Performance Evaluation of *Moringa Oleifera* as Coagulant for Abattoir Wastewater Treatment

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Abstract: Indiscriminate disposal of wastewater from abattoir exert significant and adverse effects on the surface water and public health. Thus, in this paper, raw powdered *Moringa Oleifera* seeds was used as coagulant for the treatment of 40 litres of abattoir wastewater for a period of ten (10) weeks. Completely randomized design with loading dosages of 10, 12, 14, 16, 18 and 20g of processed *Moringa Oleifera* seeds was used in the treatment. A control (wastewater from abattoir with no *Moringa Oleifera* treatment) was also included. Physical and chemical properties of abattoir wastewater were investigated before and after treatment. The results showed that the turbidity value reduced drastically on the treatments from, 15.40 to 7.63 mg/l for 16g dosage in week 7. Total alkalinity was reduced from 216.67 mg/l to the lowest value at 63.67 mg/l for 20g treatment in the 1st week. Total hardness was reduced from 116.33 to 78.40 mg/l at 14g *Moringa Oleifera* dosage; conductivity was reduced from 1395.7 to 520 mg/l for 14g *Moringa Oleifera* dosage just within the first week. BOD was found to be zero from weeks 2 to 6. The Calcium value was reduced from 31.47 in week 1 to 6.23 mg/l for 14g treatment in the 5th week. The results generally showed that 16g/500ml of *Moringa Oleifera* was able to treat abattoir wastewater and thus confirm the coagulating ability of M. Oleifera for abattoir wastewater treatment. The extract doses used in the study do not impart odour or colour to the treated wastewater.

Keywords: Moringa Oleifera; wasterwater; abattoir; dissolved oxygen; biological oxygen demand

1. Introduction

An increase in population and commercialization of animal products for consumption has led to an increase in quantities of abattoir wastes generated and consequent pollution and degradation of the environment, most especially surface water bodies. Abattoir wastes also known as slaughter-house wastes often contain blood, fat, organic and inorganic solids, and salts and chemicals added during processing operations (Pandit *et al*., 2021) which if not well managed and disposed pose serious health challenges to those living within the abattoir vicinity (Oruonye, 2015; Sindibu *et al*. 2018; Obidiegwu *et al*., 2019). The quality of freshwater is thus threatened because of pollution from these wastes as the wastewater from the abattoirs are usually released directly into the ecosystems without adequate treatment process (Adamu & Dahiru 2020; Aleksic *et al*., 2020; Ogeleka *et al*., 2021) thereby posing serious threats to surface water quality, general environmental safety and health. This has further been worsened by the fact that the amount of domestic, agricultural and industrial wastewater that flows into the world's rivers is increasing at an alarming rate (Shukla *et al*., 2021).

The discharge of raw abattoir wastewater to water bodies affects the quality of water particularly by causing a reduction of dissolved oxygen (DO) (Falodun & Rabiu, 2017) and an increase in heavy metal concentration in the water which may lead to the death of aquatic life (Simeon & Friday, 2017). The environmental impact of abattoir wastewater is not only characterized by pollution via surfactants, nitrate and chronic anions but also pathogens, which persist in the soil and reproduce continuously (Ng et al., 2022). These pathogens can also be transmitted to humans who are exposed to the water body, making those areas unsuitable for drinking, swimming or irrigation purposes (Some *et al*., 2021).

There is urgent need for treating the wastewater prior to their discharge into the surface water bodies (Olaniran *et al*., 2019). Liquid effluents discharged from the slaughter-house is extremely complicated in terms of treatment or purification because of many reasons which range from the wastes unique characteristics, its variable composition at the discharge time and substantial amount of mineral, biogenic and organic matter which are known to provide nutrients for bacterial growth. (Khan *et al*., 2021; Meena *et al*., 2021; Pandit et al., 2021).

