Waste Generation and Physicochemical Qualities of Abattoir Wastewater in Hawassa City, Southern Ethiopia

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Abstract

Background: Improper disposal of abattoir waste without any treatment has severe impacts on the environment and human health. However, there lacks sufficient studies that quantify abattoir waste and physicochemical parameters of wastewater. Thus, this study aimed to estimate waste generation and physicochemical characteristics of wastewater discharged from Hawassa municipal abattoir.

Methods: A cross-sectional study was conducted at Hawassa Municipality Abattoir. One year of cattle slaughtering data was collected from the Hawassa municipality registry from March, 2016 to February, 2017. Mathematical computational approach were used to evaluate magnitude and composition of waste generated from the actual number of cattle slaughtered. Samples were collected from two wastewater sites on sewer line into which the abattoir wastewater was discharged. Physicochemical characteristics of the wastewater were determined by different laboratory investigation methods. Statistical Package for the Social Sciences (SPSS) software version 21 was used to analyze the mean, standard deviation and one tail of t-test for two mean sample value was assumed for equal variance with 95% Confident Interval (CI) to determine significant difference of each physicochemical parameter between the two sites.

Results: Hawassa Municipality Abattoir generated 2529.76 kg of waste per day and 923,994.84 kg of waste per year. The analyzed physicochemical parameters indicated high concentrations of Chemical Oxygen Demand (COD) (579 mg/L), Biochemical Oxygen Demand (BOD5) (641.30 mg/L), NH_3 (56.32 mg/L), TDS (311.60 mg/L), Total Suspended Solid (TSS) (122.16 mg/L), and EC (838.40 µS/cm) at wastewater site 2 and elevated concentrations of PO_4^{3-} (43.50 mg/L), NO_3^- (92.24 mg/L), NO_2^- (23.99 mg/L), and DO (7.67 mg/L) at wastewater site 1. The mean difference in the concentration of COD, BOD5, NO_2^-, NH_3, TDS, TSS and EC obtained from two sites were statistically significant ($P<0.05$).

Conclusion: In this study, large quantity of abattoir waste was generated, which was directly discharged into the environment without any treatment. The mean value of most physicochemical parameters were higher than the Ethiopian Environmental Protection Agency maximum permissible limit. Therefore, Hawassa municipality office should design and implement safe abattoir waste treatment technology to safeguard public and environment.

Keywords: *Abattoir, wastewater, Hawassa, physicochemical parameters*

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Introduction

Abattoir operations result in the generation of waste in various forms (solid, liquid, semi-solid, semi-liquid) that pollute the environment and pose serious threats to human health and quality of life (Nwanta *et al*, 2008). Different studies estimates that, 20-50% of the weight of an animal carcass is not suitable for human consumption including blood, bone, urine, water, dissolved solids, intestinal content and tissue waste (Aneibo *et al*., 2009; Fearon *et al*, 2014).

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The volume of wastewater from abattoirs waste accounts for 70-75% of the waste stream and contributes to an especially high organic load and amount of suspended material (Roberts *et al*., 2011).

Abattoir wastewater is considered of having high strength waste compared to domestic wastewater even after treatment. It has a very high biochemical oxygen demand (BOD) and chemical oxygen demand (COD), Total Suspended Solid (TSS), nitrogenous, and phosphorus compounds due to the presence of blood, manure, urine, and intestinal content in it (US-EPA, 2004; Mittal, 2006).

There is a rapid urban growth and increased demand of meat in developing countries. These increase the daily amount of slaughters and abattoir wastewater which put pressure on urban wastewater systems (Ezeohaa *et al*., 2011). However, these countries have not developed a strategy for proper disposal of solid and liquid wastes generated from abattoirs (Akinro *et al*., 2011). Thus, abattoir wastewater has become a major pollutant, the main contributor of enteric pathogens in drinking water sources, and the cause of eutrophication of water bodies (Alonge, 2005; Torkian *et al*., 2003).

Studies had indicated that poor abattoir waste disposal is responsible for the pollution of surface and underground water as air. It is also responsible in disease transmission and indirectly affects the health of residents living within the vicinity of abattoirs (Adeyemi and Adeyemo, 2007; Odoemelan and Ajunwa, 2008; Chukwu, 2008).

