Removal of pollutants from chicken slaughterhouse wastewater using constructed wetland system

F Ramdani, A Prasetya, and C W Purnomo
Department of Chemical Engineering, Universitas Gadjah Mada, Indonesia
Agrotechnology Innovation Center, PIAT UGM, Indonesia

E-mail: chandra.purnomo@ugm.ac.id

Abstract. The growth of the poultry industry has a significant impact on the environment especially in the slaughtering stage that will create a high quantity of wastewater. This wastewater has high organic content that requires efficient and low-cost treatment technology alternatives, such as by Constructed Wetlands system. The purpose of this research was to determine the ability of plants to reduce the content of Chemical Oxygen Demand (COD), and the ammonia content of chicken slaughterhouse wastewater. The wetland pond dimension was 6x20x0.8m (WxLxH) and filled with coarse sand and then planted with cattail grass (Typha latifolia), umbrella plant (Cyperus alternifolius) and vetiver (Vetiveria zizanioides L. Nash). The results showed that the plants in the wetland had a good performance in treating chicken slaughterhouse wastewater. The efficiency of decreasing the total COD can reach up to 85%, while the highest ammonium removal efficiency was 80%. Meanwhile, the most efficient plant for reducing COD was shown by umbrella plant (Cyperus alternifolius).

Keywords: slaughterhouse, phytoremediation, subsurface flow, constructed wetland, wastewater

1. Introduction
The vast development of the industrial sector needs to be considered because it will provide benefits for the development of the Indonesian economy.

To meet the demand for meat in Indonesia, a high population country, one of the efforts is to establish a poultry industry, according to the Directorate General of Animal Husbandry, Ministry of Agriculture data on broiler meat production from 2013 to 2018 shows an increase from 1,497,874 tons/year to 2,144.013 tons/year or 68.86% [1].

The high growth of this industry has a significant impact on the environment. The activity of chicken slaughtering and meat processing has a negative impact on the environment. The large volume of wastewater is discharged into the environment without proper treatment. Based on the preliminary survey, it was found that the outlet water from Wastewater Treatment Plant (WWTP) plant of a chicken slaughterhouse (CSH) in Berbah district, Sleman, Yogyakarta, Indonesia had COD level of 746.67 mg/L for oil and fat content at 78.84 mg/L and for ammonia content at 71.67 mg/L. This is still above the quality standards [2]. This can be proof that common CSH has not built a proper WWTP.

Wastewater produced from CSH contains high organic material and suspended and dissolved solids (TSS/TDS) creating bad odor [3].

To whom any correspondence should be addressed (chandra.purnomo@ugm.ac.id)
A straightforward treatment to handle the content of organic liquid waste with high TSS/TDS is using the phytoremediation wetland system. Constructed Wetlands System (CWS) consists of a pond in which wastewater flowing through substrate or media planted by aquatic plants. So, it is a mimic of the water purification process that occurs in the swamps area, where aquatic plants (hydrophytes) that play an important role in the natural water recovery process [4-5].

Sub-surface Flow Constructed Wetlands (SSF-CW) utilize symbiosis between aquatic plants and microorganisms in the media around the root system (rhizosphere). Complex organic compounds contained in wastewater will be consumed by plants as nutrients, while root systems of aquatic plants will produce oxygen, which can be used as an energy source or catalyst for a series of metabolic processes for heterotopic aerobic microorganisms [6].

Plant types that can be applied for phytoremediation must have high biomass production, capable of accumulating contaminants well at the top of the plant beyond the concentration of contaminants found in the soil (hyperaccumulator), and tolerant to the local environment [7]. In this study, some local collected plants will be used to treat wastewater from a CSH using SSF-wetland. Selected plants are cattail (Typha latifolia), Cyperus alternifolius, and vetiver zizanoides. The purpose of this study was to determine the ability of plants to reduce COD, ammonium and fat/oil content from WWTP effluent of CSH.