Controlling this pollution at the point of slaughter-house wastes discharge may be a very costly procedure and is reported to be increasing and usually leads to the high cost of municipal surcharges as argued by Adamu and Dahiru (2020). Many coagulants are widely used in conventional water treatment processes, based on their chemical characteristics. The two most commonly used primary coagulants are aluminum and iron (III) salts, according to Bouchareb *et al*. (2021). Nevertheless, current studies have pointed out several drawbacks as associating Alzheimer's disease with the use of aluminum salts in treating wastewater producing large toxic sludge volumes (Ivanova *et al*., 2021; Nisar & Koul 2021). Vigneshwaran *et al*. (2020) also pointed out the negative effect of widespread use of aluminum-based chemical coagulants. The study opined that the use of aluminum-based chemical coagulants causes a variety of neurological problems, whereas bio-coagulants have natural properties that make them toxic to aquatic life (Onukwuli *et al*., 2021). In recent years, there has been considerable interest in the development of natural coagulants such as *Moringa Oleifera* (Rocha *et al*., 2020). Using natural coagulants, considerable savings in chemicals and sludge handling costs may be achieved. *Moringa oleifera* seed kernels are biological coagulants consisting of significant quantities of low molecular weight water-soluble proteins (Saini *et al*. 2016; Wagh *et al*., 2022), which in solution carry an overall positive charge. *Moringa oleifera* coagulant has been adjudged safe and very effective in removing impurities (Tunggolou and Payus 2017). It has coagulating properties that have been used for various aspects of water treatment such as turbidity, alkalinity, total dissolved solids and hardness (Arnoldsson *et al*. 2008).

Muyibi and Evison (1995) first discovered softening property of *Moringa oleifera* when wastewater turbidity was reduced by 99% and hardness reduced by between 60-70%. Nand *et al*. (2012) also reported that locally available seeds like Moringa, Cowpeas, Corn are used for adsorption of heavy metals like lead, chromium, zinc, cadmium, etc. with *M. oleifera* being the most effective in terms of heavy metal adsorption. Most recently, Nisar and Koul (2021) observed that *Moringa oleifera* seeds contain antimicrobial properties and cationic water-soluble proteins (polyelectrolytes) which possess active coagulative properties that can remove the turbidity and heavy metals like Cu, Pb, Cr, Zn, etc from wastewater, thus can treat impure water efficiently.

Rahmadyanti *et al*., (2020) reported the use of *Moringa oleifera* as coagulants in wastewater treatment which produced pH parameter content close to neutral or 6.65 ± 0.04, reduced TSS to 99.63 ± 0.10%, COD to 98.06 ± 0.04%, and BOD to 97.67 ± 0.24%. The study further reported that as a result of the treatment, the treated wastewater could be safely discharged off in the waterbody. Raj *et al*., (2010) demonstrated the successful removal of biosorption of toxic metals, Ni(II) ions from the aqueous solutions using *Moringa oleifera* seeds with maximum removal efficiency (75.64%) using the single layer ANN modeling technique which was applied to optimize this process. From the past studies, wastewater has been treated using different approaches from the use of chemical coagulants (aluminum and iron (III) salts) and natural coagulants like Moringa oleifera. Use of chemical coagulants have been observed to come with some health challenges apart from the huge cost implication in a large scale treatment. Moringa oleifera seeds have been used in wastewater treatment in doses in some past studies, ranging from 0g to 10 g/500 ml. These studies failed to arrive at optimum doses required to sufficiently treat the wastewater (Villaseñor-Basulto *et a*l., 2018; Vunain *et al*., 2019; Desta and Bote 2021). Thus, the present study will be establishing the optimum doses of Moringa oleifera seeds solution that would be required in treating wastewater.

Therefore, this study focused on the treatment of abattoir wastewater in terms of physical, chemical and bacteriological properties using Moringa oleifera seeds as coagulant and also to determine the optimum dosage of the *Moringa oleifera* required in treating abattoir wastewater.

2. Materials and Methods

2.1 Preparation of coagulant

Matured pods of *Moringa Oleifera* were chosen from dry cracked fruits. The plucked fruits were cracked to obtain the seeds from which were air- dried for 2 days. The shells surrounding the seed kernel were removed using a knife and the kernels were powdered using a mortar and a pestle then sieved using a 600 µm stainless steel sieve size to obtain a fine powder. The fine powder was stored in a sterile plastic rubber and stored in a refrigerator.

