Rainwater Harvesting Potential and Its Quality: A Case Study of Nayabazar Town Planning Area, Kathmandu Municipality

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ABSTRACT:

Rain Water Harvesting (RWH) is an old technology gaining popularity in a new way. The first known use of a modern RWH system in Nepal was at a mission hospital in Pokhara in the 1960s. A high population growth rate and an unprecedented rural-urban migration characterize population explosion in Kathmandu Valley. The water demand in the Valley is much greater than the water supply. In such situation, the appropriately designed houses could get the benefits of Rain Water Harvesting (RWH) from their roofs. Though, town planners, housing development companies develop the residential houses in a safe environment, in many places there are acute shortage of water. Nayabazar town planning area (NTPA) of Kathmandu is one of such residential areas. There are altogether 1,600 houses at NTPA; and water demand is approximately 123,876 liters/family/year. The average roof size in the NTPA is 115 m^2, the annual rainfall being 1,350 mm. Thus, the Rainwater Harvesting potential in the NTPA is around 156,000 liters/year. Cleanliness of roof, its type and storage tank is critical in maintaining good quality of rainwater. The quality of rainwater collected at NTPA falls within the limit of WHO Drinking Water Standards. Few coliforms were found in rainwater which could be removed by chlorination or other disinfection process.

Key words: RWH, Water Demand, IDW, MLD, NTPA

1. INTRODUCTION

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. The techniques were usually established to serve as a major source of drinking water in ancient time. Rain Water Harvesting (RWH) is an old technology gaining popularity in a new way. Extensive rainwater harvesting apparatus existed 4,000 years ago in the Palestine and Greece. In ancient Rome, residences were built with individual cisterns and paved courtyards to capture rain water to augment water from city's aqueducts. As early as the third millennium BC, farming communities in Baluchistan and Kutch of Pakistan impounded rainwater, and used it for irrigation dams (Limbu, 2005). The first known use of a modern RWH system in Nepal was at a mission hospital in Pokhara in the 1960s. The US Peace Corps has been active in propagating rain collection models through its volunteers; and lately the government built a large capacity rain tank in Tanahu District (Limbu, 2005). In the late 1980s, Peace Corps/ Nepal Volunteers constructed some RWH systems in some parts of Nepal as part of their in-service training. Other governmental and non governmental organizations, which have been implementing RWH projects in rural parts of Nepal, are SAPROS, DWSO, GARDP, NEWAH, IDE, ICIMOD, and WECS.

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The shortage of water in urban areas is mainly due to over-crowded population and people's high demand of water. A high population growth rate and an unprecedented rural-urban migration due to extreme hardships in rural areas characterize the urban population explosion. In 1952/54 AD, 2.89 % of population lived in urban areas of Nepal, while it reached 9.6 % by 1991, and 14.2 % in 2001 (CBS, 2002). This is creating pressure over the services in water supply over urban areas in Nepal; and Kathmandu Metropolitan city is one of them. New houses are being constructed to accommodate increased population of Kathmandu but many areas in the city are facing the problem of water shortage. At present time, water demand is approximately 200 million liters per day (MLD) but the water supply is only 90 MLD during the dry season and 120 MLD during the wet season (Limbu, 2005). To overcome this problem, the appropriately designed houses could get the benefits of Rain Water Harvesting (RWH) from their roofs.

If collected properly, rainwater is one of the purest sources of water available. Its quality almost always exceeds in rating than that of ground water or surface water. It does not come into contact with soil or rocks where it can dissolve minerals and salts nor does it come into contact with pollutants that are often discharged into local surface waters or contaminate ground water supplies. However, the ambient environment through which it falls influences rainwater quality. Rainfall in areas, where heavy industry or crop dusting is prevalent, may not have the same purity as rain falling in other areas without such industries. Studies of the chemical composition of rainfall have been carried out for many years starting in late 1880s in the United States and in Europe (Khalequzzaman, 2000). Rainwater collected in various parts of the USA falls within the safe limit prescribed by the US Environmental Protection Agency, but in few cases exceed safe drinking water limit (Khalequzzaman, 2000). In Bangladesh, one of the main purposes of RWH is to have arsenic free water (Hussain and Momotaj, 1998). This research is mainly focused on rainwater harvesting potential in Kathmandu Valley and its quality. The Nayabazar town planning area (NTPA) is taken as a case study area for rainwater harvesting.

