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Poultry Slaughterhouse Wastewater Treatment Using Combine Anaerobic Filter with Constructed Wetland Methods

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Abstract

BACKGROUND: Poultry slaughterhouse wastewater has a complex composition that is very harmful to health and the environment. A two-stage system is applied to treat wastewater, consisting of an anaerobic filter (AF) combined with constructed wetland (CW).

AIM: Experiments carried out under mesophilic conditions aim to evaluate the performance of a biological treatment combining AF and CW on three media filters.

METHODS: Observations were made for 15 consecutive days on chemical oxygen demand (COD), BOD_5, TSS, pH, and fat oils and grease FOG (35.5 mg/L). The treatment system is operated with a sewage loading of 14 m3 s-1 and an RTH of 18.2 h.

RESULTS: The results showed that before processing, the average values of COD (2881.4 mg/L), BOD_5 (967 mg/L), TSS (860.3 mg/L), pH (6.7), and FOG (35, 5 mg/L). The greater efficiency was obtained using gravel media, BOD_5 (88.9%), COD (92.9%), TSS (93.4%), and FOG (87.3%). Optimal treatment conditions in this system were found for AF with gravel media, operating at hydraulic retention time = 4.2 h, out of a total of 18.2 h. The IB value increased from 0.3 to >0.5, indicating the combined AF and CW method is suitable for treating wastewater from poultry slaughterhouses.

CONCLUSIONS: The combination of the AF method and CW is well applied to the wastewater treatment of poultry slaughterhouses, and parameters values have complied with the applicable regulations. Nevertheless, the removal of oil and grease is highly recommended in pre-treatment to inhibit the anaerobic process.

Introduction

Slaughterhouse (abattoir) wastewater generally has very complex characteristics [1], [2]. The quality and volume of wastewater are strongly influenced by meat processing technology and the utilization rate of by-products [1], [3], [4], [5], [6]. The biggest contribution to the organic load is blood and digestive mucus [1].

Currently, there are 396 poultry slaughterhouses in Bantul Regency, Yogyakarta Province, Indonesia. It is estimated that each processed animal can produce 20.5 L of wastewater [7]. All companies do not have wastewater treatment because it costs expensive and maintenance [7], [8]. All poultry slaughterhouse wastewater are discharged into waterways, even though it can be a source of health and environmental problems [2], [5], [6], [8], [9], [10], [11]. The quality of wastewater from poultry slaughterhouses has not met the regulations for disposal into the environment [12]. The content of organic matter (OM) in the waste is 550 mg L^{-1} (BOD_5), 900 mg/L (chemical oxygen demand [COD]), and 525 mg/L (TSS). In addition, wastewater contains pathogenic microorganisms which cause diseases such as typhoid, dysentery, cholera, and hepatitis [2], [6], [8], [9], [11], [13], [14], [15].

Wastewater treatment from slaughterhouses is suitable using anaerobic systems due to the high concentrations of biodegradable OM [8], [16], [17], [18], [19], [20], [21]. In addition, the anaerobic treatment produces less sludge, lower energy, higher loading rate, and substantial biogas production [21]. Anaerobic treated wastewater with an organic load (OL) of 16.5 kg/m^3/day and a hydraulic retention time (HRT) of 72 h can reduce COD up to 81% [8]. Another report stated that the COD removal efficiency was 80%, at OL 9.98 kg/m^3/day and HRT 24 h, and COD removal efficiency was 80% when operated at OL 5-6 kg/m^3/day and 2-day HRT [22]. Meanwhile, the best average efficiency at 24-h HRT was for BOD_5 (76.1%), total N (23.2%), and total P (35.4%) [23].

An alternative to anaerobic treatment for treating slaughterhouse wastewater is an anaerobic filter (AF). The advantages of AF have tolerated variations in OL, low temperature and pH, and low toxic concentrations [8], [18], [23], [24]. In addition, the use of AF does not require additional energy, so it does not require additional processing costs [8], [21], [24]. Reportedly, the use of AF reduced COD up to 60%, at 30°C, OL 60 kg/m^3/day [24], and 90% at 360°C and OL 10 kg/m^3/day for 27 h HRT [25].

