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Study of effect of the hydraulic retention time on grey water quality

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Abstract
Water pollution is one of the concerns in front of developed and developing countries. The deterioration of water quality due to urbanization, industrialization, deforestation, overcrowded population are some of the causes behind contamination which results in increasing water scarcity. It emphasizes need of purification before release of untreated water. It is an opportune time, to refocus on one of the ways to recycle the greywater which water from showers, bathtubs, sinks, kitchen, dishwashers, laundry tubs, and washing machines through reuse of urban wastewater for irrigation and other purposes. For that, Grey water treatment plant was designed for capacity of 24 lit per day. The two PVC candles of diameter 90 mm and height of 1200 mm were used. The first candle contains 15 cm, 30 cm and 45 cm for gravel, charcoal and grit, respectively set from bottom to top in the filtration unit of first column. Also depth of each bed were selected 15 cm, 30 cm and 45 cm for gravel, broken brick and sand, respectively set from bottom to top in filtration unit of second column.The inflow rate varied from 0.04643 lps to 0.008793 lps at 100%, 75%, 50%, 25% open area if controlling valve. Grey water PH value were between 5.6-5.9 while filtered water showed PH values between 5.9-6.5. The EC of the grey water before filtration was in range 160-210 µS/ppm while after flirtation values ranged between 150-180 µS/ppm. The hydraulic retention time increased from 1.83 to 52.53 hours at opening percentage of 100-25.

Keywords: Hydraulic retention time, inflow rate, grey water, wastewater

Introduction

India, being an economy in transition from a developing to a developed nation, faces two major problems. On the one hand there is a lack of infrastructure and on the other, an ever-increasing urban population. The urban population in India has jumped from 25.8 million in 1901 to about 387 million in 2011. This has thrown up two self-perpetuating problems, viz. shortage of water and sewage overload. It is estimated that by 2050, more than 50 percent of the country's population will live in cities and towns and thus the demand for infrastructure facilities is expected to rise sharply, posing a challenge to urban planners and policymakers.

The rapid growth of urban population has taken place due to huge migration of population (mostly from rural areas and small towns to big towns) and inclusion of newer rural areas in the nearest urban settings, apart from natural growth of urban population. The majority of towns and cities have no sewerage and sewage treatment services. Many cities have expanded beyond municipalities, but the new urban agglomerations remain under rural administrations, which do not have the capacity to handle the sewage. Management of sewage is worse in smaller towns. The sewage is either directly dumped into rivers or lakes or in open fields.

Water is an essential commodity on earth for all living organisms. Water quality plays important role in life of every living being. Pure and clean water and water resources is very important for maintaining an adequate food supply, environment, health and development. The deterioration of water quality due to urbanization, deforestation, contamination, tremendous increase in population are some of the agents for deterioration of water quality and which results in the increasing water scarcity. It is an opportune time, to refocus on recycling of the water through reuse of urban wastewater for irrigation and other purposes. This could release clean water for use of sectors that need fresh water and provide wastewater to sectors that can utilize wastewater viz. irrigation and other ecosystem services. In general wastewater comprises liquid wastes generated by households, industry, commercial sources, as a result of daily usage, production and consumption activities. The disposal of the wastewater is a major problem faced by municipalities, particularly in the case of large metropolitan areas, with limited space for land based treatment and disposal. On the other hand, waste water is also a resource that can be applied for productive uses since wastewater contains nutrients that have the potential for use in agriculture, aquaculture and other activities.

Grey water is wastewater that is discharged from a house, excluding black water (toilet water). It includes water from showers, bathtubs, sinks, kitchen, dishwashers, laundry tubs, and washing machines. It commonly contains soap, shampoo, toothpastes, food scraps, cooking oils, detergents and hair. Grey water makes up the largest proportion of the total wastewater flow from households in terms of volume. Typically, 50-80% of the household wastewater is grey water. Characteristics of greywater are highly variable Albalawneh *et al.* (2015) [15]. If a composting toilet is also used, then 100% of the household wastewater is grey water. Not all grey water is equally "grey". Kitchen sink water laden with food solids and laundry water that has been used to wash diapers are more heavily contaminated than grey water from showers and bathroom sinks. Therefore, different grey water flows may require different treatment methods that would render the water suitable for reuse.