2. STUDY AREA

The Kathmandu Valley, the capital region of Nepal, covers an area of 685 km^2, and has a population of 1.64 million. In order to accommodate the booming population, many houses are being constructed every year in Kathmandu Valley. Currently, town planners, and housing development companies have been developing the residential houses in a safe environment. However, many of these places face the acute shortage of water. Nayabazaar town planning area is also one of such residential areas. NTPA is a re-adjusted residential area which covers the ward numbers of sixteen and seventeen in Kathmandu Municipality. Many houses have more than two families living under the same roof; and average number of family members per family is five.

3. METHODOLOGY

3.1 RAINFALL MAP

Both the primary and secondary sources of information consists of rainfall data published by Department of Hydrology and Meteorology (DHM). Thirty four-year rainfall data of all 14 rain-gauge stations from 1971 to 2004 were collected for rainfall analysis. Point rainfall data were plotted in the Valley map and interpolated using ArcView GIS, Inverse Distance Weighted (IDW) interpolation technique.

3.2 HOUSEHOLD SURVEY

There are altogether 1,600 house holds at Nayabazar town planning area (NTPA). A sample of 160 houses was selected by random sampling method. A questionnaire survey was carried out among selected houses; and average water demand per family was estimated thereby. Finally, the total water demand was divided by the number of members in the household to find out the per capita water demand. During the field survey, some methods regarding estimation of amount of rainwater and collection of water hygienically was explained to the residents.

3.3 CHEMICAL AND MICROBIOLOGICAL ANALYSIS OF RAINWATER

Some scientists consider rainwater as the "gold standard" of water. However, rainwater is not free of pollution. It contains most of the atmospheric gases in dissolved form in proportion to their abundance. In addition, rainwater contains sediments, dust, aerosols, particulates, and anthropogenic gases that result from industrial discharge, biomass and fossil fuel burning.

Water may be contaminated with pathogenic organism. If coliforms are present in the water, it indicates faecal pollution. Sources of such pathogens may be septic tanks, urban runoffs, sewage etc. Hence, it is important to test and confirm the microbiological parameters. The chemical, physical and microbiological parameters of rainwater collected were analyzed using methods mentioned in Table 1

Table 1: Water Quality Analysis Methods

	PARAMETERS	METHOD	EQUIPMENTS/ INSTRUMENTS	REFERENCES
PHYSICAL	Color	Colorimetric	Colorimeter	Standard Method (APHA)
	Temperature	Thermometric	Thermometer	"
	Turbidity	Electrometric	Turbidimeter	"
	PH	Electrometric	pH meter	"
	Electric Conductivity	Electrometric	E.C meter	"
CHEMICAL	Total Hardness	Titration with Std.EDTA solution	Glass wares	"
	Calcium			"
	Magnesium			"
	Chloride of Na	Titration(Argentometric)with Std. $AgNO_3$ sol^n	"	"
	Ammonia	Colorimetric(Nesselerization)	Colorimeter	"
	Ortho-phosphate	Colorimetric (stannous chloride)	"	"
	Nitrate	Colorimeter (Brucine sulphate)	Colorimeter	"
	Total Iron	Colorimetric (Phenanthroline)	"	"
	DO	Iodometric method ,DOmeter	Glass wares	"
	Free CO_2	Titration with std. NaOH sol^n	"	"
MICROBIOLOGICAL	Total coliforms	Multiple tube fermentation (MPN/100ml)	Incubator,Autoclave, Glasswares, media	"
	Faecal coliforms	"	"	"

4. ANALYSIS

4.1 RAINWATER AVAILABILITY IN KATHMANDU VALLEY

With the help of point rainfall data, rainfall map of Kathmandu Valley was drawn with the help of ArcView GIS, IDW interpolation method. The average monsoon and annual rainfalls within Kathmandu Valley are shown in Figures 1 and 2 respectively. The annual rainfall potential of 1,160 mm is estimated at the valley floor; and maximum of 2,260 mm is estimated in the northern hills. Similar pattern of rainfall distribution was found during the monsoon season. Monsoon rainfall potential of 940 mm is estimated at the valley floor and southern part of valley whereas maximum of 1,830 mm is estimated in the northern hills. The rainfall analysis maps depict higher rainfall areas at the western and northern hilly region whereas low rainfall areas are valley floor and some southern part of valley. In Rainfall map, Nayabazar town planning area is shown as a small square. The monsoon and annual rainfalls at Nayabazar are estimated around 1,000 and 1,350 mm respectively.

