A Filtration System for Treatment of Kitchen Waste Water for Re-Use

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Abstract— A system was developed to provide suitable media conditions through filtration and chlorination for treatment of kitchen wastewater and comparing them for suitability. Such quality parameters as Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Ammonium-Nitrogen (NH4-N) and pH were measured before and after treatment of the waste water. The effects of treatment media (i.e. Filtered, Filtered-chlorinated and Control) and meal time on the tested parameters were determined. The Biochemical Oxygen Demand (BOD5 at 200C) average values of (10.22±1.58) mg/L, (7.99±1.12)mg/L, and (5.10 ± 0.53) mg/L obtained for the Control (CM), Filtered (FM) and Filtered-chlorinated (FCM), respectively, satisfied the FAO 1985 benchmark figures for safe discharge. The COD values of (755.11±52.62) mg/L, (634.33±61.88) mg/L, and (430.78±42.34) mg/L, recorded for the CM, FM and FCM, respectively, were outside the FAO reuse range. The mean values of NH4-N obtained; (9.09±2.50)mg/L for Control, (5.49±2.18) mg/L for Filtered, and (2.32±1.34) mg/L for Filtered-chlorinated were within the FAO 1985 reuse range. The pH values of (8.61±0.43) and (7.28±0.63) obtained for FM and FCM, respectively, agreed with the FAO 1985 and USEPA standards for irrigation water. While (10.52±0.94) obtained for the Control medium is not within the set limit. Appreciable improvement on the kitchen waste water quality was therefore achieved using this system.

Index Terms— Grey water, treatment system, filtration, chlorination, quality parameters, reuse, Nigeria

1 INTRODUCTION

In many countries, especially developing countries, many people are lacking access to water and sanitation services and this inadequate service is the main cause of diseases in these countries. Application of appropriate wastewater treatment technologies, which are effective, low cost (in investment and especially in operation and maintenance), simple to operate, proven technologies, is a key component in any strategy aimed at increasing the coverage of wastewater treatment. Water is a precious commodity so finding ways to re-use waste water is essential to sustainability [1].

Among the various existing types of waste water management, recycling of domestic waste water is easier and can be implemented in every household [2]. The potentials of waste water re-use are numerous and beginning early to formulate its environmental concerns, will help in ameliorating what could otherwise have been the health implications of uncontrolled handling of it. It has the special benefit of permitting interested user to set up gardens where vegetations are grown. When this thrives, income generation is enhanced and the general well being of these individuals are ensured. Appropriately treated grey water can also be re-used indoors for toilet flushing and clothes washing, both of which are significant consumers of water [3].

Domestic wastewater from kitchen might contain organic load from food processing, utensil washing in the kitchen, soap and detergents, with the main contaminants being proteins, carbohydrates, detergents, oil and grease and other dissolved and suspended compounds as listed by Lavik et al. [4]. The kitchen wastewater according to Swetha et al. [2] contains food particles, oil, grease and chemicals from dish washing detergents and these particles can also be removed effectively and the treated water used for agricultural or gardening purpose, if oxidized, can also be used for rearing fishes.

Septic tank is one of the most common onsite structure meant for handling waste water followed by a water absorption system. As the raw sewage flows through the treatment process, some contaminants are removed while some are transformed as a result of microbial degradation [5,6]. Leaching system sometimes called dispersal systems also performs physical and biochemical treatment [6]. The use of membrane Bioreactor has been reported for waste water treatment as documented by Bernal et al. [7].

The most common wastewater treatment and re-use system currently in many locations is the aerated wastewater treatment system [8]. After settling the solid in wastewater, the effluent is aerated to assist bacterial breakdown of organic matter, followed by a further stage of disinfection, usually using chlorine pellets. Sedimentation and aeration tank were employed by Swethal et al [2] to provide a low energy system for kitchen waste water treatment. The sedimentation tank has a partition that act as a trap to solid food particles and oil molecules before the waste water flows to the aeration tank which uses motor for the aeration purposes.

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Fat, oil and grease (FOG) constitute major contamination in kitchen wastewater. Different grease and oil traps have been recommended in a published document by Office of Environment and Heritage [9]. A grease trap is a sedimentation tank or basins that allow waste water to slow down long enough to let the grease float to the top. The grease outlet is baffled to allow water to pass under the floating grease to the treatment system. Disinfection is considered part of secondary treatment of wastewater. This can be accomplished through chemical, ultraviolet light or ozone processes [10]. The most common way to disinfect water at this stage is to use chlorine. This project focuses on the development of a system for treatment of kitchen wastewater for re-use.

2. MATERIALS AND METHOD

2.1 Design Procedure and material selection

Steps were taken to design a set-up to facilitate grey wastewater treatment necessary to warrant re-use. In this way, further gardening activity can be embarked upon especially in the dry environment and more importantly, the total environmental issues will be addressed within the location of the effluent source.

