Reduction in Fresh Water Consumption by Grey Water Reuse for Flushing and Irrigation: A Case Study of a Multistorey Hotel Building

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Abstract

Over time the concern of amount of water consumption has gained strength with depleting water resources each day all over the world. Saudi Arabia with already minimal surface and sub-surface water resources is on alert for future planning and management of water use in the Kingdom. Large scale water conservation projects are in line for future constructions. But as a matter of fact, the old buildings must also be rehabilitated according to the sustainability standards. This study has been taken up for an operational hotel building where there are no water conservation techniques in practice. Grey water recycling being the most common method for water reuse has been studied for its feasibility in this building. Various calculations were performed for water usage facilities including water required for flushing and irrigation as compared to the volume of grey water being generated by the building. It was found that the hotel building releases almost 75% of grey water daily of its average daily water requirement whereas the requirement of water for flushing and irrigating green areas came out to be 26%. A grey water treatment unit of 12,000 gallons per day (gpd) capacity was recommended to be installed at the hotel which shall replenish the water for flushing and irrigation resulting in a reduction of fresh water usage by 26% in addition to various other economic and environmental benefits. This research shall be useful for the construction industry and shall motivate the concerned authorities to rehabilitate the older buildings to make them sustainable along with new construction.

Keywords: grey water recycling; sustainability; water conservation; water reuse; flushing; irrigation

1. INTRODUCTION:

The available water resources all over the world have already rung the emergency alarm. It is due to the fact that people have been using water abundantly without even realizing that the amount of usable water for domestic purpose is in fact very limited as compared to the total amount of water available on Earth. Overtime with the increase in population, the water demand kept on increasing which resulted in decrease of surface water as well as groundwater resources. The time this reality has surfaced, the researchers and scientists have done extensive work for creating awareness about saving water as one part and developing methods to conserve this precious resource as the other part. One of the approaches for conservation of water is to reuse the used water and rely less on the fresh water use.

Grey water has been identified as one of the common sources of water which can be reused for domestic purposes after specified treatment. According to definition grey water is the used water which has not been in contact with the water coming out of water closets or urinals. This grey water is collected into a common storage facility from where the required amount of grey water is introduced into the recycling system.

