Comparison of Biological Wastewater Treatment Ability of Filter Media Made From Biomass Ash

Tahmina Sultana, Penjit Srinophakun, Umaporn Sanewirush and Pakamard Saewong

***Abstract*—** Sustainable wastewater treatment is getting more attention worldwide. Researchers have been looking for cost effective and environment friendly technologies at the same time. For fish wastewater, nitrogen discharge limit is very high because of the regular fish-food leftover and wastes from fish. In this study, different types of biological filter media were used to host and grow nitrifying bacteria. The media made from biomass ash and coal bottom ash were tested in laboratory water treatment units in comparison with commercial media in terms of nitrogen compound removal. Under a given test condition of water temperature ranging from 26^0C to 28^0C and DO >4.00 mg L^{-1}, the media made from biomass ash showed superior removal of nitrogen compounds and the toxic nitrogen wastes were removed within 16 days. In addition, scanning electron microscopic examination revealed that microstructural features of these media were suitable for growth of nitrobacteria, leading to improving nitrification performance.

***Keywords*—** Biological treatment, Aerobic biological filter, Coal bottom ash, Porous pellets.

I. Introduction

Pollution related problems have become more attentive worldwide. Fish wastewater is an imperative source of water pollution. Normally it consists of oil and grease, salt and ammonia [1]. Biological treatment for removal of nitrogen waste is mainly focused among different treatment processes. Filter media are essential for this process, providing high surface area for bacteria to grow sufficiently for the reduction of toxic nitrogen compounds [2]. With the presence of functional micro organism, ammonia discharged to the system will be converted to nitrite (NO_2^-) and finally nitrate ion (NO_3^-). This is called nitrification process [3]. The basic chemical conversions occurring this process by Nitrosomonas and Nitrobacter are expressed by,

$$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

$$NO_2- + 0.5O_2 \rightarrow NO_3^-$$

At very low oxygen concentration, some species of functional bacteria utilize the oxygen in nitrate and convert it to nitrogen gas (N_2). This process is called denitrification. Compared with the regular biological nitrogen removal (nitrification- denitrification) process, biological filtration process is an energy-efficient and sustainable wastewater treatment technology [4].

Pumice as well as porous materials from nature, are being used widely and available in the market. In this study, pellets prepared from rice husk ash (RHA) and coal bottom ash (CBA) are introduced as alternatives of those conventional media. These porous media are characterized and compared their effectiveness on nitrogen compound removal with the commercially available pumice.

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II. Experimental Procedure

A. Media Preparation

The research was conducted at the Pilot plant of National Metal and Materials Technology Center (MTEC), NSTDA, Thailand. RHA and CBA media were prepared from RHA and CBA by mixing a ready mix ash precursors with water, shaping and firing at around 1100^0C for 1hour [5] while pumice was purchased from the market, crushed and size selected to 4-12mm.

B. Testing Unit Setup

To prepare a recirculation water flow system, a 2 and 27 liter plastic boxes were used as a media container and a water tank, respectively. The water was circulated by a pump, which was fixed at the bottom of the water tank, to the media container and returned to the tank via PVC pipes (Fig. 1). 4 different sets were prepared for this study: 1) with RHA, 2) CBA 3) pumice and 4) without media. Each set had 4 duplicates. Every water tank of each duplicate was filled with 20 liters of water and the set with media was added with 1 liter of media.

C. Material Characterization

Density of the media was measured by Achimedes' method. While for the micro-structural observation, the samples were gold coated and examined in a scanning electron microscope (SEM). Surface area of each media was estimated by measuring the pore size at the surface of the media and using spherical equivalent method.

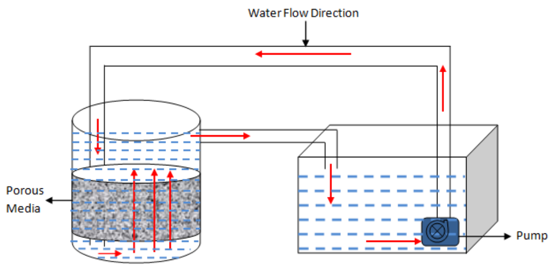


Fig. 1 Testing unit setup

D. Water Treatment Testing

15 grams of fish food was added in each tank for all experiment sets and the concentrations of total ammonia (NH_3/NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-) were regularly measured using test kit and pH, DO and temperature were monitored by portable devices.

