Designing of a Novel Lab Scale Process for Greywater Treatment

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Abstract: Greywater consists of household wastewater generated from kitchen, showers & laundry with the exception of wastewater generated from toilets which accounts for nearly 75% of the total wastewater generated. In the current era, population explosion has put forth before the civic authorities a humongous challenge of providing clean water for the population. WHO states that around 1.1 billion people today are water stressed & the numbers keep on escalating. Greywater recycling can ease this situation by substituting drinking water usage for activities like toilet flush, gardening etc., with treated greywater. Microorganisms have been exploited to degrade organic & inorganic pollutants in STP's & CETP's globally.

The present study describes development of a Lab scale process to treat canteen greywater and make it suitable for reuse. Initially a bacterial consortium comprising of 6 isolates was developed and used as Bacterial seed. The Process developed was a batch process constituting of steps like Optimization of parameters, Designing of the pilot-plant treatment set up, and the actual treatment process involving bacterial treatment filtration, disinfection each aimed at improving the quality of the treated greywater. The lab scale batch process was run at a capacity of 5 liters of greywater /batch within 20 hours. The Process designed was able to treat greywater successfully and achieve 87% BOD removal, 81% TSS removal and Coliform reduction to less than 2 per 100 ml, which met the guidelines for reuse of treated greywater both nationally & internationally. The treated greywater by this process is fit for applications like toilet flush, gardening etc.

This process design can be scaled up and promises to have a huge potential for large scale greywater treatment processes that can recycle greywater for non-potable reuse within communities.

I. Introduction

Waste water generated during different cleaning operations gives lots of greywater to the extent of 75% (Hernandez et. al 2007) and comprises of organic and inorganic pollutants like food particles, soaps, detergents , oils & fats, human hair, dead skin cells, trace amount of fecal matter and different kinds of microorganisms (Jefferson .B 2004). In modern times with two thirds of the global population facing some sort of water scarcity it has become mandatory for us to manage the available water resources including wastewater effectively and one of the many effective wastewater management strategies is greywater treatment and reuse (UN WWAP 2017). Treated greywater has the potential to replace clean potable water for purposes like toilet flush, gardening, car washing, irrigation, firefighting etc. (Jefferson et. al. 2004). Currently there are plenty of strategies available for treatment of greywater those relying on physical treatment like filtration systems e. g. sand filters and membrane filters, those relying on biological processes like membrane bioreactors (MBR), sequencing batch reactors (SBR), up-flow anaerobic sludge blankets (USAB), rotating biological contactors (RBC) etc. (Ghaitidak et.al. 2013). However each of these systems faces limitations in form of high maintenance or operational costs, requirement of skilled labour, performance issues, spatial requirements, etc. (Buchanan et. al. 2004).

The current research focuses on the designing of a novel process for greywater treatment which is economic, easy to operate and requires minimum maintenance. With this view in mind an aerobic lab scale batch process was designed to treat kitchen greywater. The treatment process consists of a bacterial treatment followed by filtration and disinfection. The treated water was tested for parameters like BOD, TSS, pH, coliforms and odour to check whether it meets the national guidelines for reuse (CPCB 1986) and the testing was done as per the Indian standards IS 3025: 1983 and IS 1622: 1981.

Bacterial treatment is the primary treatment which involves the use of a bacterial consortium (Shafy .et. al., 2014, Singh et.al. 2018). This bacterial consortium was referred as bacterial seed (BS). The next step of the process involved filtration for removal of colour and turbidity. Disinfection of the treated greywater was done with 2 ppm chlorine (4% hypochlorite) at the end of process (WHO 2006, EPA 2011).

II. Materials and Methods

2.1. Source of greywater

Greywater for treatment was obtained from kitchen sink of VES college canteen. The water primarily containd suspended food particles, oils, detergents and strong colour from spices along with high load of microorganisms due to its high nutrient concentration.

2.2. Optimization of the process parameters

The different process parameters like concentration of KMnO4, bacterial seed (BS), filter media for filtration were optimized for greywater treatment process. Different concentration of KMnO4 and BS were tried as given in Table 2.1, and the concentration providing the best result was chosen. Reduction in BOD was chosen as the parameter for optimization of KMnO4 and BS concentration. Different kinds of combinations of filter media were tested (Table 2.1) and reduction in visible turbidity and was chosen as the parameter for choosing the optimum media for filtration.