In doing so, the project was mindful of the holder materials that are corrosion-free and sizeable (selected) good enough not to create a handling problem. Selection of pump was made based on the volume of effluent to be lifted such that the set-up will allow pressure-driven filtration process and finally a cold storage facility was provided for the study of some of the effluent properties. Plastic materials were chosen over other materials such as iron and glass to avoid rust or breakage.

2.2 The system and fabrication process description

The prototype experimental wastewater treatment device was fabricated as in the sketch shown in Figure 1. From the influent intake (**1**) where the first filtration takes place (straining), the Grey wastewater from the kitchen is introduced into the Plastic Vat (**2**) that is transparent. After this introduction of the grey wastewater, a considerable resident time of 20 minutes was allowed for the fat-oil-grease (FOG) to naturally separate given the density difference between FOG and water. This FOG and some additional organic debris that float on the water find their exit through port (**3**) through a 10 mm flexible PVC pipe.

The settled grey wastewater is now pumped with the help of a water pump into the two-vessel or bucket arrangement, one on top of the other through the muslin filter cloth (**4a**) the second filtering unit. The wastewater that enters the topmost vessel is filtered across the last filtering unit (**4b**) and the filtrate goes into the bottom vessel. The filtrate was delivered through the control valve (**5**) via another PVC flexible pipe for intended re-use. This vessel-filter arrangement is all rested on a rigid stand (**6**). The wastewater pump is powered by a 12-volt battery through an on/off switch. The pump has a pumping pressure of 268 kPa and discharging capacity of or 2.5 x10^{-5} m^3/s (1.5litre per minutes). The consumed voltage of the pump and the consumed current is 12volt and 3.5A respectively. The power consumption of the pump is 42 watts.

2.3 Kitchen wastewater sampling

Sampling doses were in volumes of 75 ml of the treated Grey wastewater obtained from Smile-View Hotel in triplicate of breakfast, lunch and dinner. These samples are further categorized as Control, Filtered and Filtered-Chlorinated. Some of the quality indices that were determined experimentally include; BOD, COD, NH_4-N and the pH values. For each of the quality indices, variations in meal time also were introduced.

2.4 Testing of treated wastewater

The treated wastewater was subjected to test at the standard laboratory for the determination of some of the quality parameters using standard methods.

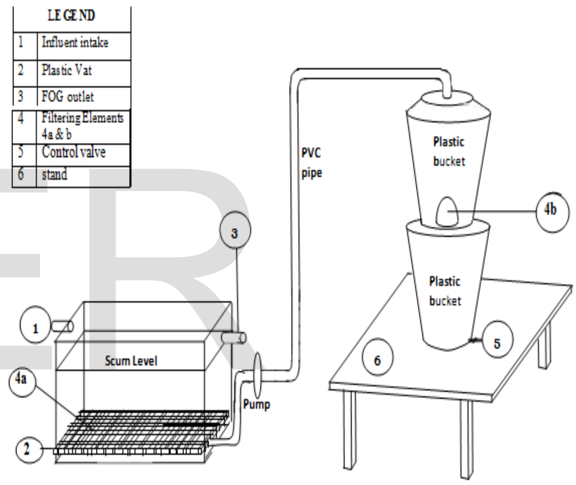

Fig.1. The filtration system for kitchen waste water treatment

The pH was determined using standard method for examination of wastewater [11], while the Chemical Oxygen Demand (COD) was determined by calorimetric method [12]. Ammonium – Nitrogen was measured by colorimetry as described by Peters and others [13]. The biological Oxygen Demand (BOD_5) was measured after 5 days of incubation at the temperature of 20^oC.

2.5 Statistical analysis

Determinations were done in 3 replicates using factorial experimental layout in CRD with waste water media and meal time as two treatment factors and each having three levels. Data obtained were subjected to analysis of variance using SPSS (version 20). Where significant difference was found among the experimental data at 95% confident level, means separation was performed using Duncan's New Multiple Range Test (DNMRT).

3 RESULTS AND DISCUSSION

The mean concentration of the quality parameters for the kitchen waste water sampled at the three different meal

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times for the three waste water media are presented in Table 1 and graphically presented on Figures 2 to 5. Table 2 presents the ANOVA results for the measured quality parameters. The summary of the comparison of means to ascertain significance of difference of means based on the ANOVA results of Table 2 at 5% level using Duncan's New Multiple Range Test (DNMRT) are presented in Table 3. Figure 2 shows that there is reduction in the magnitude of BOD_5 concentration with the filtration medium but the highest reduction was achieved with the filtered-chlorinated medium. Meanwhile, the BOD_5 values for the Control medium remain consistently the highest across the meal times. Lowest values of BOD_5 were observed with the waste water samples obtained at the Lunch time. This may be attributed to the meal type which is more of energy giving diets. Figures 3 – 5 show similar trend observed with the Control medium as it recorded the highest values for all the waste water parameters for the three different meal times. Filtered-Chlorinated medium, however, recorded the lowest values of all the waste water parameters across the meal times and as such has the highest contaminant removal efficiency.

