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Full Length Research Article

EVALUATION OF THE EFFICIENCY OF CONSTRUCTED ACTIVATED CARBON FOR THE TREATMENT OF ABATTOIR WASTEWATER

[1]Hassana Abubakar L. and [2]Nuradeen Labaran Tanko

[1] Department of Chemistry, Nile University of Nigeria, Abuja-FCT, Nigeria.
[2] Department of Petroleum and Gas Engineering, Baze University, Abuja-FCT, Nigeria

*Corresponding Author Email Address: hassanaladio@nileuniversity.edu.ng

ABSTRACT
In Sub-Saharan Africa, effluents from abattoirs that contain dissolved suspended particles which could be either organic or inorganic are discharged untreated into rivers and lakes. Activated carbon filters can be employed in the process of removing these organic compounds from effluent, thereby making the water suitable for discharge or use in other processes. 5 liters of abattoir wastewater was used for this study, during which two different synthesized activated carbon from sawdust ACC and ACH were employed as filters for the treatment of abattoir wastewater, and thus physico-chemical, heavy metal and microbial analysis were conducted. Activated carbon used was synthesized by means of physicochemical activation of waste sawdust and later heated at 250°C, the material was chemically activated using a base calcium chloride, ACC and an acid phosphoric acid, ACH, respectively. It was found that the maximum percent removal of turbidity, pH, Alkalinity, BOD_5, COD, TSS and Chloride ions were 88%, 16.4%, 0%, 89.5%, 95.2%, 96.9% and 81.9% for ACC and 99.8%, 20%, 22.9%, 92.2%, 96.2%, 97.9% and 80.8% for ACH. An increase in DO was observed at 51.1% and 53.3% for ACC and ACH respectively. It was concluded that the constructed ACC has better performance than that of ACH for most However, ACH presented better performance especially for the removal of dissolved solids. There is a need to dope activated carbon with nanoparticles for the treatment of abattoir wastewater.

Keywords: Activated Carbon; Abattoir wastewater.

INTRODUCTION
In recent years, the demand for water has generated significant attention towards treatment of wastewater. Abattoir uses large quantities of water and thus generates large quantities of biodegradable organic wastewater with medium to high strength (Akinro *et al.,* 2009). On average abattoirs use 607 gallons of water per head for cattle processing, thereby contributing to the pollutant load of water bodies (Beckett and Oltjen, 1993; Sina *et al.,* 2019). These effluents contain large amounts of fats, oil, grease, blood, urine, grit, meat tissue, hair, manure suspended particles of semi-digested and undigested food within the stomach and intestine of slaughtered animal (Bull *et al*., 1982; Adelegan, 2002; Elemile *et al*., 2019). The major environmental concern associated with abattoir wastewater is the large amount of suspended solids [Total suspended Solids (TSS) and total dissolved solids (TDS)], liquid waste and odor generation (Gauri, 2006; Bello and Oyedemi, 2009). Equally, leaching into groundwater is a major part of the concern (Muhirwa *et al*., 2010). Therefore, discharge of abattoir wastewater without treatment contributes to degradation of the aquatic environment and pollution of potable water (Keerthana and Thivyatharsan, 2018; Michael *et al*., 1988).
Physico-chemical indicators are the traditional water quality indicators used in water quality analyses (Hamaidi-Chergui and Brahim Errahmani, 2019). They include dissolved oxygen, pH, temperature, salinity and nutrients such as nitrogen and phosphorus. They also include measures of toxicants such as metals, insecticides, and herbicides (Alengebawy, 2021). The physico-chemical analyses of water can be supported by measuring the amount of organic compounds in water such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) analysis. The BOD value is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C (Egbon *et al*., 2013). This value is used to determine the amount of dissolved oxygen (DO) needed by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. COD is commonly expressed in mass of oxygen consumed over volume of solution (mg/L). COD analysis measures everything that can be chemically oxidized, rather than just levels of biologically oxidized organic matter, and thus, it is less specific than BOD analysis (Mamun, 2021). Another important water analysis is the heavy metals which are usually present in trace amounts in natural water but are toxic even at very low concentrations. Metals such as zinc, iron, chromium, arsenic, copper, manganese, mercury, selenium, and nickel are highly toxic even in minor quantity Herawati *et al.* (2000). Therefore, at elevated concentrations, they can become toxic (Yahaya, 2021).

