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Research Paper

PERFORMANCE EVALUATION OF TREATMENT OF GREYWATER BY DOWNFLOW HANGING SPONGE BIOTOWER USING AERATED AEROBIC SLUDGE AND MICROALGAE CHLORELLA

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The study evaluates the performance of Downflow Hanging Sponge (DHS) biotower with aerated aerobic sludge and microalgae chlorella in the treatment of synthetic domestic greywater for reuse applications. The DHS biotower with aerated aerobic sludge at C/N ratio 6.5 and HRT 4 h attained removals of 89.0% COD, 97.0% BOD, 60.3% ammonia, nitrogen and 50.76% phosphate without aeration from synthetic domestic greywater. The biotower with microalgae chlorella at C/N ratio 6.5 and HRT 4 h attained removals of 87.3% COD, 94.0% BOD, 59.2% ammonia nitrogen and 44.4% phosphate. The study thus reveals that the removal efficiencies obtained by incorporating chlorella in filter media and aerated aerobic sludge were found to be almost matching but superior when compared to DHS biotower employing aerobic sludge having removal efficiencies of 77% COD, 90% BOD, 54.6% ammonia nitrogen and 32.9% phosphate. The effluent quality met the USEPA standards for unrestricted irrigation. A final disinfection step is recommended before reuse to avoid risks in case of human contact. The effluent can also be used for toilet flushing. With suitable modification the system might probably give effluent meeting potability standards.

Keywords: DHS - Downflow Hanging Sponge, COD - Chemical Oxygen Demand, BOD - Biochemical Oxygen Demand, HRT - Hydraulic Retention Time

INTRODUCTION

Greywater is the wastewater generated in the bathroom, laundry and kitchen. Greywater is therefore the component of domestic wastewater, which makes up to about 60-70% of domestic wastewater volume. In terms of basic water quality parameters, it is considered to be comparable to a low or medium grade wastewater. Most greywater is easier to treat and recycle. Reuse of grey water will reduce water consumption.

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Various aerobic systems employed for the greywater treatment are rotating biological contactors, biological aerated filters, membrane bioreactors and sequential batch reactor, etc. Tawfik *et al.* (2006b) investigated a two stage RBC system for treating domestic wastewater. They found that the two-stage RBC system achieved only 86% of COD at a hydraulic retention time of 10 h. Leal *et al*. (2010) reported that sequential batch reactor at an HRT of 12 h achieved 90% COD removal from greywater. But these aerobic reactors require greater HRT and artificial aeration to meet the effluent quality standards. To overcome these difficulties a novel technology was developed by the research team of Prof. Harada of Japan in 1995 and it is known as Down Flow Hanging Sponge (DHS) biotower. DHS biotower made its first debut in Karnal city of India under Yamuna Action Plan (YAP).

DHS biotower is an aerobic treatment system similar to trickling filter. The principle of DHS system is the use of polyurethane foam (sponge) as the growing and supporting medium for microorganisms, providing longer mean cell residence time and at the same time enhancing the diffusion of air into the wastewater. This phenomenon maintains Dissolved Oxygen (DO) concentration in the wastewater at a level which exceeds the need of aerobes residing in DHS sludge, curtailing the need of any external forced aeration unlike most of the existing aerobic treatment systems. Sponge has a void ratio more than 90%, which provides an excellent site for the growth and attachment of active biomass. The DHS system has been successfully used for organic matter stabilization and nutrient control. DHS system have attracted considerable interest as an alternative to the conventional suspended growth and fixed-film wastewater treatment processes due to its high performance efficiency (Tandukar *et al.*, 2007; Mahmoud *et al.*, 2009). DHS reactors offer several advantages such as higher biomass concentration, higher Sludge Residence Time (SRT), lower Hydraulic Retention Time (HRT), and small foot print as compared to conventional treatment systems (Mahmoud *et al.*, 2009). Sponge has been considered as an ideal attached growth media because it can act as a mobile carrier for active biomass. Sponge not only can reduce membrane fouling by means of mechanical cleaning and maintain a balance of suspended-attached microorganisms in Submerged Membrane Bioreactor (SMBR), but also can enhance dissolved organic matter and nutrient removal. The high porosity of sponge helps in the entrapment of microorganisms and organic matter thus providing a longer SRT (Tandukar *et al.*, 2005). Both nitrification and denitrification takes place in DHS system. Several DHS have been developed so far. All differ in the shape and arrangement of sponge units (Tandukar *et al.*, 2005). These are known as first generation or cube type, second generation or curtain type, third generation or trickling filter type and fourth generation, etc. Mahmoud *et al*. (2010) evaluated the performance of DHS system for organic matter and nutrient removal in the treatment of presettled municipal wastewater. The system was operated at an ambient temperature of 25°C and at three different HRTs, i.e., 6, 4, and 2 h. The removal efficiencies obtained were 89, 80, and 56% for COD, 99, 90, and 72% for ammonia 43, 39 and 35 % for phosphates respectively for the three HRTs. Studies suggest that treatment systems based on physical removal alone should be avoided in wastewater treatment as they produce large amount of non-stabilized sludge.

