TECHNOLOGICAL UP- GRADATION OF GREY WATER TREATMENT SYSTEM

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ABSTRACT

Grey water recycling is now accepted as a sustainable solution to the general increase of the fresh water demand, water shortages and for environment protection. However, the majority of the suggested treatments are biological and such technologies can be affected, especially at small scale, by the variability in strength and flow of the grey water and potential shock loading. The present work is to increase the efficiency of the grey water filtration system by selecting appropriate design and use of suitable natural indigenous and synthetic materials. Presently many researchers work, by incorporating solutions to the existing problems, an innovative design/method is considered in designing the unit along with technical inputs and modifications i.e. different filtration layer, filter materials modification, layer thickness optimization, low maintenance, simple method, and cost effectiveness. It allows safe and sustainable use of grey water for landscape irrigation and non-potable use in small community and households. Finally, in providing grey water for reuse, both the demand for drinking water and the amount of wastewater generation can be reduced. It is an important step to fulfill per day water need and finally save the potable water used for low grade need of water.

*A single design unit of grey water treatment can provide two grades of water (GW1 & GW2) by using various level of treatment and their respective uses. In our research, conventional and economical way of grey water treatment followed by Sand, Charcoal, and foam covered with PP yarn and/or UV treatment (natural source/ UV lamp) method. It is expected to reproduce approximately **70-80%** of the total grey water produce from the house hold which may save more than 3 times of the fresh water needed by a family. Initially, treatment unit for single house hold (flat or independent house) is targeted in the present preposition. This way the proposed grey water treatment unit can be further used in hotels as well as high-rise buildings to fulfill the non-potable water needs.*

In treatment unit, Grey water (before treatment) passes through SS sieve - to remove big food particulates, hair, plastics, and major suspended impurities. A high density foam or foam with polypropylene yarn is placed to pre-filter the grey-water to remove more than 70-80% of total suspended solid particles (BOD and COD *level to some extend). This filtration (GW2) quality with less contamination may be re-used for agriculture purpose.*

Further, to improve the grey water quality (remove odour, smell, microbes, Bacteria, nitrogen, phosphorous) for cloth washing use, sand/charcoal will be used. The charcoal (silver impregnated) layer absorb gases and reduce the smell from waste water. The charcoal treated water will pass through sand filter to remove the remaining TSS and TDS in the treated water. To kill the bacteria, virus and microbes, sunlight (summer season) and in winter season or rainy season, ultraviolet lamp (with 8-16W) can work inside the quartz tube (allow 90% of the UV radiation pass through) at 253.7 nm wavelength from continuous flow of 1 liter/min of water. The quality of grey water (GW1) can be used for cloth washing, floor cleaning, etc. The cost of the grey water treatment unit (excluding sample testing and pilot-scale study) for 4-5 member family is estimated 10000 Rs. only for during 1.5 year maximum.

The economical performance of the plant for treatment of bathrooms, basins and laundries gray water showed in terms of deduction competency of water pollutants such as COD (83%), TDS (70%), TSS (83%), total hardness (50%), oil and grease (97%) and ions (46%). Hence, this technology could be a good alternative to treat gray water in residential area.

KEYWORDS: *Grey water, Gray water treatment unit, natural technology, pollutant.*

1. INTRODUCTION

With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. Alternative sources of water can potentially save significant amounts of precise fresh water. One alternative source of water is gray water. Scientists around the globe are working on new way of conserving water. It is an opportune time, to refocus on one of the technique to recycle water—through the reuse of gray water by economical way. Gray water is non-industrial waste water generated from domestic processes such as washing dishes, laundry and bathing. Gray water is distinct from black water in the amount and composition of its chemical and biological contaminates (from feces or toxic chemicals). Dish, shower, sink, and laundry water comprise 50-80% of residential waste water [1], [2].

Domestic in-house water demand in industrialized countries consists of 30–60% of the urban water demand and ranges between 100 to 150 l/c/d (litre/capita/day), of which 60–70% is transformed into grey water, while most of the rest is consumed for toilet flushing. Grey water reuse for toilet flushing (if implemented) can reduce the in-house net water consumption by 40–60 l/c/d, and urban water demand by up to 10–25%, which is a significant reduction of the urban water demand (additional reuse for garden irrigation may further reduce the overall demand)[3].