Adsorption on activated carbon is one of the most efficient methods used in water treatment process (Keerthana and Thivyatharsan, 2018). Activated carbons with abundant pore size distribution, high specific surface area and surface chemistry are widely used as versatile adsorbents for the adsorption of gaseous and liquid phases (Yadav, 2015). They are also among the most commonly used adsorbents in the removal process of compounds of organic origin, industrial pollutants, heavy metals, dyes and herbicides among many other toxic and hazardous compounds as stated (Reza *et al*., 2020). Such activated carbons can be produced from a variety of raw materials such as sawdust (Yang *et al*., 2017), coal (Sun, 2016) and plantain fruits (Ekpete *et al*., 2017), coconut shell (Gratuito *et al*., 2008), Coffee wastes (Obaya *et al*., 2020), plantain fruit stems (Ekpete *et al*. (2017), and maize cob (Egbon *et al*., 2013), and rice husk (Ahiduzzaman and Sadrul Islam, 2016). Two different processes (physical and chemical activation) are normally used for the preparation of activated carbons (Lua and Gua 2000; Lozano-Castelló *et al*., 2001; Hayashi *et al*., 2002; Puziy *et al*., 2003).

In Nigeria, there are several abattoirs that process millions of tons of meat at Kaduna Metropolis and thereby discharging effluents into the Kaduna River which is the main tributary of the Niger River. Most of its course passes through open savanna woodland. Its lower section has cut several gorges above its entrance into the extensive Niger floodplains. Surface waters often have elevated levels of nutrients as a result of pollution, this increases the rate at which oxygen-depleting microbes destroy the aquatic systems and result in eutrophication as observed by (Kwadzah *et al.,* 2015). Therefore, effluents should be treated before discharge into water bodies to avoid environmental pollution and human health effects.

In light of the recent awareness on water pollution, its sources as well as how it aggravates climate change and impacts the susceptibility of ground water, it is necessary to implement readily available alternatives for pollution reduction in the environment, thereby decreasing human exposure to waterborne sources of infections and diseases (Andrade *et al*., 2018).

For each slaughtered cattle, the raw blood obtained amount to 6kg of the BOD which is equivalent to 0.14-0.18kg of BOD per kg (Kwadzah *et al.,* 2015). Blood has a high nutrient value 2400mg/l of nitrogen and 1500mg/l of Phosphorus (Kwadzah *et al.,* 2015; Joseph *et al*. 2021). The COD: BOD ratio is between 1.3 and 2.0. The bacterial load ranges from 0.9 x 10^2 to 3.0 x 10^3 (CFU/mL) bacterial counts which is above the recommended level by EPA and FEPA which is 4.0 x 10^2 CFU/mL (FEPA, 1999). Wastewater discharged into the water body contains bacteria such as *E coli, Staphylococcus aureus, Klebsiella* sp*., Salmonella* sp*., Enterobacter* sp*., Shigella* sp., and *Preteus* sp., whenever blood and fat is allowed to pass through the effluent, cost of treatment increases. The authors Kwadzah *et al.,* (2015); Joseph *et al*. (2021); Otolorin *et al*. (2015) investigated how livestock activities at Tudun Wada abattoir affects the quality of water at river Kaduna as well as neighboring farmlands.

The present research is aimed at comparing the efficiency of constructed activated carbon for the treatment of abattoir wastewater obtained from the Zango abattoir in Tudun Wada area of Kaduna south, Kaduna State, Northwest, Nigeria.

MATERIALS AND METHODS

Study area

Figure 1 presents the studied abattoir. The abattoir is located within the coordinates, latitude 10030'104" N, and longitude 007024'452" E in the national grid, in Tudun Wada, Kaduna South, Kaduna state. The study area is both accessible by road and foot and it covers 104.5028km^2 (Abdullahi, 2016). The major source of water to the residence of the area are privately owned shallow wells, boreholes, and public River Kaduna, respectively. An average of one hundred cattle are slaughtered daily. The abattoir waste is not effectively managed as the heap of bones and cow dung can be found close to the shallow well and borehole which are the water source for the abattoir.

