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APPLICATION OF A LOW-COST CERAMIC FILTER TO AN ALGAE BASED WASTE STABILIZATION POND SYSTEM

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ABSTRACT

Natural treatment systems (stabilzatin pond, constructed wetland) are gaining attention in developing countries having favourable climatic conditions. But further polishing of the effluents in a cost-effective manner is still a great challenge. In this study, a low-cost ceramic filter was applied to algal based Waste Stabilization Ponds (WSP) system for further improvement the effluent's quality. The applicability is investigated through lab-scale experiment using synthetic domestic wastewater. The low cost ceramic filter was made with 80% clay-soil and 20% rice bran on weight basis. The filter was fully submerged in a glass–made rectangular aquarium reactor. Synthetic wastewater was fed continuously into the reactor that contained algae (mainly Scenedesmus) mixed liquor; the effluent through the filter was obtained using a suction pump. The analyses results of different warter quality parameters of effluents showed that solid-liquid separation was occurred effectively with high organic removal (92% BOD removal) and 50% Nitrogen removal. Low filter clogging tendency (washing frequency: 0.025 times/d) was observed under the flux value of 0.01 m/d. Simple physical cleaning was found effective for filter maintenance. It is concluded that the ceramic filter can be effectively applied for up gradation of the effluent quality of WSPs or other similar treatment systems.

Keywords: *Stabilization pond, clay, ceramic filter, algae, natural treatment, low-cost technology*

1. INTRODUCTION

Instead of conventional one, natural treatment systems for wastewater (aquatic pond e.g., algae based waste stabilization pond, duckweed based waste stabilization pond, hyacinth pond; terrestrial e.g., soil aquifer treatment, overland flow; wetland e.g., natural marshes, free water surface constructed wetland, subsurface flow wetland) are considered more advantageous, especially for developing and tropical countries due to simplicity, low cost, least maintenance, entirely natural, small carbon footprint and highly efficient. (Crites et al., 2006).

Although the use of waste stabilization pond (WSP) as natural treatment system has already been recognized worldwide, the presence of high concentration of total suspended solids in the effluents, mainly algae, being the single major shortcoming of this technology and the systems often fail to meet reuse standards that are more stringent day by day (Neder et al., 2002; Short, 2008). As such, up gradation of WSPs is necessary which can provide significant removal of TSS, mainly algae while maintaining the major advantages of the pond systems (i.e. simplicity, low cost and low maintenance). Various physico–chemical and biological methods have been evaluated to enhance algae separation from the effluents of WSPs to meet the requirements for its intended re–use or disposal in receiving water bodies. These methods include membrane filtration (Asai, 2010), fine sand/silt filtration (Naghavi and Malone, 1986), sand filtration (Esen et al., 1995), intermittent sand filtration (Harris et al., 1977), rock filtration (Saidam et al., 1995), lime treatment (Folkman and Wachs, 1973), constructed wetlands (Tsalkatidou et al., 2009), roughing filters with constructed wetland (Kimwaga et al., 2004), electro–coagulation (Azarian, 2007), Moringa Oleifera coagulant (Mwangi et al., 2008), floating aquatic plant root mats (Kim and Giokas, 2003), duckweed, attached–growth media (Short, 2008), coagulation–flocculation, in–pond chemical precipitation of suspended materials, biological harvesting, granular media filtration (Neder et al., 2002). However, these technologies have some disadvantages such as: high installation cost, operational and maintenance difficulties, high sludge production, requirement of chemical compounds, requirement of low loading rates, inconsistent performance etc. Such drawbacks could be counter balanced by using low cost ceramic filters. A low-cost ceramic filter made with locally available and cheap materials (clay soil and rice bran) was developed for the application of arsenic (As) removal from groundwater and significant removal of As was achieved due to effective Fe-As floc separation performance of the filter (Hasan et al., 2012; Nakajima et al., 2010; Shafiquzzaman et al., 2011). Another study showed its potential application to MBR process for the separation of activated sludge under aerobic condition (Hasan et al., 2011; Hasan et al., 2014). This ceramic filter seemed to be applicable to algae based WSP system for the separation of algae to further improvement of its effluents. Therefore, the aim of this study to investigate the applicability of this ceramic filter to an algae based WSP system through lab-scale experiment.

