ANALYTICAL STUDY AND PERFORMANCE EVALUATION OF A LAB-SCALE GREYWATER TREATMENT PLANT

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Abstract

This study presents the recycling 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,Nigeria. These samples were analyzed for turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), total dissolved solid (TDS) and total hardness. Analysis of Variance (ANOVA), Coefficient of variance and Correlation Matrix were used to analyse data obtained. Differences in parameter concentration between the influent and effluent parameters were considered significant at 5% level of significance (i.e $p \leq 0.05$). The concentration of these parameters decreased significantly as a result of the treatment. Coefficient of Variation indicates that most influent and effluent parameters have coefficient of variations that are less than 10% meaning that the raw greywater samples were well collected and consistent in quality. A correlation matrix show that biochemical oxygen demand (BOD), turbidity and total suspended solid (TSS) are strongly related. This shows that the system is consistent in treatment and may be adopted for treatment of greywater for non-potable uses in areas with limited water supply.

Keywords: Greywater, *Moringa Oleifera*, natural treatments systems, turbidity, total suspended solid

Introduction

The paper provides information on the design and and analytical performance of a designed greywater recycling systems. The quality of greywater varies depending upon the source of the water and the uses to which it has been put. Light-greywater typically consists of drainage from bathroom sinks, tubs,showers, and often laundry. Dark-greywater includes both light-greywater sources plusdrainage from kitchen sinks, automatic dishwashers, or other sinks involving food preparation.Reuse of greywater places the onus on householders to take moderate care over what isallowed to enter the greywater in the first place.

The term greywater throughout this paper refers to light-greywater. Greywater recycling practices must guard against risks to public health, safety, and the environment. Different qualities of greywater require different treatment processes, depending upon the potential risks. Greywater must be treated to remove substances that might be harmful to plants, human health, and the wider environment, and substances that might clog the system. The appropriate treatment method depends upon the quality of the incoming greywater and its end use. Relatively simple treatment methods can enable most light-greywater to be reused for subsurface irrigation, and toilet or urinal flushing.

Production of biologically and chemically safe water is the primary goal in the design of water treatment plants; anything less is unacceptable. The basic objective of water treatment is that water treatment may be accomplished using facilities with reasonable capital and operating costs. Various alternatives in plant design should be evaluated for production of cost effective quality water.

The treatment processes of greywater before it can be reused for non-potable purposes must be based on removal level of impurities to comply with various guidelines. The extent of treatment depends upon the quality of the raw water and the desired quality of treated water. (Hong, 2006). The choice of which treatment to use from the great variety of available processes depends on the characteristics of the water, the types of water quality problems likely to be present, and the costs of different treatments. The processes and technologies used to remove contaminants from water and to improve, protect water quality are similar all around the world. In this study , a combination of natural draft aerator, coagulation, flocculation, sedimentation, and filtration.

Problem definition

In Nnamdi Azikiwe University, Awka (NAU) Nigeria, there has been unavailability of public water supply. Therefore, the alternative sources of water supply left to the university are either the surface water which is Ezu river, located at the boundary between two nearby communities, Amansea and Ugwuoba communities and ground water supply. Unfortunately, the river cannot produce enough yield needed to serve the population of Awka whilethe second optional source which is groundwater supply, has been unreliable. This is due to the fact that the groundwater formation of Awka and its environs lie on Imo shale formation. This shale is intercalated by few lenses of sandstone which are too thin to allow sustainable yield that will serve an institution like NAU. This condition is manifested in very low yield especially during intensive dry season by shallow wells presently existing in the school hostels (Nwajuaku, 2010).

Hence in the light of the above circumstances, the reuse of greywater for purposes such as toilet flushing in the school hostels can be a potential solution to water demand particularly in the dry seasons. This is because the resident student population could contribute substantial amount of greywater for recycling.

The objective

The objective of this study is to analyse the relationship between the input, state, and output variables generated by comparing the effect of individual treatment units of influent and effluent parameter concentration to determine the presence or absence of any difference between them.

Hypothesis testing

H_{O1}: There is no significant difference between the effluent parameter concentrations from the aerator, cogulation- flocculation- sedimentation and filtration unit.

$H_{O2:}$ There is no significant difference between the influent and overall effluent parameter concentrations

$H1_1$: There is a significant difference between the effluent parameter concentration from the aerator, coagulation/flocculation/sedimentation and filtration units.