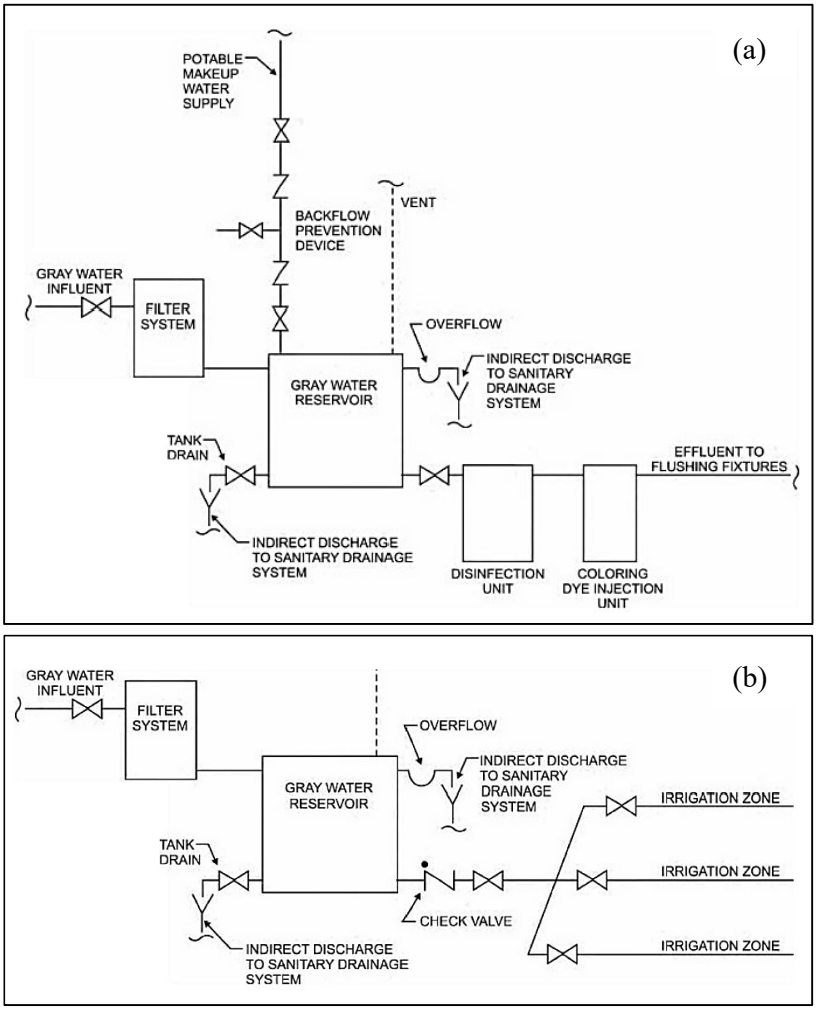

Figure 1: Typical Grey Water Recycling System and Reuse (a) for Flushing, (b) for Irrigation (IPC, 2011)

The recycling process of grey water consists of a series of treatments including physical, chemical and biological treatment methods by passing it through membranes, disinfecting with chemicals and exposing it to ultraviolet radiations respectively. The reuse of recycled grey water offers many benefits including lowering the demand of fresh water, reduction of load on sewer system, energy conservation and good plant growth resulting in reduction of overall expenses. Although the treated grey water can be used for cooling towers, chillers, industrial processes and construction activities. However, the most common use of treated grey water is supplying it for flushing toilets and irrigation of green areas (Chen et al., 2013). Common components of a grey water recycling system for the purpose of flushing toilets and irrigation are shown in Figure 1.

Having all these talks going around the world, Saudi Arabia has also started taking keen interest in water conservation and related technology. With a minimal amount of annual rainfall and having negligible surface and sub-surface water resources, the country has to rely wholly on the sea water available at its Eastern and Western coasts. To make use of seawater, Saudi Arabia has to put a lot of economic and energy resources for the process of desalination which is becoming a huge burden over the country's economy with each passing year. The water has been identified as one of the major parameter to be considered for sustainable construction activities in Saudi Arabia (Shaawat and Jamil, 2014) as well as a sustainable component for new buildings under environment criteria (Shaawat et al., 2018). Nolde (1999) shared his over a decade's experience in installing grey water recycling systems for toilet flushing in multistorey buildings in Germany. He experienced with various types of treatment units and concluded that good amount of water can be obtained after treatment which is sufficient for flushing of toilets without any hygienic risk or loss of comfort. In a similar kind of research studies, Gabarró et al. (2013) used grey water recycled water for irrigation in a sports centre. The sports centre had large green areas consisting of natural and artificial grass sections which needed to be irrigated on regular basis. The results obtained by them were good and promising quality of recycled grey water was produced by the treatment units.

It is the need of the time that water conservation measures be adopted for new construction and rehabilitation be done for the already constructed buildings to convert them to sustainable buildings. This research has been taken up with the same approach. Major aim of this research is to study the possibilities of converting old buildings into sustainable buildings in terms of water use. Water consumption is maximum in residential apartment and hotel buildings which also results in maximum grey water discharge which, if reused again, could save a huge amount of money as well as water resources collectively. This research would prove to be beneficial for the sustainable construction industry to motivate the concerned for providing recycling systems in new buildings and rehabilitate the older ones for the same.

2. EXPERIMENTAL PROCEDURES:

2.1 Data Brief:

The building selected for the case study is a multistorey hotel building located in Al Khobar, Saudi Arabia at 26^{o} 19' 20" N and 50^{o} 13' 00" E. The building comprises of 12 typical floors in addition to ground and first floor reserved for services and amenities. Each typical floor has a covered area of 9,150ft^2 and has 24 guest rooms. Figure 2 shows the 3D model of the hotel building created in Revit.