The contribution of monsoon rainfall to annual in Kathmandu Valley ranges from 72 to 85 %. At NTPA, monsoon contribution is 82% of the annual rainfall.

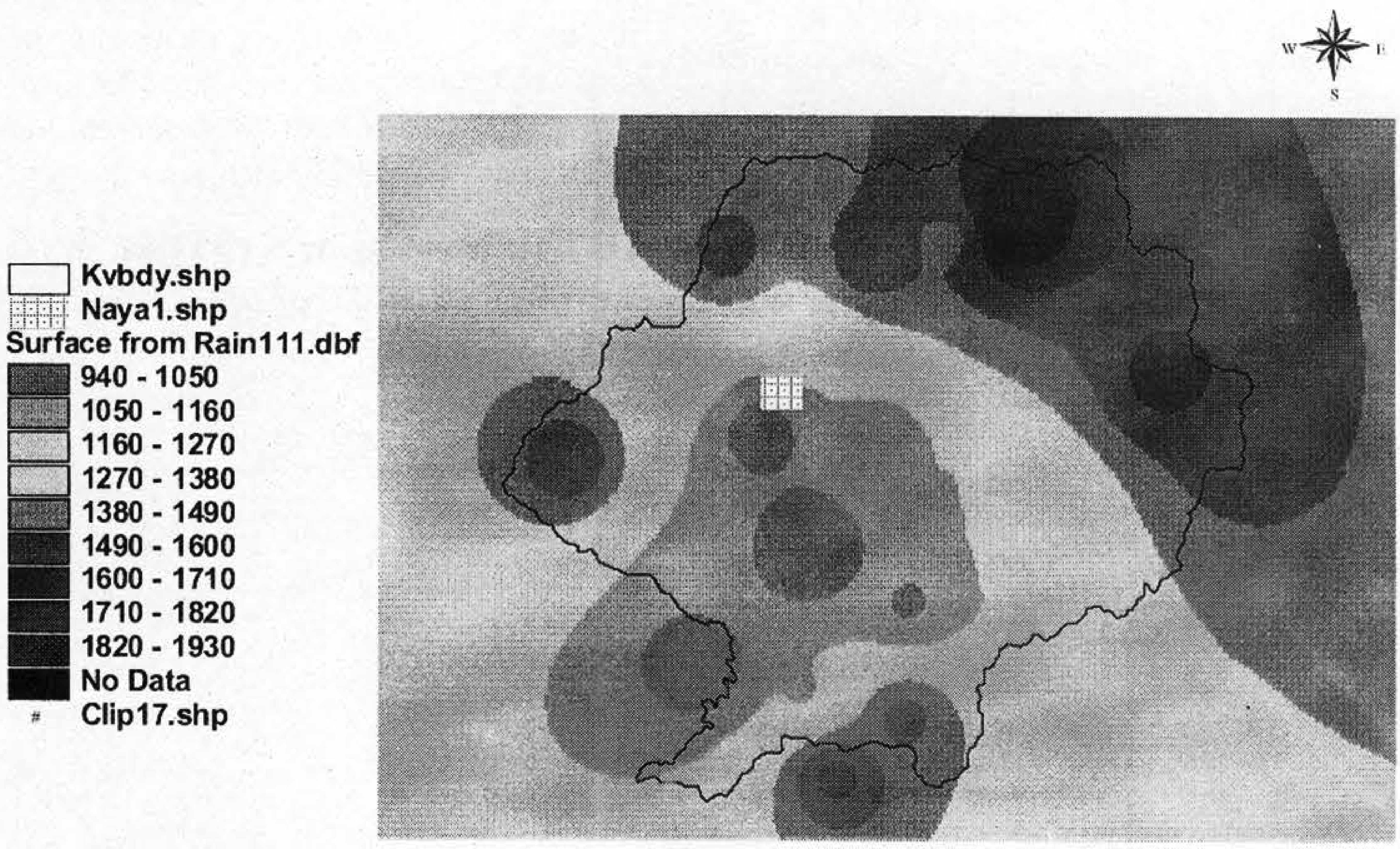

Figure 1: Average Monsoon Rainfall Distribution (1971-2004) around Kathmandu Valley

