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Treatment of High Strength Industrial Wastewater utilizing *Canna X generalis* in a Simulated Vertical Flow Constructed Wetland Set-up

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Abstract
In the Philippines, DENR has mandated the regulation of oil and grease, COD, and TSS for automotive parts manufacturers. Wastewaters from industries have varying pollution strength that requires efficient treatment systems of combined physical, biological, and chemical processes. However, these methods tend to be labor intensive and costly. Constructed wetlands have become a popular treatment method for industrial wastewater because of its simplicity requiring less technical expertise compared to other technologies. In this study, four vertical subsurface flow constructed wetlands composed of cylindrical drums with diameter of 30 cm and height of 90 cm were designed to treat industrial wastewater in parallel experiments. The four constructed wetland units had various set-ups (with & without Canna X Generalis, with & without zeolite, with & without air vent) to determine the effect of the treatment efficiency. Water quality samples were collected from each unit, and were analyzed for pH, ORP, TSS, COD, aluminum, oil and grease. The findings show that the constructed wetland with zeolite and air vents demonstrated higher removal efficiency in comparison to a constructed wetlands without these features. The removal efficiencies registered 93.35% and 90.67% for COD and TSS, respectively.
Keywords: wastewater treatment, wetland, automotive wastewater, *Canna X generalis*, natural systems

1. Introduction

Rapid urbanization gave rise to an increase in industrial wastewaters, where one of the major contributors is the automobile industry. This caused the Department of Environment and Natural Resources (DENR) in the Philippines to mandate environmental regulations for automotive parts wastewater effluents. Car components are made through the aluminum die casting process and the wastewater from this process, known as mold release agent (MRA), are characterized by oil and grease, high COD, high total suspended solids (TSS), and the presence of aluminum (Hongyu, et al., 2017). Industrial wastewater treatment technologies, however, have been noted to be labor-intensive, expensive and space-consuming (Guo, et al., 2014). With the increase in research on constructed wetlands (CW) for industrial wastewater treatment (Vymazal, 2014), CWs can be an efficient and economical solution to the problem in the Philippines. CWs are mechanically simple systems known to have good efficiency in the removal of suspended solids, heavy metals, and BOD. CWs are more effective with the presence of a macrophyte for phytoremediation; and *Canna X generalis* is one of the wetland species found to perform better in warmer climates (Yan and Xu, 2014). For a compact design, the vertical subsurface flow design can be used, where wastewater is fed at the top (Stefanakis and Tsihrintzis, 2014). Due to this, the research aims to assess the effectiveness of a simulated vertical subsurface flow constructed wetlands system with planted *Canna X generalis* in the treatment of MRA with the use of zeolite as substrate matrix in the presence of artificial aeration.

2. Methodology

Four set-ups with different conditions were created where each set-up was made of a cylindrical plastic drum (D = 30cm, H= 90cm) with a porous layer as depicted in Figure 1. All set-ups except CW#2 had perforated PVC pipes (D = 50mm) in the drainage layer as air vents; all except CW#4 contained a zeolite porous layer; and, all except CW#3 were manually planted with *Canna X generalis* at a depth of 20 cm, noting the plantlets were allowed to grow for one month first. All set-ups were soaked with 50L of tap water for 24h prior to experiments. Raw MRA wastewater was collected from an industrial plant in the Philippines and effluents were collected and analyzed in duplicates daily for 7 days. All water samples were analyzed with COD, TSS, pH, ORP, oil and grease, and aluminum content. Analysis of the results were conducted through the removal efficiencies according to the equation:

$$Removal\ (\%) = \frac{C_{influent} - C_{effluent}}{C_{influent}} x100\%$$

3. Results and Conclusion

Based on the removal efficiencies (in Figure 3 and 4), it can be observed that the efficiencies gradually increase as the hydraulic retention time (HRT) increases, except for an abrupt decrease from the TSS removal efficiency, which indicates the occurrence of a drawback possibly due to the increase in nitrate content caused by aeration and ventilation (Zheng et al., 2016).

The use of zeolite was able to improve the quality of CW#4 to CW#1 in removal of COD from 60.93% to 93.35%, TSS from 84.90% to 90.67%, 7-day removal of oil and grease from 33.95% to 97.99%, and aluminum from 52.58% to 73.20%. This supports the characteristic of zeolite of removing organic and suspended (Stefanakis and Tsihrintzis, 2014) constituents through adsorption.