$H1_2$: There is a significant different between the influent and overall effluent parameterconcentration.

Under the four general hypotheses stated above, the following hypotheses for various parameters underlisted were tested:

pH

$Ho_{1_{pH}}$: There is no significant difference between pH concentration from the aerator, coagulation/flocculation/sedimentation and filtration units.

$H1_{1_{pH}}$: There is a significant difference between pH concentration from the aerator, coagulation/flocculation/sedimentation and filtration units.

$Ho_{2_{pH}}$: There is no significant different between pH of influent and overall effluent pH concentration.

$H1_{2_{pH}}$: There is a significant different between pH of influent and overall effluent pH concentration.

This procedure was also applied in the testing of other parameter viz : total hardness, BOD, COD, TSS, and TDS.

Materials and methods

Description of the lab- scale greywater treatment plant processes

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.

The design of a water treatment plant requires a series of design considerations in order to arrive at a desirable concept that would achieve efficient treatment and deliver the water economically with an acceptable minimum adverse impact on the environment.

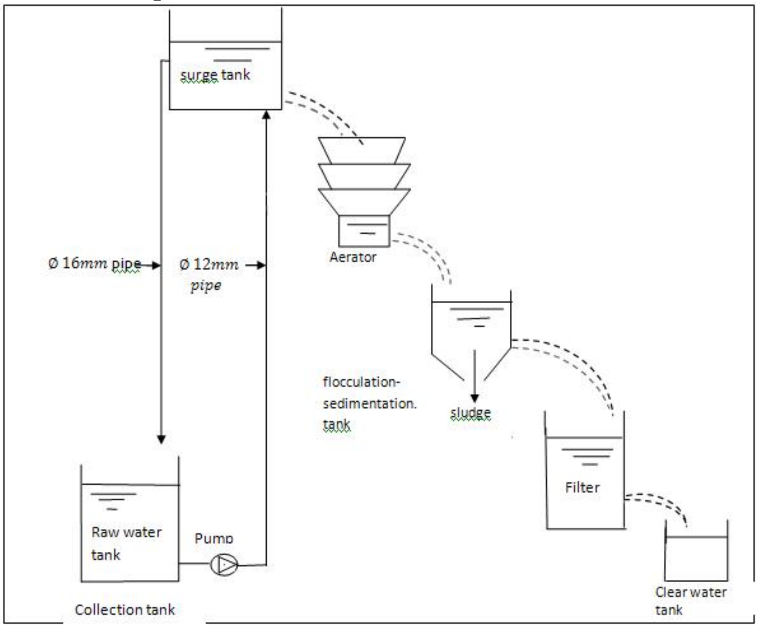

Figure 1: experimental set up

For this unit to be cascaded, the plant will be constructed at a location where there is a hill so that gravity flow can be used. Each of the various tanks will be constructed on a level platform, but at decreasing levels down the hill so that the pipes can be constructed sloping downwards. In a situation where this is not possible, Site topography can be altered by burying or raising process units, typically to provide sufficient head as far as the outfall.

Experimental procedures

Aeration

Aeration allows for the intimate exposure of water and air by intensely mixing the air and water so that chemical reactions can occur between the air and water in the aerators. The primary objective of aeration is to improve water quality by eliminating tastes and odour producing substances such as hydrogen sulfides and carbon dioxide. (Fair *et al.* 1971). In this study, a multiple tray aerator was designed and fabricated.

Multiple-tray aerators are comprised of multiple levels of slated weirs or perforated trays filled with coke or gravel for maximum removal, a collection basin, and an induced or forced draft ventilation system (Taricska *et al.,* 2009). The water first enters a distributor tray and then falls from tray to tray, finally entering an open collection basin at the base of the tray aerators. The trays were trapezoidal in shape and arranged vertically with a space of 12.7cm between them. These trays were perforated with 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. In aerators with no provision for forced ventilation, the trays are usually filled with 2- to 6-inch media, such as coke, stone, ceramic or plastic balls to improve water distribution and gas transfer by increasing surface area between the two phases (Taricska *et al.,* 2009)

Coagulantion and flocculation

Coagulation is a complex process, involving many reactions and mass transfer steps. As practiced in water treatment the process is essentially three separate and sequential steps: coagulant formation, particle destabilization, and inter-particle collisions. These processes had been achieved by adding chemical material. These chemicals involved in coagulation are known as coagulants or coagulant aids. Choice of specific coagulants and coagulant aids depend on the nature of the solid– liquid system to be separated (Fernandez 2002). Common coagulants used are aluminum sulfate, and iron (II). *Moringa Oleifera,* anatural coagulant has been successfully used in laboratory and, to some extent, in pilot and full-scale studies because of its lower costs and in some cases it achieves slightly better removal of natural organic contaminants.

