COLUMN TYPE PHOTOBIOREACTOR FOR WASTE WATER TREATMENT IN PETROCHEMICAL INDUSTRIES

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ABSTRACT

BACKGROUND

Chemical industries pollute the fresh as well as marine water resources. This paper presents the removal of chemical pollutants using filamentous cyanobacteria in column-type photobioreactor. Two different species of cyanobacteria collected from refinery effluent were used for this study. Bio Discs of two different species were prepared separately and compared the removal efficiency. Two different concentrations of effluent were prepared and applied to the photobioreactor. Effluent samples were analysed for phenol, sulphide and COD at every 2 days intervals up to 6 days. Both the microorganisms could grow well in the effluent removing the dissolved chemicals from waste water. Phenol content of Low Strength Effluent (LSE) was reduced to 8 mgL^{-1} from an initial amount of 103 mgL^{-1} after 4 days of treatment by Phormidium tenue. Both the organisms could remove sulphide effectively from low strength effluent. Oscillatoria acuminata could not remove higher concentrations of sulphide from Medium Strength Effluent (MSE) COD of the low strength effluent was reduced to zero by P. tenue from an initial amount of 240 mgL^{-1}, whereas O. acuminata could reduce to 16 mgL^{-1}after 6 days of treatment. COD was reduced to 16 mg L^{-1} from an initial value 416 mg L^{-1} from MSE and 92% removal of COD was also obtained from HSE. Bio Discs of Phormidium tenue showed better performance than Oscillatoria acuminata in removing chemicals from the synthetic effluents. Biomass developed within the reactor was harvested at every 15 days intervals from the secondary reactor and dried for biodiesel production.

KEYWORDS

Photobioreactor, Cyanobacteria, Phenol and Sulphide Removal, Waste Water Treatment.

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BACKGROUND

Phenol and sulphides are major pollutants in chemical and petrochemical industries, which causes pollution on fresh as well as marine water resources. Phenolic compounds are toxic, carcinogenic, mutagenic and teratogenic at high concentrations. Reduced sulfur compounds such as sulfides cause environmental problems because of their toxicity, odour and corrosive properties (Sarti et al, 2010). The physicochemical methods are expensive because of the addition of chemical substances, energy consumption and also generating undesirable toxic residual products that need further treatment. Microorganisms play a major role in degrading and detoxifying the toxic chemicals. Removal of these compounds can be done using aerobic and anaerobic microorganisms in specially designed bioreactors (Chen et al, 2010). Cyanobacteria play a major role in supplying oxygen to the bacterial population for the breakdown of complex organic substances. Oscillatoria sp. and Phormidium sp. have been observed to thrive in petroleum refinery effluents (Joseph V and Joseph A, 2002). Compared to bacterial systems, bioreactors utilising a symbiotic association between algae and bacteria have been reported to yield higher treatment efficiency (Borde, 2003).

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Photo Bioreactor (PBR) is a system, which can work under solar light and photosynthetic organisms can grow and perform its functions. Different designs of PBR revealed its efficiency in treating waste water as well as removal of CO_2 and VOCs from waste gas (Wang, 2008). Under suitable conditions, some microalgal species are able to accumulate upto 50-70% of oil/lipid per dry wt. (Chisti, 2007). The fatty acid profile of microalgal oil is suitable for the synthesis of biodiesel (Gouveia and Oliveira, 2009). Microalgae biofuel production has recently become a viable option as a feedstock source for fuel (Fon Sing et al, 2014). Algae systems were designed and implemented to cultivate microalgae in modular, offshore photobioreactors (Novoveska, 2016).

Present study was conducted to prepare BioDiscs of cyanobacteria in column type PBR and to evaluate the removal efficiency of phenol, sulphides and dissolved chemicals. Biomass was harvested and dried for biofuel production.

MATERIALS AND METHODS

Biofilms were collected from effluent treatment plant, BPCL, Kochi, to develop BioDisc of tolerant strains. The strains were identified using the monograph written by Desikacheri, 1959. The photobioreactor was constructed using borosilicate glass. It measured 70 cm in length and 3.2 mm wall thickness. The column is fitted with 31 nos. of polycarbonate discs (1 cm apart) fitted with polyurethane foam for biomass attachment. BioDiscs were prepared with 2 different strains of cyanobacteria. The column is illuminated with a cool-white fluorescent lamp. Air blow into the photobioreactor is provided by Teflon tubing. The conical bottom of the reactor is fitted with a biomass filter (Figure 1).