Table 1 Mean concentration of quality parameters for the three waste water media at different meal times alongside FAO 1985 and USEPA 2002 Standards

Measured parameters	Meal time	Waste water media			FAO 1985 Standard	USEPA 2002 Standard
		Control	Filtered	Filtered-chlorinated		
BOD_5, mg/l	Breakfast	11.3	7.03	5.67	30	40
	Lunch	8.23	7.6	4.70		
	Dinner	11.13	9.3	4.93		
COD, mg/l	Breakfast	806	692	396	-	120
	Lunch	731	633	414		
	Dinner	729	578	482		
NH_4-N, mg/l	Breakfast	6.43	3.2	1.7	5	4
	Lunch	8.9	5.4	4.1		
	Dinner	11.73	7.86	1.2		
pH	Breakfast	9.5	8.6	7.1	6.5 – 8.5	5 – 9
	Lunch	10.5	8.5	8.0		
	Dinner	11.5	8.7	6.7		

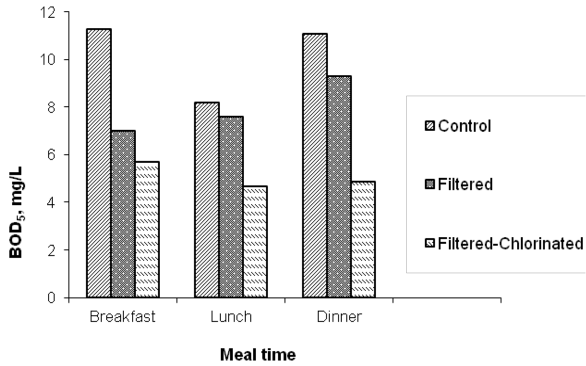

Figure 2: The BOD_5 for different meal time and waste water media.

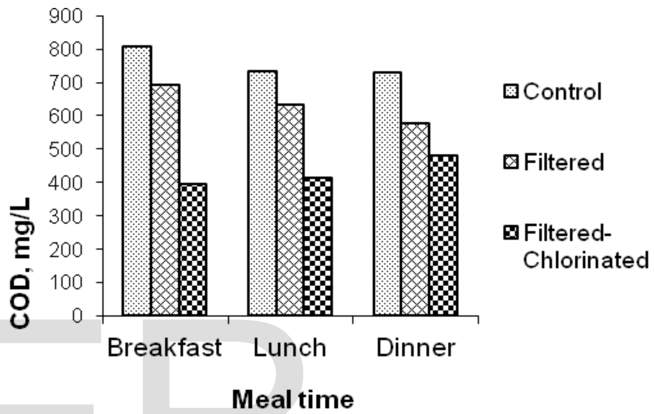

Figure 3: the COD values for different meal time across the waste media.

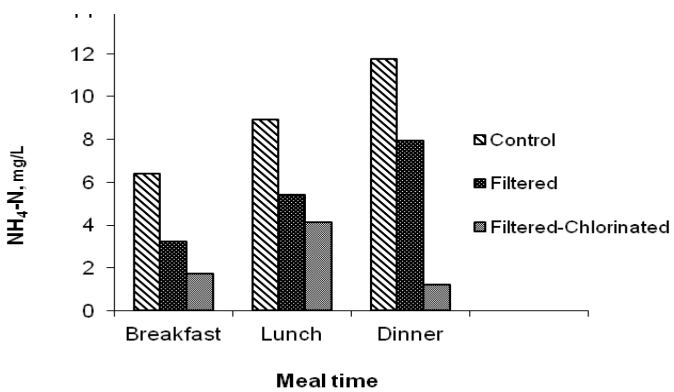

Figure 4: The NH4 values for different meal time across

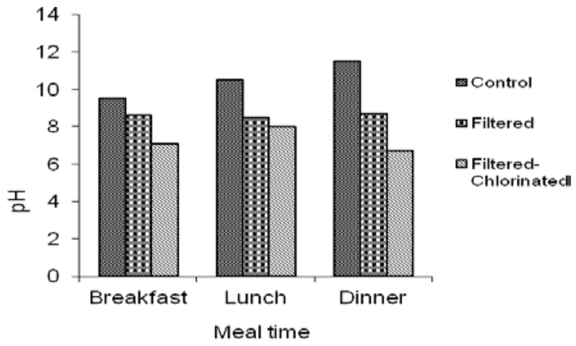

Figure 5: The pH for diffent meal time across waste water media.