III. Results And Discussion

A. Media Properties

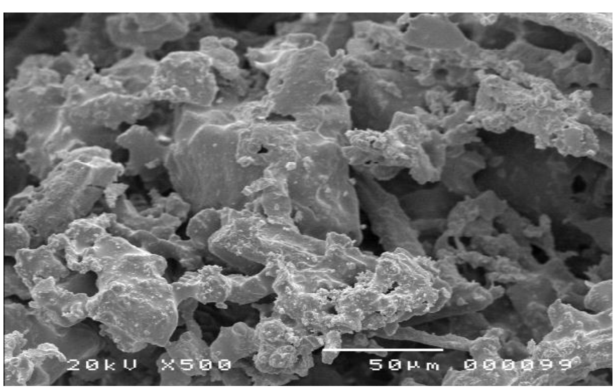
The densities and surface area are given in table I, surface area of RHA is greater than others, while those of CBA and pumice are of the same range.

TABLE I
Media Properties

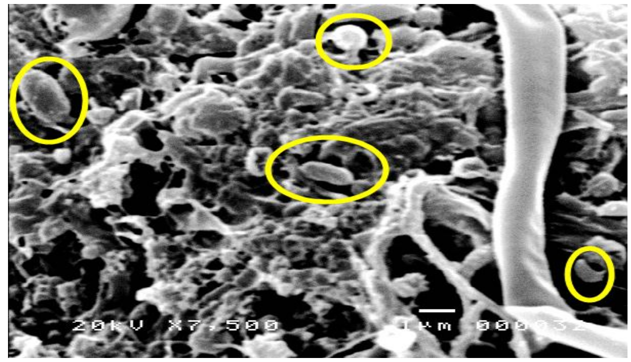
Bio filtering media	Packing Density (Kg/L)	Bulk Density(g/cm^3)	Surface area(m^2/L)
RHA	0.57	0.89	32.7
CBA	0.51	1.09	17.2
Pumice	0.31	0.69	15.7

B. Microstructure of the Media

Fig. 2 – 4 show microstructures of the RHA, CBA and pumice, respectively before and after treatment. It is evident that microorganisms are found intensively across the observed surface of all media after treatment.

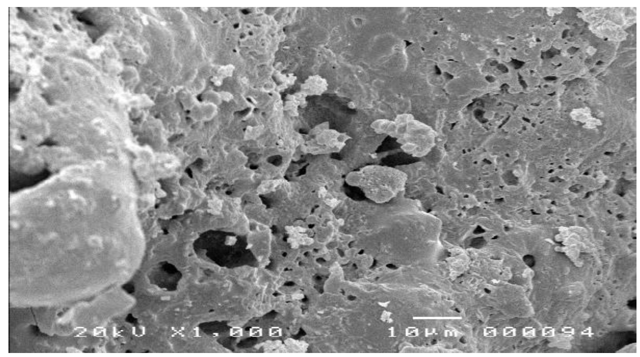


(a)

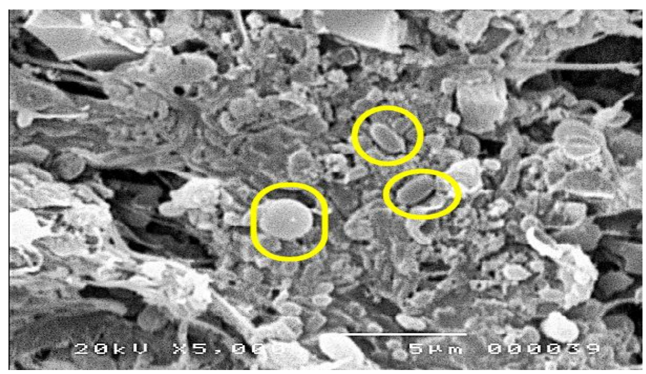


(b)

Fig. 2 RHA surface (a) before (b) after the treatment. Circles indicate the presence of the functional microorganisms.