Wastewater treatment using the constructed wetland (CW) method has been widely used, such as municipal, industrial, agricultural, and livestock wastewater treatment [9], [15], [23], [26], [27], [28], [29], [30], [31], [32]. Wetland systems are an inexpensive alternative to appropriate technology for the main organic pollutant load [23], [27], [28] [29], [31].

Slaughterhouse effluent has many OM and nutrients [1], [2], [15], so pre-treatment is required before discharge to the wetland stage to prevent over-processing. Effective pre-treatment is required primarily to remove FOG before biological processing [15], [29], [31].

Several studies have reported good results in slaughterhouse wastewater treatment. The use of gravel planted with Typha domingensis, Typha orientalis, Phragmites australis, and Scirpus validus can reduce TSS (83-89%), turbidity (58-67%), total N (14-56%), and total P (37-61%) on HRT between 2.7 and 3.6 days [33]. CW with Schoenoplectus validus, Glyceria maxima, I. pseudacorus can reduce the concentration of NH3 (20%), COD (65%), and TSS (80%) [34]. In Mexico, constructed wetlands (1,144 m2) filled with gravel and planted with P. australis and T. latifolia reduced BOD5 (91%), COD (90%), TSS (75%) [35]. Other studies have also reported the efficiency of reducing BOD5 (55-98%), COD (72-98%), TSS (34-99%) [15], [36], [37], [38].

This study aimed to evaluate the performance of a biological treatment system that combines AF and CW. Three media are used in AF: tile, ceramic, tiles, and gravel. At the same time, the type of plant used is I. pseudacorus. It is hoped that the process will reduce the values of BOD5, COD, TSS, and FOG so that they meet environmental regulations.

Materials and Methods

Description of the treatment system

The wastewater treatment (Figure 1) begins with wastewater from the production process into the equalization bath. There is a FOG catcher bath and a flow divider in the equalization bath. The wastewater is divided into four pathways (D, E, F, and G), which function as sedimentation bath, then flows into the AF basin with three different media (tile fragments, ceramics, and gravel) and one as a control. From AF, wastewater is channeled to the CW unit using the *I. pseudacorus* plant. Before being disposed into the sewer, the wastewater is channeled to the biomonitoring pond.

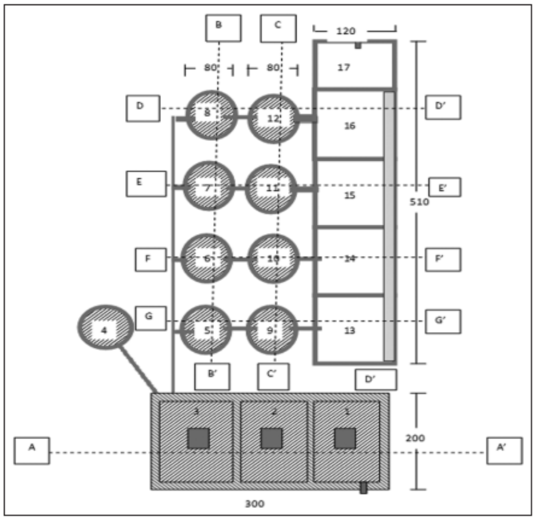

Figure 1: Schematic diagram of combine AF and CW system (1: FOG separator; 2: Equalization-1; 3: Equalization-2 and Flow divider; 4: Overflow; 5: Sedimentation-P1; 6: Sedimentation-P2; 7: Sedimentation-P3; 8: Sedimentation-control; 9: AF-P1; 10: AH-P2; 11: AF-P3; 12: AF-control; 13: CW-P1; 14: CW-P2; 15: CW-P3; 16: CW-control; 17: Bio-monitoring). AF: Anaerobic filter, CW: Constructed wetland, FOG: Fat oils, and grease

Anaerobic filter system

AF is performed using three different media (ceramic, tile, and gravel). All of the materials used the same size (2.5 cm × 22.5 cm), the building demolition waste was obtained. Seeding is done for 1½ months to breed bacteria.

Constructed wetland

CW is carried out in the second stage of processing on each medium used. Three trenches were prepared with a width of 1.0 m and a length of 1.2 m (1.2 m^2). The type of plant used is *I. pseudacorus*, with a plant density of 4 plants m^{-2}. This plant is suitable for the treatment of slaughterhouse wastewater using the CW method [35].