Gray water treatment is an environmental friendly process as a control of water pollution. Many people have investigated the various waste water treatment methods extensively on the international and national levels and many researchers tried to reduce the cost for recycling of the water. The household gray water can be reused for other purposes, especially landscape irrigation, floor washing, car washing and toilet flushing. Grey water has some pollutants that are considered as fertilizer for the plants. Phosphorous, nitrogen, and potassium are excellent sources of nutrients when reusing gray water for irrigation of landscaping and gardens. Benefits of grey water include using less fresh water, sending less waste water to septic tanks or treatment plants, less chemical use, groundwater recharge, plant growth, and raises awareness of natural cycles [4] – [8].

Throughout the world, supply of water to the urban and rural population has been a challenging risk. In India, the 'water shortage' is one of the major issues coming from the both of areas. Our designed gray water treatment process is like a low technology systems, also called extensive or natural systems, are based on filtration system by selecting appropriate design and use of suitable natural indigenous and synthetic materials. Developed unit may be able to recycle 70-80% of the total grey-water produced which saves the potable water used for low grade water need. From single unit, treated water produced will be of two grades - GW1 & GW2 which can be used for different non-potable purposes i.e. gardening, washing, cleaning, etc. The designed grey-water treatment unit will be proposed for big housing project through state agencies after its successful development. In presently many researchers work, by incorporating solutions to the existing problems, an innovative design/method is considered in designing the unit along with technical inputs and modifications i.e. different filtration layer, filter materials modification, layer thickness optimization, low maintenance, simple method, cost effectiveness, etc. [9] It allows safe and sustainable use of grey water for landscape irrigation and non-potable use in small community and households. Finally, in providing grey water for reuse, both the demand for drinking water and the amount of wastewater generation can be reduced. It is an important step to fulfill per day water need and finally save the potable water used for low grade need of water. The pollutants of gray water are reduced by a treatment system (laboratory scale) was the aim of this study. This is a socio-economical treatment method gives the wide significant in the rural and urban development.

2. METHODS AND MATERIAL

Present design of grey water treatment unit for a single household (4-5 members) which included optimization of all operating parameters (pH, TDS, TSS, BOD, COD, PO_4^{2-}, SO_4^{2-}, NO_3^-, and NO_2^- etc.) and selection of filtration materials/process as per the quality of grey water. In single house, the average water consumption is 1200-1500 liters (@ of 300 liters/person/day) and out of total water consumption, about 63% (750 liter) is grey water which can be reused. The grey water mainly contains TSS and TDS which generates BOD and COD along with organic impurities in the form of pathogen, nitrogen, phosphorous etc. The choice of filtration technique and materials may give efficient output and will be based on impurities i.e. organic (oil, pathogens, microbes, viruses, nitrogen, phosphorous, etc) and inorganic (Na, K, etc.) present in grey water. The conceptualization diagram of this treatment unit is present in figure -1.

For grey water treatment, experimental research work will be implemented in designing a unit with continuous or intermittent flow of 16-20 liters/hour (with 5-6 liter of GW-holding capacity) of grey-water. Grey water treatment unit comprise of the following parts i.e. SS/plastic sieve, foam with synthetic fiber (pp-yarn), Charcoal, Sand, Gravel/sieve – support, UV lamp along with plastic and glass tubes, pump, valves, etc.

Different stages filtration is proposed in the targeted specification of the materials used (grit, foam and fiber layer sufficient to remove 200/100/50 micron size particle impurities. Grey water (before treatment) pass through 5 - 2 mm mesh SS sieve - to remove big food particulates, hairs, plastics, major suspended impurities. A high density foam or foam with Polypropylene yarn is placed to pre-filter the grey-water to remove more than 70-80% of total suspended solid particle (BOD and COD level to some extend). This filtration will also help to avoid clogging/choking of charcoal/sand layer (particle size – 200/100/50 microns). A provision will be given for overflow to avoid excess of grey water from inlet flow. The grey water of this quality with less contamination may re-use for agriculture purpose (GW2).

