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Effectiveness of Vetiver *(Vetiver zizanioides)* in Purifying Wastewater from Pig Farm

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Livestock production such as piggery projects is one of the causes of the world's environmental problems. Untreated wastewater can cause harm to the environment and public health. This study aimed to determine the effectiveness of *Vetiver zizanioides* in purifying swine wastewater. These plants were grown in plastic drums for 5 weeks to find out the changes on the physico-chemical characteristics of the wastewater in terms of pH, nitrate, phosphorous, BOD_5 and TSS as well as its growth in terms of its height in shoots and in length of roots after 5 weeks of cultivation. Results revealed that vetiver grass was effective in purifying swine wastewater as gleaned from the percentage removal efficiency which was highest in biochemical oxygen demand (96.85 %), followed closely by nitrate (96.51 %), total suspended solids (65.01 %) and phosphorous (55.92 %). The vetiver grass thrived in swine wastewater placed in pots and in the facultative pond. The height of shoots were increased from 20 cm to an average of 33.5 cm while the length of roots also increased from 10 cm to 36.83 cm after 5 weeks of cultivation in pot trial. During the field experiment, the vetiver plant was able to adapt and tolerate the swine wastewater as evidenced by the height of its shoots and length of roots of 32.3 cm and 45.6 cm after 9 weeks of cultivation.

1. Introduction

Pollution affects us all. Unmanaged wastes and untreated wastewater discharged to wastestream usually results to pollution in the water, air, soil. Due to pollution, many valuable ecosystems have been damaged and ecosystem services have been disrupted. Health risks and hazards could no longer be ignored as a result of the exposure and vulnerability of the living population to the affected environment.

Livestock production such as pig farming generates different types of wastes which when not mitigated can lead to global warming, air and water pollution, land degradation and even loss of biodiversity. The livestock sector contributes about 14.5 % human-induced greenhouse gases (GHG) and is a large user of natural resources (FAO, 2019). It is also considered the largest sectoral source of water pollutants from animal wastes, antibiotics, as well as the sediments which could possibly be carried by surface run-off during natural disasters.

Piggery projects are sources of agricultural wastewater. According to Zhao et al. (2015), large-scale farming in piggeries and in poultry generates organic pollutants which could be difficult to handle and eventually can cause harm to the environment especially if these large quantities of organics is discharged without treatment (Tian et al., 2017).

In the Philippines, based from the report of Claudio (2015), agricultural wastewater constituted about 37 % as major source of pollution next to inadequately treated domestic wastewater or sewerage (48 %) and industrial wastewater (15 %). Moreover, the estimated total annual volume of wastewater produced is about 7, 465 million cubic meters which usually come from municipal and major agricultural industries (Mogal et al., 2015). In the region, pig farming is a lucrative business that usually results to several problems or issues which require effective and affordable technological solution to remove pollutants from the soil and water.

According to Makara and Kowalski (2015), pig manure is a two-fraction mixture of feces, urine and water. The chemical composition of pig manure depends largely on various factors such as the type and age of the animals and the feeding methods. The nitrogeneous compounds (ammonia, ammonium compounds, nitrates) and organic matter are contained in the liquid fraction while the solid fraction contains phosphoric compounds

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in inorganic form (74-87 % of the total P) and organic compounds. Based from results of studies, the typical nutrient composition of piggery raw effluent contains 49,500 mg/L TSS, 6.7 pH, 1,800 mg/L ammonium -N, 850 mg/L Total P, 618 mg/L K, 69 mg/L sulfate, 2.43 mg/L copper, and 10.1 dS/m EC (Tucker2015). Aside from nitrogen and phosphorous, elements such as potassium, magnesium, calcium, zinc, copper, manganese, sulfur and sodium are also present in the swine waste of which all of these are essential elements needed by plants (Chastain et al., 2003).

However, swine wastewater which include water used to clean sites, feces and urine and food residue has a negative impact on the environment particularly to the water quality of rivers, lakes and other bodies of water.