FSC I (2003) defined flocculation as a slow stirring process that causes the flocs to grow and to come in contact with particles of turbidity to form larger particles that will readily settle. The purpose is to produce a floc of the proper size, density, and toughness for effective removal by sedimentation and filtration. Floc formation depends on the rate at which collisions between flocs and particles occur, and how the flocs stick together after collision. Gentle mixing during this stage provides maximum particle contact for floc formation, whilst minimizing turbulence and shear which may damage the flocs.

Sedimentation

Sedimentation is a physical treatment process that utilizes gravity to separate suspended solids from water. This was the next stage of the treatment processes ,used to remove turbidity causing particles after coagulation and flocculation. 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 of 0.29m in diameter . It has a conical bottom of 0.057m and combined the functions of flocculation, sedimentation and sludge removal.

Filtration

Filtration is the process of passing water through a porous medium with the expectation that the filtrate has a better quality than the influent, the medium is usually granular bed, such as sand, anthracite, garnet, or activated carbon (Najee, 2007). Filters can be classified according to the medium type as single (mono.) medium filters, dual media filters, and mixed-media filters. 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 (Nwafor, 2010). These choices of media depths of sawdust and sand used in this experiment were guided by filter media specification recommended in (AWWA, 2001).

Table 1: summary for the design of treatment units

Units	Velocity(m/s)	Headloss (m)	Flow (m)	Length (m)	Width (m)	Depth (m)	Diameter (m)
Aeration	0.156m/s	0.09	1.77×10^{-4}m^3/s	25.4	25.4	0.05	
Sedimentation						0.29	0.29
Filtration		0.0234		0.22	0.21	0.65	

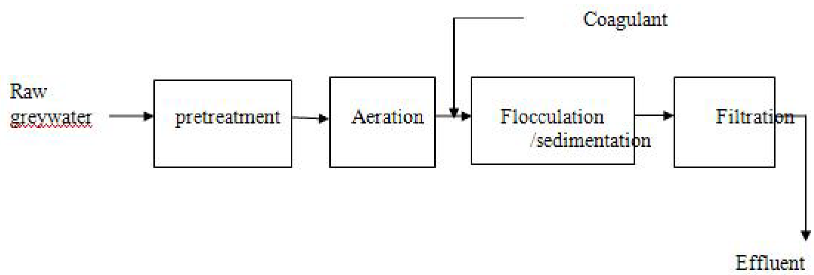

Figure 2: schematic flow diagram for greywater treatment processes

Feed greywater from a collection tank was delivered 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/s, and a headloss of 0.09m to the flocculation/sedimentation tank which was 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, followed by 5 minutes of slow mixing. Then, the water was allowed to settle for 1 hour as recommended by Doerr (2005). The flocs formed moved to the hopper of the flocculation-sedimentation tank and were removed manually after the settling period. Finally, the effluent was delivered to the filtration unit with a headloss of 0.234m and finally to a clear water tank.

Discussion of results

A one-way analysis of variance is used to show the presence of statistical significant differences in the percentage reduction of parameter concentrations between three treatment units; aerator, coagulation-flocculation-sedimentation and filtration units and also between influent and overall effluent.

Table 2: one-way analysis of variance for comparing effects of aerator, coa-foc-sed. And filtration units on ph

Source of variance	ss	df	ms	f	p-value	f crit
Between g	2.919093	2	1.459547	158.3595	2.37e-09	3.885294
Within gro	0.1106	12	0.009217			
total	3.029693	14				

The analysis in Table 2 indicates that the pH values of effluents between aerator, coagulation-flocculation-sedimentation and filtration units are significantly different. (F = 158.3 > F critical = 3.8; 2.37E-09 < p<0.05). This confirms that there is a variation in the pH value of the effluents from the three treatment units, although the value lies within the acceptable limit.