Media filtration is one of the simple and popular way used everywhere. Media filtration includes percolation of untreated water slowly through a bed of porous sand, with the influent water introduced over the surface, and then drained from the bottom. Hydraulic retention time also called as the hydraulic residence time plays essential role in filtration process. Hydraulic retention time is the measure of average length of time that a compound (water) remains in a storage unit or in contact with media. It is measured in hours (and sometimes in days). Hydraulic retention time is volume of storage per unit influent flow rate and influent flow rate is measured in cubic meter per hour.

Materials and Methods

Experimental Site

The study was conducted by using grey water of Jayprabha girls hostel of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (MS). It is located in the humid and tropical region on the west coast of Maharashtra. It is situated at an altitude of 280 m MSL at $17^0 12$ North latitude and $73^0 12$ East longitudes. The average annual minimum and maximum temperature of Dapoli are 11.4 °C and 32.7 °C respectively; whereas relative humidity ranges from 43.7 to 95.2 percent.

Grey Water Filtration

For the present study, Grey water treatment plant developed by Department of Irrigation and Drainage Engineering, College of agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli was used. Grey water treatment plant was designed for capacity of 24 lit per day. The designed grey water plant includes two PVC candles of diameter 90 mm and height of 1200 mm. The first candle contains 15cm, 30 cm and 45 cm for gravel, charcoal and grit, respectively set from bottom to top in the filtration unit of first column. The second candle contains 15cm, 30cm and 45 cm for gravel, broken brick and sand, respectively set from bottom to top. Supply pipe, connecting pipe and delivery pipe used were of 16 mm diameter. Also, air vent of 16 mm diameter was installed at the top of both candles. Drain valve of 16 mm diameter were installed at the bottom of both the candles. The head difference between outlet of storage tank and waste water treatment plant was 1.5 m. The screen filter of 1 inch (32 mm) having capacity of 7 m^3/hr was installed after second candle. The other accessories used for study includes pH meter, Electrical Conductivity meter, Storage and Supply tank of 20 litres capacity etc. The line diagram of the grey water filter is shown in Fig.1 and design parameters are showed in Table 3.

The gravitational force was used for the flow of grey water. The flow rate of feed raw water was controlled by the manual control valve of size 16 mm. The raw grey water was collected in storage tank having capacity of 20 litres which can act as settling tank. The Filtered water was collected in separate tank. Then treated water samples were analyzed by standard method. At constant operating head, best HRT was selected from available data.

