ECO HOME FOR SUSTAINABLE WATER MANAGEMENT: A CASE STUDY IN KATHMANDU, NEPAL

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ABSTRACT

Shortage of drinking water and pollution of water bodies are the growing problem in urban centers of Nepal. Kathmandu, the capital of the nation, is severely affected by these problems where water is supplied only half of the actual demand and the major rivers are turning into open drains. Similarly, ground water is depleting at about 2.5 meters every year due to over extraction. There is no sign of increase in water supply within a decade and the nation has still not developed a concrete plan to clean up its rivers. In such circumstances, local level actions must be initiated to solve this crisis where people need to be oriented on simple techniques for sustainable management of water. Some of these techniques include rainwater harvesting, wastewater recycling, and ecological sanitation system. These techniques can be implemented from a single household to community level. In last two years, these initiatives have already been adopted by a few individuals and institutitions. This paper describes a case study of a house in Kathmandu where rainwater is used for all purposes including drinking, greywater is recycled for non drinkable purposes and human excreta is utilized as a fertilizer by adopting ecological sanitation technique.

KEY WORDS: rainwater harvesting, ecological sanitation, greywater reuse, sustainable water management

1. INTRODUCTION

Problems associated with the lack of clean drinking water and polluted water bodies are common to many cities in developing countries. With rapid urbanization and increasing pressure on city governments, who often lack adequate financial as well as human resources to handle the problems, the water crisis is deteriorating daily.

The story of Kathmandu Valley's water supply and sanitation is similar to many cities in the developing world where only half of the total water demand is supplied by the city (NWSC, 2004). Many people, especially in the peri-urban communities, are relying on traditional water sources like dugwells and stone spouts, which are not safe for drinking. Groundwater abstraction from deep aquifer is more than twice the rate of recharge (IUCN/NPC, 1995) and the water table of several deep aquifers have depleted by 15 to 20 meters (AGSO/GERDB, 1997). Even though Kathmandu Valley has an average annual precipitation of 1,600 mm, many areas in the Valley is not suitable for recharging aquifers from precipitation, therefore fossil water (more than 1000 years old water) is being extracted from deep aquifer to fulfil water demand of the valley. There is high probability of land subsidence and other adverse environmental impacts like release of harmful chemicals and desertification if the excessive extraction of groundwater continues.

Discharge of more than 60 MLD of untreated wastewater into the Bagmati River is another major problem in Kathmandu. As a result of the discharge of untreated wastewater, the BOD level in the river crosses 100 mg/l during the dry season and the count of *E. coli* per 100 ml of water is in the millions (Shrestha *et al*, 2004). Two lagoon type wastewater treatment plants, built over 20 years ago, lie unutilized. Recently, a conventional wastewater treatment plant has been constructed to treat a small portion of the wastewater, but even this is not functioning well and there are concerns about the operating cost, which amounts to about US $ 13,000 per month.

Under these circumstances it is urgent that the citizens of Kathmandu adopt measures to optimize the use of current water supply system and conserve water to the extent possible and adopt on site sanitation to reduce pollution of water sources.

2. ALTERNATIVE APPROACH FOR SUSTAINABLE WATER MANAGEMENT

There are several ways to tackle existing water crisis in Kathmandu. Simple technologies like rainwater harvesting, wastewater recycling, ecological sanitation can be adopted by individual households to community level for optimal use of water resources and for reducing the pollution load to the receiving water bodies. This is also a way to involve the people and community to solve their own problem and make them realize the role of citizen for their city.

This paper describes a demonstration house called Eco home (photo 1) built by the author in November 2002 located in Kathmandu City which adopted several approaches for sustainable water management and can have first hand experience on several technologies.

The Eco home is built in 135m^2 of land which consists of rainwater harvesting system, greywater recycling, urine and faeces diversion dry toilet (Ecological Sanitation - ECOSAN Toilet), household composting, simple method on drinking water treatment. Because of all these system, the author disconnected city water supply network as it can rely on rainwater and water from shallow well throughout the year. Similarly, it does not have connection to sewer network. All these technologies are described in the following section.