Further, to improve the grey water quality (remove odor, smell, microbes, bacteria, nitrogen, phosphorous) for cloth washing use, sand/charcoal (in 1-2 layers with 10-20 cm bed size will be used. The Charcoal (silver impregnated) layer (25 cms approx. height) with particle size range of 0.7-1.0 mm absorb gases and reduce the smell from waste water. The charcoal treated water will pass through sand filter (particle size: 0.1-0.2 mm, bed size: 20 cm approx.) to remove the remaining TSS and TDS in the treated water. The gravel size of 8-12 mm was placed at the bottom layer to prevent material losses and holes blockage. To kill the bacteria, virus and microbes, sunlight (summer season) and in winter season or rainy season, ultraviolet lamp (with 8-16W) can work inside the quartz tube (allow 90% of the UV radiation pass through) at 253.7 nm wavelength from continuous flow of 1 liter/min of water. Also the microfiltration membrane is used for oxidation process of grey water for removing pollutants is mentioned in literature [10]. In between the layers a filter cloth was placed. The reason for this is that the filter cloth prevents the filter materials from mixing and therefore the layers are easier removed from the vessel. The testing at this stage is only done with tap water so the filter cloth does not distort the testing.

The quality of grey water (GW1) can be used for cloth washing, floor cleaning, etc. The flow rate of feed raw water was controlled by the manual control valve. The gravitational force was used for the flow of water from primary filtration level to final filtration level.

The present method include, sand filtration, and/or charcoal filtration with gravels (to retain the sand and to store water in the filtration system). The problem with such filter is clogging/choking of sand bed with the suspension of particulate impurities present in grey water. Analysis of impurities biomass accumulation and deposition of suspended solid at the surface of sand filter is studied [11]. No proper design in filtration system is introduced to avoid clogging problem in sand filtration. The filtration system consider the selection/combination of sand/gravel/charcoal material with suitable properties i.e. particle size, volume, bed size or layer depth, density, particle distribution. Each material/technique in the proposed unit is responsible for the successful removal of impurity at different stages from grey water. The treated water can be used for different purposes i.e. agriculture, cleaning, washing, etc. The main impurities removal targeted through this technique are TSS, TDS, odor, smell, turbidity, nitrogen, phosphorous, bacteria, etc.

It is expected from the calculation done for the material/technique that the expected outcome of the proposed unit will be suitable for 16-20 liter/hour of the Grey-water treatment with continuous flow of 5-6 liter. It is also estimated that the less cost and maintenance with enhanced efficiency of the treatment unit will give adaptability to the consumer and users. Recently, in various designs of towers/column,[12, 13] sand and charcoal materials with variable particle size placed in different layers for the treatment of grey water. The treatment method/technique selection is depends on the required treated quality of grey water. Also, the size of the grey water treatment unit/plant will vary with the place of installation i.e. family, community, hotel, building etc.

Our Studies will include the following modification in conventional method of grey water treatment:

1. Pre-filtration through foam and cotton mat
2. Sand/Charcoal filtration unit with improved rate of filtration
3. Capacity and dimension of filter unit,
4. Sand and gravel layer design, modified sand (bio-sand) use,
5. Use proper wash water gutter, sieve, etc.
6. Use low cost filter to avoid/reduce TSS content

3. RESULT

3.1 pH TEST FOR FILTER BED HEIGHT CALCULATION

The natural materials such as gravel, sand, and charcoal were used as an adsorbent in the filtration unit. The sample of water was taken before and after filtration with varying bed height of each filter bed and found the positive effect on pH level at 2 lit/min (LPM) of water flow rate as shown in figure 2.The filter bed of charcoal was given the maximum effect on pH level from 8.23 to 7.88 and the minimum effect found for bed of gravel. The bed of sand was found the fair change in pH level 8.23 to 8.16. The deviation in pH by each filter bed was found because each filter bed having the different capacity of adsorption of ions. For the further experiment the depth of each bed were selected as 0.15 m, 0.2 m, and 0.1 m for sand, charcoal, and gravel respectively set from bottom to top in the filtration unit based on pH level effect. The maximum pH effect found by charcoal bed was kept at top in the filtration unit.