The hotel building also has a good amount of grass cover and irrigable area within the site boundary including some of it designated on roof terraces for aesthetics. Currently there is no grey water recirculation system installed at the building and the whole water requirement of the building is being met by using fresh water obtained from the seawater desalination plant located at the eastern coast of Saudi Arabia in Al Khobar city.

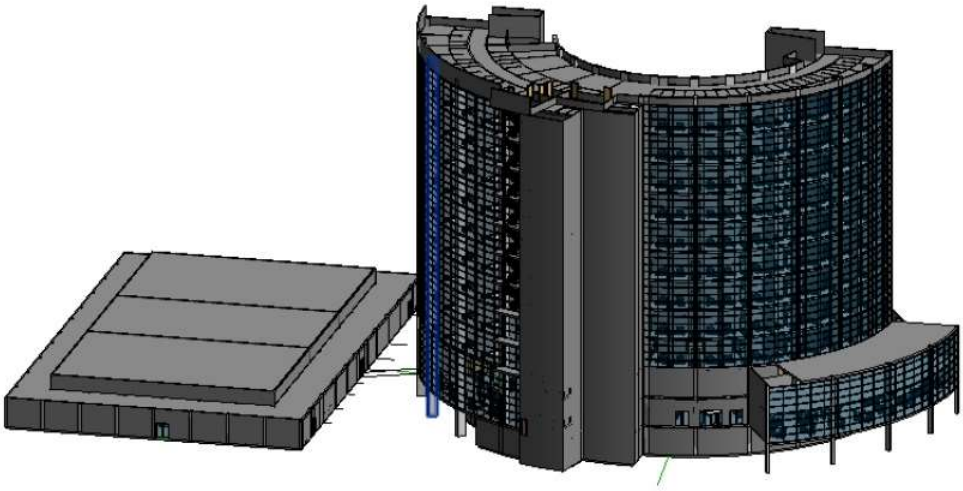

Figure 2: 3D Revit Model of Hotel Building

2.2 Research Work Methodology:

The work methodology consisted of a stepwise procedure. Figure 3 shows the workflow and the parameters required for calculation in each step. In the first step the total volume required for the building was calculated which included the demand for toilets, kitchen, laundry and cleaning etc. This demand was based on occupancy load of the building which was calculated to be 650 people maximum including staff and guests taken as at least two per room. Per capita mean water consumption was considered to be 58.6gpcd for indoor use (DeOreo et al., 2016). It is important to be noted here that this average water consumption does not include the water required for the purpose of fire fighting which is a non-recurring water demand and needs to be stored at a permanent storage facility.