Photo 1: Eco home

2.1 Rainwater Harvesting & Groundwater Recharge

The author has started to measure rainfall data of this location from 2005. Three years average rainfall (2005 to 2007) was 2576 mm and nearly 90 % of rains occurred only during 6 months (April to September). The Eco-home has roof area of 90.4 m^2 which can collect more than 180 m^3 of rainwater/year (Table 1).

Table 1 : Rainfall and water collection (2005 to 2007)

Month	Rainfall mm				Rainwater collection m3	Water Demand m3	Deficit and Surplus m3
	2005	2006	2007	Average			
Jan	45			15	1.1	8.4	-7.3
Feb	20		125	48	3.5	8.4	-4.9
Mar	53	51	76	60	4.3	8.4	-4.1
Apr	90	144	184	139	10.1	8.4	1.7
May	87	313	265	222	16.0	8.4	7.6
Jun	403	437	535	458	33.1	8.4	24.7
Jul	449	487	561	499	36.1	8.4	27.7
Aug	458	720	444	541	39.1	8.4	30.7
Sep	240	401	674	438	31.7	8.4	23.3
Oct	216	205	0	140	10.1	8.4	1.7
Nov	0	44		15	1.1	8.4	-7.3
Dec	0	0		0	0	8.4	-8.4
Total	**2061**	**2802**	**2864**	**2576**	**186.3**	**100.8**	**85.5**

Rainwater is stored in a 9,000 litres underground tank and excess rainwater especially during rainy season is diverted into a dug well. The dugwell can store nearly 10,000 litres of water and also facilitates to recharge groundwater. A first flush diversion device has been installed to divert the dirt and other particulates from the roof before storing rainwater into the storage tank and the dugwell. Recharging the groundwater has also improved water quality in the dugwell especially in the reduction of nitrate level. Eco-home can rely on rainwater for nearly nine to ten months and in the remaining months it has to extract water from the rainwater recharged dugwell. The Eco-home is inhibited by five family members, needs only 8.4m^3/ month of clean drinking water which is comparatively 50 % less than other similar households with five family members. This is mainly because of the installation of several water saving devices like greywater recycling and ECOSAN Toilet (Table 2).

Table 2: Monthly Water Demand and Clean Water Requirement at Eco-Home

Type of water use and requirement	Liters/month	%
Drinking & cooking	900	7
Dishwashing, bathing, showering, & laundry	7500	55
Toilet flushing, cleaning vehicle & gardening	5250	38
Total Water Demand	13650	100
Reuse of Treated Greywater	5250	38
Clean Water Requirement	8400	62

2.2 Ecological Sanitation

Ecological Sanitation (ECOSAN) is an ecosystem approach to excreta disposal. ECOSAN recognize :

1. Human excreta as a resource, not a waste
2. Water is a precious resource that should not be used to transport the excreta
3. Excreta should be managed as close as possible to its source.

This new approach closes the loop on sanitation by recycle and reuse. Nutrients in the human excreta are recycled and are reused for agriculture. It embraces multi-dimensional aspects. Featuring the manageable waste collection and treatment system at the source itself, it reduces the load of wastewater and the cost of wastewater treatment. It controls surface and groundwater pollution and reduces water consumption otherwise wasted in flushing the faeces.

In this system, toilet is designed in such a way that urine and faeces is separated. As urine is almost sterile, it can be used as a fertilizer after short storage with necessary dilution in water and faeces is stored for about six months to sanitize it since it contains many pathogens and microbes that are hazardous to health. The nutrient content in faecal matter is considerably lower than that in urine, especially in the amount of plant-available nitrogen[1]. The main contribution from faecal matter is the content of phosphorus and potassium that increase the buffering capacity of the soil. The soil with low pH affects the growth of plants. Normally, faeces are added with ash or lime in dry toilet that increases pH. Increase in pH also accelerate destruction of pathogens, therefore, stored feaces of more than 6 months with high pH condition are safe to apply in soil in terms of hygienic quality.