3.2 EFFECT OF FLOW RATE ON REMOVAL OF GRAY WATER POLLUTANTS

The samples of raw gray water i.e. before cascade stage and final filtered water i.e. after filtration stage were taken with varying flow rate of water. Figure 3 shows the effect of flow rate of gray water on pH level and the resultant pH were nearly constant i.e. 7.51 (average) up to 2.5 lit/min, while increases pH level for further increase in flow rate. The characteristics parameters of gray water such as TDS, TSS, COD, total hardness, oil and grease were determined and all these are pretentious by flow rate of water after flow rate of 2.5 lit/min. The gray water average organic load removal was found 84 % at the water flow rate of 2.6 lit/min. The removal capacity of organic load of gray water was decreased by raising flow rate of gray water. The results show the 100% removal of oil and grease from the gray water only up to the 2.5 lit/min water flow rate.

3.3 TIME EFFECT ON FLOW RATE OF GRAY WATER

Figure 4 shows the time required to flow the water from initial stage to final stage at various water flow rates. The input and output flow rates of water were nearly different because accumulations of gray water were percent. Difference between input and output flow rate was 30 sec. The time required for 2.5 lit/min flow rate was 135 sec from input to output of the plant which was departed time of plant operation.

3.4 PERFORMANCE OF EACH STAGE OF THE SYSTEM

The pH of gray water was changed by each stage of system as shown in figure 5. Charcoal, sand and gravel filtration stages were found the involvement for change in pH of gray water. The pH level was changed mainly between 8.23 to 7.88 in charcoal level, 7.88 to 7.43 in sand level, and 7.43 to 7.35 in gravel level respectively. Due to form and synthetic fiber filtration, fine solid particles are settled down by gravitational force and only clear water flows towards charcoal stage of the plant and found 11% of TSS was removed in the form and synthetic fiber filtration level. The major role of aeration was controlled the TDS and COD of gray water. The soap, detergents, oil and grease contained in gray water were removed by agitation operation. From the investigation, average pollutants removal efficiency of agitation operation was found up to 26 %. Ultraviolet lamp (with 8-16W) can work inside the quartz tube (allow 90% of the UV radiation pass through) at 253.7 nm wavelength from continuous flow of 1 liter/min of water to kill the bacteria, virus and microbes.

All pollutants removal efficiency was increased by the filtration stage and found 36 % to 85 % of COD, 33 % to 87 % of TSS. The average removal efficiency of all pollutants for filtration stage was increased from 26 % to 69 %. The filtration stage found major role in the system for removal of pollutants from gray water. Hence the filtration stage was studied here and data of removal of load of pollutants on gray water by each filter bed was investigated and is explained in figure 8. The result shows that, charcoal filter bed gives better performance while bed of sand and gravel in filtration stage.

3.5 PERFORMANCE OF THE LABORATORY SCALE SYSTEM

The gray water was collected from bathrooms, basins of the residential area of college hostel located at Barkatullah area zone 14; ward 53 in Bhopal city, India. Total 08 samples of gray water were taken at first day of morning and evening of every week and the performances of system were investigated for these 08 samples of gray water at steady state conditions and the average value data are summarized in table 1. The average organic load in gray water found 330 mg COD/lit. The solids in gray water were found to have about 76% dissolved and 24% suspended particles. From table 1, all the parameters found in gray water were reduced and found better performance of the natural system. The average 83 % of organic load was removed and 46 % anions and 49 % cations were found to be absorbed by the natural adsorbents used in filtration. The traces of potassium, magnesium and calcium were found and removed fully from gray water.

Table -1: Average Characterizes of Bathrooms, Basins of Gray Water from a Residential College Hostel located at Barkatullah area zone 14; ward 53 in Bhopal City, India

Sr. No.	Parameters	Raw water (mg/l)	Filtered water (mg/l)
1	pH	8.40	7.35
2	Total Hardness	380	188
3	COD	330	60
4	TDS	575	174
5	TSS	186	40
6	Oil and Grease	7.8	0.26
7	Fluorine	0.80	0.40
8	Chlorine	36.9	20.46
9	Nitrites	0.07	00
10	Nitrates	0.68	0.20
11	Phosphates	0.011	00
12	Sulphates	22.33	11.6
13	Sodium	33.2	17.11
14	Potassium	4.50	2.00
15	Magnesium	0.12	00
16	Ammonia-Nitrogen	0.79	0.20
17	Calcium	0.13	00

