# *FLOATING PLASTIC MEDIA FOR REMOVAL OF ORGANIC POLLUTANTS IN AGRICULTURAL DRAINAGE WATER*

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## ABSTRACT

Agricultural drainage water (ADW) may be considered as a strategic reserve to cope with the ever-increasing demand for water resources. However, the cost required for treating ADW harnesses its wider reuse. Thus, the current ambition is to continue developing cost-effective technologies and enable the best use of this secondary sustainable resource. This research presents a low-cost suspended carrier biofilm system for in-situ treatment of ADW to reuse it in irrigation purposes. To this end, a series of lab scale experiments was conducted to check the efficiency and the applicability of the floating plastic media (FPM) for this purpose. Additionally, we checked the differences between the fresh media and the incubated media with biofilm. The system essentially comprises two reactors with aeration, which was filled with the same volume of FPM. In the experiment, dissolved organic carbon (DOC), nitrogen oxides (NOx), total nitrogen (TN), phosphorus (PO4) and total phosphorus (TP) were measured. The results showed rapid reduction in organic pollutant concentration up to 38.7% in the first 35 min before it gradually increased to more than 51.5% at the end of the process. Further, TN, PO4 and TP removal rates were 35%, 39.8% and 27.1%, respectively. The results indicated promising features and revealed the preliminary technical feasibility of the proposed treatment system.

**Keywords:** Agricultural drainage water, In-situ, Biological treatment, Floating plastic media, Aeration

## 1 INTRODUCTION

Water shortage problems raise a need to explore all viable options to conserve current water resources and explore alternatives. The availability of ample quantities of agricultural drainage water (ADW) creates considerable opportunities for recovering significant quantities of water from this water source. However, this unconventional water source is commonly polluted by effluents from industrial and domestic wastewater in the developing countries. Therefore, the treatment and reutilization of ADW is a major concern in developing countries having a limited fresh water resource (Ahmed et al., 2003; Sorour et al., 2003; Talaat et al., 2002; Talaat et al., 2007).

Practically, biofilm processes, such as aerated bio-filter biological fluidized bed, suspended carrier biofilm reactors (SCBR), etc., are commonly used in surface water remediation. Immobilization of biomass in the form of biofilms is an efficient method to retain slow growing microorganisms in continuous flow reactors. These systems operated as aerobic or anaerobic phases with freely moving buoyant plastic biofilm carriers (Wang et al., 2005). Moreover, biofilm carriers made out of different materials and designs have been developed (McQuarrie and Boltz, 2011) and are commercially accessible.

Among them, floating plastic media has the advantages of being simple in operation, at low risk of losing the biomass and less temperature dependent (Lazarova et al., 1996). Furthermore, attached growth systems are generally considered less sensitive to toxic influent and variations in environmental conditions (Welander et al., 1997). One drawback of a fixed-bed biofilm reactor is that the pores among media are easy to clog because of biofilm growth. Clogging can create excess head loss, short circuiting and increase the backwashing frequency. Solving the clogging problem involves many kinds of suspended carrier biofilm reactors, such as circulated or moving bed biofilm reactors, which have been developed in recent years (Wang et al., 2005, Calderón et al., 2012).

On the other hand, previous researches related to surface water remediation using plastic media focused on the ex-situ treatment applications. Meanwhile, there are no previous studies conducted with plastic floating media either for ADW treatment or for in-situ treatment applications. Therefore, the objective of the study is to investigate the treatment efficiency of a packed-bed reactor using plastic media in bench-scale experiments as a preliminary step for building an effective option for in-situ ADW treatment.

## 2 MATERIALS AND METHODS

### *2.1 Agricultural Drainage Water (ADW)*

Synthetic wastewater was prepared to simulate a medium-strength ADW with C:N:P ratio of 38.7:7.9:1. Table 1 show the composition and the main characteristics of the ADW used in this experiment.

**Table 1. The composition and the main characteristics of the ADW**

| Component | Concentration (mg/l) | Parameter | Concentration (mg/l) |
|---|---|---|---|
| **D(+)-Glucose** | 167 | **BOD** | 130 |
| **Polypepton** | 83 | **TOC** | 75.5 |
| **Sodium acetate** | 58 | **TN** | 17.9 |
| **Ammonium sulfate** | 56 | **NH4** | 11.9 |
| **Potassium dihydrogen phosphate** | 22 | **ON** | 6.1 |
| **Sodium carbonate** | 83 | **TP** | 5 |
| **Sodium chloride** | 56 | | |
| **Potassium chloride** | 8.4 | | |
| **Calcium chloride dehydrate** | 28 | | |
| **Magnesium chloride hexahydrate** | 34 | | |
| **Iron chloride tetrahydrate** | 1.4 | | |

### *2.2 Experimental setup and operational conditions*

Two bench-scale systems (C0 and C1) comprise of a glass box with a total volume of 6.4 L (20x20x16 cm) were used with aeration from external air pump for each box (Figure 1). Commercial floating plastic media was purchased from MIYATA KOGYOSHO Co.ltd, Japan. The media is cylindrical shape with dimensions of (15x15ϕ) mm, relative density of 0.94 and specific surface area