High removals of organic matter and pathogens are achieved along with low sludge production when biotower is used for treatment. But the nutrient removal by biotower alone is not very effective. Therefore various methods of enhancing nutrient removal may be incorporated. Removal efficiency of aerobic reactors can be enhanced by using methods like incorporating aerobic granular sludge, microalgae chlorella, varying C/N ratio, etc.

Aerobic granules are considered to be a special case of biofilm composing of self-immobilized cells. The aerobic granulation technology was recently developed for treating high strength wastewaters containing organics, nitrogen, phosphorus, toxic substances and xenobiotics (Adav *et al.*, 2008). Simultaneous removal of organics and nitrogen by aerobic granules was due to the coexistence of heterotrophic, nitrifying and denitrifying populations (Yang *et al.*, 2004). Liu *et al.* (2007) investigated COD removal and nitrification of low-strength domestic wastewater in aerobic granular sludge sequencing batch reactors. Ammonia nitrogen removal efficiency increased to above 90% after 22-day operation. Schwarzenbeck *et al.* (2005) used wastewater from dairy plant in investigating the performance of aerobic granules for dairy wastewater treatment. The removal efficiencies of 90% of total COD, 80% of total Nitrogen and 67% of total Phosphorus were reported. Rui and Jin (2008) investigated MBR seeded with aerobic granular sludge in the treatment of high concentration ammonium nitrogen wastewater. The system achieved 90% removal rates of nitrate nitrogen and nitrite nitrogen.

Algae are important bioremediation agents, and are already being used by many wastewater facilities. Microalgae chlorella species are commonly used for tertiary wastewater biological treatment. Many studies reported that Chlorella is a common and effective species for the immobilization and nutrient removal processes. An immobilized cell is defined as a living cell that, by natural or artificial means, is prevented from moving independently from its original location to all parts of an aqueous phase of a system. Microalgae are immobilized in various polymers for different biotechnological purposes, such as morphology studies, production of fine chemicals, energy production, and wastewater treatment. Unicellular microalgae *Chlorella vulgaris* and *Scenedesmus dimorphus* are capable of removing up to 55% of the phosphates from dairy and pig farming wastewaters (Gonzalez *et al.*, 1997). Woertz *et al.* (2009) investigated nutrient removal by green algae during treatment of dairy farm and municipal wastewaters. After 12 days, ammonium and orthophosphate removals were 96 and >99%, respectively for dairy wastewater. Over 99% removals of ammonium and orthophosphate were achieved for municipal wastewater.

