FINAL REPORT
Climate Change Enabling Activities (Phase II) Project
Senior Research Program

PROJECT: A RESEARCH PROGRAM TO MONITORE QUALITY OF RAINWATER
Case Study of Kurunegala and Putalama District

Reporting Period: September 2002-February 2004

Introduction

Sri Lanka has an average annual rainfall of 2400 mm with a range of 900mm in the dry zone and 5000 mm in the wet zone. The rainfall is bi-modal and varies both seasonally and spatially. In the dry zone more than 2/3rd of the rain falls during the wet season (NE monsoon) from October to March of which 70% falls during the period October to December. The large variation in rainfall experienced due to effects of climate change leads to spatial and seasonal variation in water supply. Change of rain fall due to climatic variation and concentration of rainfall during specific period in different zones causes water shortages during months of low rainfall.

Due to the bimodal (2 seasons) pattern of rainfall in Sri Lanka rain water harvesting practice which collects, store and save rain water during the rainy seasons for usage during the dry season is feasible. People of Sri Lanka have used rainwater for both domestic and agricultural purposes for many centuries. Traditionally rainwater is collected for domestic use from tree trunks using banana or coconut leafs or from rooftops into barrels, domestic containers and small brick tanks. In recent years there has been revival of rainwater harvesting and many research were conducted to improve the technology. In 1995, Community Water Supply and Sanitation project initiated by the government of Sri Lanka with World Bank funds introduced rain water harvesting as a water supply option in Badulla and Matara districts. Since this, government and non- government organisation throughout the country have promoted rain water harvesting technology.

Rainwater harvesting has brought much relief during time of drought and water scarcity for many people living in rural areas of Sri Lanka. At present, more than 14,000 (Table 1) rain water harvesting systems are in operation throughout the country. While the concept and technology of rain water harvesting has become popular there is still reluctance by the people to use rainwater for drinking purpose. Earlier studies have reveled (Ariyabandu,1999) that only 10% of the households used the roof collected rain water for drinking purposes. However, householders used it for other purposes such as cooking, washing, toilet, gardening ect.

Table 1: Distribution of rain water harvesting units in Sri Lanka

District	**No. of Units**	**%**
Badulla	5488	**38.6**
Hambantota	3506	**24.6**
Matara	1089	**7.67**
Monaragala	963	**6.78**
Puttalam	835	**5.88**
Kegalla	759	**5.34**
Anuradahapura	677	**4.76**
Kalutara	399	**2.81**
Kurunegala	299	**2.10**
Kandy	85	**0.5**
Colombo	46	**0.32**
Gampaha	22	**0.15**
Trincomale	19	**0.13**
Total	**14,198**	

(source: LRWHF)

Consumption of rainwater is related to perception of quality (Ariyananda T., 2001) . Most of the rainwater tanks are generally not tested for water quality; therefore households have no knowledge of quality of water, only a perception of water quality. In order to recommend and convince the people to use rainwater as a drinking water source, as an adaptation measure in time of drought, a comprehensive, systemic survey of rain water quality is needed.

Objective

The objective of the project is to assess the quality of the collected rainwater in selected tank system in order to recommend the use of rainwater as a drinking water source for water scarcity periods due to climate change.

Methodology

Study site

A survey was conducted in two districts, Puttalama and Kurunegala in the North Western province of Sri Lanka (figure 1). The locations selected within the 2 districts falls within the dry zone and has an annual rain fall of 1311 mm at Maho weather station in Kurunrgala district and 1144 mm at Palavi Weather station in Puttlam district.

