu & Aheeyar, 2000)

Research done by Kumari (2008) on rain water harvesting for rural water supply shows that a 5 cu.m. tank with a roof area between 75 to 100 sq.m. can supply 300 liters/ day to a household, with an overall probability of success of 50%, in the districts of Anuradhapura, Hambantota and Puttalam. However this figure will reduce depending on the season. Substantially higher degrees of success can be obtained within the wet and intermediate zones (Ranasinghe, 2008). Further work on appropriate tank capacities for rain water harvesting in the Jaffna district has been done by Gamage (2006).

6.2 Agricultural Use

The rural sector in Sri Lanka constitutes around 80% of the population and most of those in the rural sector depend on rainfall-based sources of income, such as agriculture, livestock production and inland fisheries. Freshwater availability is a key limiting factor in food production and improvement of livelihood.

Lack of a dependable water supply is a major limiting factor in our attempts to develop the rural sector. From the total rainfall, on average around 50% of rain water is lost in the form of surface run-off and conserving this water will promote crop growth in areas where water is limited. The most effective and economical method of conserving this water is by storing it in surface tanks which are abundant in the Dry Zone. However, many small tanks are dilapidated and/or silted and need rehabilitation.

If the run-off water is stored in the land itself, it would be available to plants when there is a water shortage. In some parts of the dry zone, small ponds called "Pathahas" have been used to collect and store rain water. Such a water collecting system on farm would enable farmers to cultivate crops during the dry seasons.

Fig. 1: Run off tank at Kurundamkulama

A study was carried out in Kurundamkulama (a village in Mihintale in Anuradhapura District) to harvest/collect run-off rain water in tanks. The maha rains were collected in 5 m3 run off tank (Figure 1). Water collected was used during Yala for crop production. As a result the incomes of the families in the study increased substantially (Weerasinghe et al. 2005). Collection of run- off rain water not only conserves water but also reduces soil erosion and degradation of the land.

6.3 Recharging Groundwater

Water lost from the ground by way of evaporation, tube wells etc, needs to be replenished. Collecting rain water in ponds and pools in a manner where water percolates in to the ground raises the water table. A study conducted in Nikaweratiya on the use of *pathahas* (Figure 2) (Shanthi de Silva, 2005), shows that these elevate the ground water level, thus increasing the quantity of water available for both domestic and agricultural use even during the dry season.

Fig. 2: "Pathaha" at Nikawaratiya

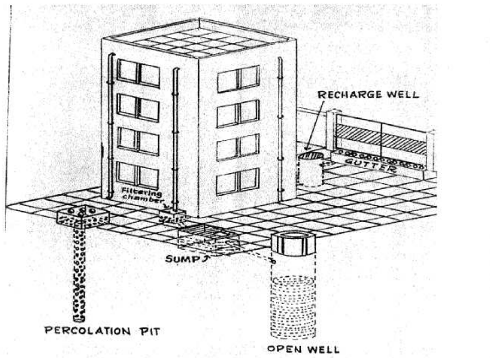

Fig. 3: Recharging structure (Raghavan 2006)

In several Indian states, ground water recharging in urban areas through recharging structures (Figure 3) is encouraged and legalized to increase the exploitable quantity of groundwater, improve the quality of groundwater and to mitigate flooding.

7. Social & Economic Aspects

As with any new technological intervention, rain water harvesting too needs changes in the attitudes, perceptions and behavior of the community if the new technique is to be successful in terms of social, economic, cultural and environmental factors. Training and awareness are key factors to ensure quality construction, proper operation and maintenance, management of harvested water, and to change myths, attitudes and wrong perceptions of the concept of rain water harvesting.

Community mobilization and training of beneficiaries are vital components, since rain water tanks will ultimately be managed at private cost at the household level. Community contribution towards the project is recommended in order to increase the sense of ownership and motivate people towards sustainable management. The beneficiaries can supply unskilled labour and local materials easily towards the project. The contribution of unskilled labour alone provides almost 15% of the total value of the system.

Institutional and commercial level rain water harvesting in schools, government offices, hospitals and other public places is highly recommended due to their large roof areas, but proper institutional arrangements are vital for sustainable operation and maintenance.
One of the major disadvantages of roof rain water harvesting technology is that it requires a higher capital investment initially for the construction of storage cisterns and other supplementary components. The cost is much higher when the rainfall is low and there is a longer dry period, which results in the need for a larger cistern to ensure water security.

The success of any technological intervention depends on the cost and the affordability of the users. Therefore the use of an appropriate tank size and use of less and cheaper materials, less labour and simple construction aids are important factors to reduce the cost of construction.

