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Treatment of Greywater for Non-Potable Applications

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Abstract

This study presents the treatment of greywater for non-potable applications such as toilet flushing, concrete production, and irrigation. In this study, a laboratory-scale greywater treatment plant was designed and fabricated to treat greywater with a combination of physical and natural treatments systems. These natural systems include natural-draft aerator system, coagulation by natural coagulant (*Moringa Oleifera*), and filtration by sand and sawdust filter media. A total of five samples of raw greywater were collected every morning from two female hostels, namely Prof. Dora Akunyili and Chief Stella Okoli hostels in Nnamdi Azikiwe University, (NAU) Awka. These samples were analyzed for turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), total dissolved solid (TDS), total hardness as well as bacterial load The performance of the plant showed percentage reduction in concentration of parameters such as turbidity (98.7%), BOD (91.4%), COD (77.7%), TSS (93%), TDS (70.3%), and total hardness (67%). The concentration of these parameters decreased significantly as a result of the treatment. This shows that the system may be adopted for treatment of greywater for non-potable uses in areas with limited water supply.

***Keywords*:** Greywater treatment plant; *Moringa Oleifera*; natural coagulant; turbidity

1. Introduction

Recycling of greywater is an environmental friendly process which serves as a control to 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 water [1].

Recycling of greywater involves installing a system which treats greywater to meet quality standard for non-potable uses. Its importance is to reduce pollutants and minimize risk of pathogenic transmission. Household greywater can be recycled to substitute precious drinking water in applications which do not require drinking water quality. Such non-potable applications include sprinkling irrigation, toilet flushing, laundry, car washing, floor washing, concrete production, etc. [2].

Researches done in the field of greywater recycling such as [3,4] have led to the development of greywater treatment technologies. They range from low devices to complex treatment systems. The low cost devices divert greywater to direct reuse while complex treatment systems incorporate treatment processes such as primary treatment, biological treatment, and disinfection. The cost and energy requirements of these systems vary and usually increase with higher levels of treatment. Thus, to reduce cost, treatment of greywater by natural system is gaining popularity in both developed and developing countries. These natural treatment systems such as sand/gravel filters, constructed wetlands (planted soil filters), trickling filters, etc are now competing with various conventional intensive technologies to treat greywater at household level [1].

The aim of this his study is to design and fabricate a laboratory greywater treatment plant for treatment of greywater collected from the female bathroom basins of the university hostel at Nnamdi Azikiwe University, Awka (NAU).

2. Materials and methods

2.1. Preparation of Sawdust

The sawdust of Iroko wood was taken from saw mill Eke-Awka in Awka, the Anambra state, Nigeria. Sawdust millers confirmed that sawdust from Iroko wood are free from colouring pigment in order to remove dust and any possible colouring pigment the sawdust was washed with water for 4 to 5 times before being spread under the sun for a period of two days to dry.

The problem of using sawdust as a filter medium is that it needs to be refreshed frequently because it can easily decomposed. It is also a likely material for micro-organism to grow.

2.2 Preparation of Moringa Oleifera (MO) Seed Powder

Dry Moringa oleifera pods were obtained from Kogi state, North central of Nigeria, because sufficient quantity could not be got in Awka during the time of this study. The seed coats were removed to get the kernels. The kernels were dried in the sun for one week and ground to powder. Figure 3.3 shows the visual samples of *Moringa Oleifera* tree, pod, seeds and seed kernels.

2.3 Preparation of Charcoal

The charcoal sample was crushed and sieved to the desired size gradation with effective size of 9.5mm. Its purpose was to provide additional surface contact area between air and greywater.

2.4 Description of the Lab- Scale Greywater treatment Plant

The laboratory scale greywater recycling plant was designed and fabricated to perform five stages of physical operation which include aeration, coagulation, flocculation, sedimentation, and filtration. Feed greywater from a collection tank was sent to the surge tank by means of a 0.5Hp pump at a flow rate of $3 \times 10^{-4}m^3/s$ (20l/mins) through a 12 mm diameter polyvinyl chloride (PVC) pipe and was controlled by a manual control valve. The surge tank was placed at a height of 1.75m from the ground and the water flowed by gravity through the aerator with a velocity of $0.156m^2/s$, and a headloss of 0.09m to flocculation/sedimentation tank, then to filtration tank with a headloss of 0.234m and finally to the clear water tank. There was also an overflow line of 16mm diameter pipe from the surge tank back to collection tank. All units were fabricated with galvanished metal sheet of 24mm gauge. This system could be reproduced into a pilot scale with higher outputs achieved by putting up a proper hydraulic profile design of the plant. In designing the hydraulics of a plant, a designer will start at either end and calculate the hydraulic drops or rises back to the opposite end taking all tanks, pipes, channels, pipe fittings, weirs penstocks and other flow obstructions into account. Fig.1 shows laboratory greywater recycling plant.