Eco-home has installed a urine diversion dry toilet at the master bed room with a bucket collection system in the basement to demonstrate its feasibility in the urban settings (Photo 2 and 3). Ash is pour instead of water after defecation and little (less than 100 ml) water is used after urination. The urine is collected in 50 litres bucket (the black container in photo 3) and faeces are stored in 80 litres plastic bin (green container in Photo 3). This toilet is being used by only two persons. The bin fills up once every four to five months and is then replaced with an empty one. The collected faeces is left for 6 months before apply into the garden as WHO recommends more than 6 months of storage in case of alkaline treatment of human excreta for the safe use in agricultural field (WHO/UENP/FAO, 2006). A part of stored faeces is also mixed with compost out of kitchen waste as a co-composting. This toilet saves more than 40 litres of clean water/day as flushing toilet consumes more than 10 litres of water in each visit. Though the toilet is attached with master bed room the author and his family never felt any odour or smell.

Collected urine is diluted in 1:10 ratio and applied in the garden (flowering plants) once every three to four weeks. In case of other crops urine applies into the soil at a ratio of 1 litre/m^2 area of land. Excess urine is also mixed with compost which facilitates composting process and produces better quality of compost.

Built on 135 m^2 of land, the Eco-Home has limited space for growing vegetation. The author has successfully established a terrace garden and small kitchen garden where urine and faeces are regularly applied as a fertilizer. Different kinds of vegetation like tomato, radish, beans, green salad, carrot, pumpkin etc are grown.. Similarly, urine and composted faeces are also applied to fruit plants like guava, and citrus.

	
Photo 2: Urine and Faeces Diversion toilet	Photo 3: Urine and Faeces collection tanks

Photos 4 : Gardens established with application of Urine and Faeces

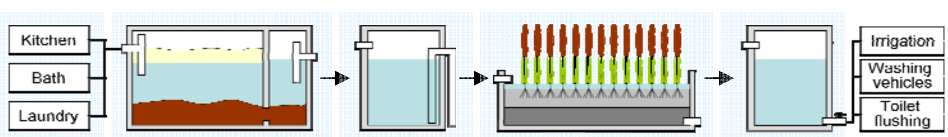
		
Terrace garden	Flower	Beans

2.3 Grey Water Recycling

In a typical household, about 5 % of the total water consumption is used for drinking and cooking, 52 % for hygienic purpose like bathing, laundry and dishwashing and remaining 43% is used for toilet flushing, gardening and cleaning (NGO Forum for Urban Water and Sanitation, 2003). Around 40% of clean drinking water is used for non-drinking purposes where low quality water is sufficient. Therefore by treating grey water from bathing, laundry and kitchen, the water can recycled for use for these purposes. It indicates that excessive amount of clean drinking water is utilized for non drinking purpose which can be simply generated by treating grey water (wastewater from bathing, laundry and kitchen). Grey water usually contains much less nutrients (nitrogen and phosphorus) and pathogens since grey water is not contaminated directly by human excrement. Therefore it can be treated and reused that saves more than 40% of water.

Eco-home produces about 250 litres/day of greywater where separate plumbing system has been fixed to separate greywater and black water. The greywater is collected in a two chambered settling tanks (500L) for sedimentation of larger particles. From here, water passes to a 200L feeding tank from where a siphon device feeds water intermittently into the vertical subsurface flow bed of the constructed wetland for further treatment. The treated water is collected into an underground tank of 2,000L (Figure 1). Even though the monthly water demand is about 13650 litres, it needs only 8,400L of clean drinking water due to installation of grey water treatment unit and dry toilet. Treated greywater is being used for toilet flushing (Eco-home has one flush toilet beside dry toilet), cleaning vehicles and gardening (Table 2).