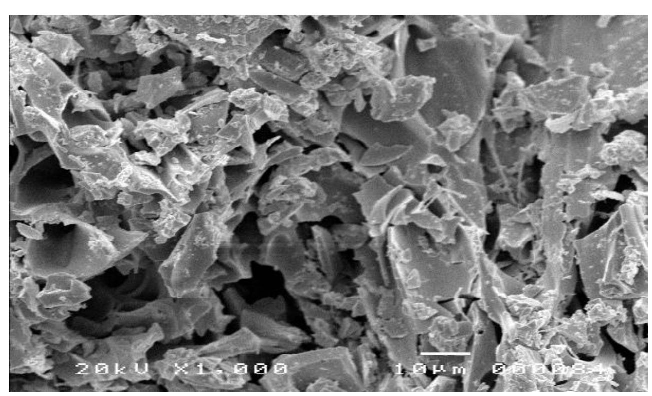


(a)



(b)

Fig. 3 CBA surface (a) before (b) after the treatment. Circles indicate the presence of the functional microorganisms.



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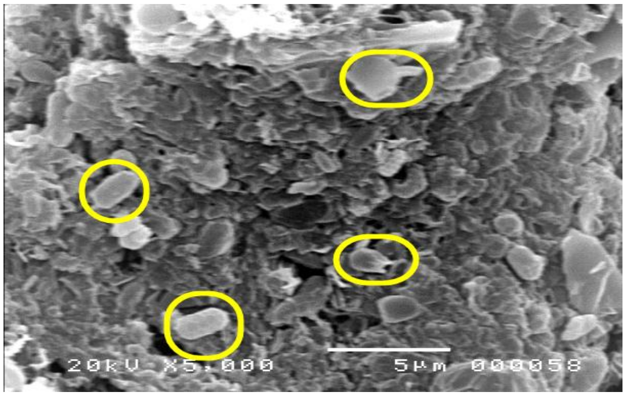

(b)

Fig. 4 Pumice surface (a) before (b) after the treatment. Circles indicate the presence of the functional microorganisms.

C. Water Quality

It was found that pH, DO levels and temperature for all sets varied from 7 to 8.2, 8.17 to 8.42 and 27^0C to 30^0C respectively, which is in suitable ranges for nitrification process to take place [3].

Average concentrations of total ammonia, nitrite and nitrate of water are given in Figs 5, 6 and 7, respectively. All sets show increasing levels of total ammonia, NO_2^- and NO_3^- with time to the maximum values. When nitrification process commences, with the presence of microorganisms, the concentrations of toxic nitrogen compounds reduce to minimum values. So nitromonas bacteria can convert ammonia to nitrite and nitrobacteria can convert nitrite to nitrate in nitrification process. Autotrophic denitrification and anaerobic ammonium oxidation process helps nitrate to convert to gaseous nitrogen compound including denitrogen [6]. From the micrographs after the treatment, not only the expected functional bar shaped cells, but also various types of microorganisms are found. Species identification will be carried out further if those play a role in the treatment process.

From these results it is clear that the RHA and CBA show a comparable treatment performance to the pumice. Nitrification process occurs in the set without media also, but it takes 7 days longer than those with the media.

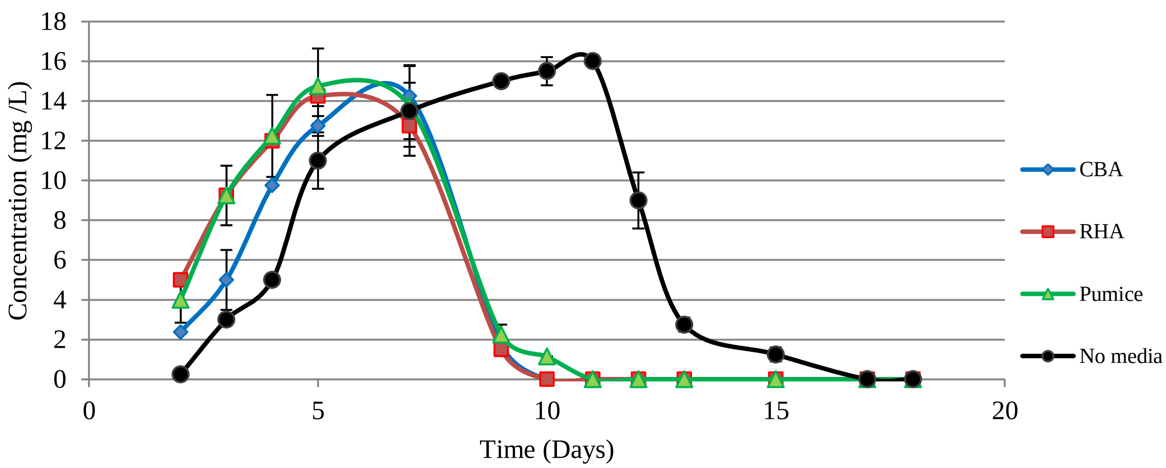

Fig. 4 Change of total ammonia concentration with time for all sets.

