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DEVELOPMENT AND PERFORMANCE EVALUATION OF A POULTRY WASTE MANAGEMENT TECHNIQUE USING GRAVITY SAND FILTER

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Abstract
The research aimed at developing and evaluating a poultry waste management technique using gravity sand filter. Poultry waste slurry prepared in a mixing tank was intermittently applied uniformly to the surface of a filter bed using a spreader as dosing technique. Two different types of configurations were designed for the filter bed. Single media bed consisted of 150mm depth of silica sand with average particle diameter of 0.5mm. Dual media bed consisted of 100mm depth of granulated charcoal with average particle diameter of 1.0mm and 50mm of silica sand with average particle diameter of 0.5mm. Design considerations important to achieving this level of treatment include; pretreatment, media characteristics, hydraulic and organic loading rates and filter dosing techniques. Each sand filter configuration was operated daily for a period of 12days. The following data were collected on a daily basis: Volume of effluents (mm^3), hydraulic residence time (Hours), unit filter run volume (m^3/m^2), filtration rate or filtration velocity (mm/hr). Head loss on the filter was calculated using Carmen-Kozeny equation for uniform sand bed. Laboratory investigations showed that effluent from the filter had biological oxygen demand (BOD_5), total suspended solids (TSS), total dissolved solids (TDS), and turbidity range between1.98 – 12.08 mg/L, 20.75 – 30.20 mg/L, 29.40 – 34.40 mg/L and 5.10 – 6.20 NTU.

Keywords: Poultry, waste, filtration, technique, management, Poultrywaste, gravity sand filter, filtration technique

1. Introduction

Poultry production forms an important aspect of livestock sub-sector in Nigeria and is considered to be the largest livestock group estimated to be about 4.2 million, consisting mainly of chickens, ducks, guinea fowls, turkeys, pigeons and ostriches (NPC, 2006). Poultry litter is a mixture of bedding material and poultry manure arising from the housing of poultry and with dry matter content not less than 55% (Onisanwa, 2014). Poultry industries produce large quantities of waste in solid and liquid form. Poultry solid waste consists of bedding materials, excreta (manure), feed, feathers, hatchery waste (empty shells, infertile eggs, dead embryos and late hatchlings), shells, sludge, abattoir waste (offals, blood, feathers and condemned carcases) and mortality (Onisanwa, 2014). Poultry waste is usually a combination of poultry bird faeces, urine, sawdust and remnants of animal feeds, drugs and pesticides (Adedayo, 2012). Poultry raised for commercial purpose could produce a large amount of manure, which unlike the manure of free ranged or pastured animals is a collectable resource. Poultry manure contains high phosphorus which has a positive effect on the growth and productivity of crops. It is also effective when combined with mineral phosphorus fertiliser for farm use (Moreki and Keaikitse, 2013). Dead birds and hatchery waste are high in protein and contain substantial amounts of calcium and phosphorus due to high levels of mineral supplements in the diet. The approximated percentages of nutrient intake excreted by poultry are: nitrogen (65.5%), phosphorus (68.5%) and potassium (83.5%), elements for soil fertility and increased crop production (Olumayowa and Abiodun, 2011).

Poultry meat and eggs provide affordable and quality food products that are consumed worldwide. Advances in knowledge and technology over recent decades favour the growth and intensification of poultry production in developing countries where there are increasing human populations. However, poultry is a potential hazard that can result in pollution of surface and ground water and the emission of large quantities of unpleasant and provocative odour (greenhouse gases) (Moreki and Chiripasi., 2011).