Table 3: *Cost estimates for different sizes of Ferro cement tanks (Aheeyar, 2009)*

Cost of cistern	**5 m^3**	**7 m^3**	**8 m^3**	**10 m^3**
Material	24,305.50	26,919.50	29,719.50	35,370.50
Skilled labour	4,500.00	5,400.00	5,580.00	8,000.00
Unskilled labour	5,000.00	5,500.00	6,000.00	10,000.00
Transport of materials	2,500.00	2,500.00	2,500.00	2500
Reusable Frame/Miscellaneous	1427.5	1,500.00	1595	1750
	37,733.00	**41,819.50**	**45,394.50**	**57,620.50**
Pipes, First flush, Gutters (26 feet), other accessories & fixing charges	5,000.00	5,000.00	5,000.00	5,000.00
Total	**42733.00**	**46,819.50**	**50,394.50**	**62,620.00**

Fig. 4: Under ground tank

Fig. 5: Partial under ground tank

Fig. 6: Above ground Ferrocement tank

Rain water harvesting system tanks can be placed above ground, underground (Figure 4-6) or partially underground.

According to the past research (Thomas and Rees, 2001), the unit cost of construction of rain water tanks shows a negative relationship with increasing size of the cistern. It is cheaper to go for a larger tank and to avoid using two smaller tanks and larger communal systems compared to small individual units.

High initial cost has been a prohibitive factor for many poor households in adopting rain water harvesting systems, though they are willing to collect rain water for their household needs. Therefore, some supportive mechanisms such as loans and subsides can be effectively used to promote the technology among poor families. Use of subsides in the past has shown positive results in introducing rain water harvesting systems among rural poor (Gould and Petersen, 1999).

Some of the social and economic benefits identified by households using rain water harvesting systems are;

- Easy access to clean drinking water
- Less time spent on collecting water
- Time saved (average 1.5 hrs per day) is used for social and economic activities
- Skills enhancement in the village
- Less reliance on external water providers
- More water security at household level
- Better sanitation due to more water availability
- Enhanced income through use of rain water for home gardening, animal rearing and brick making etc.
- Reduction in diarrheal disease
- Better quality water, especially in areas with high levels of Fluoride in ground water, saline water (after the tsunami) and brackish water.

8. Energy and Efficiency

One of the major advantages of rain water harvesting systems is their minimal energy consumption in operation. No system is viable and sustainable if it is not energy efficient in the context of the global energy crisis. i.e., escalation of energy costs as well as global warming and its consequences as a result of fossil fuel burning. Therefore, for RWH to be viable and to fall within the context of sustainable development, harvested water should be utilized spending minimum energy and avoiding energy derived from fossil fuel burning as much as possible.

Research studies undertaken by Sendanayake (2009) indicate that providing a means of low cost, low energy consuming method of supplying potable water from a natural phenomenon not only will enhance the quality of life of the population, but also will integrate them to the development on a sustainable scale more readily.

In considering parallels and absorbing new technological advances from global experiences, it is possible to supply and/or supplement existing water supply systems giving considerations to simple, practical and low cost RWH systems having optimum capacities and high water saving efficiencies (WSE), which can provide reasonable quality water.

By positioning the storage facility of the RTRWH system at a higher elevation to the end user point, water can be drawn-off by gravity thereby eliminating the need for pumping, hence the energy issues. While gravity operated systems do not consume energy and are suitable primarily for external use such as garden watering, many limitations hinder wide use of such systems in more sophisticated situations.

Of course there are limitations of gravity operated tanks such as the additional cost involved in constructing support structures. Extra space required for such structures, in certain instances restricting land use, dependence of end user point water pressure on the height of the supporting structure and poor aesthetic value for the location.

When gravity flow is not feasible, various pumping options of Water from storage facility would be necessary, such as, hand pumps, centrifugal pumps and positive displacement pumps.

While hand pumps are the most widely used in rural Sri Lanka, it can also be classified as positive displacement pumps (see figure 7), but are operated manually thereby limited to small scale draw-offs. Centrifugal pumps, working on the principle of creating a vacuum for suction by rotating an impeller at high speed, are the most widely used pumping option. However, the high starting torques required, low pumping heads and low pump efficiencies are the main draw backs of centrifugal pumps thereby needing higher energy input.

By considering the alternative energy sources, such as solar power, wind power and bio gas, solar power seems the most suitable for tropical climates, given the abundance of sun throughout the year as well as the relative low cost of components compared to wind turbines, apart from the durability and the viability in domestic usage. Hence, for RWH systems to be of self-sustaining and eco friendly nature, solar pumping of harvested water is important and development of viable, low cost solar pumping devices are vital.