Sampling and analysis

Wastewater comes from a poultry slaughterhouse in Bantul Regency, Yogyakarta Province, Indonesia. Sampling was carried out 15 times sequentially at each outlet of the processing variation. At the same time, row wastewater samples were also taken as a comparison. Sampling and examination of physicochemical parameters of wastewater (COD, BOD_5, TSS, pH, and FOG) using standard methods for the analysis of wastewater quality [40], [41], [42], [43].

The efficiency of removal is calculated:

$$\text{Efficiency removal (\%)} = \frac{A - B}{A} \times 100 \qquad (1)$$

"where A is the initial COD (mg/L), BOD_5 (mg/L), TSS (mg/L), pH, and FOG (mg/L). B is the value after treatment."

The index biodegradable (IB) is calculated:

$$\text{Index biodegradable (\%)} = \frac{BOD}{COD} \times 100 \qquad (2)$$

"Where BOD is the BOD_5 Pada P_1, P_2, and P_3. *COD* on P_1, P_2, and P_3. Interpreted of IB: >0.5 than easily biodegradable, 0.4–0.5 average biodegradable, 0.2–0.4 slowly biodegradable, and <0.2 not biodegradable [44].

Result and Discussion

Table 1 shows the characteristics of wastewater and treatment system performance results. Generally, the quality of raw wastewater far exceeds applicable regulations, reaching 8 to 14 times greater. Raw wastewater can be characterized as high strength effluent dominated by OM in suspended form and low biodegradability index (BOD_5 COD^{-1} = 0.3). The color of the raw wastewater is blackish (dark), and the pH is slightly acidic 6.7. It was possibly influenced by animal blood and OM fermentation.

Table 1: Characteristics of wastewater pre-and post-treatment using combine anaerobic filter and constructed wetland

Parameters	Row	P_1	Removal (%)	P_2	Removal (%)	P_3	Removal (%)	Guidelines for WW
COD (mg/L)	2881.4	307.6	89.3	272.5	90.5	204.1	92.9	200
BOD_5 (mg/L)	967.0	178.6	81.5	144.5	85.1	107.0	88.9	100
TSS (mg/L)	860.3	87.7	89.8	73.6	91.4	56.8	93.4	100
FOG (mg/L)	29.8	5.6	81.2	5.5	81.7	4.7	84.1	15
pH	6.7	7.2	−8.9	7.3	−10.0	7.2	−8.9	7–8

P_1: Tile; P_2: Ceramic; P_3: Gravel, WW: waste water.

The efficiency of removing OM (COD and BOD_5), TSS, and FOG for all treatments (Table 1) showed high consistency (>80%). However, the most significant removal efficiency was in treatment 3 (P_3) with anaerobic gravel filter media, COD (92.9%), BOD_5 (88.9%), TSS (93.4%), and FOG (87.3%). The value of TSS and FOG has complied with applicable regulations [12]. In all treatments, the pH value increased to neutral.

IB is the ratio of BOD_5 and COD as a measure of the biodegradability of wastewater [7], [19], [31], [44]. The measurement results of raw wastewater get an IB value of 0.3 (slowly biodegradable). Generally, wastewater from a slaughterhouse has a ratio between 0.3 and 0.6 [44]. Hence, the biological treatment process will be slow and several additional processes are needed to accelerate the biodegradation [7], [19], [31], [44]. The results showed that the IB value in the three AF media was >0.5, indicating that it was easily biodegradable. These results also show that wastewater treatment using the combination of AF and CW methods is suitable for treating poultry slaughterhouse wastewater.

Figure 2 shows the efficiency of removing OM (COD and BOD_5), TSS, and FOG based on the