There are various conventional methods being practiced for purification and removal of pollutants and contaminants, however, most of them are costly and non-ecofriendly. Because of this, there is a growing concern to develop for a low cost and effective wastewater technologies solution.

Nowadays, industries are looking for sustainable approach for the removal of pollutants present on wastewater which may be considered as green remediation technology. One ancient technology which is still being used today is the use of water hyacinth *(Eichhornia crassipes)*. In the study conducted by Rezania et al. (2015), the plant was found to efficiently treat different types of wastewater of which the pollutant removal efficiency was higher compared to other aquatic plant. In the study conducted by Abat and Ngilangil (2017) on the effectiveness of water hyacinth in the purification of piggery wastewater, water hyacinth gave an observable change in the color and odor and on pH from 7.8 to 8.62 after 30 d of observation in a pot trial. The change in color was determined by comparing the color of the treated wastewater to a distilled water and was assessed following a description such as clear, greenish, greyish, brownish, and yellowish. The odor was determined using an odor descriptor wheel, basing on its macro classification and through professional judgement. There were other experiments made on swine wastewater treatment but no study done on vetiver technology in the region.

There were many applications of the Vetiver system technology found in China, Vietnam, Australia and in other parts of the world as a phytoremediation tool for environmental protection and as a cost-effective solution in the treatment of polluted water and contaminated land (Truong, 2002).

Vetiver grass (*Vetiver zizanioides*) is characterized with stiff and erect stems having deep and penetrating roots. It has been found to be highly tolerant to high level of toxic chemicals and to adverse conditions such as drought, floods and inundation which significantly contribute to environmental protection. According to studies , vetiver grass is effective in removing phosphorous and nitrogen from water (Dela Mora-Orosco et al., 2018), and thus, is a good plant in purifying eutrophic water (Oshunsaya and Aliku, 2017) as well as in the treatment of garbage leachates (Maharjan and Pradhanang, 2017). In the study conducted by Almeida et al. (2019), Vetiver *zizanioides* has a good potential in Nitrate-N and COD removal in subsurface vertical flow constructed wetland systems.

The vetiver grass was first introduced in the Philippines as phytoremediation plant for controlling soil erosion but in the study conducted by Paz-Alberto and Sigua (2013), vetiver was found to have the highest plant survival when exposed to soil contaminated with lead. Because of the increasing concern on heavy metals contamination on soil and in water coupled with the stricter implementation of Republic Act 9275 (Philippine Clean Water Act of 2004), large scale swine industries need to adopt to mitigating measures which would provide treatment steps for the removal of nutrients and/or toxic materials before any disposal. Thus, the perspective of phytoremediation using vetiver in purifying swine wastewater is being studied.

The objective of this study is to determine the effectiveness of Vetiver *(Vetiver zizanioides)* in purifying waste water from pig farm. Specifically, it sought to determine the removal efficiency of the plant on physico-chemical properties of swine wastewater and to determine the growth of the vetiver grass after 5 weeks in pot trial and the vetiver growth after 5 weeks until 9 weeks of transplanting over a bamboo float in field trial.

1.1 Study site

The study site is the Don Mariano Marcos Memorial State University (DMMMSU) Pig Extension and Research Farm (DPERF) which is located at Baroro, Bacnotan, La Union, Philippines. It is one of the largest pig farm in Region I with a hog population ranging from 1,500 to 1,800. The wastewater is channeled through the concrete canal alongside the pig house and directed to the biogas digester for anerobic digestion which is proven to be effective technology for converting organic waste to energy (Bong et al., 2018). Since the operation of the pig farm was supplemented by biogas digester, the volume of the wastewater going to the earth ponds is reduced. According to Winquist et al. (2019), biogas plant on the farm can improve manure management and has also the potential to mitigate climate change and eutrophication. The earth ponds consist of the primary, secondary, tertiary and polishing / maturation pond and its role is to stabilize the organic material through natural processes with the aid of sunlight, water nutrients, atmospheric oxygen, algae and bacterial action. The facultative pond usually provides a storage area where anaerobic and facultative bacteria slowly stabilize the organic material before discharge to the environment. Since, DPERF is an experimental farm, swine wastewater has been a subject of extensive studies by faculty and student researchers of the University. The parameters usually being submitted to the Department of Environment and Natural Resources- Environmental Management Bureau (DENR-EMB) for monitoring include pH, nitrate, total suspended solids, phosphorous, biochemical oxygen demand, total coliform and E.coli. Previous results of the laboratory analysis of the pig effluents showed high amount of organic substances of which some parameters failed to meet the effluent standard of Class B waters. Based from DAO 2016-08 (DENR, 2016), Class B water is classified as recreational water used for swimming, bathing and others.