Figure 2: Location of Sample villages in Puttalama district

Figure 3: Location of Sample villages in Kurunegala district

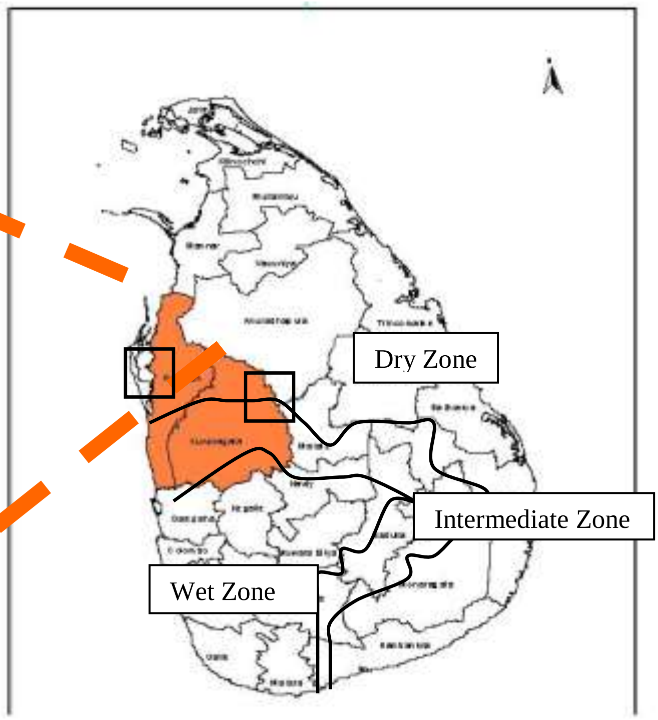
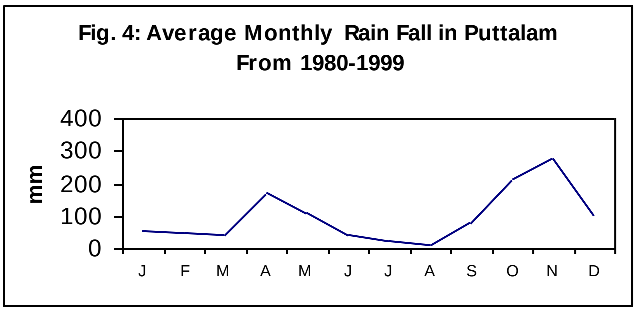
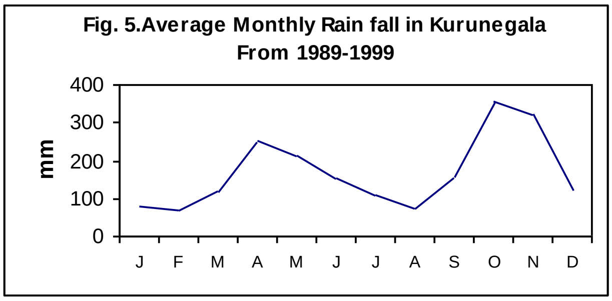


Figure 1: Map of Sri Lanka showing the rain fall zones and sampled locations

Even though both districts get adequate rain fall, there is long period of low or no rain fall between the two monsoons. In Puttlam district the dry period is from January to April and again from June-September (Figure 4). In Kurunegal district a similar dry period is experienced (Figure 5) but more rain fall is received than Puttalm district. During the dry period most water sources such as shallow wells and reservoirs (agriculture tanks) dry up and people are having to go long distance in search of clean drinking water. The only available water sources for the community during the dry season are the tube wells. The water in almost all tube wells is highly saline or mineralized.





Initial survey was conducted to select 5 households with rain water harvesting tanks in selected areas in Kurunegala and Puttlam districts. During the initial survey more than 20 households having rain water tanks were visited in each districts and only the households which were operating, maintaining and using system and interested in the survey was selected for the monitoring. In both districts a drinking water wells was sampled as the other available source of drinking water for comparison of quality.

Kurunegala district

Five tanks of four different types were selected in 2 villages Nalewa and Eramuduwawe in Kurunegala district (figure 2) . The tanks selected at Nalewa were Ferro-cement partial underground (fig: 8) and under ground thatched/tar roof tank (fig:9)constructed by Lanka Rain Water Harvesting Forum (LRWHF) in 2002. The tanks selected at Eramuduwawe were above ground ferro-cement (fig:7) and Under ground brick (2) (fig: 6), constructed by the Dry Zone Participatory project in 1999. All tanks were of 5,000 liters (5 m^3) capacity.

Table 2 Details of households selected for survey in Kurunegala district

Householder name	Village	S. No	Type of tank	Type of roof
Roshantha	Nalawa, Ambanpola	K01	Thatched roof	G.I.
B.G.Piyasena/R.L.Mudinse*	Nalawa, Ambanpola	K02	Partial- Ferro	Tile/G.I
D.M. Ranhamy	Eramuduwawe, Ambanpola	K03	Ferro-above	tile
D.M. Ranhamy	Eramuduwawe, Ambanpola	K04	brick under ground	tile
H.E.Gunasena	Eramuduwawe, Ambanpola	K05	brick under ground	G.I/tile

*B.G. Piyasena filled his tanks with well water after the first month of survey, therefore R.L. Mudinase's tank was selected thereafter.