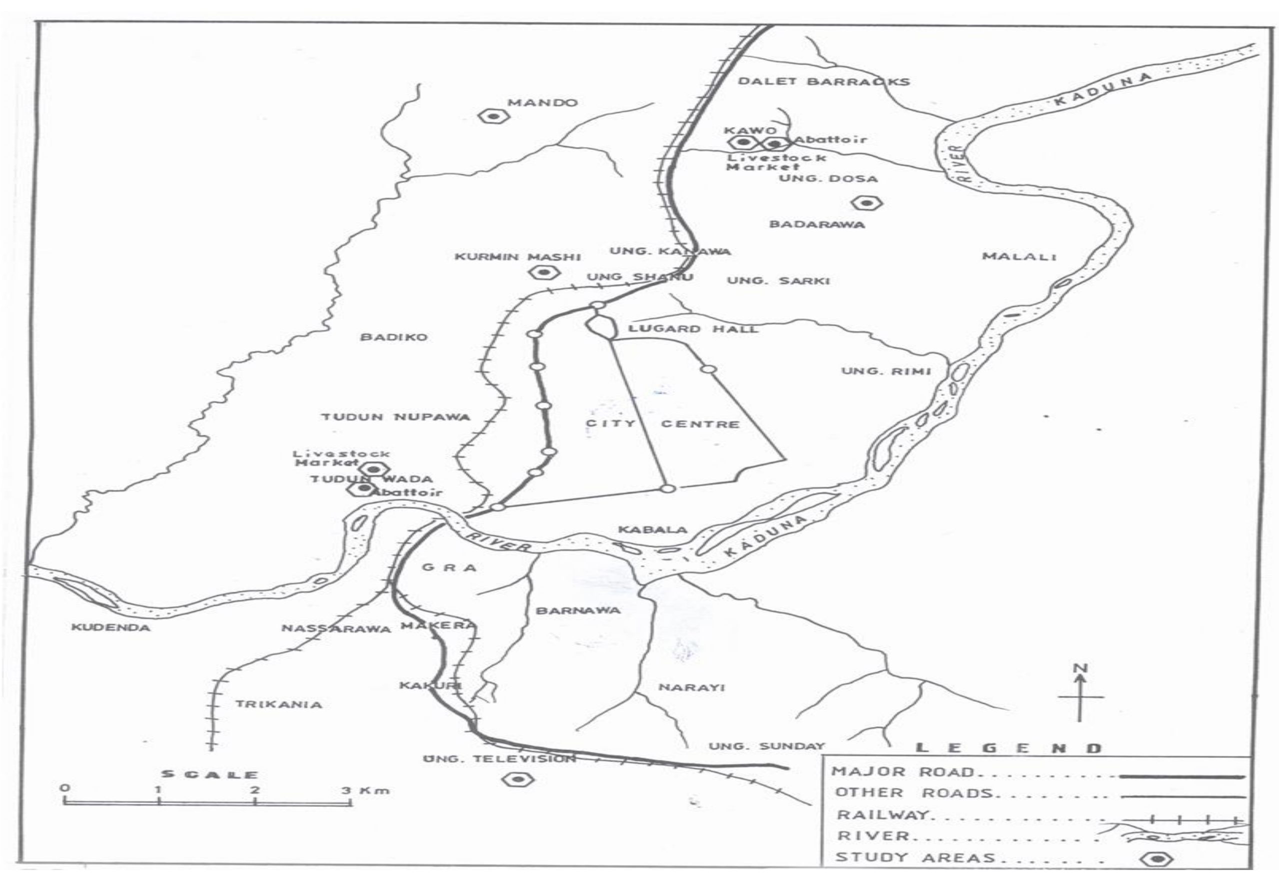

Figure 1: Map of Sabon Gari/Zaria showing Sampling Locations

Sample collection
Wastewater sample was collected from Tudun Wada abattoir in Kaduna Metropolis, Kaduna State, Nigeria. The Sawdust was obtained from a Sawmill in Deidei Lumberyards, Deidei, Abuja - FCT, Nigeria. It has been reported that most sawmills use woods such as Teak (Tectona grandis), Gmelina (Gmelina arborea), Mahogany (Khaya senegalensis), Makore (Mansonia heckeii), Iroko (Milicia excelsa), Ogea (Danniella oliverii) (Alao and Kuje, 2012). The reagents used in the synthesis were analytical grade and all solutions were prepared using deionized water. 25% Phosphoric acid and 25% calcium chloride stock solutions were prepared using concentrated phosphoric acid and calcium chloride salts (Caicedo-Salcedo *et al.,* 2019). The two activated carbon samples were synthesized by means of physicochemical activation of saw dust and later heated at 250°C for 4 h. The materials were chemically activated by using calcium chloride (ACC) and Phosphoric acid (ACH), respectively. Initially the wastewater was allowed to settle for 24 h as preliminary treatment and then the effluent was treated by the undermentioned methods (Yakout and Sharaf El-Deen, 2015; Caicedo-Salcedo *et al.,* 2019).

