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An Analysis on Optimization of Domestic Water Conservation Practices

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Abstract

Access to clean water is an essential but scarce requirement for healthy and sustainable living. Due to indiscriminate and uncontrolled use of this resource, a large amount of wastages occur which if not checked would lead to a very unhealthy shortage. This study therefore seeks to examine conservation methods as ways of optimizing access to clean water. A review of comprehensive literature was carried out to draw a variety of important conclusions as well as field studies, focusing on the middle income households within the study area. The principle water conservation factors focused on the use of water efficient technologies and alternative forms of collection, recycling and storage of water for later use. Investigating each system individually and together as combinations provided insight on percentages of potable water that could be saved. Certain combinations saved up to 80 percent of household consumptions while other arrangements still served the purpose of conserving water but had lower percentages saved. Each system and combination was rated using a point system for different categories. These categories provided constraints for each system and determined the outcome of the favored result. In conclusion different types of complicated systems can be applied in a bid to decrease water consumption, but simple household changes which manipulate the flow rate of appliances would result in one of the most efficient methods for water conservation with respect to all constraints applied.

Keywords: optimization, water conservation, systems combinations, sustainability

INTRODUCTION

Access to clean water is easily taken for granted by many with little regard to its sustainability, and approaching scarcity. An estimated 1.24 billion people according to Jasrotia et al [1], will live in water scare-countries by 2050. Africa and some western Asian countries are particularly vulnerable. Although water occupies seventy per cent of the earth's surface, and there seems to be abundance, millions of people around the world including South Africa do not have access to potable water [2]. An estimated 52% increase in demand over the coming years, is predicted. And, as it stands, the amount of fresh water is decreasing faster than it can replenish [3]. Already, 12 million people in South Africa are reported by DWAF [4] to be without adequate potable water. With increase in population comes an increase in demand for water and consequently shortages. Availability of a reliable source of water is integral to healthy living. Unfortunately on a daily basis, large amounts of water are wasted from normal household activities. A certain percentage of this daily wastage may be saved if simple measures are implemented to change the way a typical household utilises water. Water wastage does not only affect the available of wholesome water but also increases expenditure. Majority of households have common knowledge that in practice the more water is used, the higher are the payable rates. This is the stepped up tariff which is set by municipalities for consumers. Since large percentages of water wastage ends up in the sewer system, higher volumes are sent to the wastewater treatment works (WWTW), which results in more water to be treated hence increasing costs [5].

South Africa is a semi - arid country with rainfall of 450mm/yr. with only 8.6 % of it being available as surface runoff. This is considered to be among the lowest in the world when compared with the world average of 860mm/year [3]. Ultimately management of water resources for sustainable use is not a choice but a prequisite especially in regions like South African where rainfall is low [1]. Although present needs are painstakingly being met, measures must be put in place to ensure the future is not compromised if similar needs are to be sustainable. Water Conservation is a necessity and should to be implemented to save this valuable resource. Water conservation focuses on two major aspects; the storage of water for later productive use and saving of water by using as little as possible [6]. The latter being an older concept while the former is considered new and involves the manipulation of flow rate in households. Taps, showers and water closets are major sources of water wastages in households. To reduce the amount of water consumed and by extension the amount wasted daily, water efficient technologies and products which adjust the way water is consumed, without a change in daily living is required [7]. This study seeks to examine methods to reduce the water wastages within an average South African household through effective water usage.

METHODS

Investigations carried out in DWAF [8] put the average water consumption rates for domestic use at 30% over other operations requiring use of water. Jacobs et al [9] states that the major contributor to indoor water uses and wastages are toilet flushes (73%), and shower-bath (19%). The combined total, amounts to 92% of total water consumption. This is considered alarmingly high, considering that the waste water from these systems is lost and no longer available for use. The use of improved reticulation systems through flow rate regulation, the adaptation of greywater recycling processes or harvesting of rainwater may be a viable solution in conserving water.

Flow rate regulation (System 1)

The following system concentrates on manipulating household products such as taps, showers and toilets to reduce the amount of water consumed daily. The introduction of these new appliances will have a positive effect in adjusting the way water is consumed by effectively regulating the flow rates of the appurtenances. The Installation of water efficient products such as low flow tap, shower heads and dual flush toilet system can be applied in any household without affecting the day to day activities of the household and comprise to the health and safety of members of the household [7].

Taps

Taps have different flow rates. When the flow rate is high, high volume of water than is required, is ejected through the tap nozzle, which results to wastage. The use of water efficient taps would go a long way towards water conservations. Water efficient taps are fixed with tap aerators which amplify the supposed volume and flow of water. A standard tap releases between 15 and 18 litres of water per minute while a water efficient tap supplies 6 litres per minute [5].