Summary

There is a significant difference in the pH values between effluents from the aerator, coagulation-flocculation-sedimentation and filtration units. Therefore reject H$o_{1_{pH}}$.

Table 3: one-way analysis of variance for comparing effects of aerator, coa-floc- sed.and filtration units on total hardness

source of variance	ss	df	ms	f	p -value	f crit
between g	88082.8	2	44041.4	2262.401	3.2e-16	3.885294
within gro	233.6	12	19.46667			
total	88316.4	14				

The ANOVA for total hardness shown in Table 3 below, reveals that the total hardness values of effluents between aerator, coagulation-flocculation-sedimentation and filtration units are significantly affected. (F = 2262.4 > F critical 3.8; 3.42E-16 < p <0.05). The result is an indication that all three treatment units have significant effect on the parameter mentioned above.

Summary

There is a significant difference in total hardness values between effluents from the aerator, coagulation-flocculation-sedimentation and filtration units.Therefore reject H$o_{1_{total\ hardness}}$.

Table 4: one-way analysis of variance for comparing effects of aerator, coa-foc-sed. And filtration units on bod

Source of variance	*ss*	*df*	*ms*	*f*	*p -value*	*f crit*
Between g	58515.	2	29257.6	4369.849	6.65e-18	3.885294
Within gro	80.344	12	6.695333			
Total	58595.54	14				

In Table 4, one-way analysis shows that BOD varied significantly between effluent from the aerator, coagulation-flocculation-sedimentation and filtration units. (F = 4369.8 > F critical 3.8; 6.65E-18 < p<0.05).

Summary

There is a significant difference in the BOD values between effluents from the aerator, coagulation-flocculation-sedimentation and filtration units. Therefore reject H$o_{1_{BOD}}$.

Table 5: one-way analysis of variance for comparing effects of aerator, coa-floc-sed.and filtration units on cod

source of variance	*ss*	*df*	*ms*	*f*	*p – value*	*f crit*
*Be*tween g	49591.6	2	24795.8	635.7897	635.e-13	3.885294
Within gro	468	12	39			
Total	50059.6	14				

In Table 5, it can be seen that there is a variation in COD values between effluent from the aerator, coagulation-flocculation-sedimentation and filtration units. (F = 4369.8 > F critical 3.8; 6.65E-18 <p<0.05).

Summary

There is a significant difference in the COD values between effluents from the aerator, coagulation-flocculation-sedimentation and filtration units. Therefore reject H$o_{1_{COD}}$.

Table 6: one-way analysis of variance for comparing effects of aerator, coa-floc-sed. And filtration units on tss

source of variance	*ss*	*df*	*ms*	*f*	*p - value*	*f crit*
*Be*tween g	45366.53	2	22683.27	803.4215	1.66e-13	3.885294
Within gro	468	12	39			
Total	45705.3	14				

Table 6 shows that TSS values between effluents from the aerator, coagulation-flocculation-sedimentation and filtration units are significantly different. (F = 803.4 > F critical 3.8; 1.66E-13< p<0.05).

Summary

There is a significant difference in TSS between effluent from the aerator, coagulation-flocculation-sedimentation and filtration units. Therefore reject H$o_{1_{TSS}}$.

Table 7: one-way analysis of variance for comparing effects of aerator, coa-floc-sed. And filtration units on tds

source of variance	*ss*	*df*	*ms*	*f*	*p -value*	*f crit*	
*Be*tween g	94713.73	2	803.4247	236.7843	2.28e-13		3.885294
Within gro	468	12	39				
Total	97113.73	14					

The result in the Table 7 reveals that there is a significant variation in TDS between effluent from the aerator, coagulation-flocculation-sedimentation and filtration units. (F = 236.8 > F critical 3.8); 2.28E-10 < p<0.05).

Summary

There is a significant difference in TSS between effluent from the aerator, coagulation-flocculation-sedimentation and filtration units. Therefore reject H$o_{1_{TDS}}$.

The implication of the above one–way anova for comparing effects of aerator, coagulation-flocculation-sedimentation units and filtration on parameter concentrations, is that the system is efficient in reduction of parameter concentrations in effluents of individual treatment units.