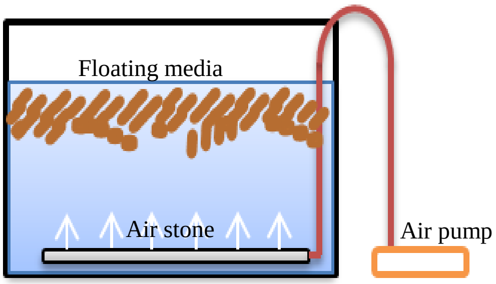


**Figure 1. Layout of the system used in the experiment**

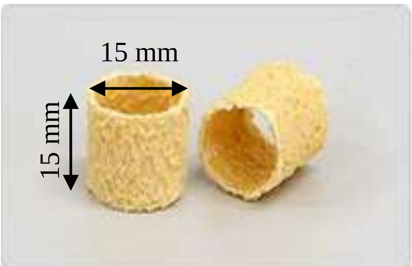


**Figure 2. Floating plastic media used in the experiment**

of 960 $m^2/m^3$ (Figure 2). The actual volume of plastic media amounted to 0.4 L, representing 10% (V/V) of the water volume (4 L). This media were incubated in continues aerated river water from Tama river, Japan with adding nutrients (Glucose, Potassium dihydrogen phosphate, Ammonium sulfate).

For the first system (C0), we added fresh media without incubation. Meanwhile, media incubated for 10 days were added to the second system (C1). For both systems, operational temperature was controlled at 24 ± 1.5 $^oC$ and pH values were 7 ± 0.4.

### *2.3 Sampling and analytical methods*

Samples from each system were collected after every 5 min for the first hour, every 10 min for the second hour and every 20 min for the third hour. All samples were filtered using 0.45 µm membrane filter and they were analyzed according to standard methods (APHA, 2005) for the following parameters: pH, dissolved organic carbon (DOC), nitrite nitrogen ($NO_2$-N), nitrate nitrogen ($NO_3$-N), total nitrogen (TN), phosphate ($PO_4$) and total phosphorus (TP).

## 3 RESULTS AND DISCUSSION

To describe the type of reaction by which the DOC was removed in the system, the first and second reaction rate equations were applied. From the results, the estimated data from the second order reaction rate showed the best fit with the observed data with correlation coefficient (R2) of 0.912 and rate constant of 0.3 L/mg.day. Therefore, the second order reaction equation shown as below could be used to express the removal of DOC in the system.

$$\frac{d[A]}{dt} = -k[A]^2 \qquad (1)$$

Where [A] (mg/L) is the pollutant concentration, k (L/mg.day) is the second order reaction rate constant of pollutant and t (day) is the reaction time.

Figure 3 shows the DOC concentrations for C0 and C1, and the DOC removal rate from C1. The DOC removal rate ranged between 5.14% and 51.78%. Moreover, the results showed rapid removal rate during the first 35 minutes which reached 41.3%. On the other hand, the DOC concentration increased for C0 rapidly before it remains around a constant value. This could be caused by a release of carbon source from pores of the plastic media. The comparison between the results from both systems indicates the major roles played by the bacteria for degrading the organic carbon form the system.