Experimental Setup and Procedure
Initial screening was conducted with a cotton fabric to remove suspended clots, faeces, wood, hay, undigested ingesta, grass, rocks, etc. Subsequently, 1.5g of Aluminum Sulfate was added to two liters of the effluent, and thus the mixture was stirred with a magnetic stirrer for five minutes. The effluent was then left for twenty four hours for flocs to form. After 24 h the water was filtered using a 150mm whatmann filter paper and stored at 4°C for further analysis. The experiment consists three treatments as three sand-gravel-filter paper (SG) and two activated carbon (ACC and ACH) coupled with bio-sand filters, the process was refluxed three times (Bustillo-Lecompte and Mehrvar, 2015).

Bio-Sand Filtration (S.G)
The base of a 1.5L bottle was cut and holes were drill into the bottles cap with the aid scissors. The bottle was inverted and placed on a 400 mL beaker. 150 mm filter paper was then placed into the bottle from the inverted bottom which now is the top. A layer of 300g of sand was added, followed by a layer of 400g of gravels. The two layers were separated by two whatmann filter papers. Then 700 mL of the stored effluent was poured through the layer of gravels down to the sand layer into the beaker (Kabir *et al.,* 2016).

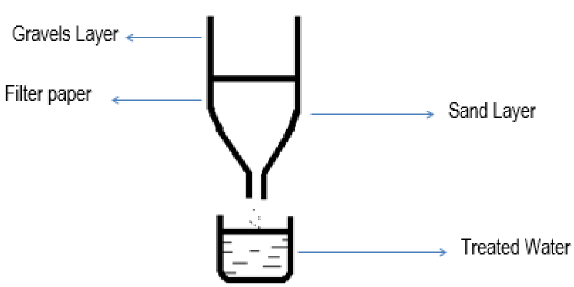

Figure 2: Schematic diagram of bio-sand filtration

Activated Carbon (ACC and ACH) Bio-Sand Filtration
The base of a 1.5L bottle was cut and holes were drill into the bottles cap with the aid scissors. The bottle was inverted and placed on a 400 mL beaker. 150 mm filter paper was then placed into the bottle from the inverted bottom which now is the top. A layer of 100g of activated carbon was added in followed by 300g of sand and finally a layer of 400g of gravels. Each layer was separated by two 150 mm whatmann filter paper. 700 mL of the waster obtained after coagulation and flocculation was poured into the bottle and the water was allowed to pass through the gravels, sand and activated carbon layers and finally into the beaker (Kabir *et al.,* 2016).

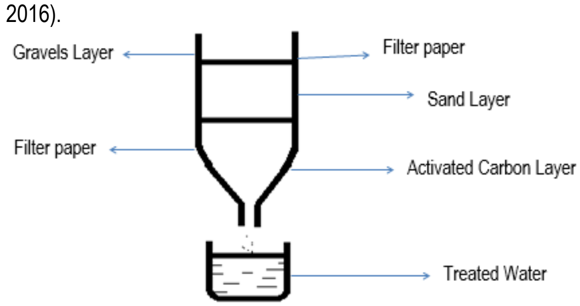

Figure 3: Schematic diagram of Activated Carbon bio-sand filtration

Physico-chemical Analysis of wastewater
For the physico-chemical analysis, the water sample analyzed included the abattoir wastewater labeled as "Raw", the water sample obtained after just the bios and filtration labeled as "WSG", the water sample obtained after the activated carbon bio-sand filtration using ACC labeled as "WACC" and finally the sample obtained after the activated carbon bio-sand filtration using ACH labeled as "WACH". The physico-chemical quality of the water samples was determined using the American Public Health Association Standard Methods (APHA, 2005). These parameters analyzed included: Temperature (T), turbidity (NTU), pH, total alkalinity (TA), total hardness (TH), electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), calcium (Ca), magnesium (Mg), sulphate (SO_4), nitrate (NO_3), and chloride (Cl).