Table 2.1: Process optimization.

KMnO4 concentration	BS concentration	Filter media
0.1 %	200 mg/L	Fine Sand + Activated carbon (0.5 mm) pieces
	50 mg/L	Rice husk ash powder (grey) + Activated carbon (0.5 mm) pieces
0.01 %	10 mg/L	Rice husk charcoal powder (black) + Activated carbon (0.5 mm) pieces.
	3 mg/L	Polypropylene spun filter cartridge (5 micron) + Activated carbon (0.5 mm) pieces.

2.3. Design of the greywater treatment system

The lab scale treatment process was designed using recycled materials in order to make it as economical as possible. The materials required for the same are listed below.

1. A 15 L plastic bucket was fitted with a tap at the bottom using a sealant. This bucket was used as the treatment chamber for bacterial treatment step.
2. A fish tank pump was used as a sparger for maintenance of aerobic conditions and it also facilitated mixing of the greywater during treatment.
3. Optimum dose of BS along with $KMnO_4$ was used for greywater treatment.
4. An antifoaming agent (Harmony ECO 5523) was used in 0.5% concentration as per the manufacturer's instructions, to control foaming.
5. An activated carbon and sand filter was constructed in a 2.25 L soft drink bottle for filtration of the treated greywater.
6. Disinfection was done with 2 ppm chlorine using 4% hypochlorite as Chlorine source.
7. The entire cost in construction and assembly of the lab scale system was between 300- 500 rupees (approximately 5- 8 USD).

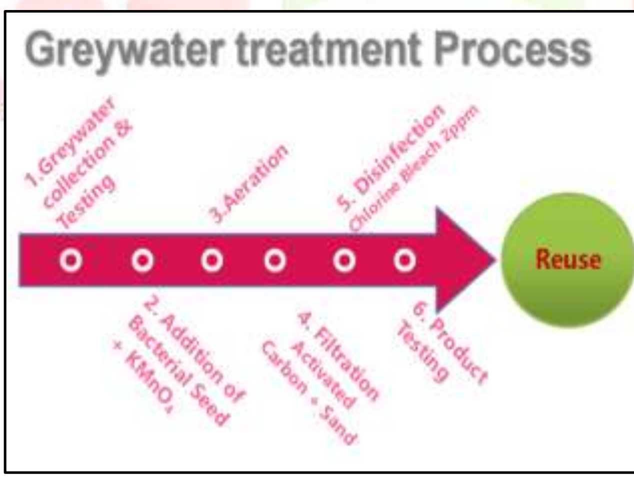
Fig 2.1: Lab scale treatment assembly

Key: From L to R- Antifoaming agent, sparger, treatment chamber & carbon and sand filter.

D. Greywater treatment process

The designed greywater treatment process is an aerobic batch process. Greywater (5 Lit) was collected from the college canteen sink and treated per batch, the collected greywater was initially tested for pH, BOD, TSS and coliform count. Bacterial treatment step was carried out for 16-20 hrs followed by filtration and disinfection. Finally the treated greywater was tested to determine whether it meets the guidelines for reuse (CPCB 1986).

Fig.2.3 Flow of the greywater treatment process Fig. 2.4: Bacterial treatment followed by filtration



III. Observations and Results

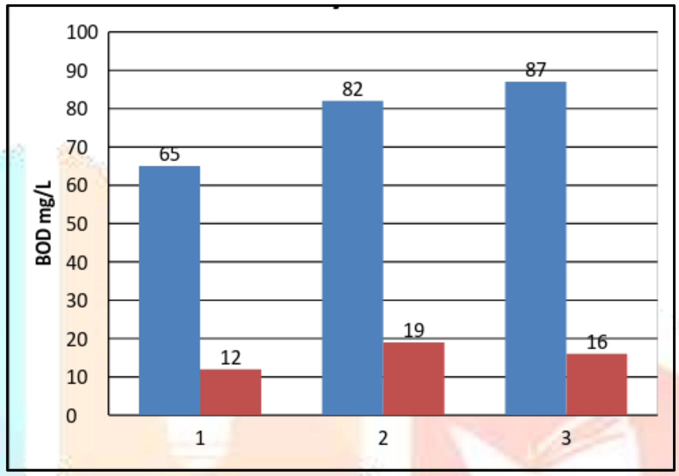
3.1. Optimization

3.1.1. Optimization of $KMnO_4$ concentration

Table 3.1 BOD reduction after KMnO4 treatment

Sample	Method Used	BOD (mg/l)		Reduction %
		Untreated	Treated	
1	$KMnO_4$ 0.1 %	65	12	94.47
2	$KMnO_4$ 0.1 %	82	19	93.04
3	$KMnO_4$ 0.01 %	87	16	94.42