Puttalama district

Five tanks were selected from Pottuwilpura, Madurankuliya, Kaladi (2) and Thabbowa in Puttalm district (figure 3). All tanks were ferro-cement above ground and (figure 8) since there were no other types of rain water tank found in Puttalm district, except for a rectangular under ground ferro-cement tank which was not in use due to cracks. Pottuwilpura and Madurankuliya tanks were constructed by LRWHF in 1999, Kaladi tanks were constructed by People's Rural Development Association (PRDA) in 1999, and Thabbowa tank was constructed in 2002 by 3rd ADB Water Supply & Sanitation project.

Table 3 of Details of Households selected for survey in Puttlama district

Householder name	Village	S. No	Type of tank	Type of roof
W.G. Jayaratna	Pottuwilpura	P01	Ferro-above	tile
Kaniyut	Madurankuliya	P02	Ferro-above	tile
W.K.Wanigasuriya	Kaladi	P03*	Ferro-above	tile
Priyanka Indrani	Kaladi	P04	Ferro-above	tile
Sugath Namal	Thabbowa	P05	Ferro-above	tile

Table 4: The construction cost of different types of tanks of $5m^3$ capacities

Tank type	Cost in Rs.
Above ground Ferro-cement tank	15,000
Under ground Brick tank	14,000
Ferro cement Partial under ground tank	6,500
Under ground thatched roof tank	4,500

2. Physical chemical and biological quality of rain water in rain water collection tanks were monitored over a period of 10 months.

a. Physical quality

Temperature: Cool water is more palatable than warm water. High temperature enhances growth of microorganism and may increase taste, odour, colour and corrosion problems. Temperature was measured *in situ* by using a Hanna HI-98129 pocket meter.

Turbidity: Turbidity in drinking water is caused by particulate matter of sediment or organic in origin. High level of turbidity can prevent effective disinfections there by can enhance bacterial growth. Turbidity was measured *in situ* by Hanna HI 93703 turbidity meter.

b. Chemical quality

pH: although pH usually has no direct impact on consumers, it is one of the important operational water quality parameters. For effective disinfections with Chlorine pH should be less than 8. Low pH can cause corrosion of the household water distribution system. pH was measured *in situ* by using a Hanna HI-98129 pocket meter.

Total Dissolved Solids (TDS): TDS comprise of inorganic salts (principally calcium, magnesium, potassium sodium, bicarbonate, Chloride and Sulphates). TDS can be important effect on taste of drinking water. The palatability of water with a TDS level of less than 600 mg/l is generally good, water with low concentration of TDS may be unacceptable because of its flat, insipid taste. TDS was measured *in situ* by using a Hanna HI-98129 pocket meter.

Conductivity : Electric conductivity measures also measure the presence of inorganic salts and also indicated the salinity of water. Conductive less than 500 μC/cm is palatable. Conductivity was monitored *in situ* by using a Hanna HI-98129 pocket meter.

Zinc: High level of Zn creates an astringent taste to water. It is tested rain water due to possible contamination from roof material. Zu was measured using Palintest test kit for Zn (PK149)

Copper: Cu variability in drinking water vary in the account of pH, hardness and Cu availability in the distribution system. High levels of Cu can cause acute gastrointestinal effects. It is tested rain water due to possible contamination from roof. Cu was measured using Palintest test kit for Cu (PK186)

c. . Biological quality

Biological quality was measured by the presence of *Escherichia coli* . *E.coli* is abundant in human and animal faeces. Therefore presence of *E.coli* in drinking water indicates potential dangerous contamination by disease causing pathogens . Presence of *E.coli* is measures by membrane filter method using Oxfam- Delagua water testing kit.

