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Characteristics of Chicken Slaughterhouse Wastewater

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The chicken slaughterhouse wastewater is a class of wastewater, which is heavily polluted with organic matters including proteins, blood residues, fats and lard. Therefore, the direct discharged of untreated chicken slaughterhouse wastewater into the environment is associated with the occurrence of eutrophication phenomenon. In the present study, the characteristics of chicken slaughterhouse wastewater were investigated to ascertain the role of these wastes in the adverse effect on the environment and natural water system. The parameter tested included biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), total nitrogen (TN), total organic carbon (TOC), orthophosphate (PO_4^{3-}), temperature and pH. The results revealed available high concentrations of BOD (1,341 - 1,821 ± 242.7 mg L^{-1}), COD (3,154.19 - 7,719.3 ± 2,282.69 mg L^{-1}), TSS (377.67 - 5,462 ± 2,696.1 mg L^{-1}) which have exceeded the EQA1974 standard limits for disposal of wastewater into the environment. The concentrations of TN (162.6 -563.8 ± 215 mg L^{-1}) and PO_4^{3-} (7.047 - 17.111 ± 4.25 mg L^{-1}) were within the range required for microalgae growth which confirm their role in the occurrence of eutrophication phenomenon. It can be concluded that the direct discharge of chicken slaughterhouse wastewater contributes negatively on the environmental biodiversity and thus they should be subjected for an effective treated before the final disposal.

1. Introduction

Development of agricultural sector and rapid industrialization has produce a large volume of wastewater. A proper wastewater treatment is needed before been discharged into the water body, to avoid environmental degradation such as eutrophication and spreading of water borne diseases (Akpor and Muchie, 2011). Slaughterhouse wastewater had been characterizing as highly polluted wastewater due to high biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solid (TSS), blood and nutrient (nitrogen and phosphorus) from slaughtering and cleaning activities (Santos and Robbins, 2004; Bustillo-Lecompte et al. 2016). According to Rajakumar et al. (2011), the presence blood and complex mixture of fats, proteins and fibres in chicken slaughterhouse wastewater contribute effectively in the increasing organic matter, which induce the occurrence algal bloom. The increasing demand of chicken production for human consumption had increase the slaughterhouse wastewater discharged in Malaysia. Discharged of untreated wastewater into sewer will reduce the quantities and quality of clean water. According to statistic by Department of Statistic Malaysia (2015), there is 289,996,253 chickens had produced in year 2014 compared to 272,451,321 number of chicken in year 2013 with increasing about 6.4%. The effluent from slaughterhouse had increase dramatically and generates large quantities of wastewater. Hence, the treatment of slaughterhouse wastewater should be implemented in order to protect nature from deterioration and prevent disease outbreak of pathogenic bacteria from animal wastes (Sobsey et al., 2006).
The variations in physical characteristics of wastewater effect on the parameters of these wastes due to their role in biological and chemical reactions. The temperature is effect on pH values, therefore both parameters should be considered for the assessment of the quality of greywater (Jais et al., 2016). COD parameter is one of main chemical characteristics of wastewater, which reveal the level of organic contents. The high concentration of COD indicates the presence high chemical reaction between organic substances in wastewater. In contrast, BOD is an indicator for the biological oxidation of organic compounds. The presence high concentrations of BOD mean available high microbial loads in the wastewater.