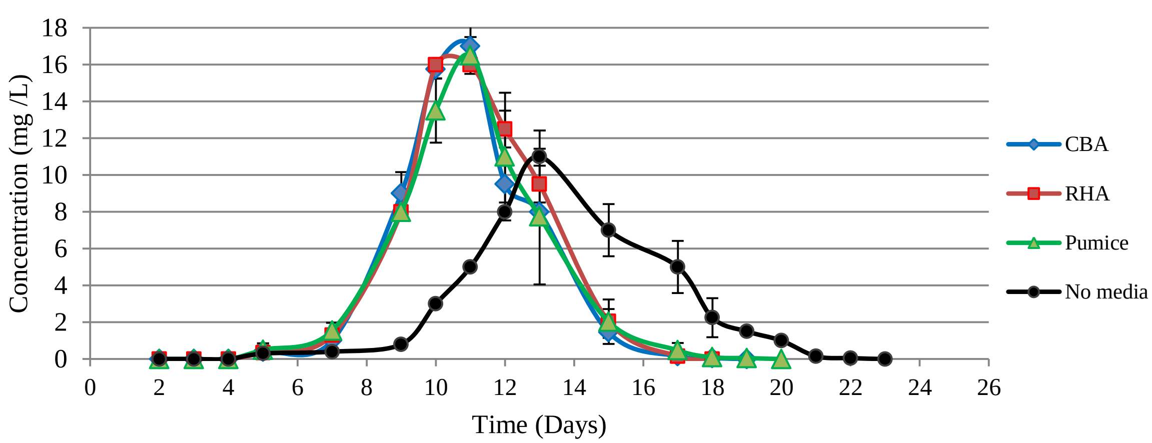

Fig. 5 Change of nitrite concentration with time for all sets.

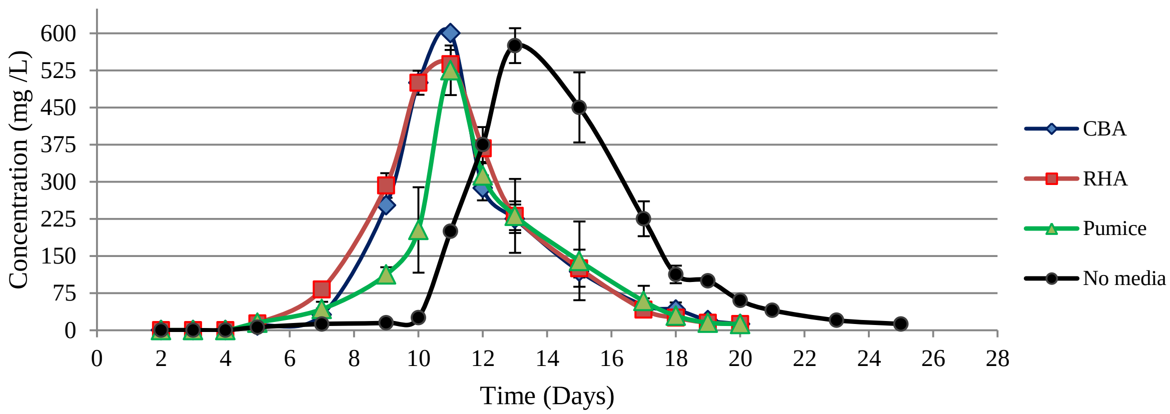

Fig. 6 Change of nitrate concentration with time for all sets.

IV. Conclusion

The media made from rice husk ash and coal bottom ash can be an alternative of the media from irreversible source. The removal of nitrogen compound is found almost same in those pellets. Future study on identification of bacterial species is recommended.

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