Figure 6: Brick under ground tank: 5m^3 capacity Constructed with brick and cement

Figure 7: Ferro-cement Above ground tank Constructed with chicken wire and mesh

Figure 8: Ferro-cement partial under ground tank: Constructed with Cement and chicken mesh

Figure 9: Thatched under ground tank: below ground is cement and chicken mesh and above ground cover is of tar sheets

Result and Analysis

Table 1.1 of Physical and Biological Quality of Rain water collected from different tanks in Kurunegala and Puttalama District. (*P03 was filled with well water during sampling period)

Tank type	**Source No.**	**Months/ Parameters**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**
Thatched roof	K01	Turbidity NTU	11.3	5.19	0	0	0	0	0	0
Partial- Ferro	K02		0.69	0.4	0	0	1.5	0	2.96	0.53
Ferro-above	K03		0.27	0.11	0	0	0.81	0.86	0	0
Brick under ground	K04		0.08	0.3	0	0	0.51	0	0	0
Brick under ground	K05		0	0	0	0	0	0	0	0.47
Well	W01		0	0	0	0	0	0	0	0
Ferro-above	P01			0	0	0	0	0	0	0.04
Ferro-above	P02			0.09	0.1	3	0	0.47	0.08	0
Ferro-above	P03*			0	0.3	28.3	3.22	0	1.89	0.44
Ferro-above	P04			0	0	0.27	0	0	0	0
Ferro-above	P05			0	0	0	0	1.32	0	0
Well	W02			0	0	2.64	0	0	0	0
SL standards			***<5***	***<5***	***<5***	***<5***	***<5***	***<5***	***<5***	***<5***
Thatched roof	K01	TDS mg/l	103	83	88		62	51	107	442
Partial- Ferro	K02		81	116	76	48	63	36	120	58
Ferro-above	K03		50	42	55	66	41	9	38	121
Brick under ground	K04		82	40	45	0	38	18	40	41
Brick under ground	K05		57	43	55	61		42	29	93
well	W01			398	350		331	857	74	
Ferro-above	P01			56	60	144		40	43	55
Ferro-above	P02			65	68	88	62	22	123	45
Ferro-above	P03*					891	936	1016	596	1040
Ferro-above	P04					423	17	49	65	78
Ferro-above	P05							47	48	50
Well	W02					90	770			
SL standards			***500***							
Thatched roof	K01	Conductivity µS/cm	213	169	120		140	98	213	880
Partial- Ferro	K02		164	231	100	97	120	70	118	115
Ferro-above	K03		105	82	90	132	82	16	77	239
Brick under ground	K04		154	83	88		73	35	81	81
Brick under ground	K05		117	86	90	122	no water	40	59	186
well	W01		213	169	120		140	98	213	880
Ferro-above	P01			118	150	202		83	88	111
Ferro-above	P02			140	140	172	127	45	248	92
Ferro-above	P03*					1784	1866	2022	1192	2083
Ferro-above	P04					846	36	98	131	158
Ferro-above	P05							100	96	102
Well	W02					183	1541			
SL standards			***500***							
Thatched roof	K01	pH	6.97	7.62	7.55		7.86	7.83	8.53	7.47
Partial- Ferro	K02		8.94	9.44	9.4	9.44	8.24	7.55	9.01	7.42
Ferro-above	K03		8.19	8.1	8.1	7.99	8.1	7.26	8.77	7.02
Brick under ground	K04		8.68	8.5	8		7.9	6.81	8.52	6.77
Brick under ground	K05		9.11	8.01	8.01	7.99		7.47	8.33	7.22
well	W01			6.9	6.5	6.8	7.02	6.88	8.74	
Ferro-above	P01			7.14	7.2	7.72		8.06	8.44	8.95