Table 8: one-way analysis of variance for differences between influent and overall effluent ph values

source of variance	*ss*	*df*	*ms*	*f*	*p-value*	*f crit*
*B*etween g	3.89376	1	3.89376	2225.006	4.51e-1	5.317655
Wthin gro	0.014	8	0.00175			
Total	3.90776	9				

The analysis in Table 8 indicates that the pH values between influent and effluent are significantly affected. (F = 2225.0 > F critical 5.3; 4.51E-11 <p<0.05)

Summary

There is a significant difference in the pH values between the influent and overall effluent. Therefore reject $\mathrm{H}o_{2_{PH}}$.

Table 9: one-way analysis of variance for differences between influent and overall effluent total hardness values

source of variance	*ss*	*df*	*ms*	*f*	*p –value*	*fcrit*
*B*etween g	91202.5	1	91202.5	11400.31	6.61e-14	5.317655
Within gro	64	8	8			
Total	91266.5	9				

The ANOVA for total hardness shown in Table 9 reveals that the total hardness values between the influent and overall effluent are significantly affected. (F = 11400.3 > F critical 5.3; 6.61E-11 < p<0.05).

Summary

There is a significant difference in total hardness values between the influent and overall effluent. Therefore reject $\mathrm{H}o_{2_{total\ hardness}}$.

Table 10: one-way analysis of variance for differences between influent and overall effluent bod values

source of variance	*ss*	*df*	*ms*	*f*	*p – value*	*f crit*
*B*etween g	69105.9	1	69105.97	20138.71	6.8e-15	5.317655
Within gro	27.452	8	3.4315			
Total	69133.42	9				

Significant difference is shown in the variance analysis table (Table 10) for biochemical oxygen demand (BOD). The one-way analysis shows that BOD varied significantly between the influent and overall effluent.(F = 20138.7 > F critical 5.3; 6.8E-15 <p<0.05).

Summary

There is a significant difference in total hardness values between the influent and overall effluent. Therefore reject $\mathrm{H}o_{2_{BOD}}$.

Table 11: one-way analysis of variance for differences between influent and overall effluent cod values

source of variance	*ss*	*df*	*ms*	*f*	*p –value*	*f crit*
*be*tween g	67240	1	67240	8150.303	2.53e-1	5.317655
within gro	66	8	8.25			
total	67306	9				

In Table 11, it can be seen that there is a variation in COD values between the influent and overall effluent (F = 8150.3 > F critical 5.3; 2.53E-13 <p<0.05).

Summary

There is a significant difference in total hardness values between the influent and overall effluent. Therefore reject H$o_{2_{COD}}$

Table 12: one-way analysis of variance for differences between influent and overall effluent tss values

source of variance	*ss*	*df*	*ms*	*f*	*p value*	*f crit*
*Be*tween g	69388.9	1	69388.9	9570.883	1.33e-13	5.317655
Within gro	58	8	7.25			
Total	69446.9	9				

Table 12 shows that TSS values between the influent and overall effluents are significantly affected (F = 9570.9 > F critical 5.3; 1.33E-13 <p<0.05).

Summary

There is a significant difference in TSS values between the influent and overall effluent. Therefore reject H$o_{2_{TSS}}$.

Table 13: one-way analysis of variance for differences between influent and overall effluent tds values

source of variance	*ss*	*df*	*ms*	*f*	*p value*	*f crit*
*Be*tween g	313290	1	313290	46759.7	2.34e-16	5.317655
Within gro	53.6	8	6.7			
Total	313343.6	9				

Lastly, analysis of variance shown in Table 13 reveals that there is a significant variation in TDS between the influent and overall effluent. (F = 46759.7 > F critical 5.3; 2.34E-16 < p<0.05).

Summary

There is a significant difference in TDS values between the influent and overall effluent. Therefore reject H$o_{2_{TDS}}$.

The implication of the above one –way anova for differences between influent and overall effluent parameter concentrations, is that the system is efficient in reduction of parameter concentrations in the overall effluent.

