ECONOMIC ANALYSIS OF GREY WATER USE-A CASE STUDY FOR A FIVE STORIED RESIDENTIAL BUILDING AT CUET

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ABSTRACT
Asia is being suffered by the scarcity of fresh drinking water due to increased urbanization & pollution. In Bangladesh, fresh drinking water also become unsuitable as water table is decreasing significantly day by day. It is however anticipated that among the day to day activities for fresh water uses, about 40% of water is used for non-potable purposes, for some of these may not have regular potable quality. In this line, the use of grey water got serious attention for its potential of non-potable purposes such as for irrigation, recreation, gardening, fish culture, toilet flushing etc. For residential establishment or building, a single pass sand filter along with sedimentation basin & chlorination chamber was designed using locally available materials with the aim of treating grey water thus to fit for non-potable domestic purposes such as toilet flushing, gardening & car washing. Economic analysis for non-potable uses of grey water was performed using project justification method. Total cost of installing grey water treatment train & total saving cost of using treated grey water for non-potable purposes was estimated using present day value. Though B/C ratio is less than 1, it is not the main concern where scarcity of fresh drinking water is more. By calculating payback period, it was found that grey water treatment system can be implemented economically for a 5-storied residential building.

Keywords: Grey water; fresh drinking water; non-potable purposes; 5-storied residential building; payback period

INTRODUCTION
An increasing global population coupled with growing urbanization in many countries already water source regions worldwide has led to increased demands on water supply (USEPA, 2004). The recycle and reuse of wastewater is considered as a strategy of water demand management (WDM) system. Reuse of wastewater minimizes the demand for the freshwater (Redwood, 2007). With the technological advancement and public acceptance, grey water seems to be a potential source of water saving (Al Jayyousi, 2003). Former studies reported that the amount of grey water produced in household is 55% - 65% of the total amount of waste water (Burnat et al. 2007). Grey water generated from sinks, baths, showers or washing machines can be treated onsite or offsite for non-potable use purposes such as irrigation, toilet flushing, car washing, dust control, soil compaction, in construction works, and in industrial processes like cooling boilers and other appliances (Almeida et al. 1999, Butler et al. 1995, Funamizu et al. 2001). Reuse of grey water in toilet flushing and gardening can save 31% - 54% of potable water in households (Christova-Boal et al. 1996). Quantity of grey water generation depends on the income level of the people. Households without in-house water connection produce grey water which is more concentrated than wastewater from wealthy areas, due to the lower water consumption and existing reuse practices (Hoffmann et al. 2011). Most grey water treatment technologies are consequential from conventional wastewater treatment and were not developed specifically for grey water treatment (Hoffmann et al. 2011). A principal concern for water reuse is the potential for the transmission of pathogenic micro-organisms from reuse applications (Asano et al. 2007). Knowledge of the pathogen content of grey water is limited. Specific pathogens & significant numbers of indicator bacteria have been reported indicating that the disinfection of grey water prior to reuse is essential to the risk of public health (Rose et al. 1991). For this reason, treatment of grey water by a low cost system is required to minimize the above problems. The objectives of this paper are:

1. To develop a cost effective treatment system using locally available material for grey water treatment train for a 5-storied residential building.
2. To design the grey water treatment approach for that building using AutoCAD.
3. To estimate the total cost of installing grey water treatment train for that residential building.
4. To estimate the total saving cost of using treated grey water for car washing, gardening & toilet flushing.
5. To estimate the payback period & cost-benefit ratio.

METHODOLOGY

Study area

Chittagong University of Engineering & Technology (CUET) was selected as the studying area. A five storied residential building of teacher's residential area was considered as the study area for this case study.

Background of Case Study

This case study is based on an experimental study which was carried out in CUET campus area. A small scale treatment train was introduced then. Sedimentation tank, filtration tank & chlorination tank was used as the treatment train. CUET campus area selected as study area. Grey water was collected from the residential area, hall, canteen & mosque. The collected water tested in the CUET Environmental Engineering laboratory. Then the treatment train was set up. A Single Pass Sand Filter which was made with locally available materials was selected. The lateral cross-sectional profile of single pass sand filter is shown in Fig. 1. The collected grey water was treated by this treatment train approach. The treated water was also tested in the same laboratory. It was found that the result was satisfactory (Hossain et al., 2015). On the basis of that result, this study was carried out for a 5–storied residential building of CUET campus.