2.2 Experimental design and procedure

The experimental design was based on completely randomized design (CRD) and was replicated three times. Forty (40) litres of abattoir wastewater was fetched from the abattoir and was dispensed into 18 beakers. 500 ml of abattoir wastewater was poured into three of the beakers mixed with 500 ml of distilled water with no *Moringa Oleifera*. This was kept as control sample. Six different concentrations of the stock solution, for the loading dose was prepared by weighing 10, 12, 14, 16, 18, and 20g of *Moringa oleifera* powder into beakers containing 500ml of distilled water each. The mixtures in the beakers were stirred using an automatic stirrer at 125 rpm for 30 minutes to obtain a clear solution and was left undisturbed to settle for 1 hour. The solution was recovered from the settled sludge by sieving and measured into a 500ml of the abattoir wastewater sample. The solution was mixed for two (2) minutes by gentle shaking to aid in coagulant formation. The solution formed was recovered and subjected to the experimental analysis for 10 weeks. After collection, the containers were properly stored in a cool dry place and the analysis of the wastewater commenced two hours after collection. The following parameters were determined: temperature, pH, total hardness, turbidity, conductivity, total alkalinity, dissolved oxygen, manganese, zinc, calcium, phosphate, nitrate and biological oxygen demand (BOD). Turbidity was measured before and after treatment with the help of digital turbidity meter (nephelometer) and was expressed in nephelometric turbidity units (NTU) as highlighted by Verma *et al*., (2020). pH was measured using pH meter before and after the addition of coagulant to wastewater. Dissolved oxygen was measured with the help of Winkler's method. About 5 L dilution water was prepared by adding 1 mL of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride solution to each litre of distilled water and aerating it for 10 hours (Kim *et al*., 2021). The biological oxygen demand (BOD) measurement followed the laboratory procedure as done by Verma *et al*., (2020) while that of total hardness, conductivity, total alkalinity, manganese, zinc, calcium, phosphate, and nitrate were performed according to Jeyasekhar (2022).

3. Results and Discussion

The chemical characteristics of *Moringa oleifera* seed used in this study are shown in Table 1. These chemical properties of *Moringa oleifera* are in two levels, serving as a coagulant and an antibacterial agent. *Moringa Oleifera* seed has been shown to act as a coagulant due to positively charged, water-soluble proteins that bond with negatively charged particles in the abattoir wastewater, causing flocs to sink to the bottom and be filtered out.

Table 1: Chemical properties of *Moringa Oleifera* seed

Properties	**Content(mg/L)**	**Properties**	**Content (%)**
Iron	7.85	Moisture content	8.24
Manganese	4.42	Crude protein	36.62
Phosphorus	56.83	ASH	6.65
Magnesium	11.33	FATS	35.11
Calcium	4.85	Crude Fiber	4.28
Zinc	51.4	NFE	9.1

3.1. pH

The average pH of the abattoir wastewater, without Moringa Oleifera treatment was found to be 6.96 mg/l at collection point and dropped to 6.80, 6.78, 6.76, 6.71, 6.65, 6.65 with 10, 12, 14, 16, 18 and 20g of Moringa oleifera treatment added respectively all in the first week. The capacity of Moringa oleifera as a coagulant resides in the presence of cationic water-soluble protein present in the seeds, which explains why the solution becomes more alkaline. This allows the alkaline amino acids in Moringa oleifera protein to absorb protons in water, resulting in the release of hydroxyl groups, causing the solution to become alkaline (Marzougui et al., 2021). Decreased pH of treated sewage water due to increased dose of Moringa oleifera seed powder in our study might be due to presence of low molecular weight proteins (Basra et al., 2014). The pH value was, however, observed to be increasing as weeks passed by from week 1 through week 10 across all the doses as shown in Figure 1. This agreed with Desta and Bote (2021) which concluded that the increase in pH value leads to the increase in the removal efficiency of M. Oleifera. From Figure 1, the pH values got to the optimum in week 5 across all doses with the minimum of 6.58mg/l, 16g/500ml Moringa oleifera dosage. The WHO recommended standard of pH for industrial wastewater discharge after treatment is between 7 to 8mg/L.