Additionally, the presence of ventilation tubes improved the removal efficiency of COD in CW#2 to CW#1 from 86.55% to 93.35%, TSS from 84.46% to 90.67%, and aluminum from 65.98% to 73.19%, with no significant effect on oil and grease removal. Then the use of *Canna X generalis* increased the removal efficiency of COD in CW#3 to CW#1 from 84.3% to 93.4%, TSS removal efficiency from 86.46% to 90.67%, and significant improvements in aluminum and oil and grease removal efficiencies. Values for pH were in the neutral range of 6.39 to 7.96 and ORP from 369 to 454 mV indicating the presence of a healthy oxidative environment.

The research showed that the vertical subsurface flow constructed wetland system with the set-up using zeolite, *Canna X generalis* and artificial aeration via air vents, is a simple and efficient treatment for high industrial wastewater (automotive MRA) due to significant removal efficiencies of TSS, COD, aluminum, and oil and grease coupled with a healthy oxidative environment.

SIMULATED VERTICAL SUBSURFACE FLOW CONSTRUCTED

Content	CW#1	CW#2	CW#3	CW#4
Canna X Generalis	+	+	-	+
Ventilation tube	+	-	+	+
Zeolite	+	+	+	-
Gravel	+	+	+	+
Sand	+	+	+	+
Cobblestone	+	+	+	+

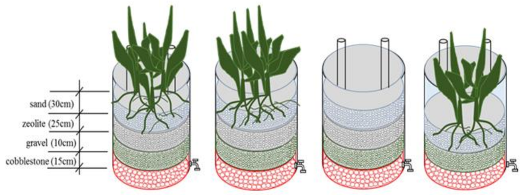

Figure 1. Design conditions for the setups

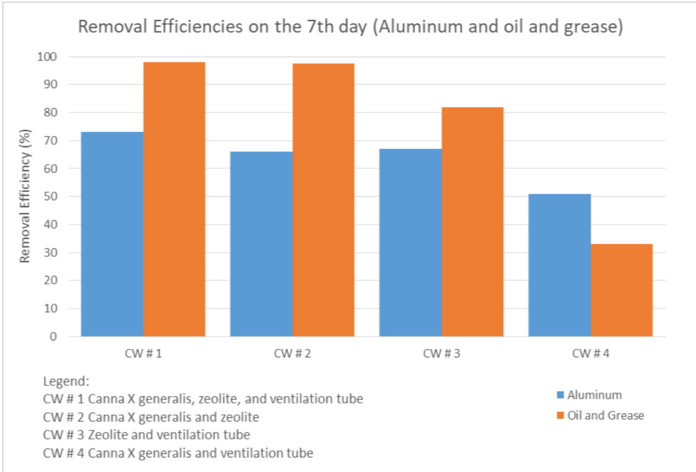

Figure 2. Removal efficiencies for aluminum and oil and grease

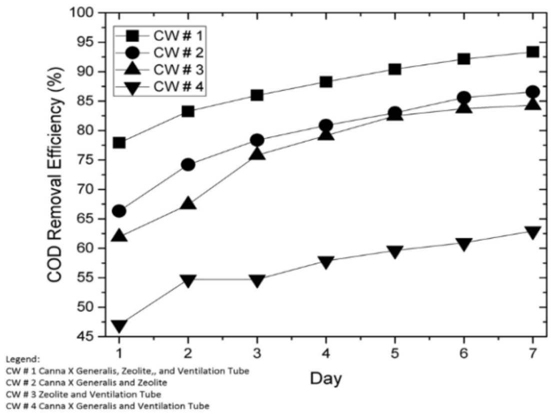

Figure 3. Removal efficiency for COD.

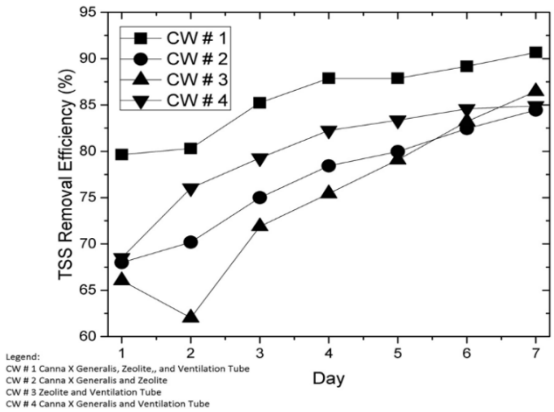

Figure 4. Removal efficiencies for TSS.

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