Greywater has low organic content, nutrients and pathogens when compared to blackwater and therefore can be treated for reuse applications. Previous studies show that greywater can be effectively treated by aerobic systems. DHS biotower has shown to be effective in removing organic matter, nutrients, suspended solids, coliforms, etc., from presettled municipal wastewater (Mahmoud *et al.*, 2010), UASB effluent of municipal wastewater (Tandukar *et al.*, 2006, 2005; Tawfik *et al.*, 2006a), artificial coke wastewater under high salinity conditions (Uemura *et al.*, 2010), etc. But the nutrient removal by DHS system is found to be low. This study focuses on the incorporation of microalgae *chlorella* and aerated aerobic sludge into DHS system for enhancing the efficiency of organic and nutrient removal so that the greywater can be reused for various purposes.

MATERIALS AND METHODS

Experimental Setup

The DHS biotower of size 12 cm x 12 cm x 50 cm and of 4.2 L effective volume was used as the treatment unit. Sponge cubes of 2.5 cm sides were filled in the reactor in two segments of 10 cm height each. The sponge volume accounted for 40% of the total reactor volume. The cubes were filled in random manner. A perforated plate was used at the top to uniformly distribute the influent. The Working model of DHS biotower system is shown in Figure 1. Synthetic wastewater was fed in to the biotower. The effluent from the biotower was given a two hour settling and used for the analysis. The composition and characteristics of the synthetic wastewater is shown in Tables 1 and 2.

Figure 1: Working Model of DHS Biotower System

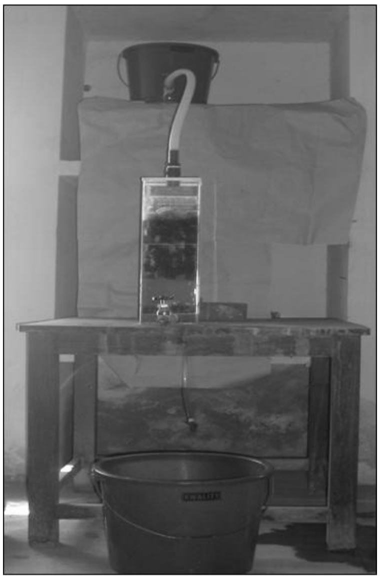


Table 1: Composition of Synthetic Wastewater

Compound	Concentration
Glucose (mg/L)	300
Sodium acetate trihydrate (mg/L)	1488.38
Ammonium chloride (mg/L)	225
Disodium hydrogen phosphate (mg/L)	150
Potassium dihydrogen phosphate (mg/L)	75
Magnesium sulphate (mg/L)	50
Cow dung (mL/L)	0.2

Table 2: Characteristics of Synthetic Water

Parameter	Value
Ammonia nitrogen (mg/L)	87
Phosphate phosphorous (mg/L)	52.3
pH	7
COD (mg/L)	425.00
BOD (mg/L)	300.00
TDS (mg/L)	1009

Preparation and Start up of the Reactors

To prepare the aerated aerobic sludge, biotower was seeded with 3 L of aerobic sludge from the activated sludge process of the dairy waste treatment plant at Thrissur. The nutrients of aerobic bacteria (Beef extract 3 g/L, Peptone 5 g/L and NaCl 5 g/L) were added to it. SVI was found to be less than 50 mL/g. It was then intermittently aerated for a period of one and a half month. The SVI was then found to be about 75 mL/g.

Chlorella was cultured using Bold's Basal medium. Bold's Basal Medium (BBM) is an inorganic salt medium widely used for the culture of free-living planktonic freshwater algae (Daphnia research group, 2007). 10% of *Chlorella* inoculums was added to the prepared BBM and intermittently aerated for 1 hour upto four weeks.

For immobilization Polyurethane foam was washed with sterile water and sterilized for 2 h at 15 lbs. Then polyurethane foam was added to the chlorella culture and aerated for 1 h upto 3 weeks (Thangaraju *et al.*, 2003).

Operating Conditions and Procedure

The synthetic wastewater was fed into the reactor by means of gravity. Throughout the study the reactors was operated at room temperature. The reactor was operated at 4 h HRT. In order to increase C/N ratio to 6.5 which was found to be optimum (results not shown), sodium acetate trihydrate was added. The biotower was operated at a HRT of 4 h with C/N ratio as 6.5 at a volumetric loading rate of 7.1 kg. of COD/m^3/h.