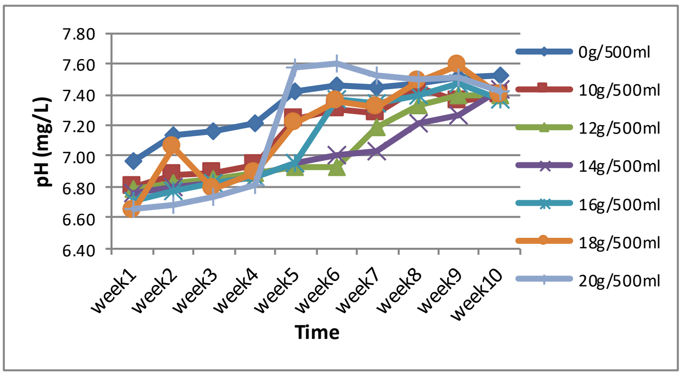

Figure 1: pH values with Moringa oleifera treatments

3.2 Turbidity

Turbidity of abattoir wastewater treated with coagulant *Moringa Oleifera* seed powder showed a substantial decline from week 2 to week 10 (Figure 2). The decline observed showed that cationic protein in the *Moringa oleifera* dosage had started reacting (Vigneshwaran *et al*., (2020; Desta and Bote 2021). The mechanism of coagulation with the seeds of *Moringa oleifera* consists of adsorption and neutralization of the colloidal positive charges that attract the negatively charged impurities in water as opined by Sotheeswaran et al. (2011). As a result of these interactions, the forces that stabilize the particles are disrupted, allowing it to attach to microscopic particulates and create precipitate. The optimal dosage of Moringa dosage was found to be 16g/500ml of *Moringa Oleifera* dose in week 7 where it went from 19.73 to 7.53 NTU which signified 63.5 % turbidity removal from the wastewater (Figure 3) as against 94.4 % turbidity removal reported by Vigneshwaran *et al*., (2020). There is a likelihood of restabilization of the destabilized particles, probably as a result of overdosing. This was evident as shown in Figure 3 as there was an improvement in turbidity level beyond week 7 at 16g/500 ml. This has been attributed to the saturation of the polymer bridge (Megersa *et al*., 2016). Can you calculate the percentage Turbidity removal by the coagulant and compare with previous works. Similar thing should be done to other parameters. There is need to also calculate the adsorptive capacity of the natural coagulant and compare with commercial ones.

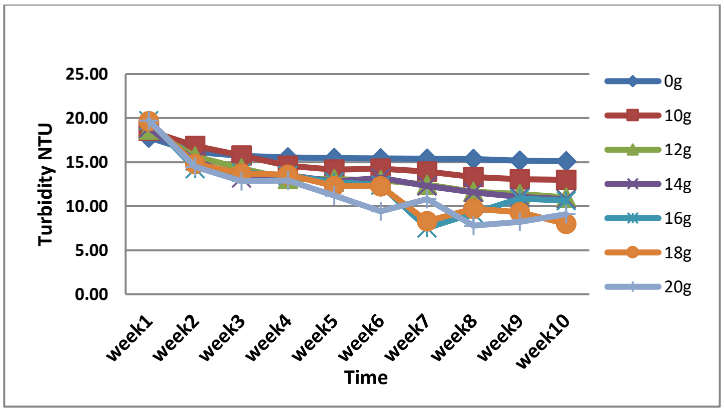

Figure 2: Turbidity values with *Moringa oleifera* treatments

Figure 3: Turbidity of abattoir effluent before and after treatment with *Moringa Oleifera*

3.3 Conductivity

The conductivity of wastewater at the point of sampling (week 1) was observed to be 1395.7 µs/cm and increased with time to 1878 µs/cm in the 5th week after treatment with *Moringa Oleifera* . There was drastic increase in average value of conductivity from the first week across all the treatments. The value at the point of collection increased from 677.7 µs/cm to 1719.67 µs/cm with 16 g *Moringa oleifera* treatment which is about 61 % increase (Figure 3). The level of percentage increase at 16g M. Oleifera treatment is common to all other treatments as observed. Generally, conductivity was observed to increase with time, though with gradual reduction with *Moringa Oleifera* treatments (Figure 4). The increase in the conductivity reading has been attributed to the ions formation in the water during the coagulation process as reported by Tunggolou and Payus (2017). Thus, higher coagulant dosage in the solution beyond optimum dosage will eventually lead to an increase in conductivity as observed due to the presence of unbound ions (Yuliastri *et al*., 2016).