Ferro-above	P02			6.93	7	7.73	8.05	8.2	8.45	8.41
Ferro-above	P03*					7.35	7.49	7.29	7.14	7.45
Ferro-above	P04					7.88	8.1	8.28	8.06	8.36
Ferro-above	P05							7.8	7.96	8.07
Well	W02						7.23			
SL standards			***6.5-9***							
Thatched roof	K01	Temperature ^{0}C	30.7	30.6	30.2		28	27.6	27.5	28.4
Partial- Ferro	K02		30.4	29.8	30.2	33.2	28.3	28.3	27	28.9
Ferro-above	K03		30.5	31	30.2	30.8	26.4	26.7	27.3	27.2
Brick under ground	K04		28.9	29.2	30		27.2	28.2	27.8	27.7
Brick under ground	K05		31	30.2	29.8	31.4		28.5	30.6	30.2
well	W01						29.5	27.1	26.9	
Ferro-above	P01			30.3	30.1	30.4		27.8	27.8	30.1
Ferro-above	P02			31.3	30.2	29.2	28.7	26.2	26.4	30.2
Ferro-above	P03*						26.6	27.7	26.6	27.7
Ferro-above	P04					30.5	28.3	28.2	27.2	28.7
Ferro-above	P05							27.9	28.1	28.6
Well	W02					30.9	29.4			
SL standards			***100***							
Thatched roof	K01	Zn (mg/l)	0	0	0	0	0	0	0	0
Partial- Ferro	K02		0	0	0	0	0	0.5	1	1
Ferro-above	K03		0	0	0	0	0	0	0.5	0
Brick under ground	K04		0	0	0	0	0	0	0	0
Brick under ground	K05		0	0	0	0	0		0.5	0.5
well	W01		0	0	0	0	0	0	0	0
Ferro-above	P01		0	0	0	0	0	0	0	0
Ferro-above	P02		0	0	0	0	0	0	0	0
Ferro-above	P03*		0	0	0	0	0	0	0	0
Ferro-above	P04		0	0	0	0	0	0	0	0
Ferro-above	P05		0	0	0	0	0	0	0	0
Well	W02		0	0	0	0	0	0	0	0
SL standards			***2***							
Thatched roof	K01	Cu (mg/l)	0	0	0	0	0	0	0	0
Partial- Ferro	K02		0	0	0	0	0	0	0	0
Ferro-above	K03		0	0	0	0	0	0	0	0
Brick under ground	K04		0	0	0	0	0	0	0	0
Brick under ground	K05		0	0	0	0	0	0	0	0
well	W01		0	0	0	0	0	0	0	0
Ferro-above	P01		0	0	0	0	0	0	0	0
Ferro-above	P02		0	0	0	0	0	0	0	0
Ferro-above	P03*		0	0	0	0	0	0	0	0
Ferro-above	P04		0	0	0	0	0	0	0	0
Ferro-above	P05		0	0	0	0	0	0	0	0
Well	W02		0	0	0	0	0	0	0	0
SL standards			***3***							
Thatched roof	K01	*E.coli* per 100 ml	200	7	10		100	245	100	200
Partial- Ferro	K02		2	0	0	0	0	0	6	0
Ferro-above	K03		0	17	5	0	200	0	7	1000
Brick under ground	K04		0	33	20	0	200	250	50	1000
Brick under ground	K05		0	0	3	0		2	0	0
well	W01		200	7	10		100	245	100	200
Ferro-above	P01			0	2	0		0	3	2
Ferro-above	P02			0	1	3	2	0	27	0
Ferro-above	P03*				1000	1000	200	1000	3	57
Ferro-above	P04				4	8	10	32	0	0
Ferro-above	P05				3	5	0	1000	46	0
Well	W02					1000	10			
SL standards			***0***							

Turbidity in rainwater tanks fall within the Sri Lankan standard for drinking water quality in all tanks in both district , except for the thatched roof under ground tank K01 in Kurunegala district and P03, in Puttlam district, which recorded above the standard level. The tank K01 is not sealed on top, there are chances for surface water run off and other materials to fall in to the tank. The tank P03 was filled with water from near by well, all time during the sampling period. Thereafter this tank was used as other source of water for comparison. High levels of TDS too recorded from P03. Well water too records high level of TDS in both districts and not suitable for drinking during the October month.

Temperature in all tanks falls well within the recommended standards. Generally higher temperature was recorded from the above ground tanks than the under ground tanks.

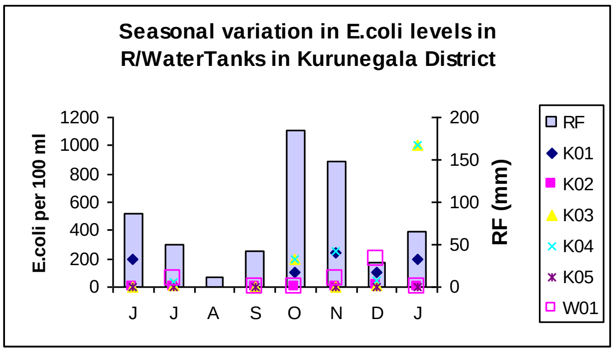
pH in all rain water tank sampled in Kurunegala district fall within the recommended standard except partial Ferro cement tanks (K02) which recorded slightly higher pH than the standard. This could be due re-plastering of this tank with cement during improvement to upper dome portion of the tank. Conductivity too is higher in this tank (K02) and Thatched roof tank (K01) also records higher values during January. pH recorded from tanks in Puttlama district falls within the recommended standards.