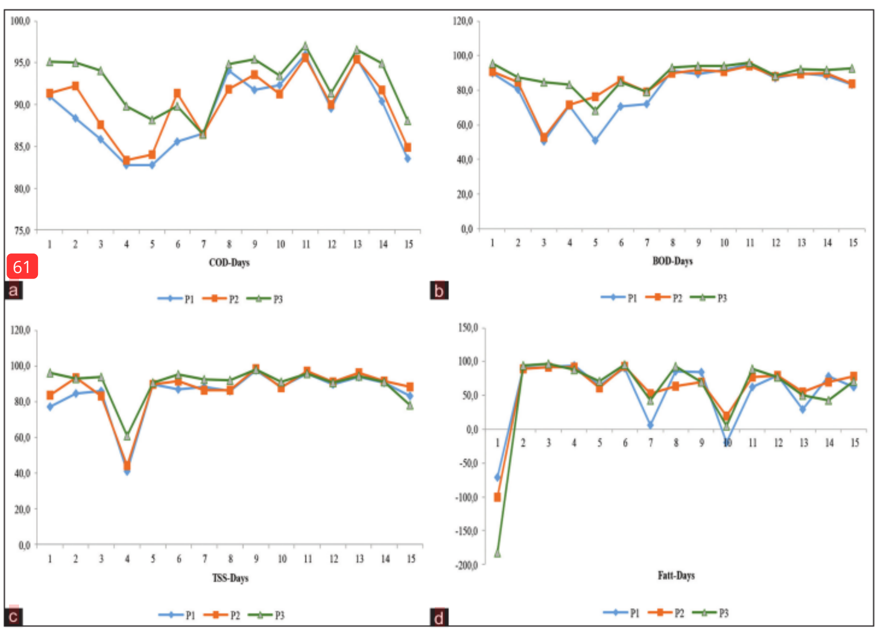

Figure 2: Efficiency removal of the parameters on three media: COD (a), BOD5 (b), TSS (c), and FOG (d). FOG: Fat oils, and grease, COD: Chemical oxygen demand

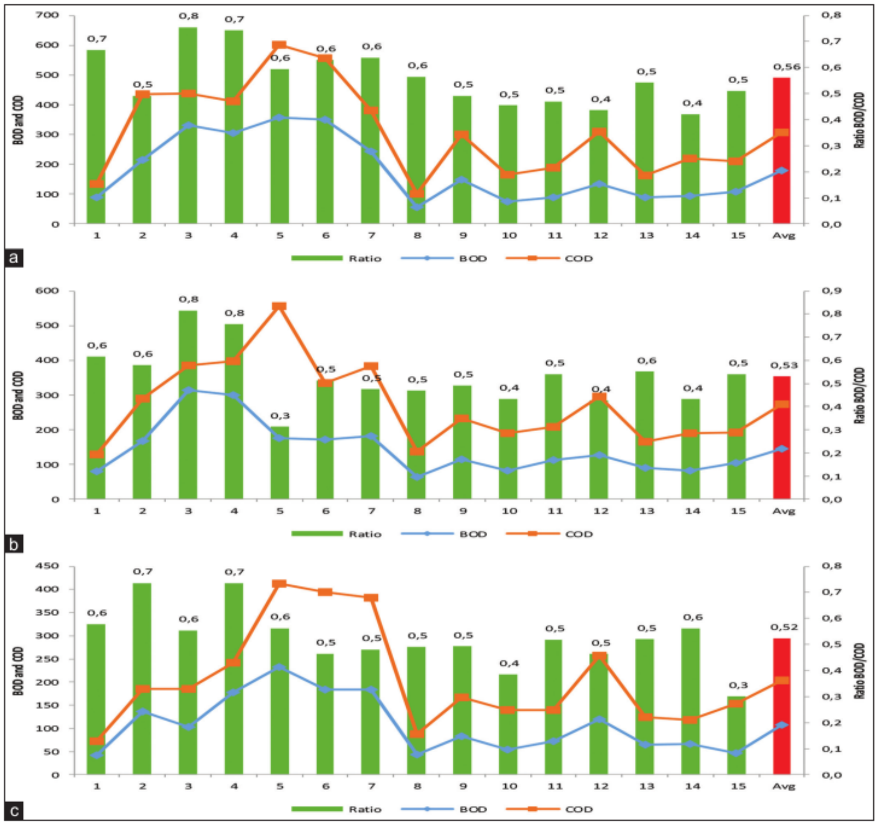

Figure 3: BOD_5/COD ratio by filter type; tile (a), ceramic (b), and gravel (c). COD: Chemical oxygen demand

type of filter media. Although fluctuated, overall gravel media (P_3) consistently gave the largest removal effect on COD (Figure 2a). The efficiency removal was consistently above 86.0%, reaching a peak of 97.0% with an average removal of 92.7%. The lowest removal efficiency uses tile fragments (P_1), with an average removal of 89.1%. The porous and rough surface allows the growth of more biofilms on the gravel [15], [29]. Studies confirm previous studies using gravel in AF [4], [9], [13], [18], [21], [28], [32]. Biofilm development in the upflow reactor is faster than downflow reactor because of the lower washout effect [1], [8], [21], [23], [24]. Successful treatment is achieved after 2–3 weeks of bacterial seeding [1].