2.5 Aeration Process

The first stage of the treatment of the greywater was aeration which was carried out in a natural draft multiple tray aerators. It was made of series of three trays and a collection tank. The trays were trapezoidal in shape and arranged vertically with a space of 12.7cm between them. These trays were perforated 0.2cm diameter holes into their bases. The first tray was a distribution tray while the other two trays were charcoal trays. Greywater tumbled over these trays as a thin sheet and passed through a collection tank. The retention time was 0.39sec while headloss through the holes was 0.09m. The primary purpose of this treatment unit was to oxidize compounds dissolved in the greywater.

2.6 Coagulation/ Flocculation / Sedimentation Process

This was the next stage of the treatment processes. The treatment was carried out in an intermittent tank with a hopper at the bottom where sludge was deposited and removed. The tank was designed as a single unit of cylindrical shape, with a conical bottom. It combined the functions of coagulation, flocculation, and sedimentation and sludge removal. For flocculation to take place, 50g of MO seed powder was added to the water in the flocculation-sedimentation tank and a hand stirrer was used to ensure good mixing. The suspension was subjected to 2 minutes of rapid mixing speed, followed by 5 minutes of slow mixing speed. Then, the water was allowed to settle for 1 hour as recommended by [5]. The flocs formed moved to the hopper of the flocculation-sedimentation tank and were removed manually after the settling period.

2.7 Filtration Process

The last stage was gravity filtration. At the upper layer of the designed filter was sawdust, while the bottom layer was sand bed, supported by 0.05m bed of gravel. The filtration rate was set at $0.047m^3/h$. The filtration media were river sand (effective size (D_{10}) of 0.55 mm, specific gravity of 2.65 and a uniformity coefficient

(D_{60}/D_{10}) of 1.6 (Enugu State Water Corporation, 2010). The sawdust had a specific gravity of 1.8 with a particle size notation -40/+60 [6]. These choices of media depths of sawdust and sand used in this experiment were guided by filter media specification recommended in[7]. Headloss through the sand filter was 0.0234m.