Heavy metals analysis of wastewater
For sample preparation, 100 mL of each water sample was digested with aqua regia made of 67% HNO_3 and 37% HCL, i.e. 3:1 (Neboh, 2013). . The samples were then heated in a closed fume cupboard using a hot plate. The remaining solution was left to cool and filtered using a whatman filter paper. Using a shimadzu flame atomic absorption spectrophotometer (AA-6300), the concentration of Mg, Ni, Cd, Cu, Mn, Zn, Fe and Pb in the wastewater samples were determined.

Microbiological Analysis of wastewater
The total aerobic plate count method was used to carry out bacteriological analysis. All the media used were prepared according to the manufacturers specifications. Nutrient agar was used to culture the wastewater to help with the growth of *Enterobacteriacea* (*E. coli*) and *Salmonella* species in the water samples, the plates were incubated for 48 h, pure culture of *E. coli* was prepared using MacConkey and M-Endo agars separately, they were incubated for 24 h. Pure culture of *Salmonella* was isolated using *Salmonella Shigella* and Simon's citrate agars were used separately; they were incubated for 24 h. A lactose broth was used for the confirmation of the isolates all at 45°C.
The bacterial isolates obtained were then characterized using both

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biochemical and microscopy tests. The biochemical tests employed include motility, citrate, indole, oxidase, catalase, fermentation, urea, glucose, nitrogen, nitrogen dioxide and lastly Tryptophan deaminase (TDA). For further reconfirmation of results, the APIWEB™ software was used to manually identify the gram positive and gram negative bacteria and yeast present in a sample. Analytical Profile Index (API) is a biochemical panel for identification and differentiation of members of the family *E. coli*. The percentage of *E. coli* and *Salmonella* was determined based on the negative and positive results from the biochemical tests such as TDX, N_2, NO_2, H_2S, Urea, etc. that are carried out sung APIWEB™ software. These results are computed into the API strips based on whether they were positive (present) or negative (absent). This analysis was also repeated on the three remaining water samples WSG, WACC and WACH.

RESULTS AND DISCUSSION

Physico-chemical analysis of water samples

Table 1 presents physico-chemical parameters analyzed in the wastewater samples (RAW, WSG, WACC and WACH). Alkalinity was determined using the following equation:

Alkalinity=

$$\frac{\text{Volume of Acid} \times \text{Normality} \times \text{Sample Volume} \times \text{Weight of CaCO3}}{\text{Volume of sample taken}}$$

Boyd *et al*. (2016).

It can be seen in Table 2 that the turbidity of RAW (768.00 NTU), WSG (85.60 NTU) and WACC (86.00 NTU) are considerably high for WHO acceptable limit which is 5.00 NTU (WHO, 2017), whereas the turbidity of WACH (1.06 NTU) is within the WHO acceptable limit, the results obtained were close to the findings by Muhirwa *et al.* (2010) on the analysis of the turbidity of abattoir wastewater. On the other hand, pH and alkalinity of the effluent of all samples are in the range of 6.80 to 8.50 and 37.00 to 49.00 (mg/L) respectively, which are all within the stipulated guideline by WHO at between 6.5-8.5 for pH and 100 mg/L for Alkalinity (WHO, 2012; WHO, 2004). The pH values gotten from the water samples are very much in line with the one from Eze and Eze (2018) which was around 6.54 and thus within the WHO acceptable limit as stated earlier.

Table 1: Physico-chemical analysis of wastewater samples

S/N	Parameter	RAW	WSG	WACC	WACH	WHO/EPA Acceptable Limit
1	Turbidity (NTU)	>768.00	85.60	86.00	1.06	5.00
2	pH	8.500	7.60	7.10	6.80	6.50-9.00
3	Alkalinity (mg/L)	48.00	49.00	48.00	37.00	100.00
4	TDS (ppm)	200.00	1810.00	1087.00	1123.00	1000.00
5	BOD_5 (mg/L)	220.00	118.00	23.00	17.00	40.00
6	COD (mg/L)	1638.00	1314	78.00	61.00	80.00
7	DO (mg/L)	2.10	2.60	4.30	4.50	7.50
8	TSS (mg/L)	153.00	94.00	4.70	3.10	100.00
9	Chloride Ions (mg/L)	1183.00	6590.00	213.20	227.00	600.00