Shower heads

Shower heads work on the same principle of flow as taps. The more flow the more water consumed. Therefore changing the shower head will also effectively save water. A standard shower head uses 15 to 25 litres of water per minute as compared to a water efficient shower head which uses 6 to 8 litres per minute [5].

Toilets

Single flush cisterns are the most commonly used models in households. For each flush 10 to 13 litres of water is utilized and removed from circulation. However to conserve water, dual flush toilets which require about 3 to 6 litres of water per flush, would be a better option. Dual flush toilets have 2 handles or buttons; one is to trigger a full flush for solids and the other to activate a minimal flush for liquids [5].

Greywater harvesting (System 2)

Greywater refers to untreated wastewater which is not contaminated by toilet waste. It comprises of water discharged from bathtubs, showers, hand basins, laundry tubs, floor wastes and washing machines. Water released from the dishwasher, kitchen sink or garbage disposal is not included [10]. This generally requires management and treatment such as screening, oil & grease removal, filtration, and disinfection if the water is required for potable use. Exall [11] considered re-use of greywater for non - potable use as an alternative towards water conservation. Its suitability for use in operations as landscaping, watering outdoor gardens, and flushing toilets is discussed in Palaniappan [7] and Zadeh et al [12]. Grey water quality is however vastly variable; the main reason for this is that household social preferences differ [13]. Additionally, commercial products such as soap and laundry powder influence greywater quality and can have an immense effect on garden health, groundwater, soil and the type of greywater treatment technology employed [14]. According to Exall [11] high levels of fecal coliform bacteria are higher in soils irrigated with grey water than with potable water. Although this may pose a slight problem the safest reuse of grey water is through subsurface irrigation of gardens or lawns to reduce human contact. Households which use the grey water systems for toilet flushing must utilise a treatment process that includes coarse suspended solid removal, disinfection and turbidity reduction [13].

Rainwater harvesting (System 3)

Rainwater harvesting requires the collection of rainwater from rooftops through a guttering system [15]. Rainwater is collected from the roof where the first litres are discarded as waste, after which the water is filtered and piped to a storage tank located in the household for future use [16]. Rainwater harvesting is regarded as a valuable means of alternative non potable water supply capable of providing relief to domestic water supply [17, 18]. For harvested rain water however, the eventual use of the water is a determinant on the type of treatment administered to it. Rainwater should be considered as a supplementary supply for non-potable use since it could pose a health risk [19]. In times of dry weather, dust and other pollutants accumulate on the roof surfaces which are washed off at the beginning of the next rain period [15]. Hence the first flush system should be implemented in any rainwater harvesting system to reduce water contamination. A typical system consists of a collection surface (rooftop), a conveyance system (gutters), treatment method (first flush diversion) and storage tank [15]. There are many available options for the design of each component many of which are not appropriate for every situation [15].

Data Analysis

The data used in this research includes; number of occupants per household, water consumption rate for middle income households, the time of usage of water in terms of flow rate, roof surface area, runoff coefficient and average rainfall data for the KwaZulu Natal region. Other considerations include cost, payback, health risks, social aspects, management and environmental aspects.

System 1

For this system the main engineering factor considered was that of flow rates. Simple fluid principles were applied to determine actual and new flow rates. These flow rates helped investigate how much water is used daily and how much can be saved.

System 2

In the greywater system, an estimated 37% of greywater is produced by a household. 25% of this amount is required for toilet flushes or irrigation purposes, while the excess is discharged as overflow to a different stream line. This stream line could recycle the water further or end in the sewer system as illustrated in Figure 1.

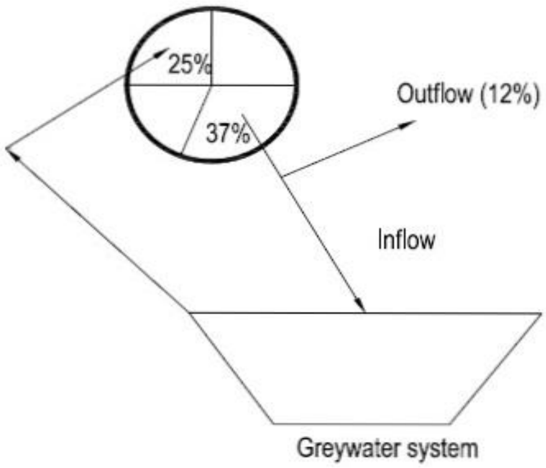

Figure 1: Flow process for Greywater system

System 3

In this system, run off flow is a function of the roof size. The larger the roof, the higher the run-off flow the converse is the case for smaller roofs. The rainwater obtained from a roof in a year is estimated as the product of the annual rainfall and the roof's plan area. In the tropics 75% of this water runs off the roof while 25% is usually lost to evaporation and splashing occurrences. However rainfall intensity could also be considered a factor in amount of available rainwater for harvesting. The flow process is illustrated in Figure 2 and 3 with consideration given to time of year.