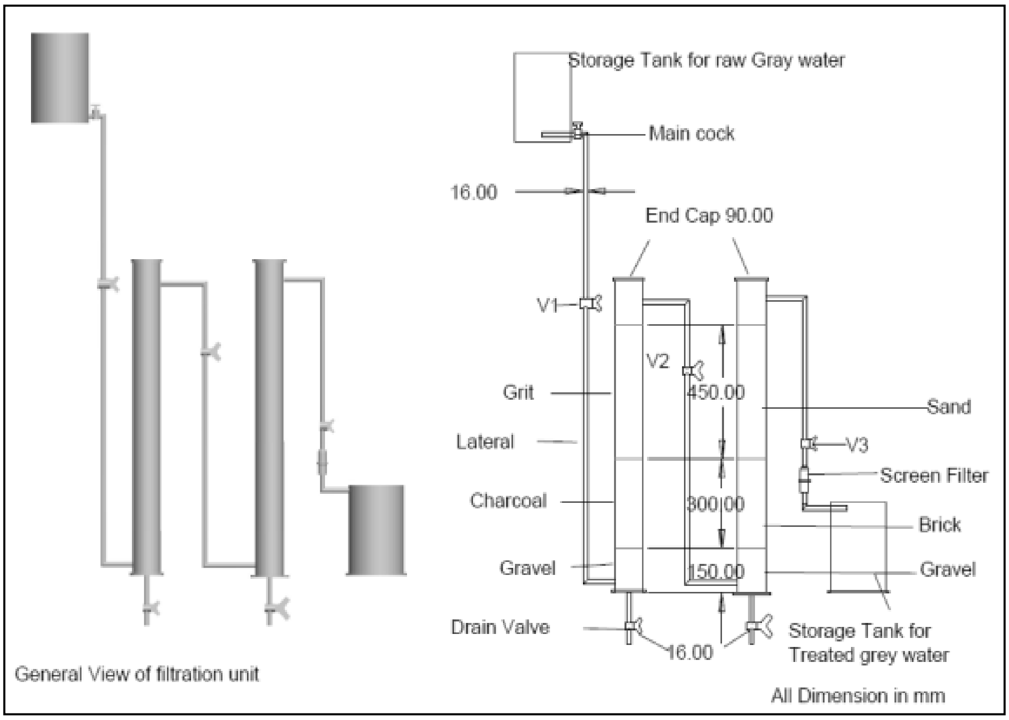

Fig 1: Grey Water Treatment Plant

Hydraulic retention time (HRT): Hydraulic retention time, mathematically; it is expressed as

HRT = V / Q

Where,V = Volume of Tank, m^3, Q = Influent Flow Rate, m^3/hr (sometimes in m^3/day also),
HRT = Hydraulic Retention Time, hours or days

HRT based analysis of Domestic grey water

Control of Inflow rate

The desirable hydraulic retention time was maintained by controlling inflow valve of grey water treatment plant. The valve opening was tested at 100, 75, 50, and 25 percent at constant operating head of 1.5 m. HRT based filtration and analysis of pH and EC of the grey water gives the best hydraulic retention time for achieving best filtration quality

pH

The effect of pH on the chemical and biological properties of liquids makes its determination very important. It is one of the most important parameter in water chemistry and is defined as -log [H^+], and measured as intensity of acidity or alkalinity on a scale ranging from 0-14. If free H^+ are more it is expressed acidic (i.e. pH<7), while more OH^- ions is expressed as alkaline (i.e. pH> 7).In natural waters pH is governed by the equilibrium between carbon dioxide/bicarbonate/carbonate ions and ranges between 4.5 and 8.5 although mostly basic. It tends to increase during day largely due to the photosynthetic activity (consumption of carbon-dioxide) and decreases during night due to respiratory activity. Waste water and polluted natural waters have pH values lower or higher than 7 based on the nature of the pollutant.pH is an indicator of the acidity or basicity of water but is seldom a problem by itself. The normal pH range for irrigation water is from 6.5 to 8.4; pH values outside this range are a good warning that the water is abnormal in quality. Normally, pH is a routine measurement in irrigation water quality assessment.

Electrical conductivity

Conductivity (specific conductance) is the numerical expression of the water's ability to conduct an electric current. It is measured in micro Siemens per cm and depends on the total concentration, mobility, valence and the temperature of the solution of ions. Electrolytes in a solution disassociate into positive (cations) and negative (anions) ions and impart conductivity. Most dissolved inorganic substances are in the ionised form in water and contribute to conductance. The conductance of the samples gives rapid and practical estimate of the variation in dissolved mineral content of the water supply. Conductance is defined as the reciprocal of the resistance involved and expressed as mho or Siemen (s).

Results and Discussion

The experiment is repeated four times and average observation of pH, EC and HRT were taken for the analysis. The results of the experiment are presented as below

Inflow rate

The data regarding inflow rate at 1.5 m operating head is presented in the Table 1. Table 1 shows that desired inflow flow rate is to be set up at 1.5 m operating head by opening required percent of controlling valve. It is also found that the inflow rate reduces with the reduction in open area of the valve. The maximum flow rate of 0.04643 litres per second was found at 100 percent opening of control valve while minimum of 0.008793 litres per second was at 25 percent.

Effect of Inflow rate on hydraulic retention time

The effect of inflow rate on hydraulic retention time is presented in Table 2. From Table 2, it is observed that with reduced inflow rate hydraulic retention time increases. The hydraulic retention time was found 1.83 hrs for 100 percent inflow rate followed by 12.66, 25.33 and highest of 52.53 hrs for 75, 50 and 25 percent valve opening respectively.

Effect of Hydraulic Retention Time

The properties of grey water such as PH and EC are tested before and after filtration through grey water filter and presented in Table 2. From Table 2, it is observed that, hydraulic retention time plays important role on pH and EC of filtered water.