The TDS of WSG (1810.00 ppm) and WACC (1123.00 ppm) are considerably higher than the WHO acceptable limit of 1000.00 ppm. Whereas the TDS of RAW (200.00 ppm) is within the WHO acceptable limit. Similarly, the BOD_5 and COD of WACC and WACH samples were in the range of 17.00 to 23.00 and 61.00 to 78.00 (mg/L), and thus within the WHO acceptable limit. However, the BOD_5 and COD of RAW and WSG samples are in the range of 118.00 to 220.00 and 1314.00 to 1638.00 (mg/L), and thus significantly higher than the WHO acceptable limit. The DO of all samples are in the range of 2.10 to 4.50 mg/L are within the WHO acceptable limit of 7.5 mg/L. Similarly, the TSS limit for wastewater by the EPA is 100, and thus WSG (94.00 ppm), WACC (4.70 ppm), and WACH (3.10 ppm) are within the acceptable limit with the exception of RAW (153 ppm). The Chloride Ions of WACC (213.20 mg/L) and WACH (227.00 mg/L) are within the EPA acceptable limit (600 mg/L). The Chloride Ions of RAW (1183.00 mg/L) and WASG (6590.00 mg/L) are significantly higher than the EPA acceptable limit (600 mg/L).

The efficiency of treatment is in the following ascending order RAW, WSG, WACC, WACH, respectively. Therefore, the purity of the wastewater in most cases significantly reduced from RAW to WACC, and thus could be attributed to the enhancement of wastewater treatment by the introduction of activated carbon filter. Also, for each of the tested parameters quoted in Table 1, the WSG value was a significantly different from those obtained for WACC or WACH. However, the values obtained for each tested parameters in WACC and WACH is significantly different, and thus which indicates that WACH is much cleaner than WACC.

Heavy metals analysis of wastewater samples

Table 2 presents heavy metals analysis for the wastewater samples (RAW, WSG, WACC and WACH). It can be seen in Table 2 that the magnesium concentration in RAW (1602.250 mg/L), WSG (1581.620 mg/L), WACC (1536.970 mg/L) and WACH are considerably high for WHO acceptable limit (200.000 mg/L). Whereas the concentration of other heavy metals (Cu, Mn, Zn, Fe and Pb) in the wastewater samples (RAW, WSG, WACC and WACH) are within the WHO acceptable limit. The concentration of Cadmium and Lead are below WHO acceptable limit, and thus undetected. Similarly, as observed in the physico-chemical parameters analyses that the purity of water reduced significantly from RAW to WACC, respectively. The efficiency of treatment is in the following acceding order RAW, WSG, WACC, WACH, respectively.

Table 2: Heavy metals analysis of wastewater samples

S/N	Element	RAW (mg/L)	WSG (mg/L)	WACC (mg/L)	WACH (mg/L)	WHO/FEPA Acceptable Range (mg/L)
1	Magnesium	1602.250	1581.620	1536.970	1567.920	200.00
2	Nickel	0.535	0.206	0.240	0.089	<1.000
3	Cadmium	Undetected	Undetected	Undetected	Undetected	0.010
4	Copper	0.095	0.093	0.069	0.057	1.000
5	Manganese	0.472	0.435	Undetected	0.309	5.000
6	Zinc	0.703	0.246	0.118	0.097	<1.000
7	Iron	4.276	0.712	0.140	0.059	0.300
8	Lead	Undetected	Undetected	Undetected	Undetected	0.500

Microbiological analysis of wastewater samples

Table 3 and 4 present microbial analysis for the wastewater samples (RAW, WSG, WACC and WACH). Using various agars on the RAW, WSG, WACC and WACH water samples, it can be seen in Table 3 and 4 that the microorganism *E. coli* was present in RAW and WSG respectively. Besides *E. coli,* the presence of Salmonella was investigated. The petri dish containing the sample and XLD agar turned yellow in RAW and no change was noticed in WSG, WACC and WACH, respectively. Therefore, Salmonella was absent in all the samples. This finding can be supported by the formation of colonies having different physical properties with the most obvious one being the color change on the petri dishes as shown in Table 3.