4. DISCUSSION

The results presented in this study establish the potential applicability of the developed methodology. This laboratory scale gray water treatment plant is a combination of natural and physical operations such as settling with cascaded water flow, aeration, agitation and filtration, hence called as hybrid treatment process. All the natural and easily available low cost materials were used for the treatment process. The coconut shell covers are the waste materials, which can be easily procured and used as an efficient adsorbent in water treatment process for the removal of water pollutants and heavy metal ions from waste water [14]. In economy of the plant, the power supply, which is an important part of the operating cost of the conventional system and it is a today's major issues of India, was required a minimum, because system works on the natural force for flowing of water from first to last stage. The easily explicable operation, less maintenance of the plant and hence does not required the highly skilled personnel. After the investigations, due to the low energy demand, low operation and maintenance cost, lesser time consuming operation, this gives a significant and efficient method for rural communities and small industrial units for treatment and reuse of gray water. The laboratory scale model shows the better and effective performance by the experiment and balances advantages and disadvantages of the system. As per the Indian standard, the treated water is used for landscaping, gardening, toilet flushing, floor washing, car washing and irrigation. Still, more research is needed about soil structure of the area which over applicable for irrigation and this will be presented shortly.

4.1 COST EVALUATION

The cost of the grey water treatment unit (excluding sample testing and pilot-scale study) for 4-5 member family is estimated below in table-2:

Table -2: The cost of the grey water treatment unit for 4-5 member family

Project:	**Grey water treatment setup (4-5 members family)**
Capacity:	16-20 Liter/hour
Basis of Costing	The above cost of material is quoted by collecting information from market (shops & stores), EFL company personal and from literature available. The cost of the above item may vary by 10-20%.
No. of Operating Hours per Day	20 hours (GW1 grade)
No. of Operating Days per Annum	300 days

	Unit cost	Specification	Cost (in Rs.)	Total cost (Rs)
	Chemicals	N.A.	-	-
	Sand – 4.5 Kg	0.1-2 mm	35/kg	160
	Charcoal – 5 Kg	0.7-1.0 mm	40/kg	200
	Foam + PP yarn/cloth	Not known	62/set	62
	UV lamp	8-16 W, 5000-6000 working hours	200/piece	200
	Tank – 1 pc	Plastic, 250 liters	1000	900
	Quartz tube	Dia ½”	350	350
	Valves – 3 Nos.	½ or ¾ inch	200/pc	600
	Sieve/grits - 4 Nos.	SS/plastic, dia-20 cm	50/pc	200
	Tube (transparent) – 6 ft and flinch		1500	1500
	Pumps – optional (0.4-2.0 Kg/cm2 pressure)	0.25 hp	800	950
	Fittings per unit		2500	2500
A.	**Total amount (Rs.)**		-	**7622**
B	Material (Sand, Charcoal, foam, pp yarn, etc.)			350
	UV-Lamp running cost			200
	Labor – maintenance yearly (cleaning weekly basis)*			1800
	Setup loss cost @10% /annum - with life of 10 years			800
	Maintenance Cost per year - Total (Rs)			**3150**
Initial cost per unit		7600 Rs.		
Running cost per year		3150 Rs.		
Treated Quantity of GW/year		1,15,200 liter		
Cost of GW / year		8640 Rs. (@0.075 Rs/liter)		
Total investment cost after first year		10,750 Rs		
Return of Investment (ROI) time		1.5 years maximum		

*Maintenance cost for single unit is high because of labor cost and it can be less by considering maintenance for several units by a single labor.

The discussed performance of method and materials used for the present proposed Grey water treatment unit and the cost evaluation of the materials used in designing the unit (along with the post maintenance cost) with the probability of 1-2 years of pay-back period ensures the success full implementation/launching of the grey water treatment unit.