One aspect of poultry operations that has not kept pace with the increase in the intensity of poultry production is waste management. The production of poultry products results in hatchery wastes, manure, litter, and on-farm mortalities all which are high in protein and contain substantial amounts of calcium and phosphorus due to the high levels of mineral supplements in the poultry diet. The processing of poultry results in additional waste materials, including offal (feathers, entrails, and organs of slaughtered birds), processing wastewater and bio-solids. Most of these by-products can provide valuable organic and inorganic materials if managed and recycled properly, regardless of flock size (Moore and Chiripasi, 2011). Poultry waste disposal employed by poultry operators are selling, burying, flushing, rendering, incinerating, compositing, livestock feeding and soil fertilising. Other waste disposal methods include conversion of poultry waste to source of energy and treatment of water contaminated with heavy metal (Moore and Chiripasi, 2011).

Recent studies have provided evidence of environmental, social and economic contributions of waste utilisation for urban food production. However, a major problem to contend with remains how waste can best be managed for healthy food production with minimal negative health implications (Nahn and Nahm, 2004). In lieu of this, concern for soil, water and air quality is the key to selecting a successful waste management plan and technique. This concern for an appropriate poultry waste management technique necessitated this study aimed at developing and evaluating a poultry waste management technique using gravity sand filter.

2. Materials and Methods

2.1 Description of Structural Components

The poultry waste management mechanism consisted of plastic slurry tank, plastic filter tank (sand and gravel and sand and charcoal), pipes and under-drains, manual control valves, spreaders, and effluent tank. Shown in figures 1, 2 and 3 are the experiment setup, manifolds and spreader of the treatment plant.

Figure 1: Sand filter treatment for poultry waste

Figure 2: Manifolds with Lateral Pipes

Figure 3: Spreader

The slurry tank was a cylindrical plastic drum. The slurry tank was connected to the filter tank, placed below the slurry tank, by a discharge outlet positioned at 5cm from the bottom of the filter tank to enable flow by gravity. This connection was made using 2 inches diameter pvc pipe. A control valve was installed 30 cm from the slurry tank in order to control flow. The filter tank was also cylindrical in shape and made of plastic material but it was of bigger size or volume compare to that of slurry tank. In the filter tank, there was a layer of a sand filter bed. Sand filter bed is a range of grain sizes for the base soil or soils to satisfy filtration requirements. A screen or spreader was provided at the top cover of the filter tank in order to spread or discharge the flow of slurry uniformly throughout the filter cross section. At the bottom of the filter tank, was an underdrain system. It had a common header pipe going down the middle of the filter with a series of lateral pipes extending from the header.

2.2 Performance Tests and Evaluation

Poultry waste (boiler waste) was obtained from Rask Integrated Farm, Ilorin, and mixed thoroughly with 100 liters of water to prepare the slurry in a slurry tank. The slurry was discharged from the slurry tank through a discharge outlet into the filter tank at a height of 120 mm above the filter bed surface. A control valve was installed on the outlet of the filter tank to control effluent flow. The effluent was collected in a measuring cylinder positioned 30cm below the filter tank. The volume of the discharged effluent was recorded 3 times daily at an interval of 1 hour for each of the configurations throughout the period of the experiment. The effluent was analysis to determine the strength of the effluent.

a. Single Media (Configuration A)

This was made up of silica sand (average particle size diameter of 0.5mm and depth 150mm) and silica gravel (average particle size diameter of 5 – 50mm and depth 130mm) as shown in Fig. 4.

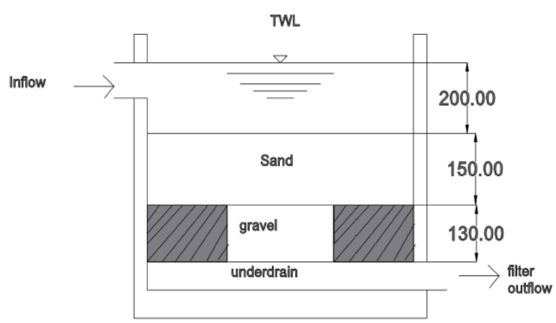

Figure 4: Configuration A

b. Dual Media (Configuration B)

This was made up of silica sand (average particle size diameter of 0.5mm and depth 50mm), coal (average particle size of 1.0mm and depth 100mm) and silica gravel (average particle size diameter of 5 – 50mm and depth 130mm) as shown in Figure 5.