Total aerobic plate count method was used to carry out the bacteriological assessments. The agars used were prepared according to the manufacturers' specification. The total coliform counts were determined MacConkey agar. Faecal coliform was determined using Eosin methylene blue medium all via pour plate technique. A lactose broth was used for the confirmation of the isolates all at 450^{o}C.

Table 3: Morphological characteristic of isolates from wastewater samples

S/N	Sample	Agar Used	Macroscopy (Colonies)	Growth Inhibited	Microorganisms
1	RAW	Nutrient	Creamish and white	✓	*Escherichia Coli (E-Coli)* Present, *Salmonella* Absent
		M-Endo	Greenish with metallic sheen	✓	
		Simon's Citrate	White which then turned blue	✓	
		MacConkey	Pink	✓	
		Salmonella Shigella (SS)	No change		
2	WSG	Nutrient	Creamish and white	✓	*Escherichia Coli (E-Coli)* Present, *Salmonella* Absent
		M-Endo	Greenish with metallic sheen	✓	
		Simon's Citrate	White which then turned blue	✓	
		MacConkey	Pink	✓	
		Salmonella Shigella (SS)	×	×	
3	WACC	Nutrient	×	×	NIL
		M-Endo	×	×	
		Simon's Citrate	×	×	
		MacConkey	×	×	
		Salmonella Shigella (SS)	×	×	
4	WACH	Nutrient	×	×	NIL
		M-Endo	×	×	
		Simon's Citrate	×	×	
		MacConkey	×	×	
		Salmonella Shigella (SS)	×	×	

Table 4: Bacteriological characteristic of isolates from wastewater samples

Sample Code	Motility	Citrate	Indole	Oxidase	Catalase	Fermentation	Glucose	NO_2	TDA	N_2
RAW	+	-	+	-	+	+	+	+	-	-
WSG	+	-	+	-	+	+	+	-	-	-
WACC	-	-	-	-	-	-	-	-	-	-
WACH	-	-	-	-	-	-	-	-	-	-

Therefore, the percentage of *E. coli* and *Salmonella* was determined based on the negative and positive results from the biochemical tests such as TDX, N_2, NO_2, H_2S, Urea, etc. that were carried out using APIWEB™ software. It can be seen in Table 4 that there is a 99.1% and 98.5% chance of *E. coli* being present in RAW and WSG respectively, and no chance that salmonella is present in the samples.

Table 5: Microbiological analysis of wastewater samples using APIWEB™

S/N	Parameter	RAW (%)	WSG (%)	WACC (%)	WACH (%)
1	*E. coli*	99.10	98.50	0.00	0.00
2	*Salmonella*	0.00	0.00	0.00	0.00

Conclusion

The results from this study show the efficiency of activated carbon synthesized from basic and acidic media coupled with bio-sand filters (ACC and ACH) and sand-gravel-filter paper (SG) for the treatment abattoir wastewater (RAW) was explored. This study reveals that both basic and acidic media have an ability to treat abattoir wastewater, one being more efficient than the other. The bio-sand filter implemented with ACH labeled "WACH" had a cleaner and clearer water output than the one fitted with ACC labeled "WACC", the one having just sand, gravels and filter paper labeled "WSG" and the main effluent sample labeled "RAW". Physico-chemical analysis were carried out on the turbidity, pH, alkalinity, TDS, BOD, COD, DO, TSS and chloride ions, where in six out of nine cases, the water sample WACH had better results than WACC.

Heavy metal analysis were also carried out, where the concentrations of Mg, Ni, Cd, Cu, Mn, Zn, Fe and Pb in the four water samples were studied. Here, the concentration of these heavy metals reduced from RAW-WSG-WACC and finally WACH in most cases.

Lastly, microbial analysis was carried out to determine the presence of the coliforms and from all four water samples, it was observed that "RAW" and "WSG" had a 99.1% and 98.5% chance of having *escherichia coli* (*E-coli*) with no traces of *salmonella*. The samples WACC and WACH on the other hand had no traces of *Escherichia coli* (*E-coli*) or *salmonella*.

In conclusion, activated carbon synthesized by the means of phosphoric acid activation (ACH) is much better at abattoir wastewater treatment than activated carbon synthesized by the means of calcium chloride activation (ACC), and in no way is the utilization of a sand bed alone (like in the case of WSG) enough to treat abattoir wastewater.

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