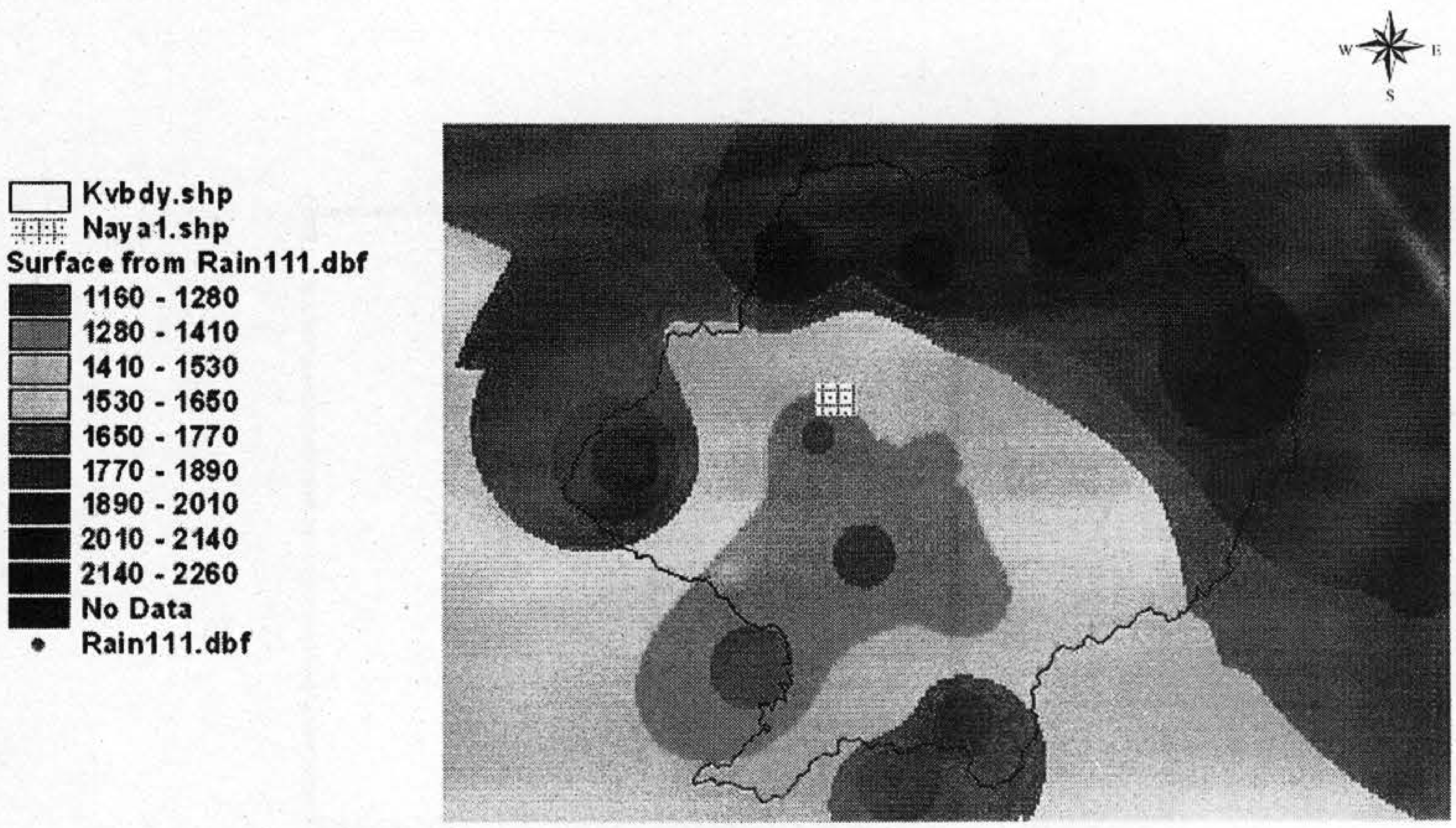

Figure 2: Average Annual Rainfall Distribution (1971-2004)

4.2 WATER DEMAND AND RAINWATER HARVESTING POTENTIAL AT NTPA

NTPA is an area facilitated by road access and green parks. Most of the house roofs are around 115 m^2. Many houses have more than two families living under the same roof and average number of members per family is five. Because of the low supply of piped water, almost all the houses have either tube wells or shallow wells dug in their courtyards. The summary of water demand of NTPA collected from questionnaire survey is presented in Table 2. The clean and grey water requirement in the area is 6.8 and 3.4 m^3 per month respectively. Thus, the total water requirement per family per year is 123,876 liters.