Table 2 Summary of ANOVA for the various quality parameters for the three waste water media and meal time

Source of variation	Df	SS	MS	F	Sig.
BOD, mg/L					
Treatment media	2	118.71	59.36	35.76*	0.000
Meal time	2	2.067	1.034	0.623^{ns}	0.548
Error	18	29.880	1.660	-	-
COD, mg/L					
Treament media	2	483642.741	241821.370	80.741*	0.000
Meal time	2	11787.630	5893.815	1.968^{ns}	0.169
Error	18	53910.667	2995.037	-	-
NH_4, mg/L					
Treatment media	2	202.451	101.226	18.774*	0.000
Meal time	2	0.728	0.364	0.667^{ns}	0.935
Error	18	97.051	5.392	-	-
pH					
Treatment media	2	47.870	23.935	45.478*	0.000
Meal time	2	2.032	1.016	1.930^{ns}	0.174
Error	18	9.473	0.526	-	-

df = degree of freedom; SS= Sum of square; MS = Mean square; F = Fisher value; * = Significant (P< 0.05); ns = not significant

Table 3: Comparison of effects of treatment media on the waste water quality parameters

Waste water media	Waste water Quality parameters			
	BOD mg/L	COD mg/L	NH_4 mg/L	pH
Control	10.22 (± 1.58^{a})	755.11 (± 52.62^{a})	9.09 (± 2.50^{a})	10.52 (± 0.94^{a})
Filtered	7.99 (± 1.12^{b})	634.33 (± 61.88^{b})	5.49 (± 2.18^{b})	8.61 (± 0.43^{b})
Filtered-Chlorinated	5.10 (± 0.53^{c})	430.78 (± 42.34^{c})	2.32 (± 1.34^{c})	7.28 (± 0.63^{c})

Different superscript letters within the same column indicate significant differences according to Duncan's New Multiple Range Test (P<0.05)

From the summary of the results of ANOVA (Table 2), it is observed that waste water media have significant effects on BOD_5 concentration and Table 3 showed that the BOD_5 mean concentration values for the three waste water media were statistically different.
The comparison of Filtered and Filtered-Chlorinated media versus Control showed significantly higher (P<0.05) reduction for BOD_5 in Filtered and Filtered-Chlorinated, 21.8% and 50.1%, respectively. The meal times showed no significant effect (P< 0.05) on BOD_5 concentration. The BOD_5 values obtained with the Control and treated waste water samples are within the permissible limits for effluent safe discharge into the environment.

ANOVA results on Table 2 showed that waste water media have significant effect (P<0.05) on COD reduction. The meal times have no significant effect on COD values. Table 3 shows that the mean concentrations of COD for the three waste water media were also statistically different (P<0.05). The comparison of the three waste water media on Table 3 showed significantly higher effect (P< 0.05) on the COD reduction in the Filtered and Filtered-Chlorinated media, 16.0 % and 43.0 %, respectively than that of Control. The lowest mean value of 430.78mg/L obtained for COD is above the recommended limits for effluent discharge into the environment.

The results of ANOVA of NH_4-N parameter showed significant effect (P<0.05) of the waste water media. Meal times have no significant effect in the reduction of the quality parameter concentrations. The NH_4-N mean concentrations for the three media were statistically different (Table 3). In comparison Filtered and Filtered-Chlorinated media showed significantly higher (P<0.05) reduction in NH_4-N concentration, 39.1 % and 74.3 %, respectively, than Control medium. The values recorded with Filtered and Filtered-chlorinated are within the tolerable limit for irrigation with waste water as well as discharge into the environment.

The summary of ANOVA results indicates that meal times have no significant effect in pH values at 5 percent probability. The results of Table 3 also indicate that differences in the mean concentration of pH values were statistically significant (P< 0.05). The comparison of Filtered and Filtered-Chlorinated versus Control media showed higher significant effects (P<0.05) on pH reduction, 18.2 % and 30.8 %, respectively. The pH values obtained with the Filtered and Filtered-chlorinated which are 8.61 and 7.28 respectively are within the limit for irrigation water [14].

4. CONCLUSION

The system that was developed for the treatment of kitchen waste water for safe discharge and reuse significantly reduces the concentrations of all the pollutants of the hospitality waste water tested in this study. The Filtered medium showed higher significant effect ($P<0.05$) in the reduction of all the quality parameters in comparison with the Control media while the highest reduction was achieved with the Filtered-Chlorinated medium. All the quality parameter values obtained with the Filtered and Filtered-Chlorinated treatment media fall within the safe standards of FAO [14] and USEPA [15] for irrigation of crops. The resultant water obtained can be used for gardening, landscaping or safely discharge into environment.

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