2. Research Method

2.1. Materials and Tools
Wastewater was collected from WWTP effluent CSH at Agrotechnology Center PIAT-UGM. Cattail grass (Typha latifolia), umbrella plant (Cyperus alternifolius), and vetiver (Vetiveria zizanioides L. Nash) obtained from a local nursery. The growth media was using river sand with a particle size of 2530 mesh. The porosity of the sand bed was measured at 0.37. The wetland pond has a dimension of 20 m in length, 6 m in width, and 0.8 m in depth.

2.2. Plant cultivation and analysis
Figure 1 shows the planting plot area of wetland pond, also the inlet and outlet of wastewater. The plant species are cultivated from the first section (close to the inlet) with Cattail grass (CT), in the middle with Umbrella (UP), and the last is Vetiver (VT). An empty distance of 1 m length was provided for each plant species, and after planting, the plant is nurtured for 30 days to adapt to the new environment before being used to treat WWTP effluent.
In detail, 20 m CW length was divided into 3 plant zones. The first 10 m length was planted with cattail grass (Typha latifolia), then the next 5 m was planted with umbrella plant, and the last section was planted with Vetiver. There are sampling wells to collect the water samples after passing each plant type. Wastewater originating from WWTP effluent was flown into remediation pond during CSH operation from 09.00 am to 16.00 pm with a flow rate of 2.5 m$^3$/h. Wastewater samples 15 ml were taken from each sampling wells for testing COD and ammonia parameters. The COD analysis is using Hanna Instrument Hi839800. The COD analysis method is first to rinse the vial with 20% sulfuric acid then take a sample of 2.5 ml of input in the vial to add 1.5 K$_2$Cr$_2$O$_7$ and 3.5 ml of sulfur reagents after that reflux with a temperature of 150 °C for 2 hours.

While ammonia analysis using Hanna Instrument HI 96715. The ammonia analysis method takes 1 ml sample into cuvette add 9 ml of HI 93733B-0 ammonia reagent B and add 4 drops of HI 93733A-0 Nessler reagent. In this research, three sets of observation time were done based on the plant life cycle. This method is done to understand the effect of crop management on the performance of treating wastewater. The first observation is at the early planting time after plant adaptation (Early). The second observation was at the optimum plant growth (Optimum), and the last was when the plant was cut or harvested for biomass (Harvest). The plant was not cut all of the stems, but it was cut about 40 cm above the ground, leaving some stems and undisturbed roots for plant regrowth.

3. Results and Discussion

3.1. COD measurement
By the stated dimension, CW pond volume is 96 m$^3$, and from sand porosity data, the void fraction in the media bed can be determined which is about 35 m$^3$. Considering the wastewater flowrate at 2.5 m$^3$/h, then the average residence time will be about 14 hours.

By this processing, time COD can be reduced effectively as shown in table 1. The initial COD of entering wastewater has some fluctuation; thus, every data set the inlet COD together with all sampling was measured. In all the plant conditions, the CW can reduce the COD to the acceptable level (no more than 200 ppm).

| Plant stage | COD in mg/L at a specific length of CW in m | % COD |
|-------------|------------------------------------------|-------|
|             | 0 | 10 | 15 | 20 | 0 | 10 | 15 | 20 |
| Early       | 676 | 515 | 373 | 170 | 0 | 23 | 45 | 75 |
| Optimum     | 739 | 559 | 378 | 116 | 0 | 24 | 49 | 84 |
| Harvest     | 770 | 589 | 370 | 113 | 0 | 24 | 52 | 85 |

In terms of COD removal, all the planting stage has similar performance (figure 2). This could be due to the central part of the plant that responsible for absorbing the pollutant is in the root zone. In all the stages, the plant root zone is preserved. The efficiency of decreasing COD content in the CW pond is significant that can reach up to 85%.
Figure 2. COD Removal for each plant stage

In the end section of CW, the highest COD removal is for the Harvest period. This could be due to the demand for nutrients during the plant regrowth is the highest; thus, the root absorbs as much as possible the organic matter from the wastewater. Laksono and Kirana stated that the composition contained in CSH waste is the organic matter, which is ready to be degraded and absorbed by a natural system.