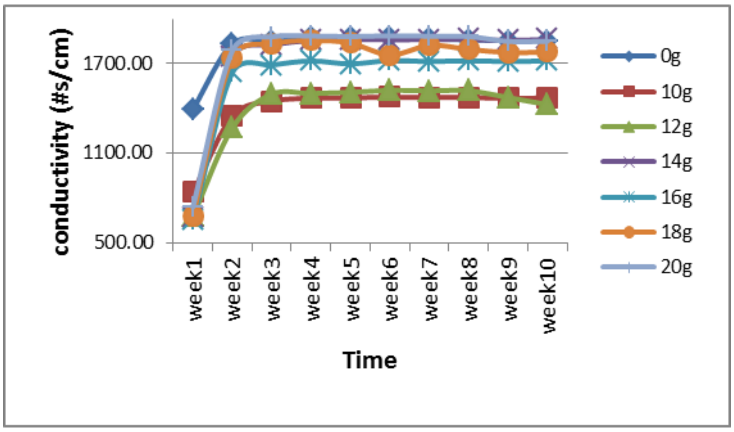

Figure 4: Conductivity values with *Moringa oleifera* treatments

3.4 Total hardness

The higher values of total hardness in the abattoir wastewater are because they contain hardness due to calcium, magnesium and other hardness-causing substances. Hardness, especially with the presence of magnesium sulphate can lead to the development of laxative effect on new consumers and cause scaling in pipelines. Calcium salts tend to cause incrustations on cooking utensils and water heaters. Hence is essential to soften the portable water

This simply implies that as the number of hardness-causing species in the sample increases, the required *Moringa Oleifera* doses will also increases. The Initial total hardness of the samples at the point of collection was estimated to be 141.3 mg/l at Week 1. There was general reduction in total hardness from weeks 1 to 10 and as the *Moringa Oleifera* doses increased as shown in Figure 5. The result, therefore, showed that the higher the quantity of *Moringa oleifera* applied, the higher the hardness that was removed. As a result of this fact, 14 g of *Moringa oleifera* had the highest potency in reducing hardness of wastewater.

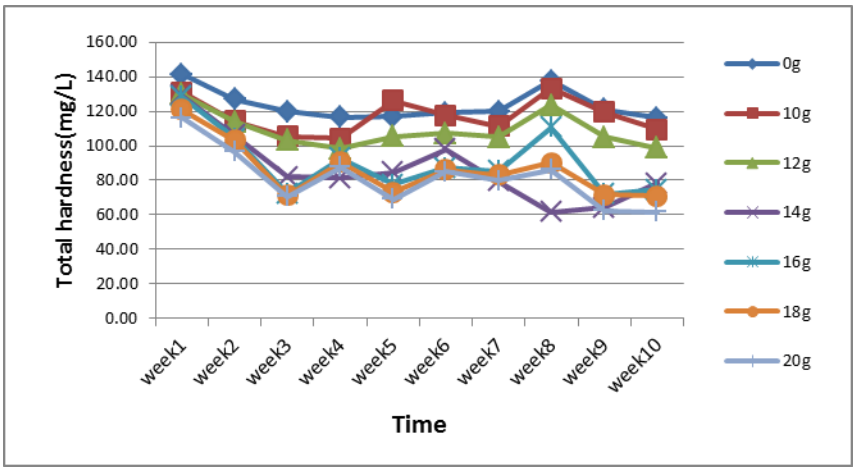

Figure 5: Total hardness values with *Moringa oleifera* treatments

3.5 Total alkalinity

Alkalinity at the collection point was 216.67 mg/L. Figure 5 shows that it decreased rapidly in the first week from 216.67 mg/l for control to 86 mg/l at 14 g *Moringa Oleifera* treatment which represents 60.3 % reduction. From Figure 6, in all the weeks, there is general reduction in total alkalinity levels as Moringa oleifera content increased. As a result of this fact, 12 g of *Moringa oleifera* had the highest potency in reducing total alkalinity of wastewater.