Fig 3.1: Optimization of $KMnO_4$ concentration



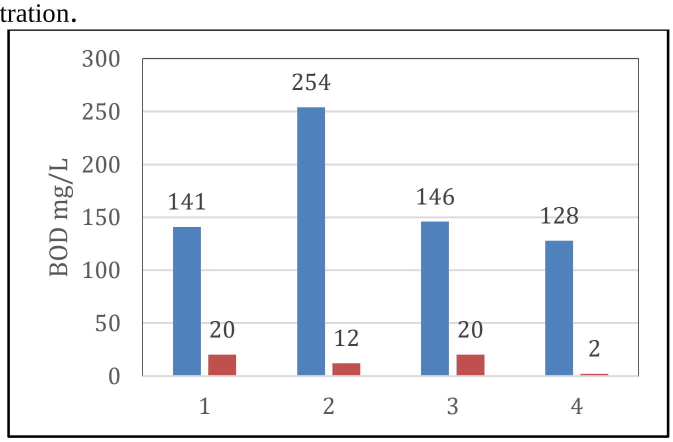
Key: Untreated greywater, Treated greywater. 1, 2 and 3 indicates sample 1, 2 and 3 respectively form Table 3.1

3.1.2. Optimization of Bacterial seed (BS) concentration

Table 3.2 BOD reduction after BS treatment

Sample	Method Used	BOD (mg/l)		Reduction %
		Untreated	Treated	
1	BS 200 mg/L	141	20	95
2	BS50 mg/L	254	12	97
3	BS 10 mg/L	146	20	95
4	BS 3 mg/L	128	2	98

Fig. 3.2 Optimization of BS concentration.



Key: Untreated greywater, Treated greywater. 1, 2 and 3 indicates sample 1, 2 and 3 respectively form Table 3.2

3.1.3. Selection of appropriate filter media

Table3.3: Optimization of filter media

Combination of filter media chosen	Observations
Fine Sand + Activated carbon (0.5 mm) pieces	Effective turbidity removal was achieved. Clear and colour free effluent was obtained. The filter also had a good life span.
Rice husk ash powder (grey) + Activated carbon (0.5 mm) pieces	Comparatively less effective than Sand + Carbon. The life span is also shorter.
Rice husk charcoal powder (black) + Activated carbon (0.5 mm) pieces.	Comparatively less effective than Sand + Carbon. The life span is also shorter.
Polypropylene spun filter cartridge (5 micron) + Activated carbon (0.5 mm) pieces.	Dissatisfactory results were obtained due to high initial turbidity.

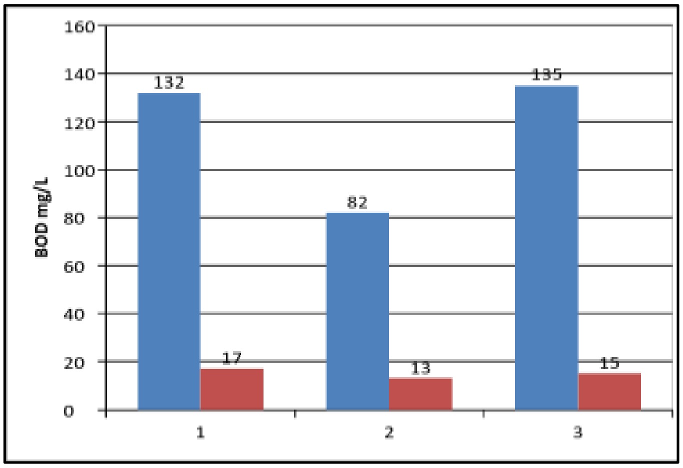
3.2. Lab scale treatment process

The results of the lab scale process as described in Table 3.4. An average 87 % reduction in BOD was obtained along with a TSS reduction of 81 %, the average BOD and TSS values of treated greywater were 14 mg/l and 50 mg/L respectively. There was negligible visible turbidity post filtration. After disinfection the coliforms levels were reduced to an MPN value of 2 / 100 ml. Apart from these the pH of treated greywater was in the range of 7-8 pH units, the DO levels were 3.5- 4.5 mg/L and there were no offensive odours.