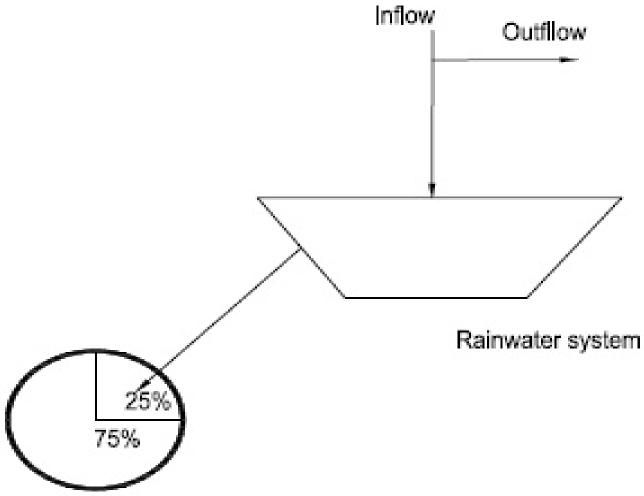

Figure 2: Flow process for Rainwater system A

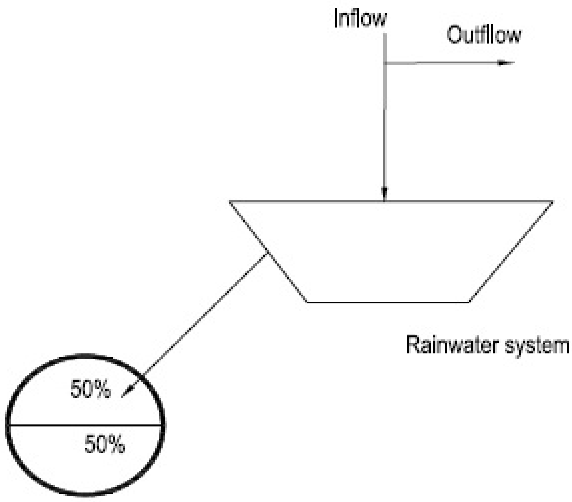

Figure 3: Flow process for Rainwater system B

RESULTS AND DISCUSSION

System 1

System 1 manipulates the total water consumption by the highest percentage regarding each system considered individually. When applied to a household results indicate 52 % saving when the maximum water consumption is considered. This results in the municipality supplying only 48 % of total water as opposed to the 100% normal supply. With an annual saving of 164 kl/household/year which provides much needed relief as it is 52 percent less water required.

System 2

The total amount of greywater produced in a household amounts to 37% of total water consumption. For the purpose of system 2 only 25% is required for irrigation hence the supply will always meet the demand. The remaining 12% will be discharged as overflow before the filtration process and pumping processes. This is done to ensure that the filter and pump will only be utilized for the required amount of water needed for irrigation purposes. This system saves a total 25 percent of the total water consumed. This amounts to an annual saving of about 79.2 kl/household/year.

System 3

Primary data analyzed for this system was that of rainfall. Rainfall is an important determinant in this system. Consequently, high amounts of rainfall would result to higher amount of water available for harvest. Therefore, months which experience dry periods would result to no water in the system unless previously stored in times of heavy rainfall. However the analysis shows that on an average between peaks of rainfall, there is average water saving of 17% annually.

Comparison of Systems

Comparisons of each system in terms of amount of water saved and cost reduction is shown in Figure 4 and 5. However, to further determine the best conservation method, the systems were combined as shown in Table 1 and the matrix of results considering all variables is shown in Table 2:

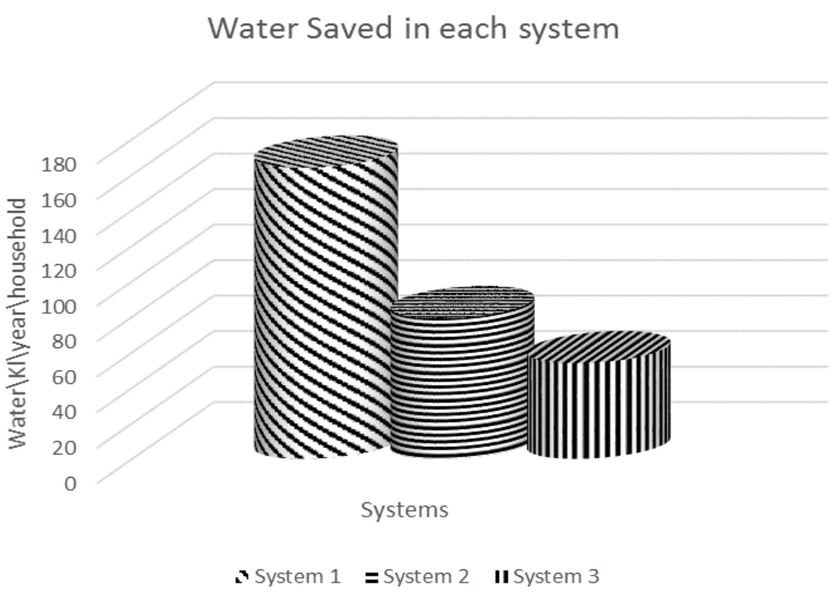

Figure 4: Comparison of systems in terms of Water saved

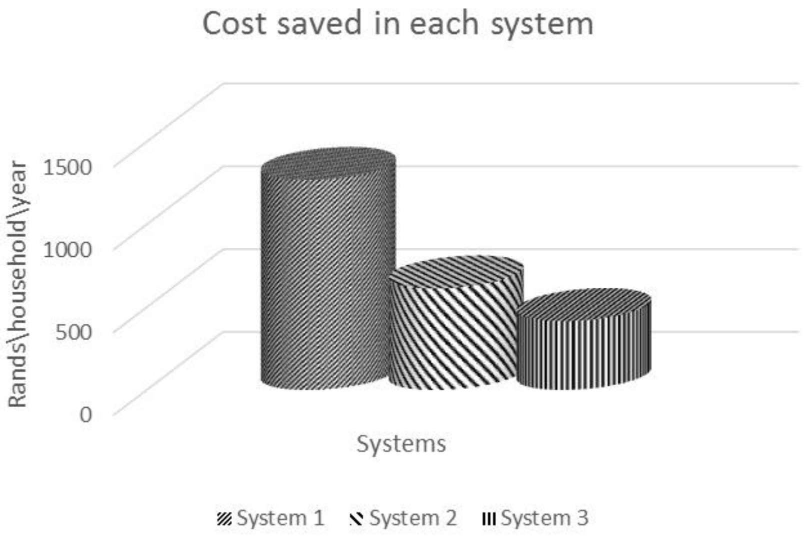

Figure 5: Comparison of systems in terms of Rand saved

Table 1: Combination systems for water conservation

Combination A = System 1 + System 2	System 1(Manipulation of flow rates)
Combination B = System 1 + System 3	System 2(Greywater recycling)
Combination C = System 2 + System3	System 3(Rainwater harvesting)
Combination D = System 1 + System 2 + System 3	

Table 2: Matrix of results

System	Cost	Payback	Health Risks	Social Aspect	Management	Environmental Aspect	Conservation	Total
1	7	7	7	7	7	4	2	41
2	5	4	4	6	5	3	1	28
3	6	1	5	5	6	3	1	27
Comb A	4	1	4	4	4	2	3	22
Comb B	3	5	5	3	3	3	4	26
Comb C	3	5	5	3	3	5	5	29
Comb D	1	3	3	1	1	6	6	21

Three systems were applied to middle income households to determine a percentage of water saved for a period of one year. Within the period different trends of water usage and rainfall data were analyzed. This was done so that supply of water to each system could be compared to demand needs. Values are justified from aspects considered in the literature review. The literature review influenced categories such as health risks, social aspects, management and the environmental analysis. All the categories were critically investigated to determine the most correct point scheme. When the systems are combined all categories in the table show increase in water conservation, and the relationship between water conservation is directly proportional to the number of systems in use.

CONCLUSION AND RECOMMENDATION

The study sought to investigate and experiment water conservation through utilization of different water conservation methods. The three systems employed manipulation of flow Rate, greywater recycling, rainwater harvesting highlighted in the investigation was found sufficient. Further optimization in terms combining different systems was carried out which led to increases in amount of potable water saved. Based on the results combination D serves as the best outcome for conserving water. Although combination D as shown in table 3 provides the most water conservation, it scores low in terms of cost considering that middle income households are the focus for this study. System 1 however individually scores the highest on the table examining all categories considered. Therefore this is regarded as the best system for implementation within any middle income household since it is cheap, has the best payback and still serves the purpose of conserving at least 50% of total water consumed.

It is necessary to note that though different types of complicated systems can be applied in attempting to decrease water consumption, simple household changes which manipulate the flow rate of appliances would result in one of the most efficient method for water conservation with respect to all constraints applied.

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