2. METHODOLOGY

2.1 Manufacturing of low cost ceramic filter

The low-cost ceramic filter was manufactured according to the previous study (Hasan et al., 2012; Nakajima et al., 2010; Shafiquzzaman et al., 2011). The ingredients of the filter were clay soil and rice bran which were collected from a local brickfield and a rice processing factory respectively in Khulna city, south–western part of Bangladesh. The ratio of clay soil (dried, ground and sieved by 0.5 mm mesh) and rice bran (dried and sieved by 1 mm mesh) was 80:20 on weight basis. Sufficient amount of water was added with the mixture to make dough for making filter. A hollow cylindrical shape of the filter (10 cm height, 10 cm outer diameter and 4 cm inner diameter) was made with the dough by using a dice of wood and PVC pipe. After sun dried the filter was burnt at 900^{o}C in a small scale local kiln in the same region. The pore size of the filter was 1–5 µm. The manufacturing cost for one ceramic filter was estimated to be US$0.2–0.3.

2.2 Experimental set up and specification

Figure 1 shows the schematic interpretation of the experimental set up. A glass–made rectangular aquarium tank (28 litre effective volume with 60 cm (Length) × 30 cm (Width) × 26 cm (Height)) was used where the ceramic filter (filter area: 0.04 m^2) was fully submerged in algae mixed liquor. The reactor was artificially lightened (6000±500 lux and 12 hrs. cycle of dark and light) and was totally covered by black fabrics to prevent entering the light from outside. Synthetic wastewater (domestic), with glucose as the carbon source was fed continuously into the reactor. The initial concentration of BOD, N and P were kept constant as 20 mg/L, 40 mg/L and 4 mg/L respectively. The permeate effluent was obtained through the filter by suction pump. The algae mixed liquor was prepared by culturing the algae (mainly Scenedsmus and collected from Lake Biwa, Japan) around two weeks according to the conditions stated in Table 1 using the same synthetic wastewater. A pressure gauge was connected to record the transmembrane pressure (TMP). Water heater was also placed in the reactor to maintain the temperature of 25^{o}C.

The experiment was continued for 70 days with a flux value of 0.1 m/d and HRT of 7 days. The reactor was monitored by daily (at morning: after 30 minutes of light on and at evening: before three hours of light off) measurements of the reactors volume, temperature, pH, dissolved oxygen (DO) and TMP. The reactor volume was kept stable by controlling the feeding pumps. The BOD, T–N, NO_2–N, NO_3–N, PO_4–P concentrations in the effluent and SS and Chlorophyll–a (Chl–a) for algae concentrations in the reactor were measured periodically.

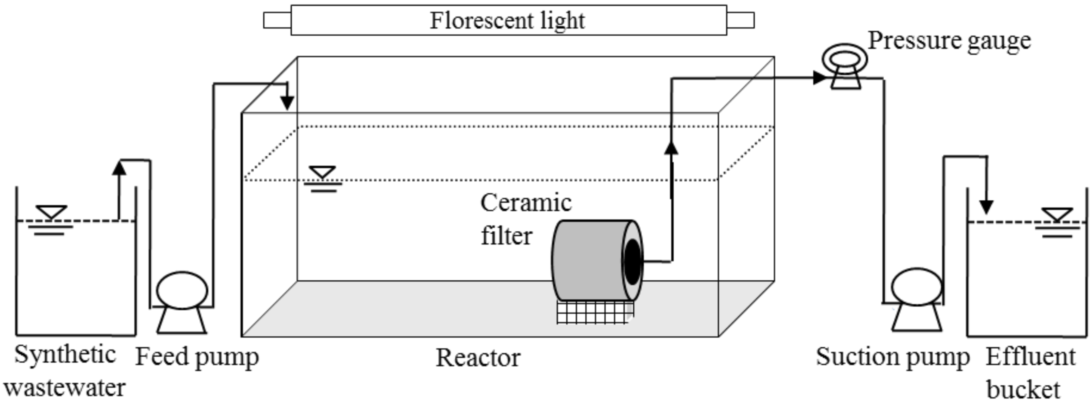

Figure 1: Sketch diagram of the experimental set up.

Table 1: Algae culture conditions

Parameters	Descriptions
Membrane module	Flat type, 0.4 µm pore size, Kubota, Japan
Reactor volume (L)	28
HRT (d)	7
Light: Dark cycle (hr)	12:12
BOD (mg/L)	20
P (mg/L)	4
N (mg/L)	40

2.3 Analytical methods

BOD, T–N, NO_2–N, NO_3–N and PO_4–P were measured by using the Japan Industrial Standard method (JISC, 2008). Molybdenum blue-ascorbic acid reduction colorimetric method was used for PO_4–P. T–N was measured by potassium peroxodisulfate digestion followed by ultraviolet spectrometry method. HITACHI U-2900 spectrophotometer was used for PO_4–P and T–N measurement. pH and DO were measured by using pH meter (HORIBA, F–21) and DO meter (HACH HQ 30d), respectively. Chl–a was measured by UV method (HPLC) using HITACHI U–2900 Spectrophotometer.