2. Methods and procedures

2.1 Pot Trial Experiment

The vetiver grasses were gathered from an adjacent farm near DPERF. The wastewater used was collected from the earth ponds and was placed in three plastic drums with a capacity of about 10 L for about ¾ full. Vetiver grasses of the same health and weight were planted in an improvised floater, the shoots and roots were pruned to 20 cm and 10 cm. Six bundles of vetiver grass were distributed in each drum and cultivated for about 5 weeks. The growth of the vetiver was observed and after 5 weeks, samples of the wastewater from each pot were taken and composite samples were sent for laboratory analysis in terms of nitrate, phosphorous, total suspended solids and biochemical oxygen demand.

2.2 Laboratory analysis

The samples were placed in a clean plastic bottles with caps, sealed, properly labelled and submitted to an accredited laboratory in the region for examination. Following the Standard Methods for the Examination of Water and Wastewater (APHA, 2012), Nitrate was analysed using the ultraviolet spectrophotometric screening method while Phosphorous was determined using Vanadomolybdophosphoric acid colorimetric method. Total suspended solids (TSS) was analysed using the gravimetric method.

2.3 Removal efficiency

Effectiveness of the vetiver grass in purifying wastewater is determined by its removal efficiency. The removal efficiency was calculated using the formula (de la Luz-Pedro et al., 2019)

$$\%\ \text{Removal Efficiency} = \frac{C_0 - C_t}{C_0} \times 100\% \quad (1)$$

where C_0 is the initial concentration of parameter, C_t is the final concentration of parameter at time t.

2.4 The field trial experiment

Five bamboo floats with a length of 150 cm and width of 100 cm were constructed and positioned in the facultative pond of the earth ponds. On the 20 holes dug on each raft, equal weights of vetiver grass were placed for each hole. The shoots and roots of the grass were again pruned to 20 cm and 10 cm. The cultivation was done in 5 weeks until 9 weeks. The growth of the vetiver grass was observed in terms of the length of the roots and height of the shoots.

3. Results and discussion

3.1 Removal Efficiency of the Vetiver Grass after 5 weeks of Cultivation

Table 1 shows the removal efficiency of the vetiver grass after 5 weeks of cultivation in pot trial experiment. The BOD before treatment showed high concentration of 666 mg/L but was reduced to 21 mg/L after treatment with vetiver grass. There was also a very high reduction observed on the nitrate concentration from 21.8 mg/L to 0.76 mg/L. In terms of phosphorous, the laboratory results showed more than half reduction from 105 mg/L to 46.28 mg/L. The amount of total suspended solids was decreased from 28.3 mg/L to 9.9 mg/L. The decrease could also be attributed to the process of sedimentation, since the solids was observed to settle down at the bottom of the plastic drum. Thus, as the vetiver grass adapts to its environment and it continues to grow, the roots of the plant absorbs nutrients from the wastewater and converts these organic into inorganic substances making the wastewater cleaner after 5 weeks.