Table 3.5: Lab scale treatment of greywater.

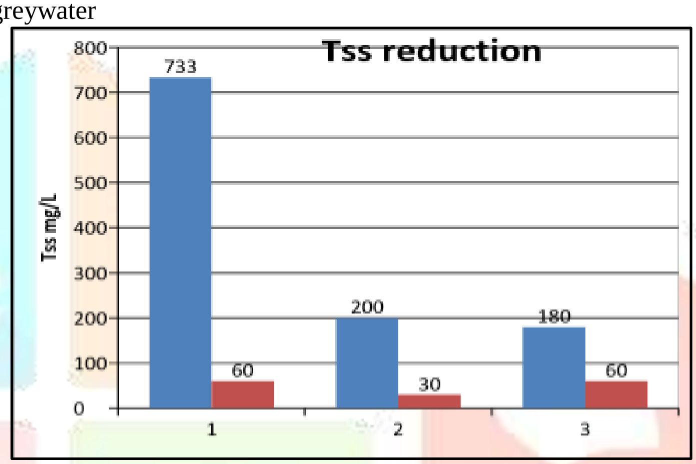
Sample	BOD (mg/l)		BOD Reduction %	Average BOD Reduction	TSS (mg/l)		TSS Reduction %	Average TSS Reduction	MPN (Coliforms/ 100 ml water)	
	Untreated	Treated			Untreated	Treated			Untreated	Treated
1	132	17	87	87 %	733	60	91	81 %	>1600	<2
2	82	13	84		200	30	85		>1600	2
3	135	15	89		180	60	67		>1600	<2

Fig. 3.5: BOD reduction of treated greywater



Key: Untreated greywater, Treated greywater. 1, 2 and 3 indicates sample 1, 2 and 3 respectively form Table 3.5.

Fig. 3.6 TSS reduction of treated greywater



Key: Untreated greywater, Treated greywater. 1, 2 and 3 indicates sample 1, 2 and 3 respectively form Table 3.5.

IV. DISCUSSION AND CONCLUSION

A). Discussion

1. Of all the different concentrations 0.01 % $KMnO_4$ and 3 mg/L BS were found to be optimum for greywater treatment.
2. The combination of Activated carbon + sand was the most suitable amongst the different combinations tried out for reduction in turbidity and colour of the greywater. The life span of the filter was also better compared to other media.
3. The treatment process reduced BOD and TSS to 14 mg/L and 50 mg/l respectively (87 % and 81 % reduction). The coliform counts were also brought down after disinfection from greater than 1600 to less than 2 MPN/ 100 ml.
4. The reduction was significant and the BOD, TSS, and coliform count in treated greywater met with national as well as international guidelines for reuse (CPCB 1986, Ghaitidak et.al, 2014).

B. Conclusions:

1. The greywater treatment process designed combined bacterial treatment with filtration and disinfection for effective treatment of greywater.
2. Bacterial seed (BS) a consortium consisting of 6 isolates was prepared and used.
3. Activated carbon and sand filter was constructed for the purpose of reduction in colour and visible turbidity.
4. The lab scale process started from sample size of 100 ml for optimization purpose which was scaled up and a 5L system was constructed for lab scale treatment of greywater.
5. The 5L system was economical in its design and utilized resources which were easily available. The entire cost in construction was less than 500 rupees.
6. The treatment was successful in reducing BOD, TSS and coliform levels in greywater, other parameters like colour, turbidity, pH, odour etc. were also satisfied and the treated greywater met with the standards for safe reuse.
7. The process is successful and treated greywater at the lab level and should be tested in the field.

8. The greywater obtained as a result of the treatment process has the potential to save precious drinking water by substituting it for activities like toilet flush, gardening, car wash irrigation etc.
9. Thus a successful process for treating greywater was designed at the lab level which has the potential to be scaled up to treat greywater for practical applications and provide the community with some benefit of the research work done in lab.

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