TDS and Conductivity is low in rain water tanks since rain water contains no minerals and has very little dissolved substances. Since mineral content of the water depend on the surface it passes through and collecting rain water from roof surface will have minimal materials added to the water.

Zn was recorded only in ferro- cement partial under ground tank(K02) and brick under ground tank(K05). Both these tanks receive water from G.I. roofs. However, levels fall within the recommended standard levels. No appreciable Cu content was recoded in any of the tanks or well water.

E.coli levels in the ferro-cement rain water tanks were generally lower than the under ground tank, in Kurunegala district. The brick underground tank K05 and partial under ground ferrocement tank K02 with GI and tile roof recorded better bacterial quality water. This is because G.I roofs gets heated and any contamination in the roof is perished within the roof surface. Similar, observation was recorded by Vasudevan etal (2001).
Low *E.coli* levels were recorded from 3 of the Puttlam tanks. High *E.coli* levels recorded from P03 which contained well water. High *E.coli* levels were also recorded from the wells in this area.

Seasonal Changers in Physical and Biological Parameters



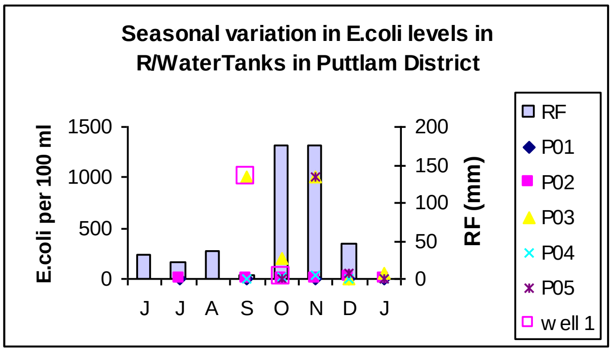


Figure 10 & 11: Variation in *E.coli* levels in Rain water Tanks in Kurunegal and Putlam Districts compared with Rain fall pattern in nearest station during the year

Seasonal rainfall pattern Kurunegala district is similar to rain fall pattern in Puttlam district. However, total amount of rain fall received is higher at Maho in Kurunegala district (554.4 mm June- Dec 2003) than the rain fall at Vanathavillu at Puttlam district (492.7 mm June- Dec 2003) . This study too indicate higher bacteria levels in rainwater tanks during the rain season in both districts (Figure. 10 and Figure 11). Most of the rain water tanks sampled did not have a proper first flush system therefore contamination on the roof get in the tanks with the rain.

Turbidity too in the rain water tanks is high during the rain period, indicating dust and debris from the tanks getting in to the tank with the rain.

TDS and conductivity is not affected by the rain fall pattern in the rain water tanks in either of the districts. Conductivity is higher in well water during the dry season and reduces during the rainy season.

Monitoring the presence of mosquitoes larvae and other insects breeding dry and wet season in different tanks

Type of Tank	Capacity (m^3)	Presence of Mosquitoes (x) other insects (√)by			
		Dipper method		Household interview	
		Wet season	Dry season	Wet season	Dry season
Ferro above	5	-	-	-	
Brick under ground	5	-	√	x	
Thatched roof	5	√	√	X	x√

The thatched roof tank has a more chance of mosquitoes getting in since the thatched roof can not be completely sealed

Discussion and Conclusion

Bacterial levels recorded rain water tanks is above the SL recommended standard for drinking water of zero *E. coli* . However, the recorded levels in rain water tanks are at low (<10) to intermediate (<100) risk levels according to WHO recommended standard (WHO, 1993). Out of 58 rain water samples tested for *E. coli* , 43% contained zero *E. coli* bacteria (WHO recommended standards), 62% of the rain water samples contained less than 10 bacteria (WHO low risk level) and 72% of the samples contained less than 100 bacteria (WHO intermediate risk level).
All other parameters tested comply with SL standard and WHO recommended standards for drinking water , except slightly high level of pH in one tank due to cement dissolving. Water quality in shallow wells in both districts does not comply with recommended standards for biological and chemical quality due either to bacterial contamination from cess pits and/or high mineral contents. During the dry season the minerals contents in the wells increase make it more unsuitable for drinking. Then the householder tends to go long distance 1-5 Km in Puttlam district and 1-3 Km in Kurunegala district to fetch drinking water. At Nalawa in Kurunegala district during the dry season the well owner limits the well water to 1 pot per household.