Table 2: Water Demand at Nayabazar Town Planning Area (NTPA)

S.N.	TYPES OF WATER USE	REQUIREMENT (Litre/family/month)	PERCENTAGE
1.	Drinking and cooking	772	7.47
2.	Washing utensils, bathing and washing clothes	6,115	59.23
3.	Toilet flushing, vehicle washing and gardening	3,436	33.28
Clean water requirement		6,887	66.71
Grey water requirement		3,436	33.28
Total water demand		10,323	100.00

Annual RWH Potential at NTPA

$$= \text{Roof Area x Rainfall depth}$$
$$= 115\ m^2 \times 1.35\ m$$
$$= 156\ m^3$$
$$= 156{,}000\ \text{liters}$$

During monsoon months, the harvested rainfall water exceeds water demands for a family. The water demand per family and rainwater availability is presented in Figure 3.

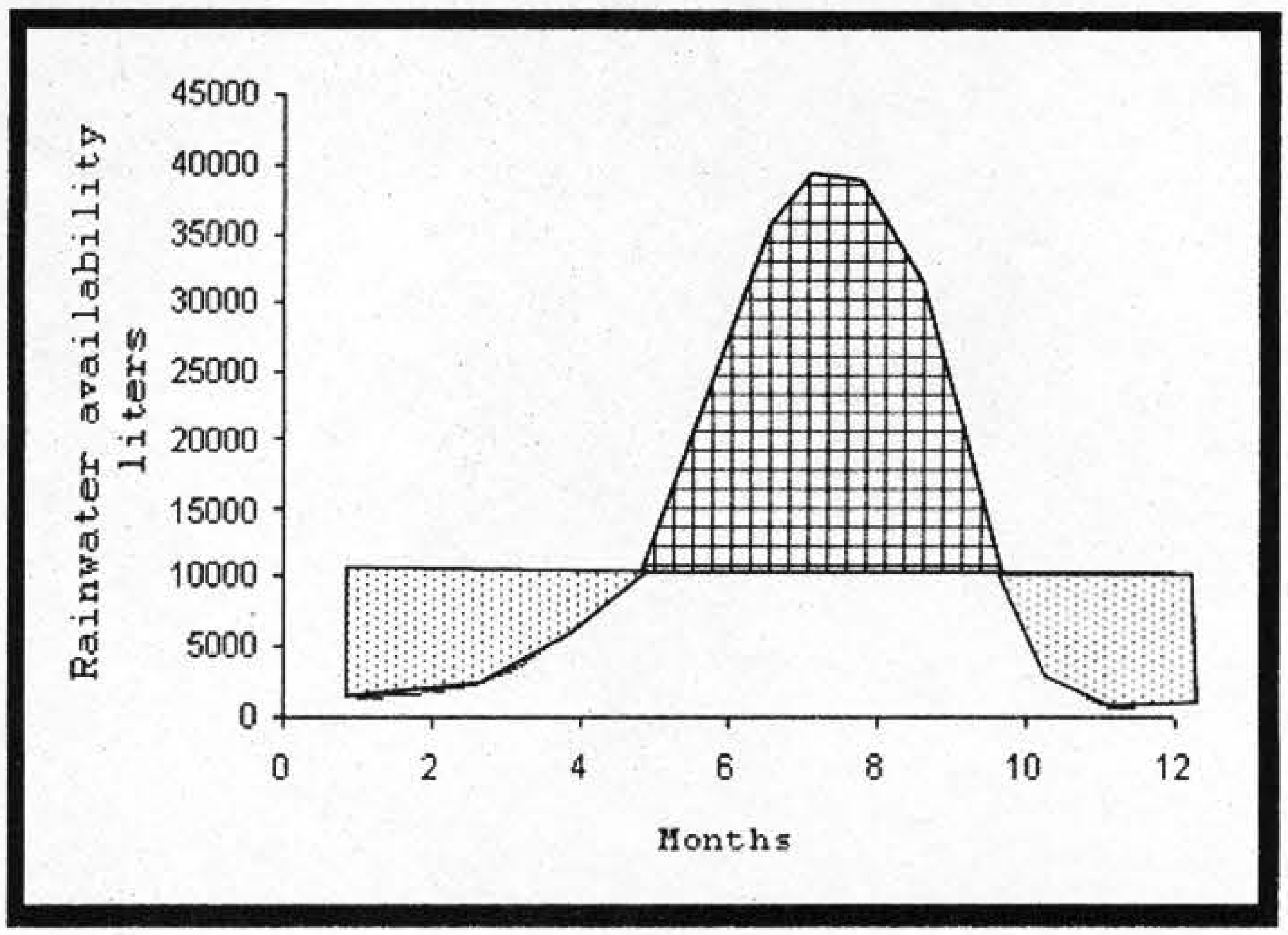

Figure 3: Rainwater Deficit: Dotted Area, and Surplus: Squares

4.3 RAINWATER QUALITY

There are several reasons for harvesting and reusing rainwater today including:

- Self- sufficient water supply located close to the user,
- Soft water with low mineral content,
- Mitigation of urban flooding, and
- Reducing erosion caused by flooding.

Rainwater is one of the purest sources of water available. The harvested rainwater is potable if the proper prevention measures against contamination are undertaken. The catchment surface (roof), gutters, and storage tanks should be clean. The filtration mechanism should be properly maintained. Factors like the cleanliness of roof, roof type, and storage tank are critical in maintaining good quality of rainwater. The quality of direct rainwater collected from CGI roof and cemented roof at Nayabazar area is presented in the Table 3.

Table 3: Rainwater Quality at Nayabazar Area (2005 Monsoon Rain)

S.N.	PARAMETERS		UNIT	WHO Acceptable	CGI ROOF	CEMENTED ROOF
1	PHYSICAL	Color	TCU	-	-	-
		Temperature	^0C	25	25	25
		Turbidity	NTU	5	<5	<5
		pH	-	6.5-8.5	7.0	7.3
		Electric Conductivity	µs/cm		31.0	100
2	CHEMICAL	Total Hardness as $CaCo_3$	Mg/l	500	6	44
		Calcium	Mg/l	75	1.6	12
		Magnesium	Mg/l	30	0.49	3.5
		Chloride	Mg/l	250	19.6	39.2
		Ammonia	Mg/l	1.5	0.6	0.1
		Phosphate	Mg/l	-	0.02	0.02
		Nitrate	Mg/l	15	NIL	0.03
		Total Iron	Mg/l	0.3-3	NIL	NIL
		DO	Mg/l	>5	7.2	7.0
		Free CO_2	Mg/l	-	25	20
3	BACTERIO-LOGICAL	Total coliforms	Col/100ml	0	5	10
		Faecal coliforms	Col/100ml	0	1	8

5. RESULT AND DISCUSSION

The rainfall distribution within the Kathmandu Valley is erratic. The total rainwater available in this Valley varies from 1,160 to 2,260 mm. Since NTPA lies at low rainfall zone, the Rainwater Harvesting Potential falls at low potential category. The average annual rainfall over the NTPA is 1,350 mm out of which 1,000 mm falls only during the monsoon season. Thus, it indicates the large amount of rainwater storage is needed to fulfill the demand in non-monsoon season.

The water demand per year is 123,876 liters/family. The average roof size of the area gives 156,000 liters/year of rainwater storage. Generally, on average, 2 families (5 members each) are living in a house. Thus, per capita rainwater available at NTPA is 15600 liters/year.

The monsoon surplus rainwater should be stored in a large tank for non-monsoon use. In Bangladesh, the minimum volume of the storage rainwater tank V, required for rainwater, can be computed by the equation (Feroze M.1999),:

$$V = 0.365\ f\ q\ N$$

Where,

f = Fraction of water required to be stored for consumption of total available rainwater at a constant rate throughout the year,

N = Number of people, and

q = liters per capita per day.

At NTPA, it is observed that there is a shortfall of 54.5 m^3 in the dry periods, and an excess of 86 m^3 of rainwater during rainy season. The mass curves for both water demand and rainwater availability are shown in Figure 4. For full utilization of rainwater potential, 79 per cent of the available rainwater is required for uninterrupted water supply at a constant rate throughout the year. However, if only drinking and cooking water is harvested, the sizes of the storage tank and catchment area would be smaller and within affordable range of a family. Substituting f = 0.79, the minimum volume of the storage tank required for rainwater becomes: V = 0.288 q N