Fig. 1 lab-scale greywater treatment plant

Fig. 2a natural-draft aerator

Fig.3a coagulation/flocculation/sedimentation unit

Fig. 4a filtration unit

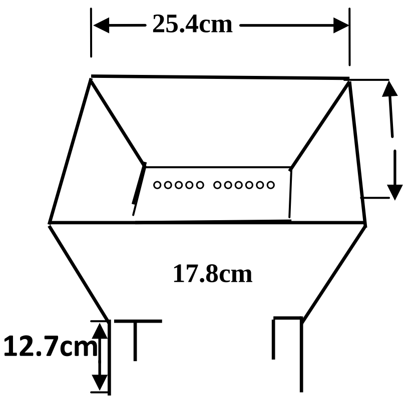

Fig. 2b aerator unit

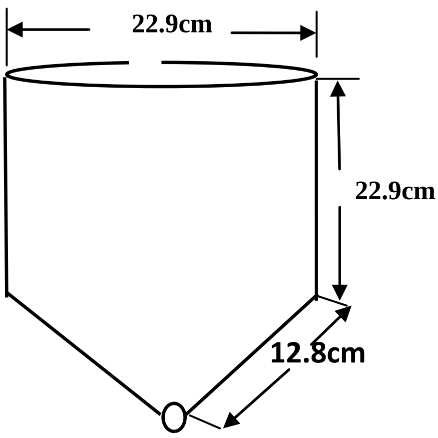

Fig.3b coagulation/flocculation/sedimentation unit

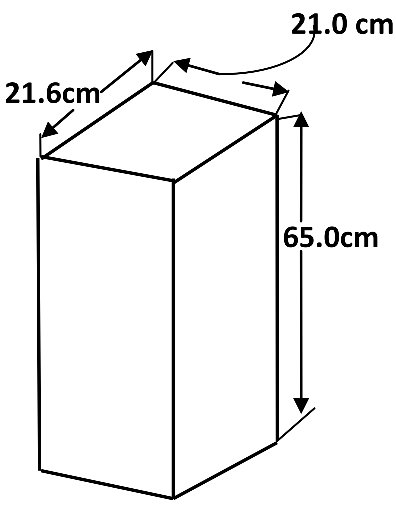

Fig. 4b filtration unit

3. Results

3.1 Preliminary Survey Result for Filter Effectiveness

This preliminary survey was important to ensure proper selection of filter media depth for overall performance of the recycling plant. Three different bed depths (0.12m sand below 0.18m sawdust, 0.12m sand below 0.21m sawdust and 0.12m sand below 0.24m sawdust) were selected and their performances were assessed based on their parameters removal efficiencies. Individual results of experiment 1 (0.12m sand below 0.18m sawdust), experiment 2(0.12m sand below 0.21sawdust), and experiment 3(0.12m sand below 0.24m sawdust) were obtained and partial percentage removal of parameter concentrations of effluents between coagulation-flocculation-sedimentation tank and filtration tank were calculated and presented in Table 1 below. The result shows that experiment 3 produced the highest percentage reduction in terms of turbidity (50%), BOD (58%) and TSS (59%). Based on this result, the medium depth of 0.12m sand below 0.24m sawdust was chosen for the design of the dual media filter in this study. The table also reveals that the pH values do not change in all the three experiments. Although, the values vary, but they are still within the range of 6-9 approved by the U.S Environmental Protection Agency [8] standard for greywater reuse. This result is also supported by the report of [9] on the treatment of river water with *Moringa oleifera* seed powder. It was observed that after treatment the range of pH was found to be between 7-7.5.

Table 1: Partial Percentage Removal of Parameter Concentration of Effluents after Filtration Operation

			Experiment1 0.12sand+0.18sawdust		Experiment2 0.12sand+0.21sawdust		Experiment3 0.12sand+0.24sawdust	
Parameter	Raw water	Coa-Floc-Sed.	Filtration	% R*	Filtration	% R*	Filtration	% R*
Turbidity	62	1.6	1.0	38	1.0	38	0.8	50
pH	8.40	7.55	7.19	NA	7.19	NA	7.13	NA
Total Hardness(mg/l)	282	158	96	39	94	41	90	43
Biochemical Oxygen Demand (BOD)(mg/l)	179	31	16	48	15	51	13	58
Chemical Oxygen Demand(COD) (mg/l)	229	122	60	46	57	49	50	55
Total suspended Solid(TSS)(mg/l)	178	32	18	44	16	50	13	59
Total Dissolve Solid(TDS)(mg/l)	523	210	175	16	173	18	169	20

NA - Not Applicable

% R* - Percentage reduction

3.2 P^H test for Selection of Filter Depth

In Table 2, different depths of sand and sawdust within the range of 0.12-0.36 are used as single filter media. The result shows that the pH values of the effluents vary, but the values are still within the range of 6-9 approved by U.S Environmental Protection Agency [8] standard for greywater reuse. This is a clear indication that sawdust if used as a single filter medium or in combination with sand has no effect on the pH of the greywater during treatment as shown in Table 2.

Table 2: Ranges of pH values of effluents from filtration unit using different depths of sand and sawdust as single medium

Depth of sand/sawdust(m)	Effluent pH value with sand	Effluent of pH value with sawdust
0.12	7.52	7.52
0.18	7.52	7.51
0.24	7.45	7.44
0.30	7.45	7.44
0.36	7.45	7.44

3.3 Performance of each Stage of the System

Table 3 shows partial percentage removal of parameter concentrations by aerator, coagulation-flocculation-sedimentation, and filtration units. From the table, it can be seen that in the filtration stage, removal efficiency of total hardness increases slightly from 41.5% to 42.6%. Total suspended solids (TSS) increases from 48.8% to 83% while chemical oxygen demand (COD) increases from 35.8% to 60%. This result agrees with the findings of [10] which reported that majority of COD removal efficiency occurred during filtration process in the treatment of wastewater sequence comprising of coagulation (with *Moringa Oleifera*), flocculation, sedimentation and sand filtration.

3.4 Performance of the Laboratory Scale System

Influent mean result, effluent mean result and overall percentage removal between influent and effluent mean parameter concentrations are given in Table 4. A total of five samples of raw greywater were collected every morning from two female hostels, namely Prof. Dora Akunyili and Chief Stella Okoli hostels in Nnamdi Azikiwe University, (NAU) Awka. These samples were analyzed to investigate the performances of system and the average value data are summarized in table 4. The average organic load in gray water found to be 211 mg COD/lit. and Turbidity was found to be 64.6 NTU . After treatment, all the parameters found in greywater were reduced, showing better performance of the natural system.