3.2. Ammonia measurement
The presence of ammonia compounds can cause toxic conditions for aquatic life. The free ammonia level in the water increases with increasing pH and temperature. The living organism in water is affected by ammonia at the concentration of 1 mg/L and can cause death because it can reduce the oxygen concentration in water [8]. The presence of ammonia in waters can be in the form of dissolved ammonia (NH₃) and ammonium ion (NH₄⁺). Non-ionized free ammonia (NH₃) is toxic to aquatic organisms. Ammonia removal in the CW pond is presented in Table 2.

| Plant stage | COD in mg/L at a specific length of CW in m | % Ammonia |
|-------------|-------------------------------------------|-----------|
| Early       | 106                                       | 0 10 15 20| 0 22 41 74 |
| Optimum     | 105                                       | 0 10 15 20| 0 23 30 76 |
| Harvest     | 100                                       | 0 10 15 20| 0 20 35 80 |

Based on Table 2, it can be observed that the ammonia level in the inlet is about the same in all the data sets. All the stages can reduce the ammonia level to meet the requirement at a maximum of 25 ppm. Except for the early planting, the stage is slightly higher. The best result of ammonia reduction is the same as COD removal which is after the harvesting stage.

Figure 3 shows the removal profile of ammonia. In the early stage, the removal is quite steady. While for the other stage, the significant removal has happened in the end part of CW. It seems vetiver uptake of ammonia is relatively higher than others in all stage, while for CT is remain the same at the time.
3.3. Suitable plant
To determine the best plant in removing the pollutant, the total COD uptake during the whole trial is compared with the uptake per plant (table 3). Since the plant physiology and also the speed of spreading is different for each species, for instance, CT has bigger stems than VT, but VT will spread quickly then the number of plants in the same cultivation area is different among the plant type.

Table 3. COD removal in 14 days

| Plant type | Total COD removed (g) | COD uptake per plant (g) |
|------------|-----------------------|--------------------------|
| CT         | 92,835                | 773                      |
| UP         | 112,254               | 3741                     |
| VT         | 103,522               | 3450                     |

In terms of COD uptake per plant, UP shows the highest value than the others. The ability of a CW in removing pollutants indeed is a combination of many factors. Chemical adsorption is the interaction between pollutants and binding sites on the surface of the plant or substrate which leads to the removal of pollutants from the solution. Meanwhile, physical adsorption, mechanical filtration, and sedimentation (deposition of contaminants in the wetland base) are also important [9]. Plants and beds act as filters, increasing sedimentation of suspended solids and, therefore, physically increasing the removal of contaminants [10].

The other removal mechanism is photodegradation processes include irradiation with ultraviolet or visible light accelerating the decomposition of contaminant compounds. Photodegradation of water pollutants addresses the naturally occurring self-cleaning of some pollutants in surface waters, as well as several alternative non-photochemical approaches to water treatment [11].

Many microbial consortiums also live in the media (sand and gravel), as well. These microorganisms are also able to digest the pollutant especially in the bottom part of the sand bed, that anaerobic
conditions might occur. The bacteria also can immobilize inside the porous structure of media and creating a film that can effectively be treating the waste [12].

By including all the physical, chemical, and biological processes that might happen in a CW above, it is not easy to determine the best plant in removing the pollutant. The simple calculation provided in table 3 is just for a hint of the plant type in correlation with COD removal. A more careful works need to be taken in order to find a suitable plant.

4. Conclusion
The use of the Constructed Wetland method with Cattail (Typha latifolia), Umbrella (Cyperus alternifolius) and vetiver (Vetiveria zizanioides L. Nash) plants can help to overcome environmental problems caused by the Chicken Slaughterhouse industry. The highest COD reduction efficiency was 85%, while the highest ammonia removal efficiency was 80% and for the highest COD uptake that was in the Umbrella (Cyperus alternifolius) plant at 3741 per plant (g).

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