Many factors could result for poor abattoir waste management in developing countries. Such factors include low industry commitment, lack of disposal restrictions, lack of abattoir waste control systems, low awareness of individuals, inconsistent governmental policies, and poor enforcement of local legislation (WHO, 2002; Tekki *et al*., 2012). The Hawassa Municipal Abattoir has been disposing its waste into the environment without any disposal management or treatment which poses a threat to the environment and public health. Therefore, this study, was focused on quantification of abattoir waste composition and determined the physicochemical characteristics of abattoir waste water, which will help to design management systems.

Materials and Methods

Study setting and design

A cross-sectional study was conducted at the Hawassa Municipal Abattoir (HMA), from March 2016 to February 2017. The abattoir is located in Hawassa city, the capital city of the South Nation, Nationalities, and Peoples' Region (SNNP) of Ethiopia. Hawassa is located 275 km to south of Addis Ababa, the capital city of Ethiopia. The city has a total population of 302, 000, of whom 155,340 are males and 146,660 females (WPPR, 2019). The HMA is located in the sub-city of Monopol, which is approximately 4-5 km from the center of the Hawassa city administration. The city has licensed the municipal abattoir operation, which creates job opportunity for more than 200 individuals (HMA office, 2016). However, problems such as poor waste management, poor sanitation, and poor layout were observed in accordance with the National Meat Inspectors' Manual on Abattoir Hygiene and Sanitation (NMAHS, 2007).

Data collection method

Determination of abattoir waste generation

One year (from March 2016 to February 2017) data of slaughtered cattle were collected from registration book of Hawassa municipality office to estimate the abattoir waste generation rate. The amount of waste generated was estimated based on the following: "One cattle could produce 12.6 kg of blood waste; 8.0 kg of intestinal content waste; 6.4 kg of tissue waste; and 11.8 kg of bone waste" (Aniebo *et al*., 2009).

Physicochemical analysis of abattoir waste

Samples for physicochemical parameters were collected from two wastewater sites for three consecutive weeks in May 2016. Site 1 was near the evisceration room, and site 2 was at the immobile abattoir wastewater site, 150 m from the first site. Waste water samples were collected by pre cleaned bottle according to American Public Health Association (APHA) methods using grab sampling (APHA, 1995). The first sample was collected as soon as the abattoir wastewater was released from site 1 and the second sample was collected after 24 hours from the immobile abattoir wastewater site 2. Untreated abattoir wastewater samples were collected three times from each of the wastewater sites. Then, samples were transported to the Hawassa University chemistry laboratory and preserved at 4°C until physicochemical analysis was done.

Twelve physicochemical parameters were selected to analyze abattoir wastewater. Seventy-two samples were analyzed and the experiments were repeated three times for each site. Unstable parameters such as pH, temperature, conductivity, and dissolved oxygen (DO) were measured immediately on-site following the standard protocols and methods of American Public Health Association (APHA, 1995). Electrical conductivity was measured using a conductivity meter (model HI 98130 HANNA, Mauritius, Iramac Sdn. Bhd). The pH and temperature of the abattoir wastewater were measured using a portable Hanna Waterproof pH meter and thermometer (HI 991300), respectively.

Dissolved Oxygen was determined using Winker's titration (Stirling, 1999). Chemical Oxygen Demand (COD) was measured by DR/2010 HACH (Love land, USA), according to HACH instructions. Biochemical Oxygen Demand (BOD5) test was done based on a measurable depletion of oxygen over a five day period by diluting the sample with dilution water according to 5210A method of APHA (2005) instructions. Other characteristics such as NH_3, $PO4^{3-}$, NO_3^- and NO_2^- were measured at wavelength of 640 nm, 640 nm, 520 nm and 570 nm, respectively by digital Palin test photometer, round test tubes, and 10 mL glass (PT-515). Total suspended solids (TSS) and total dissolved solids (TDS) were measured by filtration method according to APHA standards (APHA, 1995).

Quality control

Prior to sampling, 1 L polyethylene sampling bottles were first cleaned by incubating them with 10% Nitric Acid in order to remove contaminants from the bottle for 24 hours in a hot water bath. Then, the bottles were washed and rinsed with de-ionized water. Waste water samples were collected according to APHA methods. The first sample was collected as soon as the abattoir wastewater was released from site 1 and the second sample was collected after 24 hours from the immobile abattoir wastewater site 2. In order to obtain accurate and precise result of all measured parameters, the mean value obtained for three times from two sites were recorded.