Fig. 1: Lateral cross-sectional profile of single pass sand filter

Procedure

In this project, a case study was carrying on implementation of a grey water treatment train. The grey water treatment system was designed for a 5-storied residential building. The implementation of grey water treatment train for that building is shown in Fig. 1 & Fig.2. The figures show the ground floor plan & roof slab plan. Assuming each family has 5 members, grey water treatment system was designed for 50 members. Water consumption of a family having five members at Goran in Dhaka city is presented in Table 1 (Abedin and Rakib, 2013). Cost of separate plumbing system for the treatment system is presented in Table 2. Cost of installing grey water treatment train is presented in Table 3. Some examples of cost saving by using treated grey water are presented in Table 4. Pay back calculation of the installation cost of grey water treatment train is presented in Table 5. It is assumed that the treated grey water is used for toilet flushing, car washing and for gardening. Grey water cannot be stored for more than 24 hours treated or untreated. So, treated grey water must be used within 24 hours. So, every day the water tank has to be cleaned. The excess water is to be allowed for ground water recharge or the water can be drained out safely. As the water is treated, it will not cause any harm to the environment. Waste water pipelines are used to discharge the waste water except black water from any type of building. Black water is discharged separately. The waste water which was used to discharge directly to the environment is now being collected in a sedimentation tank which volume is 112.5 cft. The water is stored in that tank for 8 hours. The sedimentation tank is built under the ground level. Then the water is allowed to pass through the single pass sand filter by a 2 HP motor. The volume of the filtration tank is 138.58 cft. After filtration the treated grey water was stored in a chlorination tank. The chlorination tank is under the ground level. Volume of the chlorination tank is 100 cft.

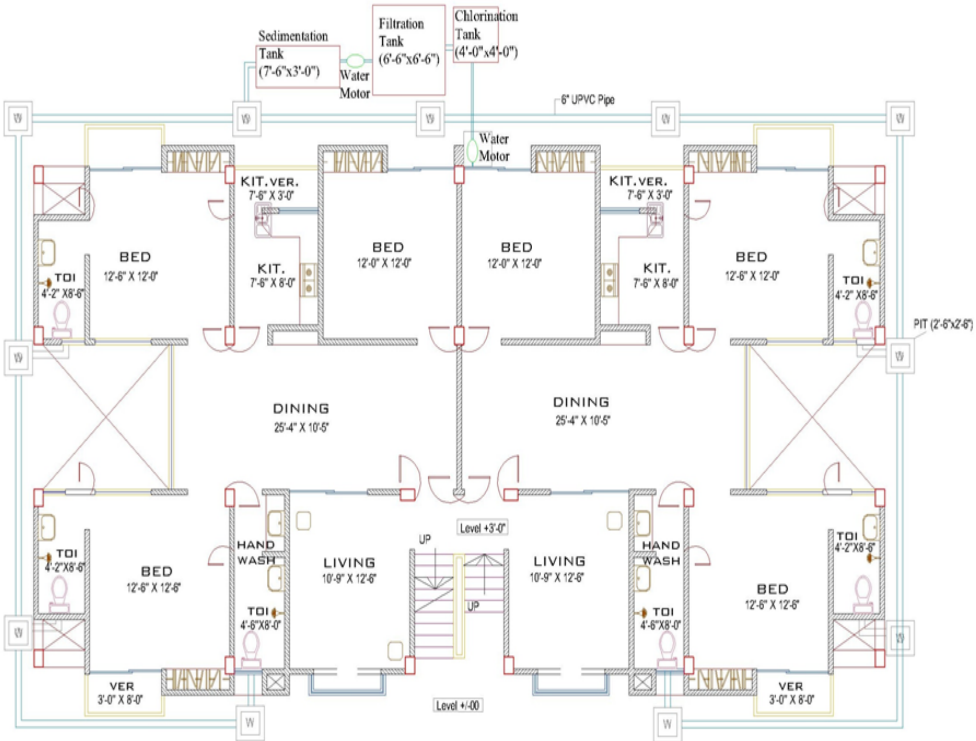

Fig. 2: Implementation of grey water treatment system for a 5-storied residential building (Ground floor plan)