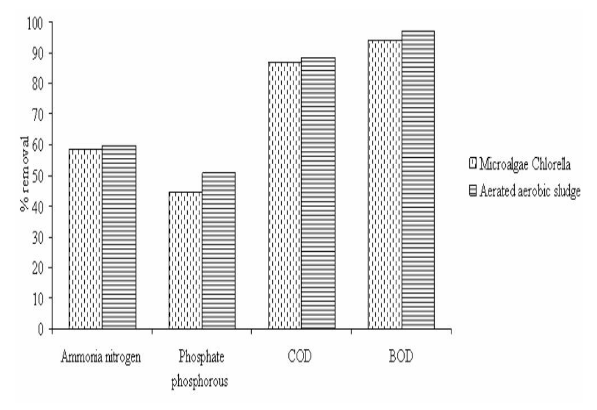
Sampling and Analysis

The effluent of biotower was collected in plastic bottles and analyzed for ammonia nitrogen, phosphate phosphorous COD, BOD. All analysis was carried out as per standard methods. (APHA, 1972)

RESULTS AND DISCUSSION

The results obtained by treating synthetic wastewater with C/N ratio 6.5 at an HRT of 4 h with aerated aerobic sludge and microalgae chlorella are shown in Figure 2. It can be observed that removals efficiencies obtained by incorporating chlorella in filter media and aerated aerobic sludge were found to be almost matching. When compared with the performance of DHS biotower employing aerobic sludge an enhancement in treatment efficiencies were obtained for the parameters tested. The removal efficiencies in a DHS biotower using aerated sludge were 77%, 90%, 54.6% and 32.9% for COD, BOD, ammonia nitrogen and phosphates,

Figure 2: % Removal of Nutrients and Organic Matter by Incorporating Aerated Aerobic Sludge and Microalgae Chlorella



respectively.

Various studies have reported that aerobic granules have high settling velocity (Beun *et al.*, 1999, Liu and Tay, 2004, Xiao *et al.,* 2008). High settling velocity increased the biomass retention capacity of the reactor and subsequently enhanced the organic degradation capability (Adav *et al.*, 2008). SVI values between 50 mL/g and 150 mL/g indicate good sedimentation characteristics of the sludge yielding high biomass concentration in the aeration tank (Garg and Garg, 2006). In the present study, aerated aerobic sludge had an SVI of 75 mL/g. Thus aerated aerobic sludge used also had good sedimentation characteristics, high biomass retention and organic degradation similar to aerobic granular sludge. In addition to these the activity of aerobic microorganisms increased due to the aeration of the aerobic sludge. The above factors contributed to the enhanced removal of organic matter and nutrients.

Lau *et al.* (1997) immobilized *Chlorella vulgaris* in carrageenan and alginate to treat domestic wastewater. Over 95% of ammonium and 99% of phosphates were removed from the wastewater. When compared to the above studies, percentage removal of nutrients by chlorella was found to be lower in the present study. This may be due to reduced amount of light penetrating through the sponge which would then limit the growth and metabolic activities of the algal cells. This can be solved by using photo bioreactor and/or using shallow reactors.

CONCLUSION

The treatment of greywater in DHS biotower using aerated aerobic sludge and chlorella showed promising results. The removal efficiencies obtained by these methods were found to be almost similar. A significant enhancement of removal efficiency in organic matter, and nutrients were observed when compared to DHS biotower employing aerobic sludge. The sludge production was negligible, which was an advantage as no sludge handling equipment was needed. No clogging of sponge was noticed during the period of study which also was an added advantage as no backwashing or replacement of the packing material was needed. The effluent quality met the USEPA standards for unrestricted irrigation except for pathogens. Hence a final disinfection step is recommended before reuse to avoid risks in case of human contact. The effluent can also be used for toilet flushing. The study suggests DHS biotower as a potential method for greywater treatment and reuse applications.

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