Data analysis

SPSS software version 21 were used to analyze the mean and standard deviation of physicochemical parameters obtained from two sites. Moreover, t-test (one tail) for two mean sample value was assumed for equal variance with 95% Confidential Interval (CI) to determine significant difference of each physicochemical parameters between the two sites of the abattoir.

Results

Abattoir Waste Generation Rate of Hawassa Municipality

On average 65 of cattle were slaughtered per day which produces an average of 2529.76 kg of abattoir waste. The waste comprised of 821.5 kg of blood, 769.4 kg of bone, 521.6 kg of intestinal content, and 417.3 kg of tissue waste. Similarly, 923,994.84 kg/year of abattoir waste was generated from 23,814/year of slaughtered cattle. It was comprised of 300,060.18 kg (32%) of blood, 281,008.74 kg (30%), of bone, 190,514.4 kg (21 %,) of intestinal content, and 152,411.52 kg (17%) of tissue (**Table 1**). However, the waste generation rate varied from month to month **(Table 2).**

Physicochemical characteristics

The mean (±SD) value of COD obtained from site 1 and site 2 were 253.3 mg/L (±24.79) and 579.0 mg/L (±75.32), respectively. In same way the mean value of BOD5 from site 1 and site 2 were 325.33 mg/L (±62.08) and 641.3 mg/L (+56.07), respectively. The concentration of phosphate (PO_4^{3-}) was 243.5 mg/L (+10.69) at site 1 and 32.96mg/L (+2.94) at site 2. The mean (±SD) level of nitrate (NO_3^-) decreased from site 1 (92.24 mg/L (+14.14)) to site 2 (81.08 mg/L (+3.74)) and the level of nitrite (NO_2^-) was less in site 2 (11.18 mg/L (+1.04)) than site 1 (23.99 mg/L (+5.20)). The mean concentration of NH_3 at site 1 and site 2 were 18.17 mg/L (+7.29) and 56.32 mg/L (+10.19), respectively. The mean concentration of dissolved oxygen (DO) was decreased from site 1 (7.67 mg/L (+3.79)) to site 2(3 mg/L (+0.87)). Furthermore, the mean level of TDS at site 1 (110.40 mg/L (+18.89)) was less than the mean level of TDS at site 2 (311.6 mg/L (+11.34)). There was a statistically significant difference between the two sites in parameters such as COD, BOD5, NO_2^-, NH_3, TSS and EC (p-value<0.05) **(Table 3).**

Table 1: Abattoir waste generated at Hawassa Municipality abattoir, Southeastern Ethiopia from March 2016-February 2017.

Period	Number of cattle slaughtered	Abattoir waste composition and total waste generated (kg)				
		Blood	Intestinal content	Tissue	Bone	Total
Daily	65.2	821.5	521.6	417.3	769.4	2529.76
Weekly	456.4	5,750.64	3,651.2	2,920.96	5,385.52	17,708.32
Monthly	1,956.0	24,645.6	15,648	12,669	23,080.8	75,892.8
Yearly	23,814.3	300,060.18	190,514.4	152,411.52	281,008.74	923,994.84

Table 2: Number of slaughtered cattle and waste generated from Hawassa Municipality abattoir, Southeastern Ethiopia from March 2016–February 2017.

Month	Monthly cattle slaughtered	Waste generated in kg/month				
		Blood	Intestinal content	Tissue	Bone	Total
March	851	10723	6808	5446	10042	33019
April	2426	30568	19408	15526	28627	94129
May	2255	28413	18040	14432	26609	87494
June	2053	25868	16424	13139	24225	79656
July	2425	30555	19400	15520	28615	94090
August	1809	22793	14472	11578	21346	70189
September	2348	29585	18784	15027	27706	91102
October	1786	22504	14288	11430	21075	69297
November	2075	26145	16600	13280	24485	80510
December	1695	21357	13560	10848	20001	65766
January	1784	22478	14272	11418	21051	69219
February	2248	28325	17984	14387	26526	87222