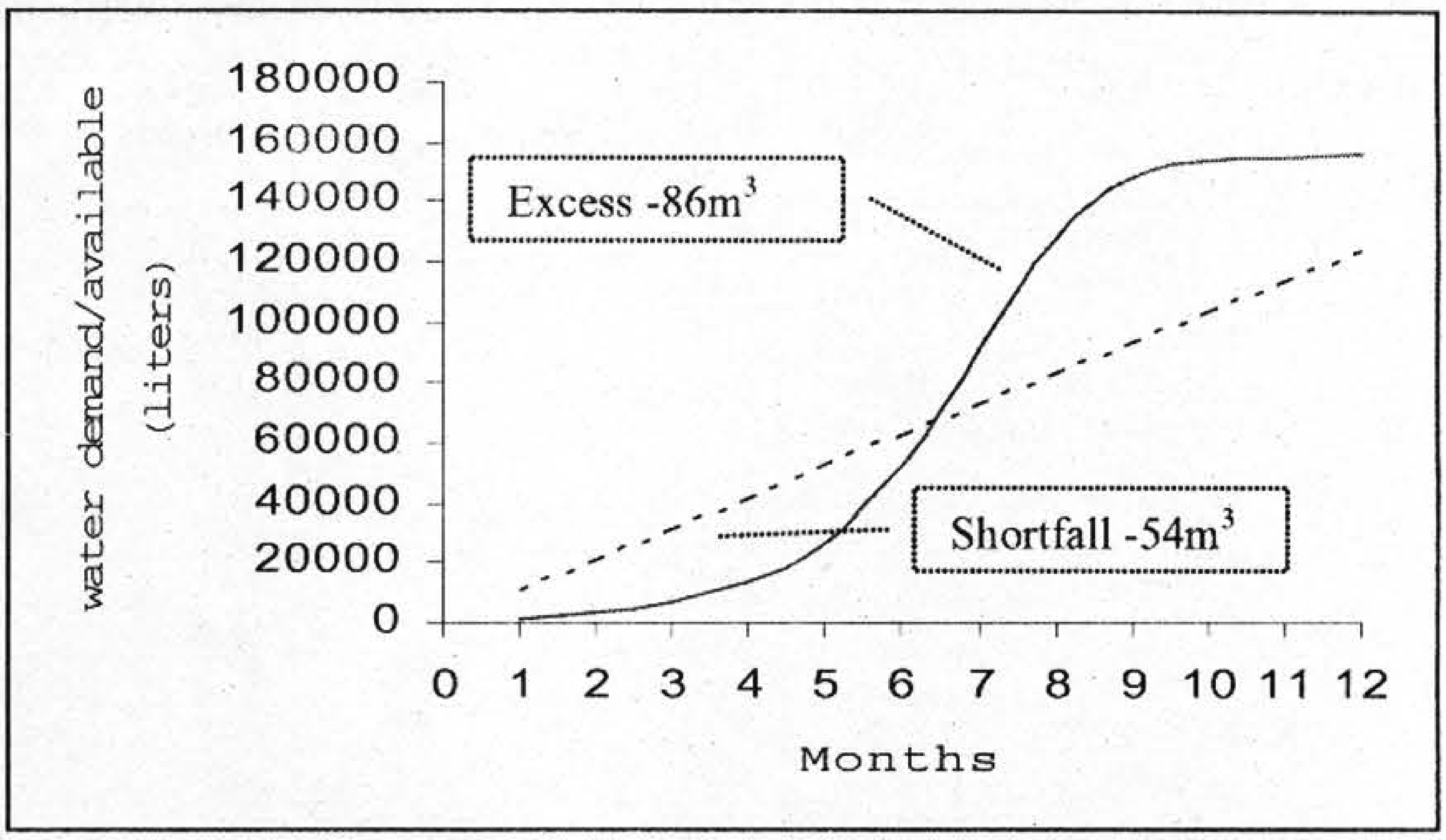

Figure 4: Water Demand and Rain Water Mass Curve (NTPA)

Harvested rainwater can be stored in either cemented tanks underground or hard plastic tanks above ground. It depends on the availability of the space. Storage of harvested rainwater is also the important factor, which determines the quality of rainwater. According to Khalequzzaman (2000), rainwater collected in various parts of the USA contains (in milligrams per liter): Fe (0.015) , Ca (0.075-1.41), Mg (0.027-1.2), Na (0.22-9.4), K (0.072-0.11), HCO_3 (4-7), SO_4 0.7-7.6), Cl (0.22-17), NO_2 (0.02), NO3 (0.02-0.62), Total Dissolved Solids (8.2-38), and pH (4.9-6.4). Most of these concentrations fall within the safe limit prescribed by the US Environmental Protection Agency. The quality of rainwater collected in Nayabazar Town Planning Area (NTPA) also fall within the limit of WHO Drinking water standards. Rainwater quality from CGI and cemented roof at NTPA contains (in milligrams per liter): Fe (0.0), Ca (1.6-12), Mg (0.49-3.5), NH_4 (0.6-1.0), DO (7-7.2), Cl (19.6-39.2), and NO_3 (0.0-0.03). The pH value found was 7.0 – 7.3 which are good for drinking purpose. The turbidity was less than 5 NTU.