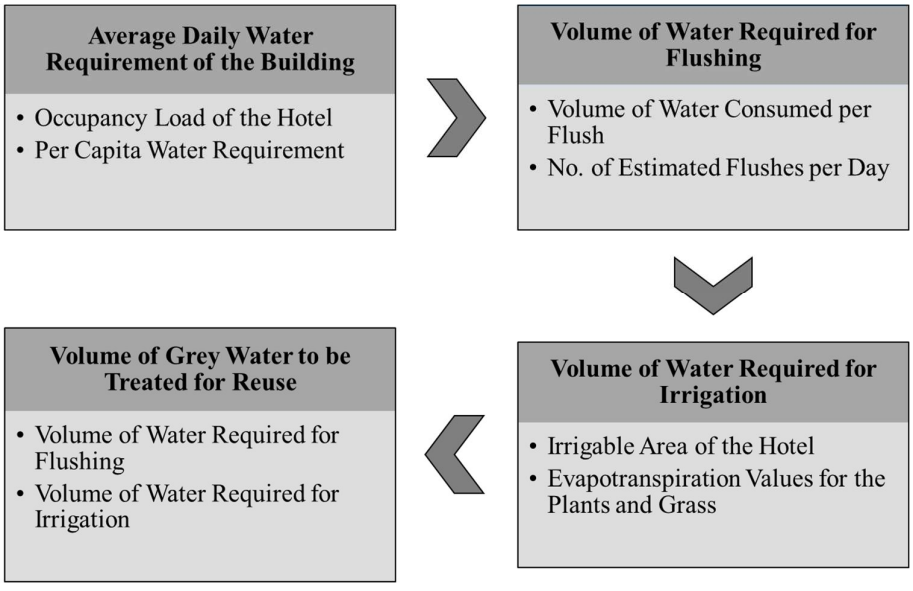

Figure 3: Methodology of Research Work along with Required Parameters

The first step of workflow was followed by the calculations for the volume of water required for flushing. For the purpose of conservation of water for the building, water saving equipments were considered to be used which consume the minimum amount of water required for the purpose. Hence for flushing, water closets with dual flush system were selected. A dual flush WC offers two options of flush volumes as required, the larger one delivering 1.6gal and the smaller providing 0.8gal per flush (IPC, 2017). An average number of flushes per day per person is found to be 5 out of which the large volume flush is found to be 1.5 on average (DeOre et al., 2016).

The third step consists of the calculation of water required for the irrigation of plants and lawn area of the building. This amount of water is not included in the indoor use of the building and it is considered that this volume of water is in addition to the average daily water requirement of the building. The total irrigable area for the building under study was found to be approximately 35,000ft^2. Potential evapotranspiration (PET) value of 0.3in/day was considered for natural grass and hot humid climate of the study area (Allen et al., 1998). The final step of the methodology was related to the overall calculation of water required and the amount of grey water which is needed to be treated and recycled for reuse. The amount of water available for recycling was also calculated in terms of percent of the total water requirement of the building.

3. RESULTS:

3.1 Amount of Water for Various Facilities

With a mean water consumption of 58.6gpcd the average daily water requirement of the hotel building was found to be 38,090gallons for an occupancy load of 650 people for indoor use only. Whereas flushing water requirement for the building was calculated as 3,380 gallons per day as shown in Table 1.

Table 1: Calculation of Water Required for Flushing

Parameter	Larger Flush	Smaller Flush
Occupancy Load	650	650
Flush Volume	1.6gpf	0.8gpf
No. of Flushes/day/person	1.5	3.5
Flush Volume	1,560gallons	1,820gallons

It can be observed from the above calculations that the amount of water required for flushing WCs makes up 9% of the average daily water requirement of the building per day. According to the report published by Water Research Foundation (DeOreo et al., 2016) the leakage losses/wastage and unaccounted for water can be taken as 12% and 4% respectively of the average daily water requirement. In the next step, by using the criteria of irrigation water demands, the volume of water required to irrigate the 35,000ft^2 lawn and green area of the hotel building was calculated to be 6,550gallons making it 17% of the average daily water requirement.

3.2 Calculation of Grey Water Reuse

By putting all statistics together in Table 2, we can determine the amount of grey water being released daily by the hotel building. It is seen that almost 75% of the average daily water requirement of the building is being released as grey water. This amount includes used water coming out from dishwashers, kitchen sinks, laundries, bathtubs, lavatories and cleaning floors etc. As already discussed that the reuse of grey water shall be considered for flushing toilets and irrigation for this research.

Table 2: Calculation for Grey Water Reuse

Source	Volume of Water	Percent of Average Daily Water Requirement
Average Daily Water Requirement/day	38,090gallons	
• Water for Flushing WCs/day	3,380gallons	9%
• Leakage Losses/Unaccounted for Water per day	6,100gallons	16%
• Grey Water Release/day	28,610gallons	75%

These two water facilities need a total of 26% of average daily water requirement equalling to 9,930gallons of water per day. Hence if a grey water recycling plant of capacity 12,000gpd is installed having a mean yield efficiency of 0.85 (Abdel-Kader, 2013) at the hotel building, that would reduce the consumption of water by 26% resulting in conservation of water and economic resources. The excess water, in the form of effluent, shall be discharged from the plant and connected to the sewer system around the building. This approach of recycling and resupplying the water to the designated usage is represented as a schematic diagram in Figure 4.