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The nutrients in wastewater refer to total nitrogen (TN) and total phosphorous (TP). Nitrogen in the wastewater is available in organic form included ammonia (NH_4^+, NH_3-N) and inorganic forms which included nitrite (NO_{2-}) and nitrate (NO_{3-}). Nitrates are the most common stable form of nitrogen found in water which originating from natural decaying process of biological matter. Excessive nitrates level in wastewater may lead to harmful algae bloom, oxygen depletion, poison for fish and poor odours (Al-Gheeti *et al.,* 2015). The most common form of TP is orthophosphate (PO_4^{3-}) which resulted from using the detergent compounds and hygiene products (Eriksson et al. 2002). High phosphorus concentration in wastewater may lead to eutrophication. Generally, the simple yet affordable method to reduce phosphorus content in wastewater is by using chemical precipitation (Warmadewanthi et al., 2017). The characteristics of different types of the wastewater have been reported in literature. However, very few studies have been performed on the chicken slaughterhouse wastewater. Therefore, the present work aimed to investigate the characteristics of these wastes in order to determine presence or absence the adverse effects for their disposal into the environment and natural water system. The parameters tested included BOD, COD, TSS, TN, TP, TOC, temperature and pH.

2. Materials and Methods

A 10 Litres of chicken slaughterhouse wastewater (CSWW) was used in this study and was collected from Parit Hj Abdul Kadir, Parit Raja (Location coordinate 1°51’03N; 103°05’37E). Sample was collected from the discharge point of the slaughterhouse as illustrated in Figure 1 and sampling was done at two conservative days in order to gets its effluents trend and pattern. Sampling was done for 5 times a day at 8 am, 9 am, 10 am, 11 am, and 12 pm through grab sampling method to ensure that all the variations in effluent content were covered. Samples was collected using plastic bottle of Polyethylene Terephthalate (PET). Then, the samples were transported to UTHM and analysed in UTHM environmental Laboratory within 24 hours. The chicken slaughterhouse wastewater was analysed for nutrient composition included TN, TOC and orthophosphate (PO_4^{3-}). pH was measured by using 4500-H-B method with Oakton pH 700 Benchtop Meter (Oakton, USA). TN was measured according to 4500-NH_3-B method by using DR 6000 Spectrometer (UV-VIS Hach, USA), while PO_4^{3-} was determined based on Method 1060. The concentrations of heavy metals were conducted by inductively coupled plasma mass spectrometry (ICP-MS) and mercury analyser. BOD, COD, TSS and temperature are determined according to APHA (2012).

Figure 1: Chicken slaughterhouse wastewater collection from discharged point

The samples were preserved and certain test was conducted within its maximum storage life, according to the Standard Method of Examination of Water and Wastewater, APHA, (2012). The preservation of sample is important to maintain the characteristics of wastewater especially for their temperature. The change of temperature may affect the condition of the effluent samples. Investigation of the physic-chemical parameters was carried out before storage of the samples. The parameter was biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, turbidity and total suspended solid (TSS). Table 1 shows the storage and maximum holding time of the samples.

Table 1: Storage and maximum holding time of samples (APHA, 2012)

Parameter name	Storage	Maximum storage
Biochemical oxygen demand (BOD)	Preferable to analyse as soon as possible. Otherwise, refrigerate (< 6 °C) in the dark.	48 h
Chemical oxygen demand (COD)	Preferable to analyse as soon as possible. Otherwise, acidify with sulfuric acid to pH < 2 Refrigerate (< 6 °C) in dark	28 d
pH	Analyse immediately	Determine insitu if possible, or upon arrival to laboratory.
Turbidity	Refrigerate (< 6 °C) in dark	Up to 48 h

3. Results and discussion

Characteristics of chicken slaughterhouse wastewater was obtained from four times of sampling. The slaughterhouse wastewater composition obtained from this study was compared to one of the recent study (Bustillo-Lecompte et al., 2016) and Malaysia standard for industrial effluents (2009) as presented in Table 2. It can be noted that pH (7.3-8.6 ± 0.42), BOD (1,341-1821 ± 242.7 mg L^{-1}), COD (3,154.19 – 7,719.3 ± 2,282.69 mg L^{-1}), and TSS (377.67 - 5,462 ± 2,696.1 mg L^{-1}), have exceeded the EQA1974 regulations (Standard A and B). However, the range was less than that reported by Bustillo-Lecompte et al. (2016). Regulation and standard are importance for wastewater treatment to make sure that the discharged of wastewater into the sewer do not cause any harmful environmental impact. According to Bustillo-Lecompte et al. (2016), slaughterhouse wastewater had considered as a most harmful wastewater to environment and it is classified as agricultural and food industrial waste.