From the results, it could be gleaned that the vetiver grass gave the highest removal efficiency on biochemical oxygen demand (96.85 %) followed closely by nitrate (96.51 %), total suspended solids (65.01 %) while for phosphorous, the removal efficiency was 55.92 %. The higher removal of BOD showed the beneficial effect of the vetiver. Biochemical oxygen demand is the amount of oxygen needed to oxidize organic matter in the water to carbon dioxide and used as an indicator on the strength of pollution.

Table 1: Removal Efficiency of the Vetiver Grass on Swine wastewater after 5 weeks of cultivation

Parameter	Before Treatment	After 5 weeks	Removal Efficiency (%)
pH	7.6	7.52	-
Nitrate, mg/L	21.8	0.76	96.51
Phosphorous,mg/L	105.0	46.28	55.92
Total Suspended Solids, mg/l	28.3	9.9	65.01
Biochemical Oxygen Demand, mg/L	666.0	21.0	96.85

Source: Department of Science and Technology Regional Standards and Testing Laboratory

This study confirmed the study conducted by Maharjan and Pradhanang (2017) in Nepal where the vetiver plants were found very effective in treating polluted water with very high nitrate and phosphate levels.
Likewise, the study made by Boonsong and Chansiri (2008) in Chulalongkorn University community showed that vetiver can reduce around 61.01-62.48 % of nitrogen and 17.78-35.87 % of phosphorous. Nitrate and phosphorous may have served as nutrients for the aerobic bacteria to break down contaminants into smaller pieces. The microorganisms in the roots supply oxygen essential for vetiver's growth through the process of photosynthesis. As the microorganisms consume the organic mass of the wastewater and utilize the nutrients for their growth, the cleaning action of the wastewater is enhanced as observed in the reduction of the biochemical oxygen demand concentration. This means that the reduced nutrients were absorbed by the roots of the plants for their growth. The decrease of the total suspended solid from 380 mg/L to 70 mg/L was also attributed to the vetiver root system. In a pilot test conducted by Li et al. (2018), using hydroponics and immobilized biofilm treatment for water quality control, results showed that the removal efficiency of media-filled beds (MFD) on total ammonia nitrogen (TAN) is higher (71.4%) compared to that of nutrient film technique (NFT) with only 43.5 %. The immobilized biofilm units reflected a higher percentage (71.8%) and 15.7 % for TAN in MBS and FB. This result proved that aquatic plants in media-filled beds perform better, however, more total ammonia is removed using immobilized biofilm units.

3.2 Vetiver growth in pot experiment

Figures 1a and 1b show the growth of the vetiver grass in the pot experiment after 5 weeks. It could be gleaned from the figures that vetiver can grow well in an adverse environment. The average height of the shoots and length of roots at the start of the experiment were 20 cm and 10 cm. After 5 weeks, the shoots were increased to an average of 33.5 cm while the roots were increased to about 36.83 cm. The root systems of the vetiver were responsible for the removal of the pollutants as was reported in the study of Yeboah, et.al, (2015) on three selected food and beverages industries in Ghana. According to Truong (2002), the more roots the vetiver, the stronger the absorbability to pollutants.