Figure 1 : Schematic Flow Diagram of Greywater Treatment (Eawag/Sandec, 2006)



V: 250 l

Settlement tank

Feeding tank

Vertical flow Reed bed (4.8 m2)

Storage tank

Vertical Flow Reed Bed Treatment System

Vertical subsurface flow bed of the Reed Bed Treatment System (RBTS) is a type of constructed wetland consists of a rectangular bed (4.8 m^2) filled with 20 cm of gravel (20 to 40 mm) at the bottom, 10 cm of small gravel (10 mm) in the middle and 60 cm of coarse sand on the top. The bed is planted with *Phragmites karka* (Reed) and water is distributed 1 to 2 times a day through a 50 mm diameter perforated pipe that is fixed above the surface level of the bed and connected to the feeding tank (Figure 2 and Photo 5).

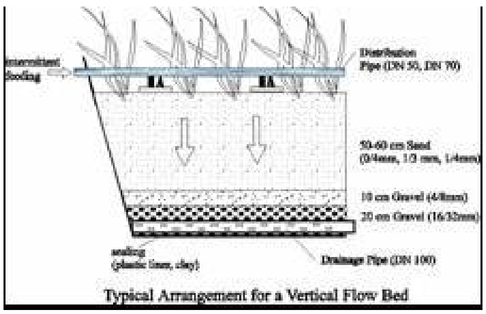


Figure 2: Cross Section of Vertical Flow CW

Photo 5 : Operational Constructed Wetland

As the wastewater flows through the bed it gets treated through natural processes by mechanical filtration, chemical transformation, and biological consumption of potential pollutants in the wastewater stream. The plants grown in the wetland bed not only offer a root mass for filtration, but also provide oxygen and carbon for water treatment. Plants act like biological pumps, converting sunlight into chemical energy and carrying oxygen from their leaves to their roots. Pollutant digesting microbes colonize in the oxidized zone surrounding the root surface where it consumes the available oxygen in the process of breaking down pollutants. The plants themselves also take up pollutants (Gersberg et al, 1986).

The author established similar system at a private house with family size of seven in 1998 for treatment of 500 litres of greywater. The system was monitored from April 1998 until May 2000. During this time span, the treatment efficiency was stable (Table:3). It is expected that the performance of the Eco-home greywater treatment system should be similar or even better as the system was built in similar structure and hydraulic loading rate is only 52 mm/day compare to 83 mm/day in previous one.

Operation and maintenance

The system is in operation since early 2003 without any problem. Following maintenance actions needs to be done to ensure a proper operation of the system:

- Sludge removal from the settlement once in two years.
- Regular inspection of dosing chamber for proper siphonic action as vertical bed needs intermittent feeding of greywater.
- Plant cutting once a year
- Regular inspection of pipes and fittings of settling tank to observe clogging problem due to accumulation of oil and grease.

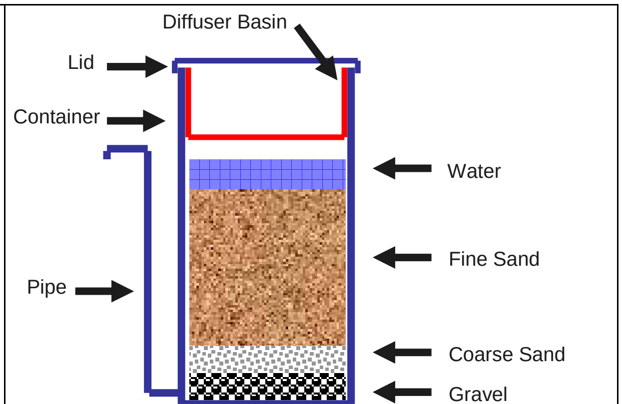
Table 3: Performance of Greywater Treatment System in Kathmandu, Nepal (Shrestha, 1999)

Parameters	Range influent (mg/l)	Range effluent (mg/l)	International guidelines
BOD5	100–400	0–12	10
COD	177–687	7–72	100
TSS	52–188	1–6	10
NH4-N	4–26	0–2	30
PO4-P	1–5	1–4	30