It observed from study that quality of gray water is not constant and varies with space and time. This variation in the PH and EC values of the raw grey water is attributed to the daily changes in the content of the water coming from source. It implies that water quality is not constant throughout the day or in season. From Table 2, it is seen that, the pH and EC values of grey water varies between 5.6 to 5.9 and 160 to 200 mS/cm within space and time respectively.

From Table 2, it is also observed that the values of all pH after the filtration were increased. It shows due to filtration, some of the chemicals were filtered out and pH tends to achieve desirable range of irrigable water. Before filtration, water is in most acidic state and is unsuitable for direct irrigation is to be used for irrigation after filtration. Hydraulic retention time has prominent effect on pH. The percent variation in the pH before and after filtration is 3.30, 8.19, 6.34 and 12.30 percent at 100, 75, 50 and 25 percent inflow. Variation in the pH is maximum i.e. 12.30 with highest hydraulic retention time i.e.52.53 hrs. Variation in the pH was minimum with low hydraulic retention time. Study found that for brining pH of the gray water within irrigation water range, hydraulic tension time is to be kept maximum as possible.

From table 2, it is observed that, hydraulic retention time has profound effect on electrical conductivity. Study showed that the values of electrical conductivity for every hydraulic retention time after the filtration was decreased. From percent reduction in electrical conductivity, it is observed that maximum percent reduction in electrical conductivity was found in 12.66 hrs HRT i.e. 11 percent followed by 1.83 hrs i.e. 10 percent. The 25.33 and 52.53 hrs HRT showed less reduction in electrical conductivity of filtered water. But overall reduction in electrical conductivity was found after filtration. The decrease in the EC is due to use of media for filter design. The maximum EC value of 180 µS/ppm was found at 100 percent while minimum EC value 150 µS/ppm was at 25 percent respectively. The increase in the HRT also brings EC of the grey water lower level.

Table 1: Inflow rate at various opening percent

Sr. No.	Opening percentage	Flow rate, Q (lit/sec)
1	100%	0.04643
2	75%	0.03081
3	50%	0.02115
4	25%	0.008793

Table 2: Effect of Hydraulic Retention Time

Sr. No.	Opening percentage	Grey water		Filtered water		Average HRT, hrs
		Average PH	Average EC, mS/cm	Average PH	Average EC, mS/cm	
1	100%	5.7	200	5.9	180	1.83 hrs
2	75%	5.6	190	6.1	170	12.66 hrs.
3	50%	5.9	170	6.3	160	25.33hrs
4	25%	5.7	160	6.5	150	52.53hrs

Parameters of filtration media

Table 3: Designed parameters of filtration media of small scale domestic waste water treatment plant

Sr. No.	Design Parameter	Results obtained
1.	Discharge (Q)	24 lit/day
2.	Flow velocity (v)	3.8 m/day
3.	Surface area of filter bed (A)	6.35×10^{-3} m^2
4.	Hydraulic Loading Rate (HLR)	3.77 m/day
5.	Volume of filter unit (v)	$0.011m^3$
6.	Hydraulic Retention Time (HRT)	1.3 hrs
7.	Average interstitial velocity (V_a)	9.7m/day
8.	Equivalent vertical hydraulic conductivity (K_z)	8.18 m/day
9.	Types of flow through filtration media on the basis of Reynolds number (N_R) 1. Gravel 2. Grit 3. Sand 4. Broken brick 5. Charcoal	All are Laminar flow
10.	Frictional head loss through media, (h_L)	1×10^{-3} m

Conclusion

The inflow rate varied from 0.04643 lps to 0.008793 lps at 100%, 75%, 50%, 25% for different control valve open area. The hydraulic retention time was found 1.83 hrs for 100 percent inflow rate followed by 12.66, 25.33 and highest of 52.53 hrs for 75, 50 and 25 percent valve opening respectively. Study showed for brining pH of the gray water within irrigation water range, hydraulic tension time is to be kept maximum as possible. It is observed that maximum percent reduction in electrical conductivity was found in 12.66 hrs HRT.The filtration quality of grey water improves with increase in the hydraulic retention time.

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