4.2 EXPECTED OUTCOME IN PHYSICAL TERMS

i) **New/ Upgraded Product:** Grey-water treatment unit with multi-grade treated water output of different quality can be used for various non-potable purposes i.e. irrigation, cleaning, washing, etc.

ii) **New/ Upscaled Process:** Such combination of technique is not being used for GW-treatment purpose; the up-scaling of the process can be identified in the proposed treatment system.

iii) **New/ Upgraded System:** A GW-treatment unit – upgraded version with combination of treatment techniques and component used

iv) **Services (including Software):** Not applicable

v) **Feasibility Analysis**

vi) **Any other**

The feasibility of the present proposed grey-water treatment system is well reported in literature. Each component of the treatment system is acting efficiently to remove these impurities. The present preposition is done on the evaluation of successful studies in this area and also involves the calculation of materials-used/process/efficiency. This all fact full searched data and calculative information from literature is used to design the proposed prototype for the grey-water treatment unit. The proposed treatment unit can give better performance and feasibility stand to the grey-water treatment process.

4.3 OUTCOME/ DELIVERABLES AND THEIR EXPECTED IMPACT

The following Outcomes/Deliverables are expected in the present work

- On completion of experiments, first proposed GW-treatment unit suitable for 16-20 liter/hour of grey-water treatment with continuous flow will be developed.
- Grey water treatment systems provide scientific data and explore the possibility of effective removal of organic and inorganic impurities.
- Test results showing feasibility of GW-treatment unit suitable for residential/ commercial purpose.
- The present work will produce the treated safe and sustainable grey-water for landscape irrigation and other non-potable use.
- Test results shows the calculation criteria for material selection which help to decide the design of GW-treatment unit for house-holds/hotels/high-rise buildings.
- The less cost and more efficiency will show adaptability of the treatment system to the consumers and users.
- The observed data, its interpretation and results will be documented in the form of scientific national/international publications/patents.

4.4 OBJECTIVES OF THE PRESENT GREY WATER TREATMENT UNIT

The objectives of the present proposal are as follows:

- To develop the grey-water (GW) filtration process by using indigenous and inexpensive material along with combination of existing techniques.

- Test and optimize the GW-treatment unit under various test conditions and modify the unit and material design as per the technical requirement.
- To consider techno-economical feature for the development of GW-filtration unit.
- Developed unit may be able to recycle 70-80% of the total grey-water produced which saves the potable water used for low grade water need.
- From single unit, treated water produced will be of two grades - GW1 & GW2 which can be used for different non-potable purposes i.e. gardening, washing, cleaning, etc.
- The designed grey-water treatment unit will be proposed for big housing project through state agencies after its successful development.

5. CONCLUSIONS

The present study demonstrate the reuse and treatment of residential bathrooms, basins waste water called as gray water for the purpose of landscaping, gardening, irrigations, plant growths and toilet flushing. Based on finding of this study, this treatment technology can be considered as a viable alternative to conventional treatment plants since they are characterized by high potential for COD, TDS, TSS, total hardness, oil and grease, anions and cations removal. The benefits found are low energy demand, less operating and maintenance cost, lower load on fresh water, less strain on septic tank, highly effective purification, and ground water recharge. Hence, this is an environmental friendly, without chemical operation, cost effective and resourceful plant for urban development.