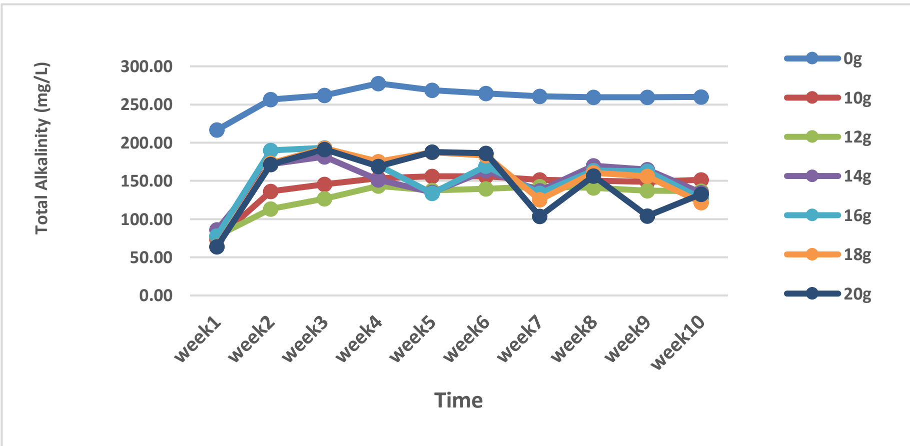

Figure 6: Total alkalinity values with *Moringa oleifera* treatments

3.6 Zinc

Zinc as one of the heavy metal in wastewater was observed at the collection point to be 1.42 mg/L, as shown in Figure 7. Figure 7 shows the general decrease in zinc values from week 1 to week 5. The lowest value was observed as 0.62 mg/L in week 5 with 14 g *Moringa Oleifera* content. This shows the efficiency of *Moringa Oleifera* to remove the heavy metal. The zinc content at the point of collection was, however, found to fall below the allowable zinc content in water of 5 mg/L stipulated by World Health Organisation (WHO). The high content of zinc has been attributed to high blood volume found in wastewater.

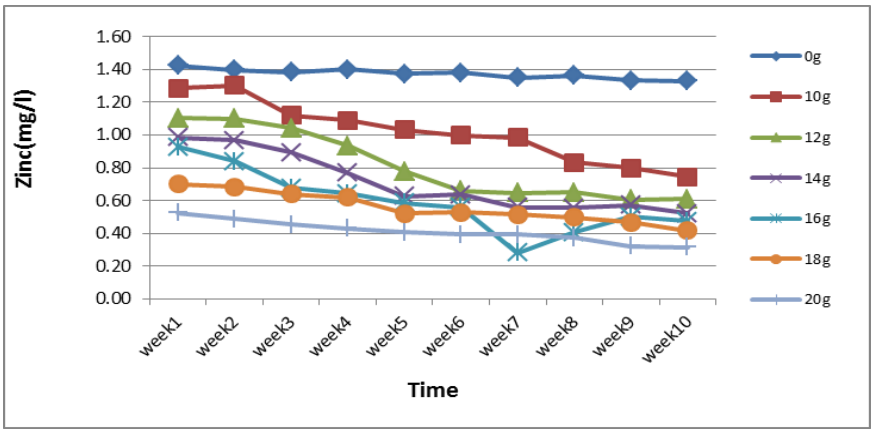

Figure 7: Zinc values with *Moringa oleifera* treatments

3.7 Dissolved oxygen

From Figure 4.6, the dissolve oxygen was 6.67mg/l at point of collection. It reduced from 5.67, 5.00 and 4.67mg/l with *Moringa Oleifera* treatment of 16, 18 and 20g. In week 2 and 3, there was also significant treatment of the dissolved oxygen. In week 4, there was complete treatment across the samples, from 0.54mg/l to 0mg/l. the dissolved oxygen in the sample has been totally evaporated by the *Moringa Oleifera* dosages in the abattoir wastewater. Decrease in the DO levels from 6.67 mg/L to 0.62 mg/L and 4.67 mg/L to 2.07 mg/L for both control and 20g *Moringa Oleifera* treatments respectively was observed showing the total decrease of 90.7% and 55.7 % for both treatments respectively, which is in agreement with published observations (Yuliastri *et al*., 2016). The decrease in DO levels has been attributed to the presence of natural and organic compounds present in *Moringa Oleifera* seeds (Verma *et al*., 2020).