Table 2: Characteristic of chicken slaughterhouse wastewater (Minimum, maximum and mean value), (n=12)

Parameter	This study			Bustillo-Lecompte	EQA1974	
	Minimum	Maximum	Mean	*et al*., (2016)	Standard A	Standard B
pH	7.3 ± 0.42	8.6 ± 0.42	8.02 ± 0.42	4.90-8.10	6.0-9.0	5.5-9.0
BOD	1341 ± 242.7	1821 ± 242.7	1602 ± 242.7	610-4635	20	50
COD	3154.19±2282.69	7719.3 ± 2282.69	5422.25 ± 2282.69	1250-15900	50	100
TSS	377.67 ± 2696.1	5462 ± 2696.1	3438.223 ± 2696.1	300-2800	50	100
TN	162.6 ± 215	563.8 ± 215	361.25 ± 215	50-841	NR	NR
TOC	194.9 ± 222.66	651.5 ± 222.66	419.3 ± 222.66	100-1200	NR	NR
PO_4^{3-}	7.047 ± 4.25	17.111 ± 4.25	12.256 ± 4.25	NR	NR	NR
F^-	0.221 ± 0.15	0.642 ± 0.15	0.493 ± 0.15	NR	NR	NR
NO_3	1.643 ± 0.58	3.265 ± 0.58	2.241 ± 0.58	NR	NR	NR
Cd	0.000021± 0.02	0.034 ± 0.02	0.01234 ± 0.02	NR	0.01	0.02
Cu	0.00351± 0.32	0.573 ± 0.32	0.2085 ± 0.32	NR	0.2	1
Hg	0.000421 ± 0.001	0.002513 ± 0.001	0.001454 ± 0.001	NR	0.005	0.05

*All parameters are expressed as mg L-1 except for pH, N/R = Not Reported; Cadmium (Cd); Copper (Cu); Mercury (Hg).

The increasing of population led to increase demand of chicken thus contribute to high number of slaughterhouse and the main problematic lies in the effluent generated from the direct discharge of chicken slaughterhouse facility. Then, characterization of wastewater in term of COD and BOD before treatment is needed in order to determine the impact of discharged wastewater to the environment. The ratio of COD to BOD is used to select the appropriate treatment methods. The COD: BOD ratio was 4:1 which indicate the presence high concentration of organic compounds resulted from the presence of detergents in chicken slaughterhouse wastewater. The variation of the strength and characteristics of chicken slaughterhouse wastewater are caused by several factors such as production capacity, type and weight of animal, methods of transportation, animal receiving and holding, processing technology, amount of carcase, washing temperature, cleaning and sanitizing procedure, and labours behaviour (Budiyono et al., 2011). According to Bustillo-Lecompte et al. (2016), preliminary treatment of slaughterhouse wastewater by equalization, flotation and screener can reduce 30 % BOD and 60 % TSS from wastewater. Removal of BOD concentration in chicken slaughterhouse wastewater is vital because high BOD concentration may increase energy and cost for wastewater aeration and oxygen supplies (Bukhari, 2008). According to Bukhari (2008), reduction of BOD concentration entering the aeration tank would reduce the energy requirements. Thus, it will save cost and enhance oxygen level in wastewater. Discharged of this treated wastewater to the sewer will reduce eutrophication occurrence (Al-Gheethi et al., 2015). Besides that, BOD has correlation with total suspended solid (TSS).