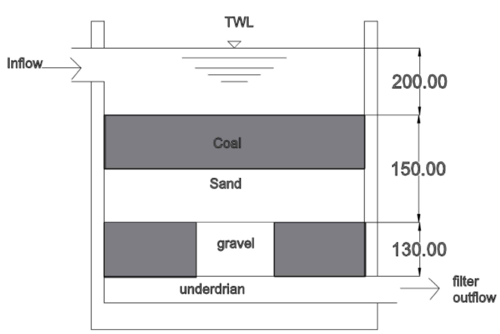

Figure 5: Configuration B

2.3 Measurement of Parameters

The slurry was filtered for a period of 12 days using two configurations of gravity sand filter namely: Single media (Configuration A) and dual media (Configuration B). Samples obtained from configuration A and B were coded A1 – A12 and B1 – B12, respectively. During filtration, the effluent volume, filtration velocity and head loss were measured daily for each configuration. Also, the dissolved oxygen in the effluent was determined in accordance with ISO 5815-1 (2003) and ISO 5814 (2012) for each configuration in order to evaluate the Biochemical Oxygen Demand (BOD_5). Other water quality parameters such as Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) were also determined in accordance with ISO 7027-1 (2016), while turbidity of the effluent was determined in accordance with ISO 7027-1, 2016. The study investigated and evaluated the effect of time of operation on the BOD_5, TSS, TDS, turbidity, filtration rate and head loss in each of the gravity sand filter configurations.

2.4 Data and Analysis

Descriptive statistics and One-Way Analysis of Variance (ANOVA) were performed using Statistical Package for Social Sciences (SPSS). The Tukey HSD test was used to further compare the means of the treatment parameters.

3 Results and Discussion

Tables 1 and 2 present the daily operating records for single and dual media filter configurations A and B, respectively, operating for the period of 12 days. They present the number of hours operated, unit filter run volume, filtration rate and head loss for the single media filter configuration on daily basis.

Table 1: Daily Operating Records for Single Media Filter (Configuration A)

Sample No	Time & Date		Hours of Operation	UFRV (mm^3/mm^2)	Filtration rate(mm/hr)	Head loss (mm)
	Start	Stop				
A1	26/05/2016 13:45	26/05/2016 16:40	2:55	166.70	57.15	31.00
A2	27/05/2016 08:20	27/05/2016 11:30	6:05	165.55	52.27	34.30
A3	28/05/2016 14:20	28/05/2016 17:40	9:25	163.89	49.17	37.70
A4	29/05/2016 08:55	29/05/2016 12:30	13:00	162.22	45.27	41.40
A5	30/05/2016 09:00	30/05/2016 12:45	16:45	160.00	42.67	45.20
A6	31/05/2016 08:25	31/05/2016 12:15	20:35	156.67	40.87	48.40
A7	01/06/2016 8:55	01/06/2016 12:55	24:35	152.77	38.19	51.80
A8	02/06/2016 13:25	02/06/2016 17:35	28:45	148.88	35.73	54.00
A9	03/06/2016 09:05	03/06/2016 13:30	33:10	144.44	32.70	57.30
A10	04/06/2016 08:40	04/06/2016 13:20	37:50	138.89	29.76	62.30
A11	05/06/2016 13:05	05/06/2016 18:00	42:45	133.33	27.12	66.20
A12	06/06/2016 12:20	06/06/2016 17:35	48:00	126.67	24.13	72.40

Table 2: Daily Operating Records for Dual Media Filter (Configuration B)