2.4 Drinking Water Treatment

Photo 6: Water Purification


Bio Sand filter



Bio Sand Filter


SODIS

Eco-home is adopting SODIS techniques for treating rainwater for drinking purpose. SODIS uses solar energy (radiation in the spectrum of UV-A light - wavelength 320 to 400 nm) to destroy pathogenic micro organisms thereby improving the drinking water quality. In this process, water is filled in a PET (Poly Ethylene Tereptalate) bottle of 1 to 2 liters and exposed in the sun for a day (about 6 to 7 hours) (EAWAG/SANDEC, 2002). Water from dugwell is treated with bio sand filter prior to treatment with SODIS. Biosand filter is a miniature version of a slow sand filter for intermittent use (Photo 6). Water is simply poured in the top of the filter and microbial contamination is removed as it flows through sand media and the *schmutzdecke*

(Biological layer) that forms at the sand-water interface (CAWST, 2007). This innovative intermittent design, called the Biosand filter, contains five-centimeters of standing water above the fine sand media which functions to preserve biological activity when the filter is not being used. Because of its relatively small surface area, this scaled-down filter also has a much higher flow rate of 0.6 m/hr (or 30L/hr) compared to 0.1 m/h of traditional slow sand filters. Much like its continuous counterpart, the Biosand filter requires no chemical additives with its primary materials consisting of sand and concrete (which can be found anywhere). Besides pathogens, the Biosand filter can also removes turbidiy, iron and odour from the water.

2.5 Composting of organic waste

A 100 litre plastic bin with two compartments separated by a steel grill (Photo 7) has been used for composting of organic waste. Urine is also mixed with organic waste to facilitate composting process. In addition to composting bin, vermin composting by using special worms (*Eisenia foetida*) is also practiced for composting of kitchen waste. Both of these techniques are found to be appropriate for composting of organic waste at the household scale.

Photo 7: Composting out of Organic Waste

		
Compost bin	Vermicomposting bin	Compost

3. PROMOTION AND AWARENESS

Today Eco-home has become a model house for demonstration of water and waste management at household level. People from all walks of life visit this house to understand the concept of sustainable water management. A movie called "Jal Pari" has been produced to tell the story of this house. The movie is now documented as a training material for water education. Several national and international newspapers highlighted Eco-home as a best practice on water management. Several hundreds households in Kathmandu Valley are now practicing some of the components like rainwater harvesting, water purification and waste management

4. COST OF THE SYSTEMS

It usually assumed that this type of system may not be economically viable. However, in author experience, investment cost was only 2.4 % more than normal price. For example, total cost of the building was about USD43,000 and additional USD 1000 was invested for greywater recycling, rainwater harvesting and ecosan toilet. Without these water management systems, the author may need to spend nearly USD 370/year to buy water from private tanker trucks. As such, the payback period is less than 3 years. In addition to the cost for buying water, the author saves significant amount of time to extract water from the city water supply and relieves from mental tension for not having sufficient water.

5. CONCLUSION

Supply of inadequate and poor quality water and disposal of untreated sewer into river are major issues of all urban centers in Nepal. It is time for sustainable management of water resources that can be started from individual level. Even though rainwater harvesting is one of the best options to solve the current water crisis, it is not a complete solution due to the rainfall pattern in the country. However, greywater recycling and adoption of ecological sanitation together with rainwater harvesting can be a complete solution for the current water crisis. The Eco-home has demonstrated an excellent example to demonstrate all these options. Similarly, it has successfully demonstrated the use of human excreta as a fertilizer to grow many kind of vegetations. It has also been understood that with the real life example it is easy to convince people for large scale replication. It has also been noted that people's attitude toward rainwater harvesting and greywater recycling is very positive but attitude toward Ecosan toilet is still not acceptable because of the socio cultural barrier associated with feces. Therefore, it is important to educate and make the children aware from the young age towards water and waste management.

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