High BOD will disturb organic matter decomposition in the wastewater, thus cause suspended solids in the wastewater failed to be digested under anaerobic conditions (Henze and Comeau, 2008). As consequences, it will deteriorate wastewater treatment processes. Besides that, the higher value of TSS in chicken slaughterhouse wastewater can be due to the erosion of soils near the sewer, blood, feather and fats of processing chicken (Kundu et al., 2013). TSS value obtained from this study was ranged 377.67 to 5,462 ± 2,696.1 mg L^{-1} which higher compared to Bustillo-Lecompte et al. (2016) with range 300-2,800 mg L^{-1} and it also exceed standard A (50 mg L^{-1}) and B (100 mg L^{-1}) limit. High TSS in water can cause several environmental problems such as increase water turbidity, reduce light penetration and transmittance, inhibit aquatic plants photosynthesis, clog aquatic organism gills and cause suffocation due to lack of oxygen in the water (Bilotta and Brazier, 2008). According to Pahazri et al. (2016), total nitrogen (TN), and total phosphorus (TP) are related to the microbial contamination in the wastewater, and high microorganism in the wastewater may lead to pathogenic activity. In this study, the TN, TOC and PO_4^{3-} in the investigated chicken slaughterhouse wastewater were between 162.06 - 563.8 ± 215 mg L^{-1}; 194.9 - 651.5 ± 222.66 mg L^{-1} and 7.047 - 17.111 ± 4.25 mg L^{-1}, respectively. According to Nguyen et al., (2012), high phosphorus level in wastewater may deteriorate the water quality and lead to eutrophication. TN and TP in this study is within the range that required for microalgae growth (Pahazri et al., 2016). These findings confirm that the discharge of nitrogenous chicken slaughterhouse wastewater into the natural water system would contribute in the occurrence of eutrophication phenomenon (Kundu et al., 2013).

Nitrite, nitrate and phosphorus are essential for microalgae growth and they can be limiting factors for microalgae growth (Carayo et al., 2005). Phycoremediation may decrease the nutrient level in the wastewater. Nitrate concentration are closely related to the phosphorus which previous studies by Henze and Comeau, (2008) had demonstrate that biological phosphorus removal cannot be done when nitrate concentration is high. Nitrate concentration in wastewater was classified as high range when it exceeds 0.5 mg/L (Henze and Comeau, 2008). In this study of CSWW, the nitrates level was 1.643 – 3.265 ± 0.58 mg L^{-1}, which can be classified into high range. Microalgae prefers phosphorus in the form of orthophosphate (PO_4^{3-}) which is easy to binds to iron for microalgae growth.

Nitrites and nitrate are oxidized forms of nitrogen from nitrification process and excessive nitrites and nitrate level in wastewater may lead to harmful algae bloom, oxygen depletion, poison for fish and poor odours (Al-Gheethi et al., 2015). Nitrites and nitrates can be removed from wastewater by microalgae phycoremediation as demonstrated by Dominic et al. (2009). Previous studies by Dominic et al. (2009) had successfully removed nitrate in water sample up to 84 %, 82.5 %, 96.23 % when treated with *Chlorella vulgaris, Synechocystis salina* and *Gloeocapsa gelatinosa* respectively. However, if the nitrogen in the wastewater not removed carefully, the emission will increase the greenhouse gasses in the atmosphere.

Heavy metals are transition elements and some heavy metals such as mercury (Hg), Cadmium (Cd) and Copper (Cu) are highly toxic. However, in this study, the heavy metals concentration in chicken slaughterhouse wastewater was extremely low compared to Malaysia effluent standard A and B, which values for Cd, Cu and Hg are 0.000021-0.034 ± 0.02 mg L^{-1}, 0.00351 - 0.573 ± 0.32 mg L^{-1}, and 0.000421 - 0.002513 ± 0.001 mg L^{-1}. Heavy metals have negative correlation with pH of wastewater ($p<0.001$) and it can determine the solubility and biological availability of chemical constituents. The higher level of heavy metals in wastewater will lower the pH values of wastewater and the water are highly toxic and polluted which can kill aquatic lives (Johansson et al., 1995). According to Johansson et al. (1995), the concentration of heavy metals in water is 2-5 times higher in low pH (6.2-6.5) compared to the high pH value, 7.0 due to acidification process. Thus, to reduce heavy metals content in the CSWW biologically, microalgae can be used as tools to absorb heavy metals as demonstrated by Gani et al. (2016) had used *Botryococcus* sp. to treat meat processing wastewater and Jais et al., (2015) had used *Scenedesmus* sp. to treat wet market wastewater. According to Jais et al. (2015), heavy metals in wet market wastewater had successfully removed using microalgae with 65.76 % for Iron (Fe) and 84.14 % for Zinc (Zn).