3. RESULTS

3.1 Operational conditions

It was observed that average value of pH at morning was 8.4±0.2 while at evening it was 8.5±0.2 during 70 days of operation. The higher value at evening might be due to uptake of CO_2 by algae during photosynthesis period. Therefore, the differences were observed in the morning and evening. The DO concentrations were found almost 2–3 times higher at evening time (average value: 8.5±1.6 mg/L) rather than morning (average value: 3.2±1.0 mg/L) which are also due to the O_2 production by algae during photosynthesis. Although the temperature was kept at 25°C, the high temperature during the evening time (average value: 29.5±1.1 ^oC) rather than morning time (average value: 25.7±0.5 ^oC) might be caused by the thermal radiation of the lights. In the case of actual stabilizing ponds, the wind aids re–aeration, but in this experiment the reactor was covered with black fabrics, so the influence of wind etc. cannot be considered. Though zooplankton and detritus also exist in SS in this study, but majority percentage would be algae as DO increases in evening period. The concentration of SS and Chl–a was 49.6±11.0 mg/L and 0.18±0.07 μmol/L respectively.

3.2 Organic removal

Figure 2 shows the BOD concentration in influent and effluent. Though the influent BOD concentration was 20 mg/L but the actual measurement was found 23.36 ± 1.30 mg/L on average. The average value of effluent BOD was 1.84 ± 2.0 mg/L and it took almost one week to decrease the BOD concentration <5 mg/L from 23.36 mg/L. Therefore, 92% BOD removal rate was achieved that indicated sufficient biodegradation of organic matter in 7 days HRT.

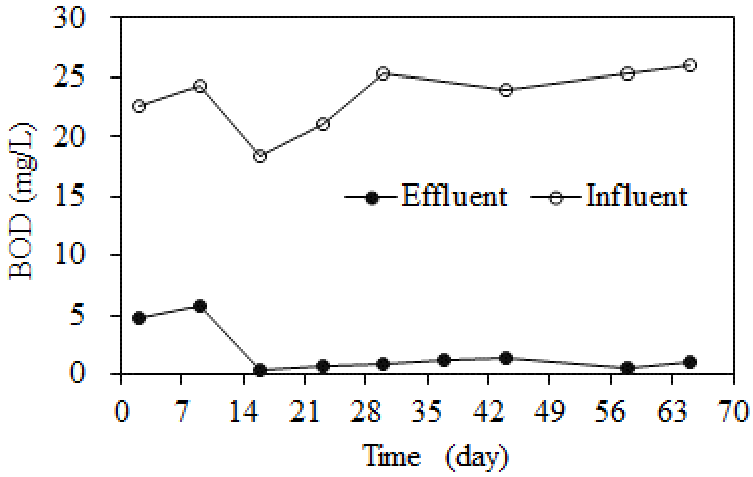

Figure 2: BOD concentrations in influents and effluents.

3.3 Nitrogen removal

Figure 3 shows the change of nitrogen (T–N, NO_2–N and NO_3–N) concentrations with time According to figure 3, NO_2–N concentrations decreased whereas NO_3–N concentration increased during 0 to 21 days and then remain stable. This suggested that nitrification was carried out via oxygen supply by photosynthesis of algae. The deviation between summation of NO_2 (3.9 ± 5.7 mg/L), NO_3 (12.2 ± 4.1 mg/L) and T–N (21.3 ± 3.5 mg/L) emphasized insignificant denitrification activities due to lack of organic carbon. Consequently, the nitrogen removal rate was around 50%.

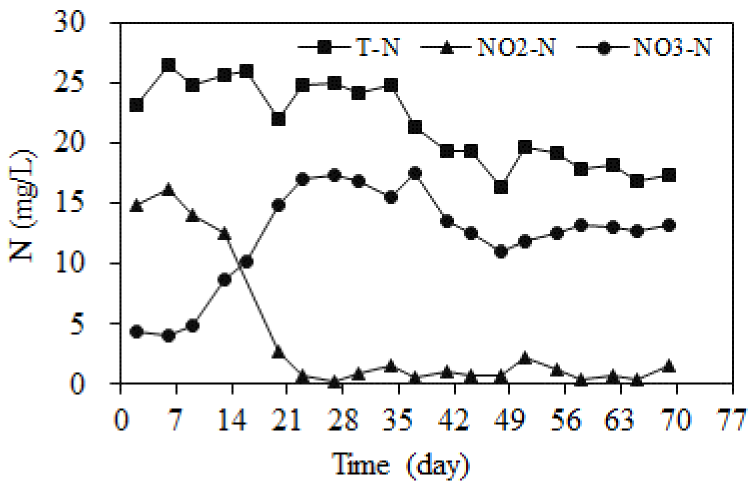

Figure 3: Nitrogen concentrations in effluents.