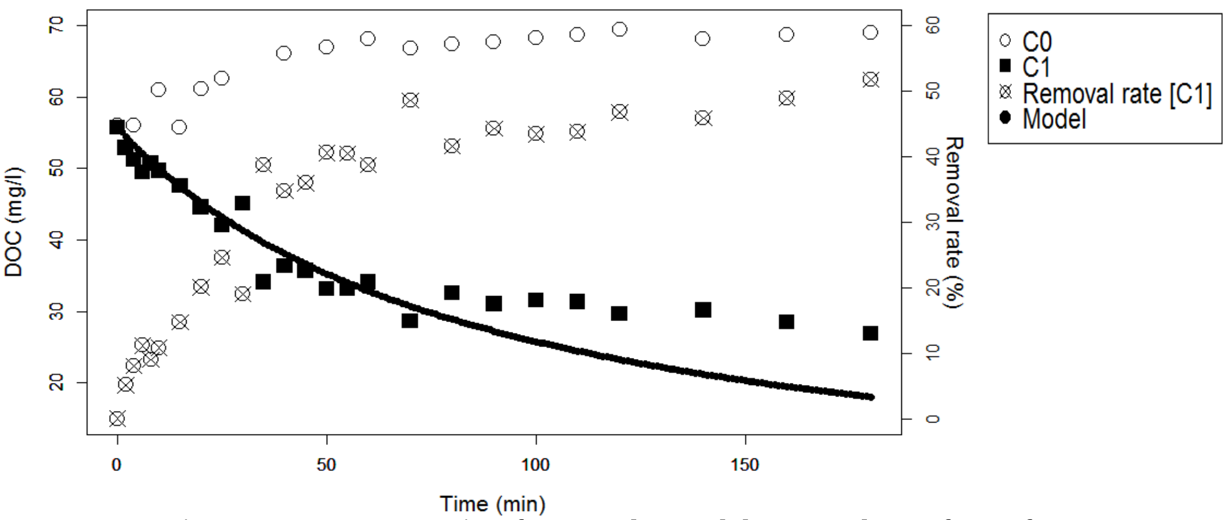


**Figure 3. DOC concentrations for C0 and C1 and the removal rate of DOC for C1**

Figures 4-6 illustrate the reduction of nitrogen and phosphorus concentrations in the system up to 35%, 39.8% and 27.1% for TN, PO4 and TP, respectively. Additionally, Table 2 shows the statistical results for testing the slope of regression line of TN, $PO_4$, and TP. Moreover, the final C:N:P ratio was calculated and it showed reduction from 38.7:7.9:1 to 22:5.5:1. The three elements (C, N and P) are

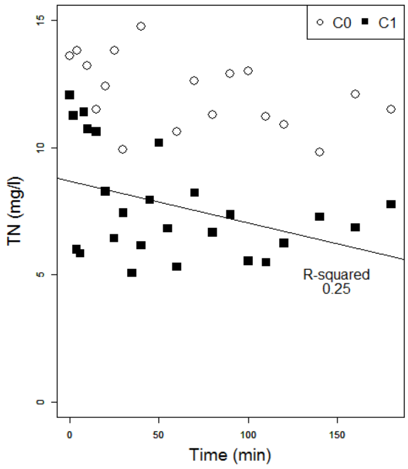


**Figure 4. Relationship between the reaction time and TN concentrations for C0 and C1**

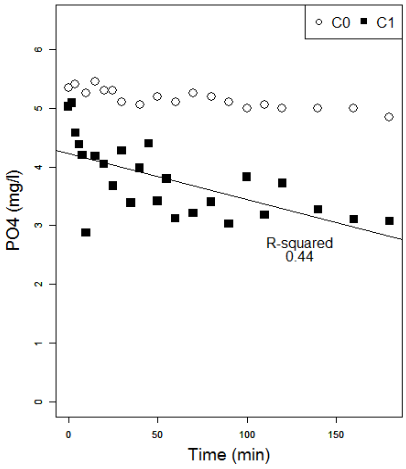


**Figure 5. Relationship between the reaction time and $PO_4$ concentrations for C0 and C1**

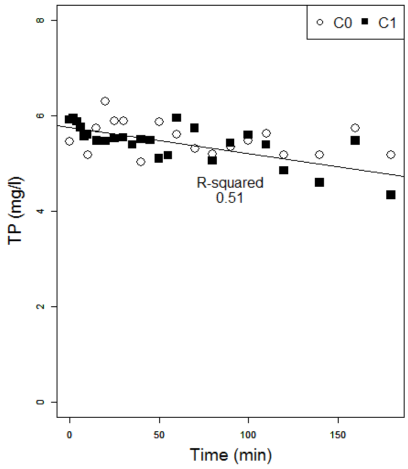


**Figure 6. Relationship between the reaction time and TP concentrations for C0 and C1**

needed in large amounts for microbial growth. Therefore, more studies related to the function and structures of microorganisms are highly recommended.

**Table 2. Statistical results for test of the regression line slope (* p<0.01, ** p<0.001).**

| Parameter | slope | Intercept | $R^2$ |
|---|---|---|---|
| **TN** | -0.041 * | 8.61 | 0.25 |
| **PO4** | -0.009 ** | 4.31 | 0.44 |
| **TP** | -0.005 ** | 5.82 | 0.51 |

## CONCLUSIONS

Agricultural drainage water (ADW) as unconventional water sources is threatened by pollution from industrial and domestic wastewater in the developing countries, whereas there are no researches related the application of in-situ bioremediation for it. As the ADW can flow through the in-situ system by gravity, no external power for pumping will be consumed in the whole treatment process. Therefore, this research aims for developing a low-cost in-situ treatment system for ADW. To this end, we tested the applicability of using floating plastic media for treating this medium-strength ADW. From the results, advantages from using this plastic floating media and the suspended carrier biofilm concept could be summarized as follows:

1. It showed rapid organic removal in a relatively short time which makes it a good option for the in-situ treatment applications.
2. It will reduce the reaction time up to 20-25% of the equivalent gravel based systems with the same removal rate.

However, the reduction in the nitrogen and phosphorus concentration was low (20-35%) comparing to the organic removal (51.5%).

No previous studies were conducted with this type of media either for ADW treatment or for in-situ applications. Thereby, as a next step, testing the system under continuous flow conditions with deeper researches related to the bacterial species and system design are recommended for better understanding of the treatment process.

## ACKNOWLEDGMENTS

The authors are extremely grateful to JSPS Core-to-Core Program, B. Asia-Africa Science Platforms for supporting this research.

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