Table 14: coefficient of variation for influent mean result

Parameter	**Influent mean**	**Standard deviation**	**Coefficient of variation(%)**
Turbidity (ntu)	64.6	2.87054	4.44356
Ph	8.432	0.020396	0.241889
Total hardness(mg/l)	285	2.280351	0.800123
Biochemical oxygen demand(bod)(mg/l)	182	1.897367	1.042509
Chemical oxygen demand(bod)(mg/l)	211	2.828427	1.340487
Total suspended solid (tss)(mg/l)	179.2	2.993326	1.670383
Total dissolve solid (tss)(mg/l)	526.8	2.925748	0.555381
Calcium	0.13	0.018974	14.59513
Magnessium	0.11	0.006325	5.749596
Sulphate	21.1	0.43359	2.054927
Nitrate	0.636	0.035553	5.590059
Phosphorus	0.0288	0.004956	17.20766
Ammonia-n	0.434	0.030725	7.079397
Faecal coliform	34800	748.3315	2.150378
total coliform	26200000	1166190	4.451108

Table 14 shows that the highest coefficient of variation is 17.207 while the least coefficient of variation is 0.241. This is an indication that most influent parameters have coefficient of variation that are less than 10% meaning that the raw greywater samples were well collected and consistent in quality (Westgard et al.,1998).

Table 15: coefficient of variance for effluent mean result

Parameter	**Effluent mean**	**Standard deviation**	**Coefficient of variation**
Turbidity (ntu)	0.82	0.074833	9.125994
Ph	7.184	0.048826	0.679652
Total hardness(mg/l)	94	2.75681	2.932776
Biochemical oxygen demand(bod) (mg/l bod	15.74	1.374918	8.735185
Chemical oxygen demand(bod) (mg/l)cod	47	2.280351	4.85181
Total suspended solid(tss)(mg/l)tss	12.6	1.624808	12.8953
Total dissolve solid(tss) (mg/l)tds	172.8	1.469694	0.850517

Calcium	0	0	-
Magnesium	0	0	-
Sulphate	10.6	0.275681	2.600764
Nitrate	0.218	0.020396	9.355999
Phosphorus	0.013	0.001095	8.426501
Ammonia-n	0.744	0.031369	4.216233
Faecal coliform	324	20.59126	6.355327
total coliform	205600	2576.82	1.253317

In Table 15, the highest coefficient of variation is 12.8 while the least coefficient of variation is 0.677. This means that most effluent parameters have coefficient of variation that are less than 10% meaning that the system is consistent in treatment.

Table 16: correlation matrix for influent parameter

	Ph	**tubidity**	**t.hardness**	**bod**	**cod**	**tss**	**tds**
Ph	1						
Turbidity	0.013664	1					
T. Hardness	-0.17201	0.947167	1				
Bod	0.516811	-0.22033	-0.13868	1			
Cod	-0.5547	0.197066	0.496139	0.074536	1		
Tss	-0.288278	0.055863	-0.058601	-0.21129	0.1889822	1	
Tds	0.040219	-0.96208	-0.98925	0.108084	-0.435031	-0.1552	1

In Table 16, Correlation matrix for influent shows that the correlation between biochemical oxygen demand (BOD) and turbidity is -0.220 , and between total suspended solid (TSS) and turbidity is 0.055. A correlation coefficient of zero indicates that there is no linear relationship between these parameters.

Table 17: correlation matrix for effluent parameter

	Ph	**tubidity**	**t.hardness**	**bod**	**cod**	**tss**	**tds**
Ph	**1**						
Turbidity	-0.40506	1					
T.hardnes	0.5349	-0.77557	1				
Bod	0.927128	-0.20216	0.495991	1			
Cod	0.071851	0.820413	-0.73173	0.146717	1		
Tss	-0.33277	0.888235	-0.7144	-0.27932	0.8096878	1	
Tds	0.652178	0.03637	-0.24681	0.508732	0.5967624	0.134005	1

Correlation matrix for effluent reveals that the correlation between biochemical oxygen demand (BOD) and turbidity is -0.202, and between total suspended solid (TSS) and turbidity is 0.888 (meaning that as TSS decreases, turbidity decreases) as shown in Table 3.15. This indicates that both parameters are strongly related and does not mean that one parameter causes change in the other.

Conclusion

The statistical analysis showed that there is significant variation between the influent and effluent parameters. This mplies that the system is efficient in reduction of the following parameter concentrations. parameters; turbidity, BOD, COD,TDS TSS, and Total hardness.. This system should be adopted for providing water for use during dry season in areas with limited water supply for non-potable uses because of its low maintenance and operational costs. To save these costs, the plant will be constructed at a location where there is a hill so that gravity flow can be used. Each of the various tanks will be constructed on a level platform, but at decreasing levels down the hill so that the pipes can be constructed sloping downwards. This will eliminate the need for the pumps commonly used in every operation throughout the process. The 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.

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