Sample No	Time & Date		Hours of Operation	UFRV (mm^3/mm^2)	Filtration rate(mm/hr)	Head loss (mm)
	Start	Stop				
B1	18/06/2016 12:20	18/06/2016 14:55	2:35	166.70	64.53	43.60
B2	19/06/2016 13:48	19/06/2016 16:30	5:17	165.55	61.32	41.40
B3	20/06/2016 09:34	20/06/2016 12:24	8:07	163.89	57.84	39.10
B4	21/06/2016 10:02	21/06/2016 13:00	11:05	162.22	54.68	37.00
B5	22/06/2016 11:46	22/06/2016 14:54	14:13	160.00	51.06	34.50
B6	23/06/2016 12:05	23/06/2016 15:25	17:33	156.67	47.00	31.70
B7	24/06/2016 14:30	24/06/2016 18:05	21:08	152.77	42.63	28.80
B8	25/06 13:09	25/06 16:59	24:58	148.88	38.84	26.20
B9	26/06 08:42	26/06 12:42	2858	144.44	36.11	24.40
B10	27/06/2016 14:05	27/06/2016 16:20	33:13	138.89	32.68	22.10
B11	28/06/2016 11:50	28/06/2016 16:10	37:33	133.33	30.77	20.80
B12	29/06/2016 12:20	29/06/2016 16:50	42:03	126.67	28.15	19.00

Table 3 shows the effluent quality through configuration A and configuration B, respectively. The analysis of variance result in Table 5 shows that the p-value corresponding to F statistics is less than 0.05, suggesting that the effect of configuration on the head loss of sand filter, effect of configuration on the BOD of effluent and effect of configuration on the TDS of effluent were significantly different. On the other hand, the effect of configuration on the filtration rate of sand filter, TSS of effluent and turbidity of effluent corresponding to the F statistic of one-way ANOVA were greater than 0.05 respectively, suggesting that the treatments were statistically insignificant. Shown in tables 4 and 6 are configuration B effluent quality and Tukey HSD test result for the effects of treatments on the effluent.

Table 3: Configuration a Effluent Quality for Single Media Sand Filter

Sample Number	DO_0 (mg/L)	DO_5(mg/L)	BOD_5 (mg/L)	TSS (mg/L)	TDS (mg/L)	TS(mg/L)	Turbidity (NTU)
A1	122.20	118.02	4.18	21.84	30.96	52.80	5.25
A2	118.80	112.68	6.12	21.45	31.95	53.40	5.30
A3	116.20	110.00	6.20	24.20	30.20	54.40	5.40
A4	113.10	105.90	7.20	24.70	29.80	54.50	5.45
A5	112.00	104.62	7.38	25.20	30.60	55.80	5.60
A6	105.60	98.16	7.44	22.80	33.50	56.30	5.70
A7	100.80	92.98	7.82	25.80	30.60	56.40	5.80
A8	96.00	86.02	9.98	23.20	33.70	56.90	5.90
A9	92.80	82.66	10.14	23.40	34.40	57.80	6.00
A10	88.20	77.64	10.56	28.90	31.60	60.50	6.10
A11	78.40	67.58	10.82	29.80	30.80	60.60	6.15
A12	73.60	61.52	12.08	30.20	31.50	61.70	6.20
Control	***139.80***	***125.48***	***14.32***	***46.80***	***52.10***	***98.90***	***9.80***

Table 4: Configuration B Effluent Quality for Dual Media Sand Filter

Sample Number	DO_0 (mg/L)	DO_5 (mg/L)	BOD_5 (mg/L)	TSS (mg/L)	TDS (mg/L)	TS (mg/L)	Turbidity (NTU)
B1	123.66	121.68	1.98	20.75	29.4	50.15	5.1
B2	117.14	113.32	3.82	20.35	30.35	50.7	5.2
B3	115.5	116.6	3.9	23	28.7	51.7	5.25
B4	112.34	107.48	4.86	23.47	28.38	51.75	5.3
B5	112.24	107.22	5.02	23.92	29.08	53	5.4
B6	105.7	100.62	5.08	21.66	31.84	53.5	5.45
B7	103.82	95.38	5.44	24.5	29.05	53.55	5.5
B8	97.56	90.06	7.5	22.04	32.01	54.05	5.55
B9	95.92	88.26	7.66	22.22	32.68	54.9	5.6
B10	92.66	84.6	8.06	27.46	30.04	57.5	5.7
B11	79.6	71.3	8.3	28.28	29.27	57.55	5.8
B12	74.7	65.2	9.5	28.69	29.91	58.6	5.9
Control	143.62	131.1	12.52	44.4	49.5	93.9	9.6