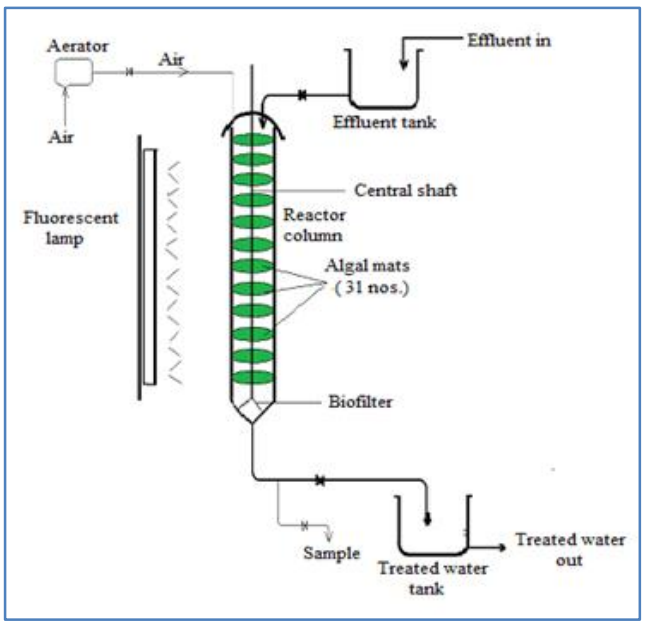

Figure 1. The Schematic of Experimental Setup of Column Type Photobioreactor

An inlet was provided through, which the waste water was applied to the reactor and synthetic effluent was introduced from top of the reactor. Two different concentrations of synthetic effluent (Low Strength (LSE) and Medium Strength (MSE)) were prepared by adding phenol, sodium sulphide and petrol to study the performance of the photobioreactor. Outlet was provided at the other end of the reactor. Waste water characteristics like phenol, sulphides and COD were analysed at every 2 days intervals up to 6 days (APHA 1998).

RESULTS AND DISCUSSION

Biological treatment of waste water using cyanobacteria offers the advantage of greater flexibility and lower operational costs over other treatment systems. The biofilm brought from the Effluent Treatment Plant (ETP) of a petroleum refinery were of Phormidium tenue and O. acuminata. Phenol content of low strength effluent was reduced to 8 mgL^{-1} from an initial amount of 103 mgL^{-1} after 4 days of treatment within the photobioreactor when loaded with BioDisc of P. tenue. Both the organisms could remove phenol effectively from low strength effluent after 6 days of treatment in the photobioreactor (Figure 2).

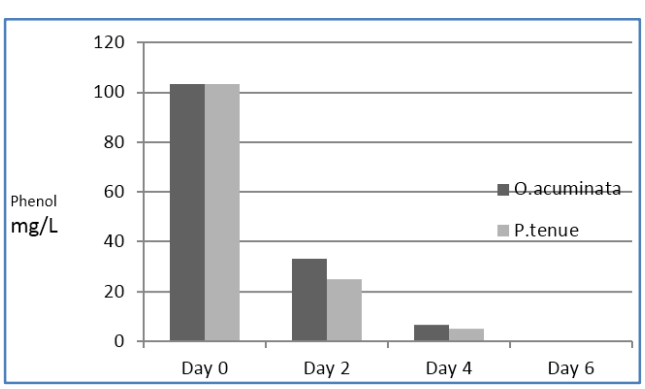

Figure 2. Removal of Phenol from Low Strength Effluent

Phenol content of MSE was reduced to 6.6 mgL^{-1} from an initial amount of 210 mgL^{-1} after 6 days of treatment in the photobioreactor (Figure 3).

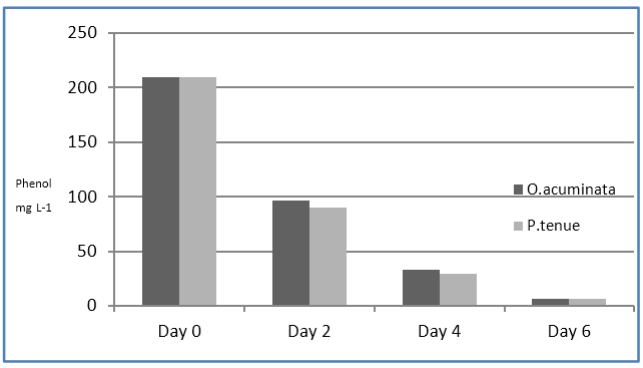

Figure 3. Removal of Phenol from Medium Strength Effluent

Both the organisms performed well in removing phenol from the medium strength effluent.