6. ACKNOWLEDGMENT

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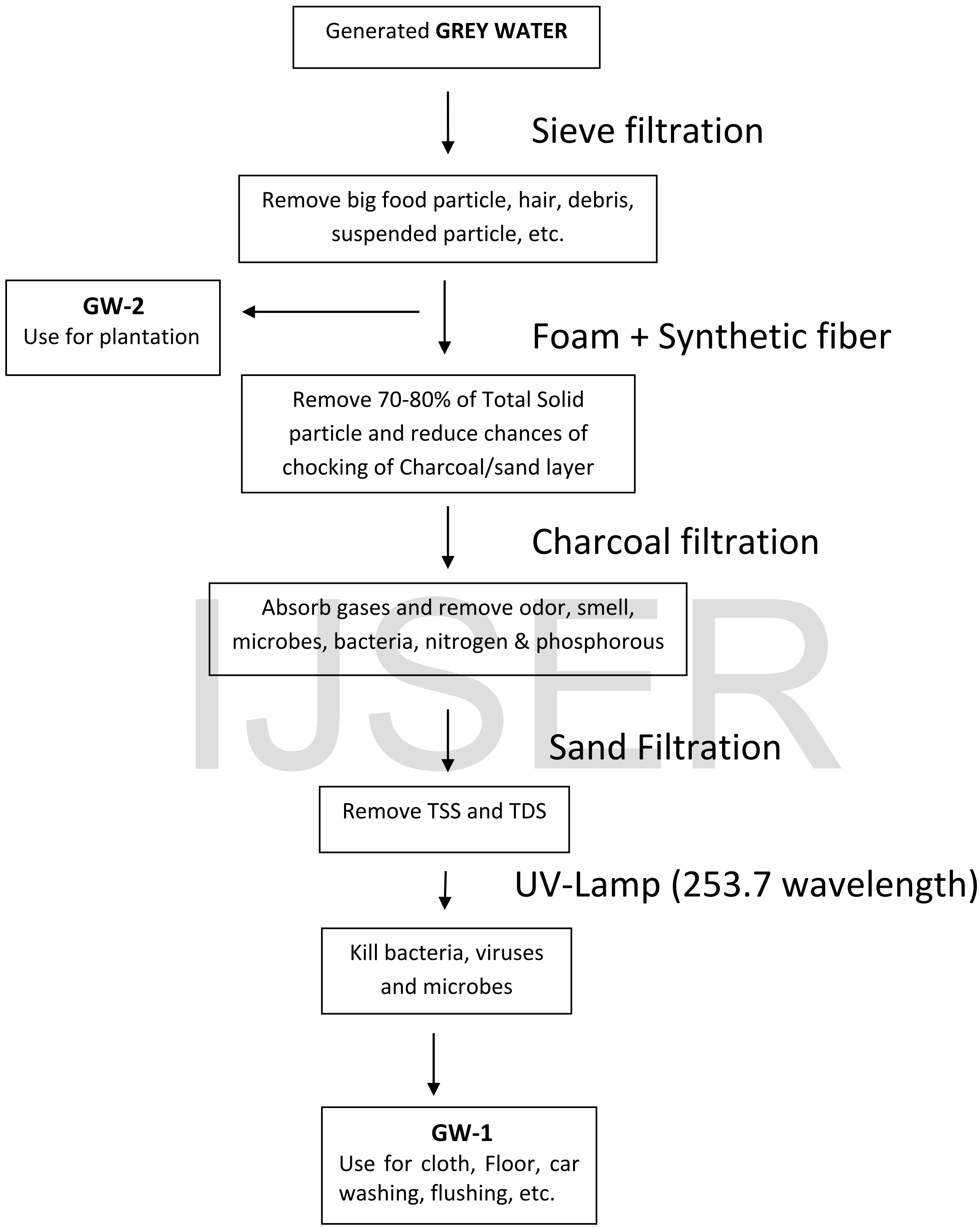