Table 1 Water consumption

Area	Water consumption on Holidays (Liter/day)	Water consumption on Weekdays (Liter/day)
Family member	5	5
Bathing	300	280
Cloth washing	200	180
Dish washing	180	150
Hand washing	30	30
Ablution	70	45
Floor washing	80	80
Consumption(lpcd)	172	153
Total consumption (approximately for 50 members)	8600	7650

(Abedin and Rakib, 2013)

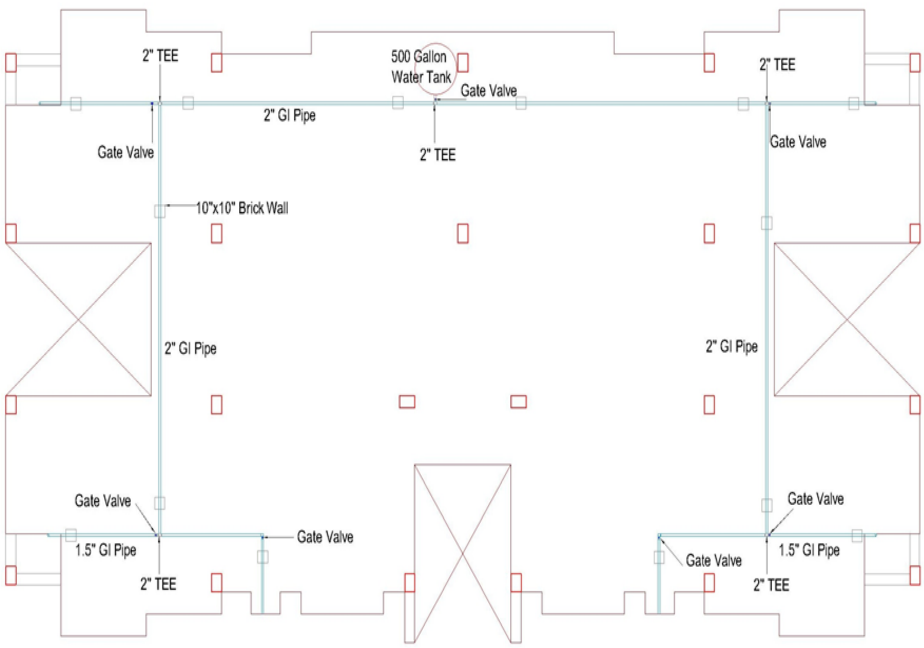

Fig. 3: Implementation of grey water treatment system for a 5-storied residential building (Roof slab plan)

Table 2: Cost of separate plumbing system for a 5-storied residential building

Name of materials	**Price (TK)**
Tank (500 litre)	3750
Motor (2 HP)	20,000
GI pipe	77036
Water tape	300
uPVC wastewater pipe	425
Elbow	902
Tee	3757.5
Bend	5365
Union	4785
Gate valve	5950
Reducer	450
Total=	1,37,964.5

Table 3: Cost of installing grey water treatment train

Name of Materials	**Volume (cft)**		**Price (TK)**
Sedimentation Tank	Cement (per bags)	43	43*400=17200
	Sand	79.6	79.6*20=1592
Filtration tank	Brick chips	159.2	159.2*95=15124
	Rod (kg)	22.39	22.39*81.91=1833.96
Wire Net			4*1000=4000
Water Tape			3*100=300
Concrete Block			50*10=500
Coarse Sand	69.31		69.31*65=4505
5 mm Gravel	6.93		6.93*160=1109
10 mm Gravel	20.8		20.8*180=3744
Earth work in excavation	212.5		212.5*0.3048^3*67=403.2
Brick flat soling			742.1
Shuttering works			4018.99
Plaster works			76089.84
2 HP motor			20,000
Labour Cost			2910
Total=			1,54,072.09