Table 5: ANOVA for the Effects of Treatments on the Effluent

Treatments	$F_{statistic}$	$F_{critical}$	p-value
Effect of Configuration on the Filtration Rate	1.59	4.30	0.22
Effect of Configuration on the Head loss of Sand Filter	19.02	4.30	*0.01
Effect of Configuration on the BOD of Effluent	5.29	4.30	*0.01
Effect of Configuration on the TDS of Effluent	7.13	4.30	*0.01
Effect of Configuration on the TSS of Effluent	0.28	4.30	0.60
Effect of Configuration on the Turbidity of Effluent	4.58	4.30	*0.04

*significant at 5%, $df_1 = 1$, $df_2 = 22$

Table 6: Tukey HSD Test Result for the Effects of Treatments on the Effluent

Treatments	Tukey HSD $Q_{statistics}$	Tukey HSD p-value	Tukey HSD inference
Effect of Configuration on the Head loss of Sand Filter	6.1682	0.001	** $p<0.01$
Effect of Configuration on the BOD of effluent samples	3.6117	0.018	* $p<0.05$
Effect of Configuration on the TDS of effluent samples	3.78	0.014	* $p<0.05$
Effect of Configuration on the Turbidity of effluent	3.03	0.040	* $p<0.05$

Shown in figure 8 is the relationship between TSS and hydraulic residence time. The figure shows that the removal of TSS concentrations was similar for both configurations, so design factors such as pretreatment, maximum water depth, and filter area apparently have little effect on particle removal. It was observed that TSS removal dropped at about 28 hours after treatment was started, but increased as the experiment proceeded. There is similarity in the trend of observation with the work of Moreki and Keaikitse (2013) who reported that TDS and TSS removal from selected poultry operations around Gaborone fluctuated as the treatment proceeded.

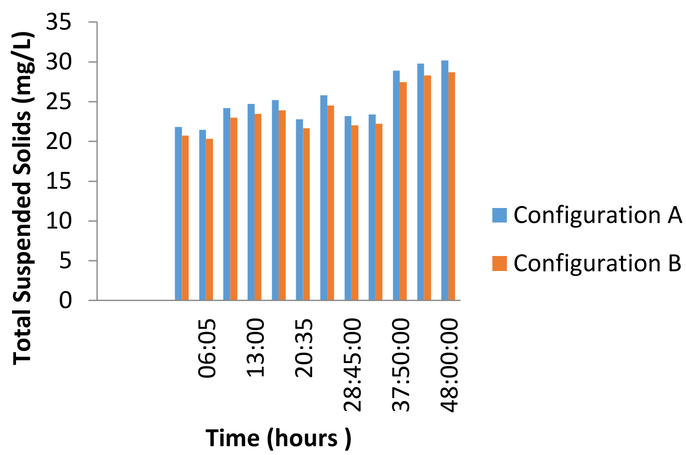

Figure 8: Relationship between TSS effluent quality and Hydraulic residence time

The trend for TDS removal in both treatment configurations is shown in figure 9. The removal of TDS is similar to that observed for TSS and is statistically not significant for both configurations. Similarly, TDS removal was not a function of time, indicating that the accumulation of material on and within the filter had little impact on particle removal. Moreki, *et. al.*, (2011) report a similar trend in the fluctuation of TSS and TDS during treatment.