Discussion

In this study period a total of 23,814 slaughters were performed per year at Hawassa Municipal Abattoir (HMA). The number of cattle slaughtered per month varied due to the existence of different fasting and meat-eating holidays throughout the year. During meat production huge amount of wastes generated. According to the current study, Hawassa Municipality Abattoir generates 2,529.76 kg/day and 923,994.84 kg/year of waste. This finding is consistent with findings at Minna abattoir in Nigeria (2,394 kg/day and 873,810 kg/year) (Ahaneku *et al*., 2015) and is slightly higher than findings at Tamale abattoir in Ghana (2,134 kg/day and 778,910 kg/year) (Sulley, 2006). Abattoir waste is characterized by high COD relative to Municipal Solid Waste (MSW) and HCW due to the presence of blood waste (Chukwu, 2011). The mean concentration level of COD found in this study from site 2 was significantly higher than site 1. The study also shows that the mean value of COD obtained from two sites in this study was higher than the permissible limit set by the EEPA (150 mg/L), WHO (120 mg/L) and the Environmental Protection Agency (EPA) (120 mg/L) (WHO,2002; EPA, 2003).

In addition, the mean BOD5 found from site 2 was significantly higher than site 1. That means the concentration of BOD5 at site 2 increased by two-fold as compared to site 1 within 24 hours. This indicated that the load of microorganism obtained at stagnant waste water (site 2) was higher than at source of abattoir waste water (site 1). Moreover, the values obtained from both sites were higher than national permissible limit recommended by the EEPA and WHO (50 mg/L) (EEPA, 2003; WHO, 2006).

This high amount of BOD and COD in this study can contaminate surrounding land (like Kote Jabessa). It can also enters to water bodies such as Lake Hawassa and the Bishan Guracha River which could have devastating effects on the aquatic organisms. This was found in similar studies that high concentrations of COD abattoir waste released into water bodies which resulted in the decline of aquatic organisms in these bodies of water (Muhirwa *et al*., 2009; Chima *et al*., 2013). In another similar study conducted at Abuja abattoir in Nigeria indicated that the continuous discharge abattoir waste with high concentrations of BOD into open environment had a severe impact on the environment due to high concentrations of BOD5 (Magaji and Chup, 2012).

In present study, the mean concentration of PO_4^{3-}, NO_2^- and NO_3^- were higher from both sampling sites than the national maximum permissible limits of 0.1 mg/L, 0.3 mg/L and 50 mg/L, respectively (EEPA, 2003). This can be a potential risk for environmental contamination and is enough to cause eutrophication in surrounding bodies of water.

The mean value of PO_4^{3-} and NO_3^- and NO_2^- at immobile (site 2) lower than at source of abattoir waste water (site 1) for two reasons. The first reason is due to high concentration of urine and undigested stomach contents found in the wastewater (Muhirwa *et al*., 2010). The second justification might be due to the phytoremediation of plants found near discharge ditches, which could have the potential to reduce the amount of these compound through the pipe line. In fact, such phytoremediation cannot completely prevent these pollutants from contaminating surface water and leaching into the groundwater (Reichenauer and Germida, 2008). The mean difference for the above values was only significantly higher only for nitrite (NO_2^-). One study indicates high concentration of nitrite cause methaemoglobinaemia or blue baby syndrome in infants (0.4-200 mg/kg of body weight) and stomach cancer in adults (Vigil *et al*., 1965).

The mean concentration of NH_3 at site 2 was significantly higher than site 1. A similar study conducted by the National Institution Occupational Safety and Health (NIOSH, 2010) indicated that the mean value of NH_3 increased from source waste water to immobile abattoir waste water. The high mean value of NH_3 level at immobile gives extreme pungent and suffocating odor and resulting in environmental pollution (John *et al*., 2010). This is happened due to the urine found in abattoir wastewater at immobile site. A similar report were found in other study (O'Neil, 2013).

The other parameter is DO at site 1 was higher than site 2. The mean value of DO recorded at site 2 is below the EEPA permissible limit (2003). This indicated that the abattoir wastewater has high levels of organic matter when it leaves the abattoir but loses some of that organic matter by the time it reaches the immobile sites. The other reason is due to the temperature difference between site 1 (20.59^{o}C) and site 2 (22.9^{o}C). The same finding reported that, decreases in DO were due to low level of temperature (Addy and Green, 1997). High BOD value is another factor that leads to low concentration values at immobile sites. This was indicated in studies the relationships of increased temperature and BOD values for decreased levels of dissolved oxygen (Savita *et al*., 2005; Umunnakwe *et al*., 2009).