Figure-1: Conceptualization of Grey water Treatment

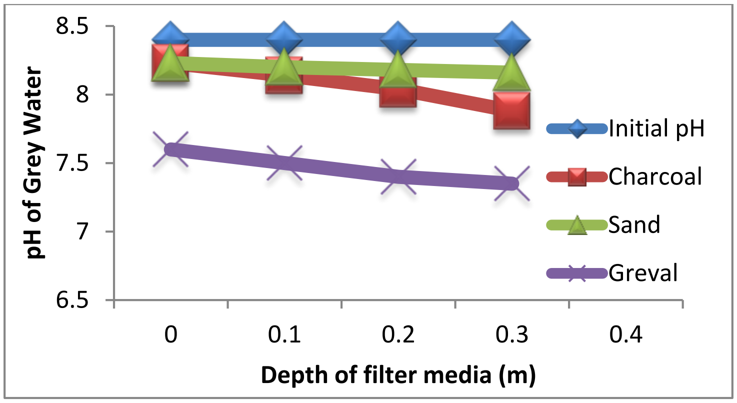

Figure 2: Effects of filter bed heights on pH level change

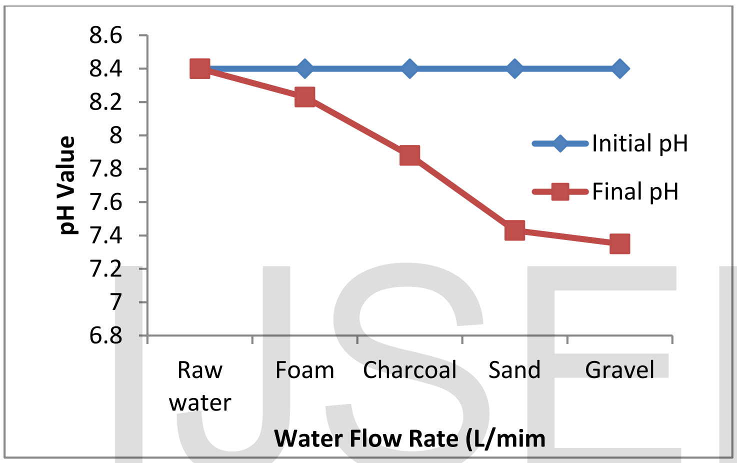

Figure 3: Effect of water flow rate on pH level

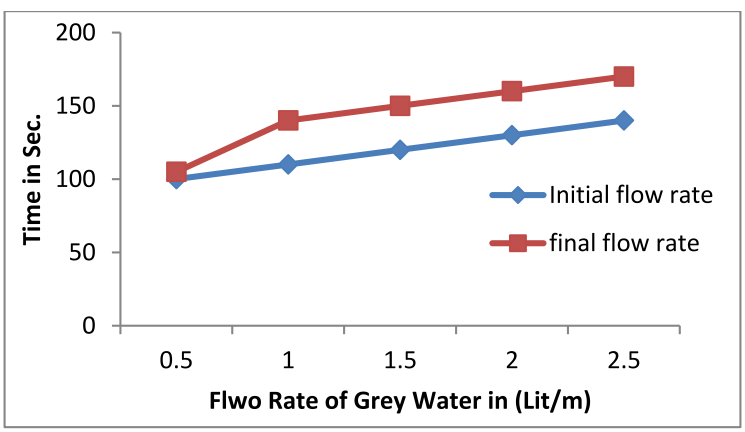

Figure 4: Time effect on plant operation

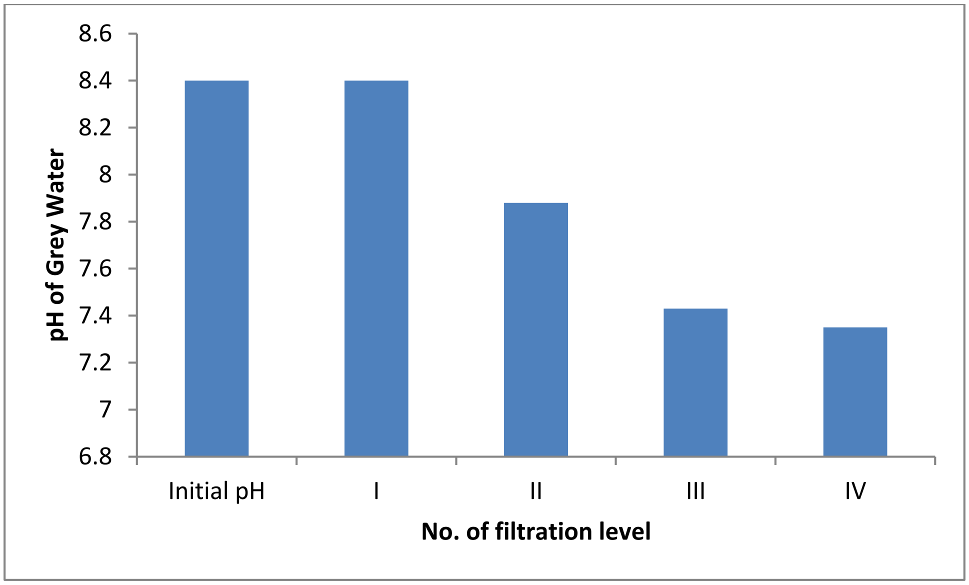

Figure 5: pH level of gray water change in each stage of plant at 2.5 Liter/min water Flow Rate (I- Foam + Synthetic fiber, II- Charcoal, III- Sand, IV- Gravel)