Table 3: Partial percentage removal of parameter concentration by each treatment stage

Parameter	Influent mean value	STAGES⟨ % Partial Removal (%R*)⟩					
		Aeration mean	% R*	Coa-floc-sed. mean	% R*	Filtration mean	**%R*
P^H	8.43	8.30	-	7.52	-	7.27	-
Total Hardness	285	279.8	1.8	163.8	41.5	94	42.6
BOD	182	155.8	14.4	32.46	79.2	15.74	51.5
COD	211	187.8	11.0	120.4	35.9	47	61
TSS	179.2	147.2	17.9	75.2	48.9	12.6	83
TDS	526.2	355	32.6	204.6	42.4	172.8	15

Table 4: Influent and effluent mean result and total percentage removal after treatment

Parameter	Influent mean	Effluent mean	total % R*
Turbidity (NTU)	64.6	0.82	98.7
pH	8.432	7.184	14.8
Total Hardness(mg/l)	285	94	67
Biochemical Oxygen demand(mg/l)	182	15.74	91.4
Chemical Oxygen demand (mg/l)	211	47	77.7
Total suspended solid(mg/l)	179.2	12.6	93
Total dissolve solid(mg/l)	582.6	172.8	70.3
Faecal Coliform(MPN/100)	34800	324	99.1
Total Coliform(MPN/100)	26200000	205600	99.2

4. Discussion

The results reveal that greywater recycling plant achieves percentage removals of 98.7% for turbidity. The decreasing trend observed for turbidity values in this research corroborates the report of [11] who reported that the use of *Moringa oleifera* seed powder showed decreased turbidity in river water with increased dose from 50, 100 and 150 mg/l respectively. In the same vein, [12] reported that the use of *Moringa* seed powder achieved highest turbidity removal over the use of alum and alum with *Moringa* respectively. In an earlier study, [13] recorded 90-99% removal of turbidity in water from treatment plant using *Moringa.*

The results recorded 91.4% for biochemical oxygen demand. This was supported with the findings of [14]. In his study, different doses of *Moringa oleifera* seed powder was used for the treatment of grey water samples. After treatment with *Moringa,* the The BOD removal efficiency of the *Moringa oleifera* seed extracts increased with increased concentration of the seed extracts used 65.7%, 67.1 and 80.1% BOD removal was achieved for 50mg/l, 100mg/l and 150mg/l respectively for the raw sample of grey water while 71.4%, 74.3% and 81.4% BOD removal was recorded for 50mg/l, 100mg/l and 150mg/l respectively for the filtered grew water sample.

Total dissolved solid (TDS) was found in this study to decrease with 93% reduction. This is supported by the finding of [9] who reported maximum reduction for both total solids and total dissolved solids in ground water after treatment with *Moringa oleifera*.

Table 5: Comparison between effluent quality result and United State Environmental Protection Agency (U.S.EPA) water quality criteria for toilet flushing

Parameter	**Effluent quality result**	**USEPA water quality (http://www.ccmerca)**
Turbidity (NTU)	0.82	2 to 5
pH	7.184	6 - 9
Total Hardness(mg/l)	94	-
Biochemical Oxygen demand (BOD)(mg/l)	15.74	5 - 30
Chemical Oxygen demand (COD)(mg/l)	47	-
Total suspended solid (TSS)(mg/l)	12.6	5 – 30
Total dissolve solid (TSS)(mg/l)	172.8	-
Faecal Coliform(MPN/100)	324	Non-detectable
Total Coliform(MPN/100)	205600	-

In this study, it can be seen that *Moringa* acts as antimicrobial agents against microorganisms as there was an observed percentage reduction of 99.1% for faecal coliform and 99.2% for total coliform at the end of all the treatment processes and this agrees with the findings of [14] which reported that the highest antimicrobial efficiency of 97.50% was recorded with 150mg/l dose of *Moringa oleifera* seed extracts on the filtered grey water sample while 50mg/l and 100mg/l dosage of *Moringa oleifera* seed extracts achieved 68.33% and 85.00% antimicrobial efficiency on the filtered grey water samples respectively. The result obtained here further corroborates the findings of [15] that the use of *Moringa* seed extract achieved 90.00-99.99% bacterial removal in untreated water.

4.1. Comparison of Effluent Quality with Water Quality Criteria approved by United State Environmental Protection Agency (USEPA, 2013)

The effluent quality result obtained after filtration operation was compared with the water quality criteria for toilet flushing recommended by United State Environmental Protection Agency [8] in Table 5. The table indicated that pH value, BOD, COD, and TSS of the effluent were within the USEPA standard. Turbidity was far above standard while faecal coliform was greatly reduced though not to the standard approved by USEPA.

5. Conclusion

The present study demonstrate the treatment of residential bathrooms, basins waste water known as grey water for the purpose of landscaping, irrigations, concrete production, and toilet flushing. Based on the findings of this study, the treatment technology can be considered as a viable alternative to conventional treatment plants in rural region since they are characterized by high potential for COD, TDS, TSS, total hardness, and turbidity removal. Hence, it is environmental friendly, without chemical operation, cost effective and resourceful plant for rural development. Moreover, the amount of sludge produced, was less than that from conventional coagulant because of *Moringa Oleifera* seeds that was used.

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