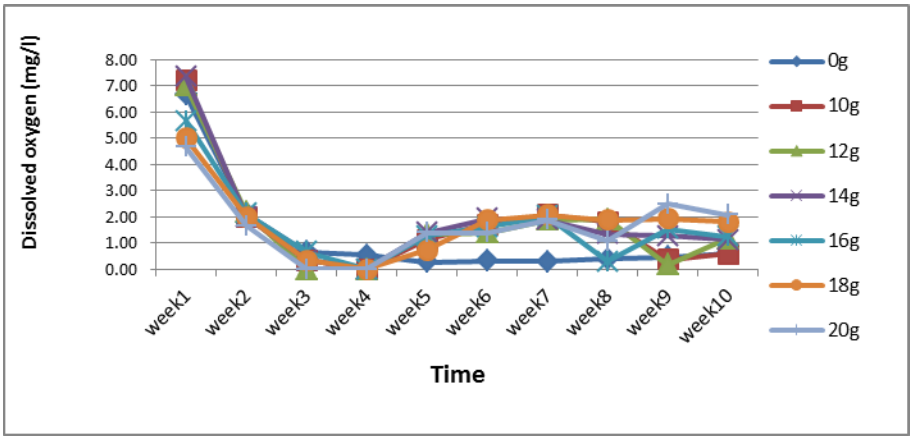

Figure 8: Dissolved oxygen values with *Moringa oleifera* treatments

3.8 Biological Oxygen Demand (BOD)

Initial BOD value recorded was 4.33 mg/l at the point of sampling. The BOD level was determined by comparing the dissolved oxygen levels of the sample before and after 5 days of incubation in the dark. The difference between the two DO levels gave the required amount of oxygen required for the decomposition of organic materials in the wastewater. Higher BOD concentrations recorded at the point of collection was due to high blood volume in the wastewater. This is in conformity with the findings of Ma *et al*., (2020) and Iloms *et al*., (2020). This fact had a great influence on the rest of the parameters and the nature of the wastewaters. This, thus, means that during the week 2 all the organic matters present in the wastewater samples have been fully decomposed as shown in Table 1.

Table 1**:** BOD Values For the wastewater samples

Moringa Content (g)	**WEEK 1**	**WEEK 2**	**WEEK 3**	**WEEK 4**	**WEEK 5**
0g	4.33	0.00	0.00	0.00	0.13
10g	4.87	0.00	0.00	0.00	0.00
12g	4.33	0.00	0.00	0.00	0.00
14g	5.33	0.00	0.00	0.00	0.00

Performance evaluation of Moringa oleifera as an environmentally friendly natural coagulant has been assessed. It was observed that Moringa oleifera is suitable for the treatment of wastewater containing undesirable heavy metal concentrations like zinc and manganese. From the experimental analysis and the results obtained, the following conclusions can be drawn:

i Moringa oleifera is an eco-friendly and economically advantageous and available.

ii Moringa oleifera is an effective natural coagulant which can be used in improving the physicochemical characteristics of water in terms of pH, turbidity, total alkalinity, total hardness, dissolved oxygen, BOD, calcium and conductivity.

iii Moringa oleifera seeds present a more efficient and cheaper way of treating abattoir wastewater which should be adopted in treating them before being discharged into surface water body as 16g/500ml of *Moringa Oleifera* was able to treat abattoir wastewater and thus confirm the suitability of using M. Oleifera for abattoir wastewater treatment. The observed coagulant behavior of *Moringa Oleifera* has been attributed to the water-soluble, positively charged proteins present in *Moringa Oleifera* seeds.

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