Table 4: Examples of cast saving from treated grey water reuse system

<table>
<tr><th colspan="2">For Toilet Flushing</th><th>For Gardening</th><th>For Car Washing</th></tr>
<tr><td>Appliances</td><td>Standard toilet charges</td><td rowspan="7">Water required for vegetable garden = 630 gallons/ 1000 sq. ft.
An approximate area of 100 sq. ft. is used for gardening.
So, daily use (litres) = 238.5
Annual water use (litres) =87,052.5</td><td rowspan="7">Water required for a car = 60.6 litre/ vehicle
There are three cars in this residential building (Assume)
So, daily use (litres) = 181.8
Annual water use (litres) = 66,357</td></tr>
<tr><td>Litre/flush</td><td>6</td></tr>
<tr><td>Flushes/person/day</td><td>4.8</td></tr>
<tr><td>No. of occupants</td><td>50</td></tr>
<tr><td>Total flush/day</td><td>240</td></tr>
<tr><td>Daily Use (litres)</td><td>1440</td></tr>
<tr><td>Annual Water use (litres)</td><td>5,18,400</td></tr>
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Table 5: Calculation of pay back period.

Parameters	**Amount (TK)**
Initial investment	292036.59
Annual cash flow	38,325
Pay back period (years)	7

RESULTS AND DISCUSSIONS

From the chlorination tank, the treated grey water is stored in an overhead tank on the roof by a 2 HP motor. The overhead tank is of 500 litres. Then the treated grey water is supplied to use for non-potable purposes like toilet flushing, gardening and car washing.

Total capital expenditure required for installing grey water treatment system, C = cost of installing grey water treatment train + Cost of separate plumbing system for a 5-storied residential building

=TK. 137964.5+ TK. 154072.09 =TK. 292036.6

If the life of the system, Y= 5 years, the annual depreciation charge = C/Y= TK. 58,407.32

If annual simple interest is 5%, then a locked up capital of TK. C would earn an average annual interest = (C/2)*(r/100) = TK. 7300

Total annual cost= C/Y+ (C/2)*(r/100) = TK. 65,708.233

Total water required for the five storied residential building for gardening, toilet flushing & car wsahing (for 1 year) = 518400+87052.5+66357= 671809.5 litres.

Total production of grey water (daily) = 8660 liters on holidays.

Loss (daily) = 1660 liters (approximately).

Total amount of treated grey water (daily) = 7000 liters.

Use of grey water for toilet flushing, car washing and gardening (daily) = 1860.3 liters.

Excess amount of treated grey water (daily) = 5139.7 liters.

Total amount of treated grey water (annually) = 2,555,000 liters.

These excess amount of treated grey water can be used for recharging ground water. Or it can safely exposed in the environment. It will not be a cause of theat to the environment

In the conventional system, a pump of 1.5 KW can fill up a tank of 500 litres within half an hour.

So, electricity required = 0.75 unit

Cost/unit = 10 BDT.

For 2,555,000 litres, total water production cost = 38,325 TK for 1 year.

Benefit/Cost ratio = annual benefit/ annual cost

= TK. 38,325 / TK. 65,708.233

= 0.5833< 1

Though B/C ratio is greater than 1, this treatment system has a considerable profit because cost per unit of electricity is increasing day by day in Bangladesh. In new future, when the water table will go down significantly then no doubt total cost by pumping would increase more along with fresh water scarcity. Generally lifetime of a building is 100 years and the pay back period of this treatment system is 7 years. So the treatment system will be more profitable with the time being along with payback period while sustainability of fresh water is really an issue where non potable water can be used for some aspects as discussed in Table 4.

Again, water from CWASA or DWASA is now available in a lower cost. But as the rivers which are main source of water is being polluted at an alarming rate, the treatment cost of the would be more than anticipation. Then the total cost of grey water treatment system would be less than total benefit. Hence, for the project justification only cost benefit ratio cannot be taken as an indicator.

CONCLUSIONS

Operating filter of this treatment system resulted in higher pollutant removal efficiencies as a result of the extended infiltration depth and three separate layers. Such a system would be suitable for the treatment of high strength grey water to reduce the organic load, nutrient load and pathogen load. However, the support and incentives of the local authorities to prioritize grey water interventions is essential to have a wider application of such filter systems. In addition, acceptability by the users and making the filters affordable may pose a challenge to their sustainability.

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