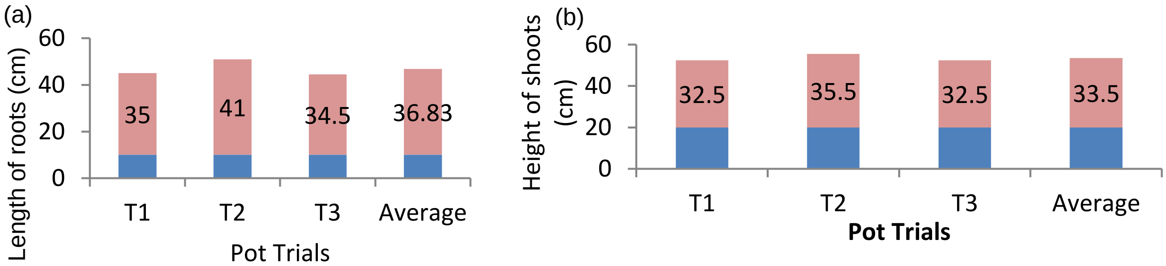

Figure 1: (a) Length of roots (b) Height of shoots fter 5 weeks

3.3 Growth of Vetiver in Field Trial

Table 2 showed the growth of vetiver in field trial after 5 weeks until 9 weeks of cultivation. As gleaned from the table, the height of shoot of the vetiver after 5 weeks increased to an increment height of 13.50 cm while the length of the roots was measured to about 9.9 cm increased in length. However, after 9 weeks, there was a difference of 32.5 cm from its height after 5 weeks. The length of the roots gave also a difference of 45.6 cm increase. This implies that the vetiver grass has a high ability to absorb nutrients and organic substances during its growth stage.

Table 2: Growth of Vetiver after 5 weeks until 9 weeks of cultivation

Parameter	Initial	After 5 weeks	Difference	After 9 weeks	Difference
Height of shoot (cm)	20	33.50	13.50	65.80	32.3
Length of root (cm)	10	19.90	9.90	65.50	45.6

As the plants continue to grow and when they reached 9 weeks, it was observed that the shoots of the plant especially at the tip became thinner and getting older. The results confirmed the report of Sakranukit (2006) that a 8-week-old vetiver grass has a better treatment quality than the 16-week-old one because, at 16 weeks, the grass starts flowering and stop growing.
Figure 2 shows the comparison of growth of the vetiver after 5 weeks and after 9 weeks in the five bamboo floaters. From the figure, during the 5 week-period, vetiver grass planted in bamboo float 3 (BF3) and bamboo float 5 (BF5) gave the highest height increment. BF4 gave the lowest increment in terms of height. Similar trend was observed on the length of roots. BF3 gave the highest root length followed by BF1 and least was BF5.

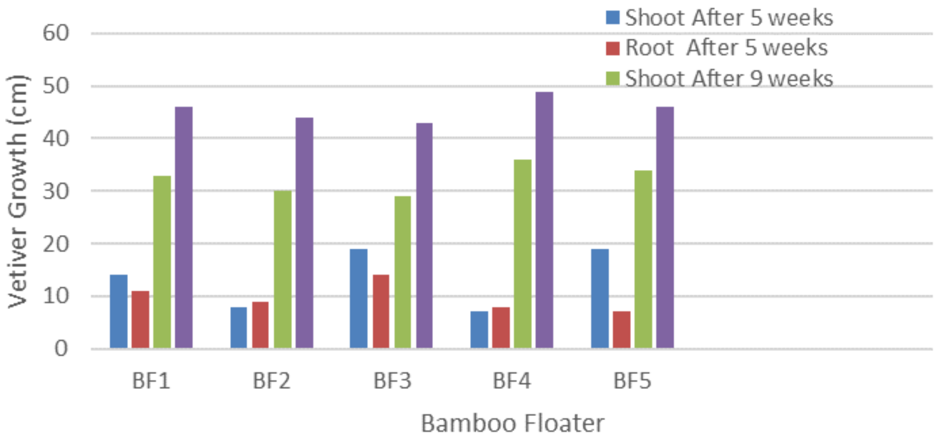

Figure 2: Comparison on the height of shoots and length of roots of vetiver after 5 weeks and after 9 weeks.

After 9 weeks, BF5 gave the highest increment but not far from BF3. The root length was observed to be better in BF4 followed by BF5 and BF1 while BF3 gave the lowest. The position of the bamboo float in the facultative pond did not influence the growth of vetiver in terms of height of the shoots and length of roots.

4. **Conclusions**

In this study, vetiver grass *(Vetiver zizanioides*) is effective in purifying wastewater from pig farm. There is high removal efficiency in nitrate and in biochemical oxygen demand but only moderate in phosphorous, and total suspended solids. The vetiver grass was observed to grow well in swine wastewater with the root system increasing in number and in length and was responsible for the absorption of the pollutants making the wastewater cleaner and safer to the environment.

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