Unlike in centrifugal pumps where a number of variables dictate the overall efficiency, only the volumetric efficiency (which is governed by the cylinder-piston assembly design), indicate the overall efficiency of a PD pump. As such PD pumps are typically 15% to 20% more efficient than a centrifugal pump of similar power rating. The capability of delivering at low pump speeds is one of the major advantages displayed by the PD pump.

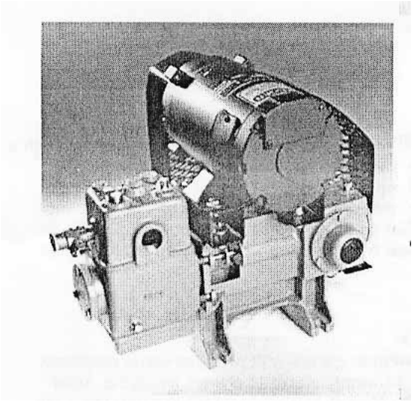

Fig. 7: An advanced positive displacement pump

This is in contrast to a centrifugal pump which needs a minimum rotational speed for the impeller output head to overcome the static head . Therefore, PD pumps can be used in low power input situations as well as when the power input is variable.

As such delivery reliability of PD pumps are much higher in Photo Voltaic (PV) pumping situations. Although centrifugal pumps are superior in higher output flow rates, PD pumps are much superior in achieving higher delivery heads at low output rates. Therefore, in overcoming higher heads, such as that found in multi-story building situations, multi-staging is not required compared to the case of using centrifugal pumps.

By considering the alternative energy sources, such as solar power, wind power and bio gas, solar power seems the most suitable for tropical climates, given the abundance of sun throughout the year as well as the relative low cost of components compared to wind turbines, apart from the durability and the viability in domestic usage. Hence, for RWH systems to be of self-sustaining and eco friendly nature, solar pumping of harvested water is important and development of viable, low cost solar pumping devices are vital. The best type of pumps for PV powered RWH situations are PD pumps due to their higher efficiency and low starting torque. These characteristics allow down-sizing of the PV array and hence the cost. Since RWH systems in households require a limited quantity of collected rain water to be pumped up per day, a pump with a low delivery rate (say 1-2 L/min) would be sufficient. Such pumps are available at 80 – 100 W rating, usually double acting and piston type PD pumps. The total cost of a complete system inclusive of the battery can be around Rs.100,000 - 120,000.

In sizing solar pumps, PV technology can be effectively used to pump harvested rain water to service points. The selection of a suitable PV array for pumping of collected rain water is in the following manner.

The hydraulic energy required (kWh/day)

$$= \text{volume required } (m^3/\text{day}) \times \text{head } (m) \times \text{water density} \times \text{gravity}/\ (3.6\times10^6)$$

$$= 0.002725 \times \text{volume } (m^3/\text{day}) \times \text{head } (m)$$

$$\text{The solar array power required } (kW_p) = \frac{\text{Hydraulic energy required (kWh/day)}}{\text{Av. daily solar irradiation } (kWh/m^2/\text{day} \times F \times E)}$$

Where, F = array mismatch factor = 0.85 on average and
E = daily subsystem efficiency = 0.25 – 0.40 typically

To ensure uninterrupted power supply a deep cycle battery (Usually a lead-acid type) can be integrated to the system via a charge controller thereafter the battery size can be determined according to the load. The load, in this case the pump, has to be of high efficiency type to reduce the cost on PV array. PD pump with a DC motor is ideal for its overall efficiency and the requirement of low starting current can be operated under low light conditions.

9. Conclusions and Recommendations

Even though Sri Lanka presently has no water scarcity except in some areas during the dry season, due to increase in population, urbanization, pollution of water sources and climate change issues, it may face water problems in the future. Adopting rain water harvesting and utilizing it to the maximum will help the Country to overcome either all or some of these problems.

- Using rain water for drinking purposes should be encouraged in dry zone districts where the groundwater is both mineralized and contaminated, especially in areas where a high incidence of kidney problems due to polluted ground water has been reported.
- Rain water harvesting should be encouraged as a supplementary water source in urban areas to reduce water bills, save on energy, save on water treatment costs and to reduce flooding in some areas.
- To encourage householders to adopt rain water harvesting by offering incentives such as tax rebates.
- Incorporate rain water harvesting in all public and commercial buildings with large scale use of pipe borne water.
- Potential areas for recharging should be identified and encouraged.
- Rain water harvesting system components for urban houses should be made available locally.
- Professionals should use innovative designs incorporate rain water harvesting in new buildings.
- The delivery of harvested water would have to be made depending on the energy sources available and in particular in rural areas where mains grid power is not currently available, alternative energy sources specially Solar Energy should be harnessed with appropriate pumping mechanisms.