3.4 Phosphorus removal

Low removal of phosphorus was observed during the experiment (figure 4). Literature also reported the lower removal rate of phosphorus in the stabilizing pond which would to be approximately 15% to 50% (Garcia et al., 2000). It also stated that phosphorus removal in the stabilizing pond method is insignificant in the absence of added chemical for coagulation and reported that phosphorus can be reduced to 1 mg/L or less by adding aluminium sulphate or ferric chloride (Reed, 1995).

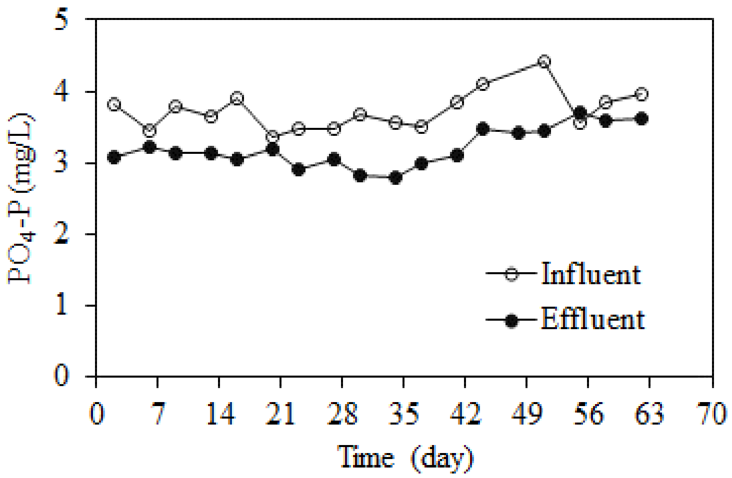

Figure 4: Phosphorus concentrations in influents and effluents.

3.5 Filter maintenance

A green layer of accumulated algae on filter surface was found during the operations that increase the Transmembrane Pressure (TMP). While reach the TMP value equal to 3.0 MPa the filter was cleaned physically using soft brush with water rinse and found effective to reclaim the flux performance (figure 5). Therefore, reversible fouling of the filter was observed during the operations. It was required only one time cleaning the filter during 70 days of operation indicated low clogging tendency (washing frequency: 0.025 times/d) under flux value of 0.1 m/d. Also, if necessary the filter could be replaced by a new one because its manufacturing procedure was easy and inexpensive.

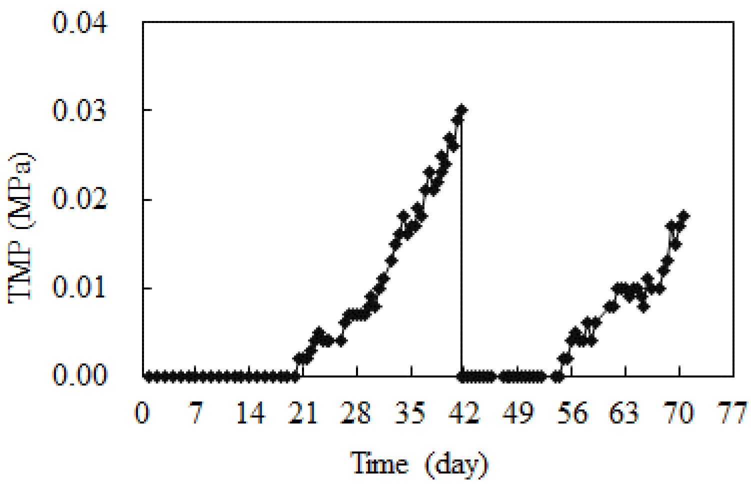

Figure 5: TMP profile during 70 days of operation.

4. CONCLUSIONS

The main conclusions could be summarized as follows:
Efficient solid-liquid separation, especially algal community was achieved while using the low-cost ceramic filter; 92% BOD and 50% nitrogen removal was observed; low clogging tendency of filter was found under flux value of 0.1 m/d; simple physical cleaning was found effective for filter maintenance; more trials are required to identify optimum hydraulic loadings and associated size and shape of the filter prior to real–scale application.

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