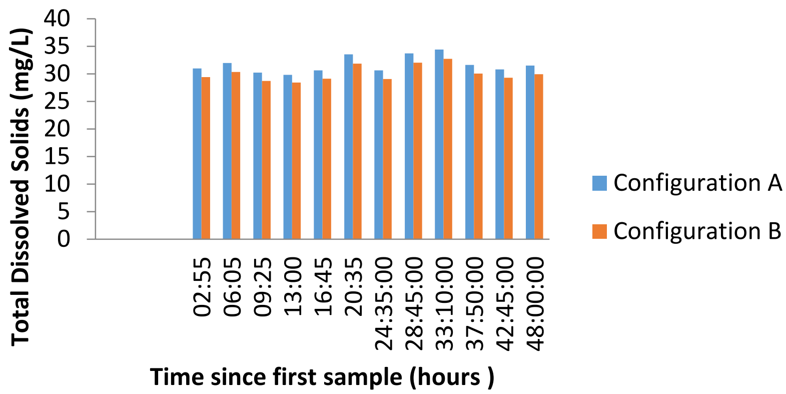

Figure 10: Relationship between TDS and Hydraulic residence time

Figure 10 shows the relationship between effluent quality in terms of BOD and detention. It can be observed from figure 10 that filter configuration A recorded higher removal values of BOD throughout the detention time than configuration B. The highest value of BOD removal recorded for Configuration B was 9.81 mg/L. Removal of BOD in configuration B was much more significant than the BOD removal in configuration A. Grant *et. al.*, 2008 who used both configurations in the treatment of broiler droppings recorded a similar trend.

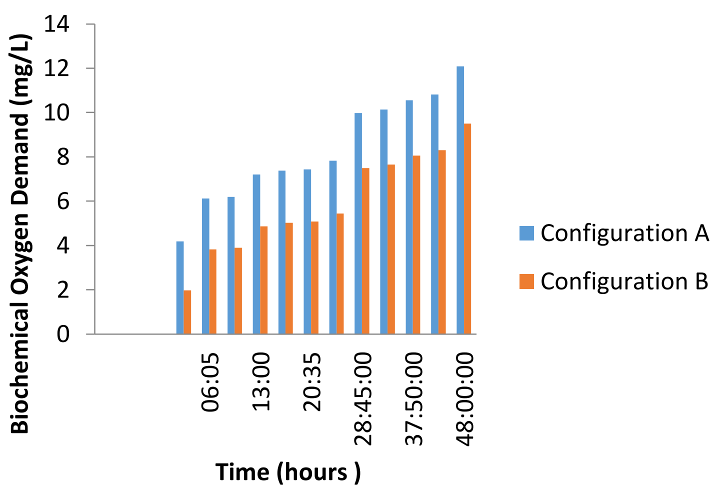

Figure 10: Relationship between BOD and Hydraulic residence time

Figure 11 shows the extent of turbidity in both configurations. The observation that turbidity removal and hydraulic residence time. The removal of turbidity increased with the hydraulic residence time. Early in the life of the filter a substantial amount of turbidity was removed by deep bed filtration process. Configuration A recorded higher removal of turbidity than configuration B. However, the differences in turbidity removal by both configurations was not significant.