Slaughterhouse wastewater characteristics had correlation among others as illustrated in Table 3. Different ratio among slaughterhouse wastewater can affect effectiveness of wastewater treatment process and environmental degradation.

Table 3: Correlations among slaughterhouse wastewater characteristics (Henze and Comeau, 2008)

Parameter	High	Medium	Low
COD/BOD	2.5-3.5	2.0-2.5	1.5-2.0
COD/TN	12-16	8-12	6-8
COD/TN	1.6-2.0	1.4-1.6	1.2-1.4

According to Henze and Comeau (2008), ratio of COD to BOD was high when achieved 2.5 - 3.5 and low when 1.5 - 2.0. However, in this study, the chicken slaughterhouse wastewater (CSWW) ratio for COD: BOD was 4:1, which relatively high. High COD to BOD ratio had increase organic matter degradation time (Henze and Comeau, 2008). High BOD and COD will lead to occurrence of eutrophication, which can be toxic to aquatic organisms, destruct organism nursery grounds, and extinction of certain species (Al-Gheethi et al., 2015). Previous studies by Li et al., (2008) reveled that the amount of COD and BOD in the slaughterhouse wastewater are between 3,000 and 5,577 mg L^{-1} and between 750 and 2,895 mg L^{-1}, which is 4:1 COD to BOD ratio that follow the correlation as stated in Table 2. The high concentrations of BOD and COD in slaughterhouse might be due to presence of blood and complex mixture of fats, proteins and fibres, which contribute in the increasing, the organic matter (Kundu et al., 2013).

The COD to TN ratio was high when achieved 12 - 16, in this study, the ratio for COD:TN was 13:1. The COD to TN ratio may influence the nitrogen removal in the wastewater. Nitrogen in the wastewater is available in form of nitrite (NO_2) and nitrate (NO_3). Ntrates are the most common stable form of nitrogen found in water which originating from natural decaying process of biological matter. Excessive ratio of COD to TN in wastewater may lead to harmful algae bloom, oxygen depletion, poison for fish and poor odours (Al-Gheeti et al., 2015). Then, the COD to TSS ratio in this study was 1:1 and categorized as low. In this study of chicken slaughterhouse wastewater (CSWW), TSS resulted from cleaning of chicken stomach, intestinal mucus, undigested food, blood, feather and loose meat (Bazrafshan et al., 2012). Generally, high TSS in water can cause several environmental problems such as increase water turbidity, reduce light penetration and transmittance, inhibit aquatic plants photosynthesis, clog aquatic organism gills and cause suffocation due to lack of oxygen in the water (Bilotta and Brazier, 2008). The correlation of CSWW characteristic in Table 3 can be used as a guideline for wastewater treatment process and as precaution to protect environment from jeopardize.

4. Conclusions

Characterization of chicken slaughterhouse wastewater (CSWW) is importance in order to determine the impact of discharged wastewater to the environment and suitable method for wastewater treatment which is low cost, effective and do not harm the environment. By considering the characteristics of slaughterhouse wastewater, the appropriate treatment method can be applied based on their level of pollutant. The major requirement in wastewater treatment is the removal of nutrients and heavy metals, which would lead to reduce microbial loads in the wastewater to acceptable limits prior to discharge and reuse and also reduction of toxicity level in the wastewater.

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