No chemical pollution was recorded in any of the rain water tank. A trace of Zinc was recorded in three rain water tanks. Two of these tanks are located in households having part G.I roof. Therefore, there is an indication that Zinc source would be from the roof material.
In Puttlam district during the months of August- September before the on set of rain some of the tanks did not have rainwater but they were filled with well/river/reservoir water. Thereby, tank is used for storage of water.

Mosquitoes larvae were neither recorded nor reported from the above ferro cement above ground tanks, these tanks all contained well sealed lids and were well covered. Brick underground tank reported presence of mosquito larvae at one incidence during the wet season during cleaning. Mosquito larvae were reported from the thatched roof tank both in the dry and wet season. The thatched roof tank has a more chance of mosquitoes getting in since the thatched roof can not be completely sealed. Other insects such as ants were reported in both the brick under ground tank and thatched roof tank.

Householder interview records that rainwater is been used for drinking by 70% of the households. Other use of rainwater is for cooking, washing, toilet use, gardening and for animals.
One household use it for commercial activity such as ornamental fish tanks.

Changers in water availability and accessibility are predicted and experiences due to climate change. A 7% decrease in annual average rain fall in Sri Lanka is been observed over last few years (Chanadrapala, 1997). A larger variation in rainfall pattern is been experienced. Longer dry spells and shorter heavy rainfall is been experienced. The monsoon rains failed last season (Maha 2003) and many of the reservoirs and wells in Kurunegala and Puttlam district is already (at the beginning of the dry season) dry.
Having a rainwater tank in the households enable people to be better prepared for dry spells. Although even the dry zone of Sri Lanka get enough rain fall during the year, usually rainwater is mostly run off and lost the after the rainy season. Rain water harvesting system collects and store water in the households for use during the dry season. Therefore, rainwater harvesting can be used as an effective adaptation measure to over come the irregularities and variation of rain fall predicted due to climate change. Householders can also use the rain water harvesting tank to store water brought from else where when there is no rain, thus increasing the storage capacity in the home and better water security.

Recommendation

Technical

- All rain water tanks should befitted with filter and first flush system to improve bacterial and physical quality of water.
- Householder should be made more aware on Operation and maintenance of the tanks
- Corroded GI roof can be source of metal contamination (Zn) of rain water, therefore care should be taken to replace corroded GI sheets.
- Rain water tank should be securely covered for protection as well as to prevent dust and runoff as well as insects getting into the tank.

Financial and Other implications

- Introduce a loan scheme or a subsidiary to households to bear the initial cost of constructing a tank. Since this the main constraint in replicating the technology.
- Drinking rain water should be encouraged in dry zone district where the groundwater is both mineralized and contaminated. High content of calcium and minerals thought to be the cause of high incidence of Kidney problems in the dry zone areas.
- Quality Rainwater should be popularized therefore more people will be encouraged to use for drinking.

Reference

Ariyabandu R. de S (1999) Development of Rain water harvesting for Domestic water use in Rural Sri Lanka. Asia-pacific Journal of Rural Development , Vol. 9, July, Number 1

Ariyananda T. A. (1999) Comparative Review of Drinking Water Quality from Different Rain Water Harvesting Systems in Sri Lanka, Proceeding of the 9th International Rainwater Catchment System Conference, Brazil.

Ariyananda T. A. (2000) Quality of Collected Rainwater from Sri Lanka, Proceeding of the 26th WEDC Conference, Dhaka, Bangladesh, 2000

Ariyananda T. A. (2001) Quality of Collected Rainwater in Relation to Household Water Security, proceeding of Workshop in Rain water harvesting, IIT Delhi, India, 2001

Chandrapala, L 1997: Comparison of Arial precipitation of Sri Lanka on District Basis During the period 1931-1960 and 1961-1990, Proc. National Symposium on Climate Change 7-8 March Colombo

Sri Lanka standard 614: part2: (1983). Specification for Portable Water. Part 2- bacteriological Requirement. Bureau of Ceylon standard, Colombo, Sri Lanka.

Vasudevan P. ,Tandon M., Krishnan C. and Thomas T. (2001). Bacteriological Quality of Water in DRWH Proceeding of workshop on Rain water harvesting, IIT Delhi, April 2001.

WHO 1993, Guideline for the Drinking-water Quality, (2nd Edition), Vol.1, World Health Organization, Geneva, 188p