The cemented roof collected rainwater shows a little more concentration than CGI roof. But in both cases most of the physiochemical parameters are within the limit of WHO drinking water guidelines (Table 1.3). But some coliforms were found in collected rainwater; and according to WHO guideline, there should not be a single coliform in drinking water. Since the major cause of diseases such as diarrhea, cholera, typhoid, jaundice, pneumonia, dysentery etc. are these coliforms, cleanliness of roof and storage tank is critical in maintaining good quality of rainwater. If the coliform is present, a "boil water" or "UV treatment" or "chlorine addition" advisory should be issued until the cause of the problem can be identified.

6. CONCLUSION

Thus, the above study confirms that rainwater fulfills the demand of a family water requirement of NTPA. Rainwater serves 63 % of water demands for two families under the same roof. But the storage tank should be big enough to accommodate the rainwater. While storing the rainwater, there are various things to remember. Rainwater storage tanks should be protected from contaminants like leaves, dust, pesticides, industrial pollution, vermin, insects, bird droppings etc.; and the roofs must be clean. Water may be contaminated with disease causing pathogens. Sources of such pathogens may be septic tanks, unclean roof etc. So, it is important to test and confirm the microbiological parameters before drinking rainwater.

Rainwater collected from roof needs to be have filters like a coarse mesh and a sedimentation tank to prevent debris from flowing into the storage tanks; and it is also important to have first flush system installed in the storage tanks to wash the first run off water. The quality of rainwater directly collected in NTPA is potable with slight treatment of water. Coliforms were found in rainwater collected which could be treated by chlorination or other methods. The quality of rainwater collected in NTPA also falls within the limit of WHO Drinking Water Standards.

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REFERENCES

APHA, 1995. Standard Methods for the Examination of Water and Wastewater. 19th Ed. New York: American Public Health Association.

CBS, 2002 . Centre Bureau of Statictics Year book. CBS publication

Coombes, P. J., J. R. Argue, and G. Kuczera, 2000. Figtree Place: A case study in Water Sensitive Urban Development. Urban Water Journal, Vol. 1, No. 4. London, UK

DHM. 1971-2004. Climatological Records of Nepal. Nepal: Department of Hydrology and Meteorology Publication.

Dixit, M., 1996. Rainwater Harvesting. Paper presented at 22nd WEDC Conference, New Delhi, India.

Feroze, M., 1999. Rainwater Harvesting Potential in Bangladesh. 25th WEDC Conference Report, pp. 363-365, Ethiopia.

Gurung, R., 2004. Traditional Rainwater Harvesting. Unpublished M.Sc. Dissertation, CDES, Tribhuwan University.

Hussain, M.D. and Z.A.T. Momtaj, 1989. Rainwater use in Bangladesh. A Case Study in Dacope Upozilla, proc. conf. Rainwater cistern system, Manila, 2-4 August.

Khalequzzaman, Md., 2000. A Report. Georgia Southwestern State University. Americus, GA 31709, USA.

Limbu, B., 2005. Assessment of Rainwater Harvesting Potential in Kathmandu Valley. Unpublished M.Sc. Dissertation, SchEMS, Pokhara University.

Rahman, M., F.U. Anam, 2000. Rainwater Harvesting and Reliability Concept. Proceedings of 8th ASCE Specialty Conference on Probabilistic Mechanics and Structural Reliability, PMC2000-084.

Shakya, P., S. Sharma, 2004. An Integrated Drinking Water Quality Assessment of Rain Water Harvesting Jars and the Related Socioeconomic Conditions and Gender Issues of Chappani VDC-1, Palpa. Proceedings of the International Conference on Great Himalayas, Jan 12-15, 2004, Kathmandu, Nepal.

WHO, 1993. Guidelines for Drinking Water Quality. 2nd Edition. Geneva: WHO Publication.