The decrease in COD is influenced by HRT; the longer the HRT, the efficiency of COD reduction [8]. In this study (Figure 2), the lowest COD value was on the 4th day, then varied on the following days. This is probably due to oil and grease collecting in the filter. Several studies explain that oils and fats undergo anaerobic biotransformation to produce volatile fatty acids (VFAs), which inhibit the anaerobic process [8], [22], [45]. Therefore, before anaerobic treatment, oil and grease removal must be carried out.

Similar to COD, the best BOD_5 removal efficiency was also shown in the use of gravel media (Figure 2b). The efficiency removal was between 68.0% and 96.0%, with an average removal of 68.2%. Consistently, the efficiency of BOD_5 removal was always highest at 15 days of observation. The rapid decrease in COD value causes the ratio to BOD_5 also to increase. In raw wastewater, the ratio of BOD_5 and COD is 0.34 (slowly category). After treatment, the ratio increased to >0.5; it was categorized as easily biodegradable [46]. BOD values were low in the third (P_2, P_3) and fifth (P_1), then increased on the following days (Figure 2). This is also caused by oil and fat that collects on the surface of the filter. Furthermore, it produces VFA, which interferes with the anaerobic process.

TSS is the number of suspended solids in wastewater, which can be in the form of organic or inorganic materials. In the first treatment (P_1), the efficiency of TSS removal was consistently between 40.7% and 97.6%, with a mean removal of 85.2%. Similar in P_2, the efficiency of TSS removal was between 44.4% and 98.3%, with an average removal of 87.2%. Most removals were recorded on gravel media (P_3). The efficiency was consistently above 61%, reaching a peak of 97.8% with a mean removal of 90.3% (Figure 3c). The TSS removal is also affected by the oil and grease on the filter surface.

Similarly, the trend of FOG removal was also observed. In the first treatment (P_1), the FOG efficiency removal is peaked at 93.7%, with an average removal of 55.3%. In P_3, the maximum efficiency of FOG removal at 96.3%, with an average removal of 53.6%. The best removal was on gravel media (P_2), with the maximum efficiency at 93.3% and an average removal of 59.5% (Figure 3d). In the first measurement, it is seen that the efficiency of getting a negative value in the three media. It is estimated that due to the unpreparedness of the grease trap at the equalization stage. This unpreparedness can also be seen from the low BOD_5 and COD measurements on days 1 to 7. High FOG content in poultry slaughterhouse wastewater requires suitable pre-treatment and maintenance to not interfere with the biodegradation process [5], [44], [47].

Experiments carried out under mesophilic conditions and observations were for 15 days, so the effectiveness of long-term processing is unknown. In addition, the effect of pH and wastewater quality testing at each stage was not carried out. Further research allowed to (i) compares the filter's performances in terms of methane production, (ii) study the reactor's behavior during feedstock overloading conditions, (iii) determine the parameters governing the process kinetics for biomass growth and methane production, and (iv) study more effective types of aquatic plants.

Conclusions

A wastewater treatment system with a combination of AF and CW has been built to treat poultry slaughterhouse wastewater. This system can remove OM as BOD_5 (88.9%), COD (92.9%), TSS (93.4%), and FOG (87.3%). Although not entirely, the parameters of TSS and FOG have complied with the regulations in Indonesia. The IBI values in the three media increased from 0.3 to >0.5. Optimal treatment conditions in this system were found for AF with gravel media, operating at HRT = 4.2 h, out of a total of 18.2 h. Nevertheless, the removal of oil and grease is highly recommended in pre-treatment to inhibit the anaerobic process.

Author contributions

All the authors contributed equally to the preparation, development, and completion of this manuscript.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that the other authors have read and approved the manuscript and that there were no ethical issues involved.

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