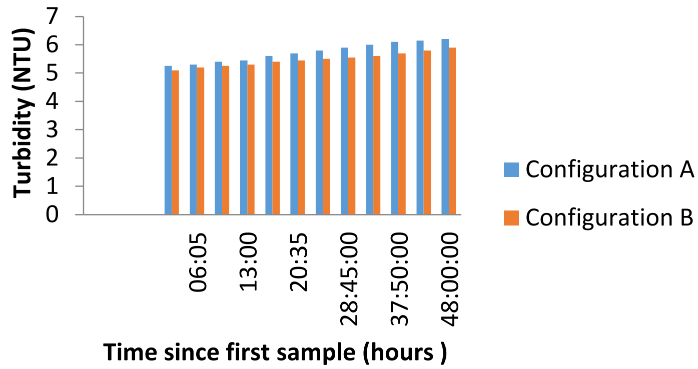

Figure 11: Relationship between Turbidity and hydraulic residence time

The filtration rate and hydraulic residence time is shown in figure 12. The filtration rate performance for both configurations decreased with hydraulic residence time. Figure 12 shows that filtration rate reduces as the filter ages due to the filter clogs. It can be observed that at the beginning of the experiment configuration A and Configuration B had filtration rates of 65.30 and 58.5 mm/hr, respectively. The steady reduction in the filtration rate observed is similar to the steady drop in filtration rate reported by Grant *et. al.*, 2008.

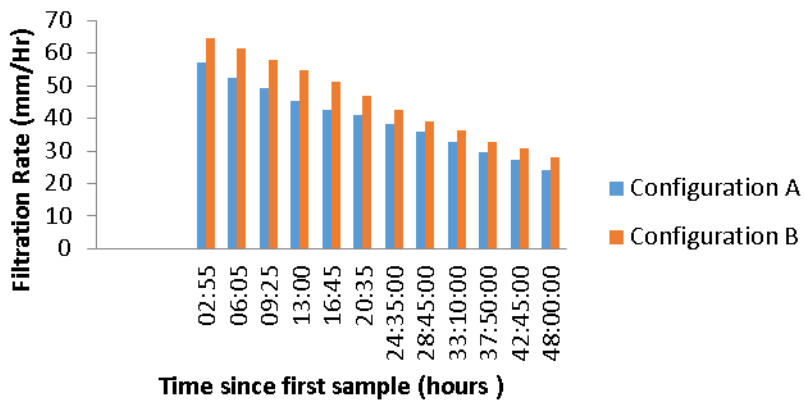

Figure 12: Relationship between Filtration rate and hydraulic residence time

Head loss is a function of time, indicating that the accumulation of material on and within the filter had little impact on the clogging or ripening of the sand filter. Figure 13 shows that head loss in both configurations is statistically significant. Pretreatment reduces the total sediment load to the filter by about 65-70%, but may not reduce the head loss in the filter since much of this sediment likely is fairly coarse, which would result in little loss of permeability if it accumulated on the surface of the filter. This was also corroborated by Adene *et. al.*, 2006.

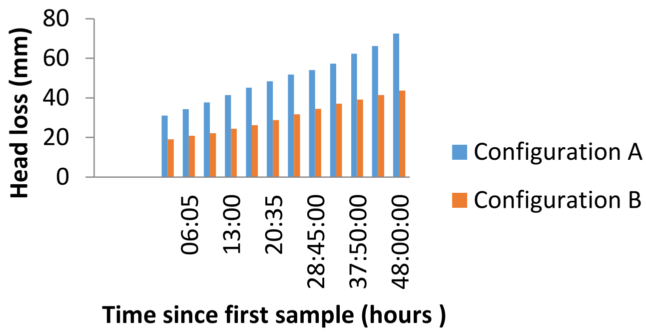

Figure 13: Relationship between Head loss and hydraulic residence time

4 Conclusion

From the study, the following conclusion were drawn:

(i) Configuration B operated on higher filtration rate with an average filtration rate of 45.50mm/hr compared to configuration A operating at an average filtration rate of 39.60mm/hr, during the 12days operating period.

(ii) Head loss in configuration B is lower than that of configuration A. this infers that configuration A clogs or ripens faster and backwashing would be required more often than that of configuration B.

(iii) Configuration B produces better effluent quality with percentage BOD removal 53%, percentage TSS removal 50%, TDS removal 42% and turbidity removal of 45% compared to configuration B producing effluent quality with percentage BOD removal of 42%, TSS removal of 46%, TDS removal of 40% and turbidity removal of 40%. The sand filter could, therefore, be said to be effective in the treatment of poultry waste.

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