The mean concentration of TDS at both sites was much higher than the national wastewater discharge limits recommended by EEPA (80 mg/L) and WHO (250 mg/L). As study conducted by Environmental Protection Agency South Australia (EPA-SA, 2009) indicated, the solid waste found in abattoir wastewater is due to paunch manure which is the greatest source of environmental pollution. Additionally, the mean value of TSS increased from site 1 to site 2 and was greater than the recommended value set by EEPA (30 mg/L) and recommended by WHO and EPA (50 mg/L) (EEPA,2003; WHO, 2002).

Limitation of the study

The magnitude of abattoir waste was estimated based on assumptions that was adopted from Nigerian context, which might be lower or higher abattoir waste estimation in our study area.

Table 3: Analysis of wastewater discharged by Hawassa Municipality abattoir, southeastern Ethiopia, 2017.

Parameter	Sites and values of physicochemical character		Maximum permissible limit			Differ -ence	P-value
	Site 1 (Mean ± SD)	Site 2 (Mean ± SD)	** EEPA	*** WHO	**** EPA	(S2-S 1)	(α=0.05)
COD (mg/L)	253.3 ± 24.79	579.0 ± 75.32	150	120	100	325.7	**0.010***
BOD_5 (mg/L)	325.33 ± 62.08	641.3 ± 56.07	50	50	50	315.97	**0.012***
PO_4^{-3} (mg/L)	43.5 ± 10.69	32.96 ± 2.94	0.1	1-10	5	-10.54	0.203
NO_3^- (mg/L)	92.24 ± 14.14	81.08 ± 3.74	50	10	20	-11.16	0.128
NO_2^- (mg/L)	23.99 ± 5.20	11.18 ± 1.04	0.3	1	2	-12.81	**0.006***
NH_3 (mg/L)	18.17 ± 7.29	56.32 ± 10.19	30	50	10	38.15	**0.003***
DO (mg/L)	7.67 ± 3.79	3.00 ± 0.87	≥5	-	-	-4.67	0.053
TDS (mg/L)	110.40 ± 18.89	311.6 ± 11.34	80	250	-	201.2	0.000
TSS (mg/L)	61.65 ± 19.31	122.16 ± 27.75	30	50	50	60.51	**0.021***
EC (µS/cm)	634.09±71.31	838.4 ± 33.06	1000	400	-	204.31	**0.005***
pH (pH.M)	6.78 ± 1,68	7.17 ± 1.04	6-9	6.5-8.5	5-9	0.39	0371
Temp (°C)	20.59 ± 1.48	22.9 ± 2,85	40	20-30	25-35	2.31	0.141

*statistically significance at 0.05 (CI=95%); **EEPA = Ethiopian Environmental Protection Agency: Maximum Permissible Limit of Effluents Discharge Regulations (2003); ***WHO = World Health Organization: Permissible Limit of Effluents Discharge Regulations (2002); ****EPA = Environmental Protection Agency: Permissible Limit of Standards for Effluent Discharge Regulations (2003).

Conclusion

This study concluded that a large quantity of waste was generated by Hawassa Municipality abattoir as compared to other studies. The difference in mean concentration level of COD, BOD5, NO_2-NH_3, TDS, TSS and EC statistically significant (p-value < 0.05) between two sampling sites, while, $PO4^{3-}$, NO_3^-, DO, pH and temperature were not statistically significant (p-value > 0.05). Except electric conductivity, temperature and pH, the other remaining physiochemical parameters are higher than that of national maximum permissible limits, which are the potential to pose threats on environment and public health. Therefore, this study recommends that the Hawaassa municipality office should design abattoir sustainable waste treatment to safeguard the environment and ensure public health. Moreover, the magnitude of waste estimated was an assumption. Therefore, actual waste generation by the municipals abattoir should be measured for further designing of intervention.

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Author contributions

ST and SS: involved in conceiving the idea, developing methods and data analysis. ED and TH: Participated in data collection, analysis. All authors involved in manuscript writing, reanalyzing the data and reviewing the comments of the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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