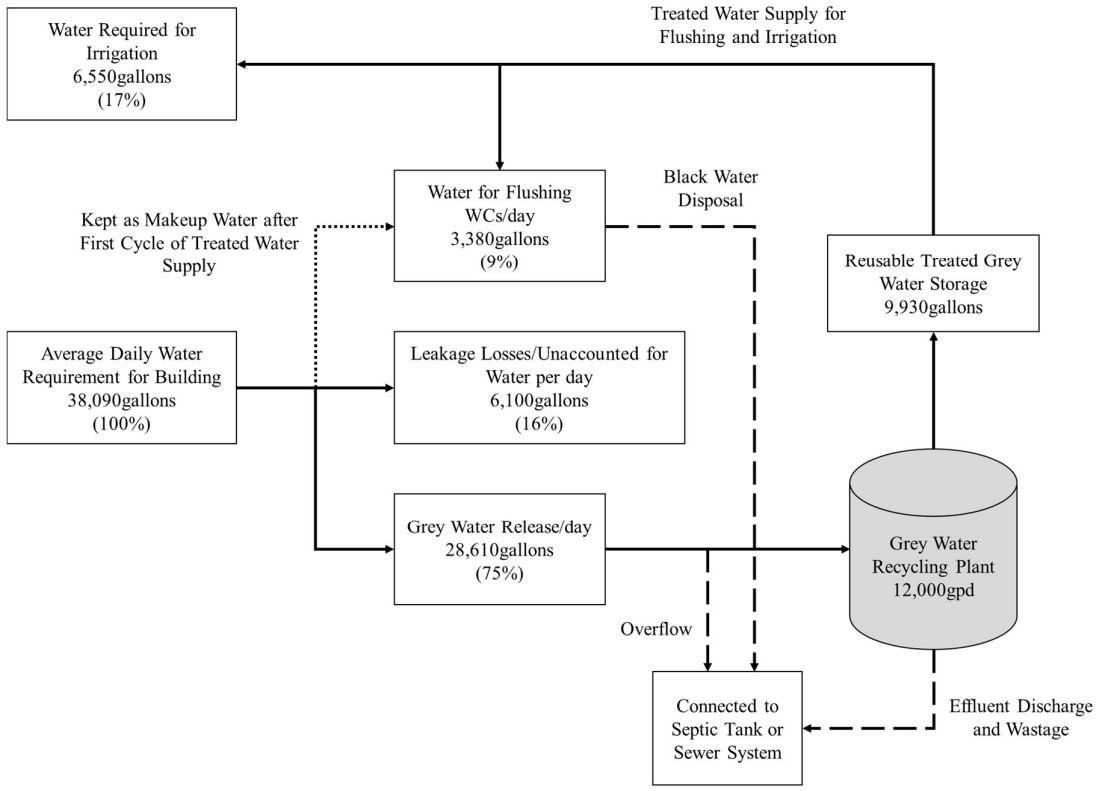

Figure 4: Schematic Diagram for Grey Water Recirculation System and Amount of Water Saved for Hotel Building

4. CONCLUSIONS:

A multistorey hotel building was put to test to study the feasibility of installing a grey water recycling system for the purpose of saving water in order to play a role towards sustainability. Various calculations were performed regarding volume of water required for flushing and irrigation in addition to average daily indoor water requirement of the whole building. Expected volume of grey water released from the building was calculated based on the preliminary calculations which helped in obtaining the required amount of grey water to be treated. It was observed that almost 75% of the used water released by the building is grey water amounting to 28,610gallons, whereas only 26% was required to be treated for reuse in flushing and irrigation processes. A grey water recycling plant of capacity 12,000gpd was proposed for the hotel building. After the first cycle of the treatment the building would be able to save 26% of fresh water which would help them in saving expenses as well. It is also recommended to the hotel authorities to extend the recycling plant by adding specific equipment and prevent the remaining part of grey water going to waste. It shall produce additional treated water which could be used for cooling towers and chillers resulting in further reduction of cost and freshwater consumption.

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