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References

Aheeyar M.M.M (2009) Economic and Social Aspects of RWH Systems. In Ariyananda T. (Ed). Rain Water Harvesting Practitioners Guide for Sri Lanka. *Lanka Rain Water Harvesting Forum.*

Ariyanbandu R. De S. and Aheeyar M.M.M. (2000) Evaluation of the Effectiveness of Rain Water as Domestic Water source in Rural Sri Lanka. *Lanka Rain Water Harvesting Forum*

Ariyananda T. and Gunasekara J. (2004) Study of potential Feasibility of Roof Rain Water Harvesting in Urban Area. *Proceeding of 7th Symposium of Lanka Rain Water Harvesting Forum, Colombo, Sri Lanka.*

Ariyananda T. and Wickramasuriya S.S.(2009) Rain Water Harvesting In Sri Lanka. Economic Review: Water & Development. Vol. 35, Nos 3&4 (June/July)

Arumugam, S. (1969). Water resources of Ceylon. *Water Resources Board, Sri Lanka.*

Gamage, N.P.D. (2006). Guidance on use of rain water tanks for the Jaffna Peninsula. *Annual Transactions, Institute of Engineers, Sri Lanka.*

Gould, J. and Petersen, E.N. (1999). Rain water catchment systems for domestic supply: Design, construction and implementation. *Intermediate Technology Publications Ltd., London.*

Han, M. (2004). Rain water harvesting: A new paradigm to meet MDG and sustainability. Rain Water Harvesting Workshop, *IWA 4th World Water Congress and Exhibition, Morocco.*

Heijnen, H and Mansur U. (1998) Rain water harvesting in the community water supply and sanitation project. Proceeding of the Symposium on *Rain Water Harvesting for Water Security Feb. 1998.* Lanka Rain Water Harvesting Forum. *Publication* Sri Lanka. P53-56

Heijnen, H. and Pathank N. (2006) Rain Water Quality Health and Hygiene Aspects. Proceeding of International Workshop in Rain Water Harvesting, Kandy, Sri Lanka

Jayasinghe, M.T.R. (2004). Rain water harvesting to supplement water for large housing projects. *Annual Transactions, Institute of Engineers, Sri Lanka.*

Kumari, D.M.C.S. (2008). Drought mitigation using rain water harvesting in the dry zone of Sri Lanka. *M.Eng. dissertation.* University of Moratuwa.

National Rain Water Harvesting Policy & Strategy, Ministry of Urban Development and Water Supply, Government of Sri Lanka.

Ranasinghe, R.K.W.K. (2008). Improved water conservation practices using rain water harvesting in the wet and intermediate zones of Sri Lanka. *M.Eng. dissertation.* University of Moratuwa.

Raghavan S. (2006) Rain Water Harvesting – Need, Relevance And Importance Of Groundwater Recharge In Urban Areas With Particular Reference To Coastal Cities. Proceeding of International Workshop in Rain Water Harvesting, Kandy, Sri Lanka

Sendanayake, S. (2007). *Development of solar powered pumping for the integration of rain water harvesting in multistorey houses.*

Shanthi de Silva (2005) Impact of Artificial Recharging of Groundwater with Rain Water: a case Study in Kotewehera of Sri Lanka, *Lanka Rain Water Harvesting Forum, Sri Lanka*

Thomas, T. and Rees, D. (2001) New technology for roof rain water harvesting. *Rain water harvesting Workshop, Indian Institute of Technology New Delhi, India*

Weerasinghe P.A, Ariyananda T.N, Weeraratna C.S. (2005) Rain Water Harvesting for Home Gardens in Dry Zone of Sri Lanka. *Proceeding of XII IRSCA Conference, New Delhi, India*

Author Names and Affiliations

Dr Tanuja Ariyananda, Director, Lanka Rain Water Harvesting Forum,
28/3A, Subadrarama Lane, Nugegoda, Sri Lanka Tel: +94 115 524612 email: **tanuja@sltnet.lk**

Prof. S.S. Wickramasuriya, Department of Civil Engineering, University of Moratuwa. Katubedda, Moratuwa, Sri Lanka + 94 11 2650 567/8 ext 2015 email:sunilw@civil.mrt.ac.lk

and Corresponding Author

Prof. Dayantha Wijeyesekera, Chairman, Tertiary & Vocational Education Commission,
No 7 Barnes Av Mt Lavinia, Sri Lanka.+94 777312238 email: **dayantha@sltnet.lk**