Cyanobacteria have high nutrient removal capacity and they are likely to tolerate the highly variable conditions that characterise polluted effluents; (Subramanian G. and Uma, 1996). A marine cyanobacterium Phormidium valderianum was found to degrade phenol completely at 100 mgL^{-1} by its intracellular oxidases and Laccase enzymes and such strains could be effectively used for treatment of phenol-containing wastes; Shashirekha S et al (1997). Sulphide content of the low strength effluent was reduced to 3.2 mgL^{-1} from an initial amount of 8.8 mgL^{-1} after 2 days of treatment inside the reactor. BioDisc of P. tenue completely removed the sulphide content from low strength effluent after 4 days of treatment in the reactor (Figure 4).

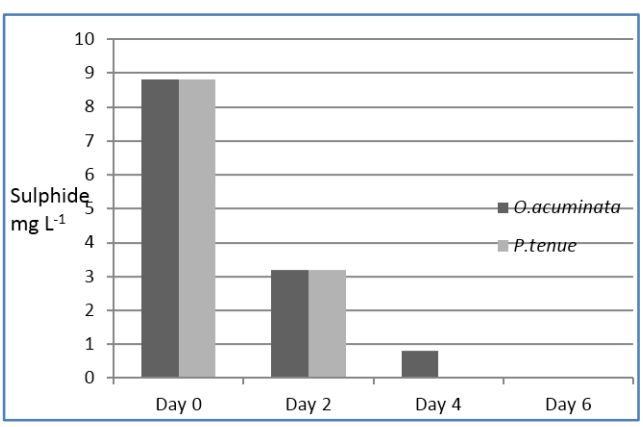

Figure 4. Removal of Sulphide from Low Strength Effluent

Sulphide content of MSE was reduced to 1.6 mgL^{-1} and 2.4 mgL^{-1} from an initial amount of 19.2 mgL^{-1} by P. tenue and O. acuminata, respectively (Figure 5).

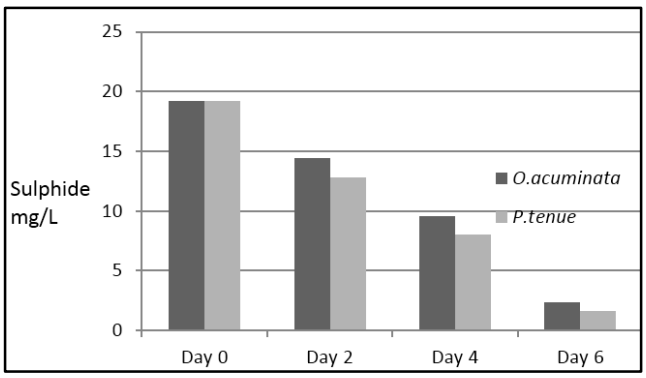

Figure 5. Removal of Sulphide from Medium Strength Effluent

Reduced sulphur compounds maybe used by the microorganisms as energy source. Several laboratory scale studies revealed the removal of sulphides from waste water streams by phototrophic bacteria (Ferrera I, 2004). Aerobic microorganisms can oxidise sulphides, 75% removal of sulphide was reported in a process of simultaneous desulfurisation and denitrification; (Wang A J et al 2005). COD of the low strength effluent was reduced to zero by P. tenue from an initial amount of 240 mgL^{-1} (Figure 6), whereas O. acuminata could reduce to 16 mgL^{-1} after 6 days of treatment.

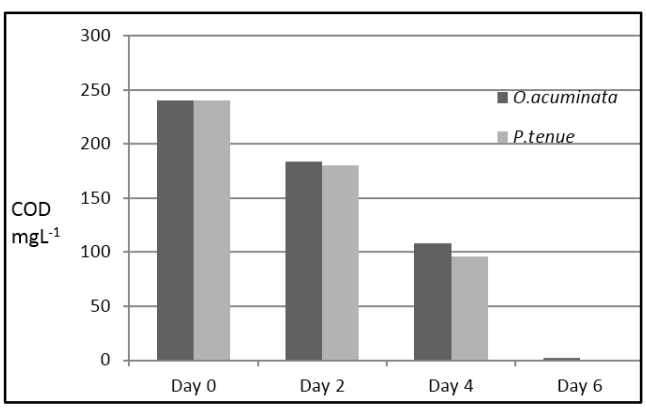

Figure 6. Removal of COD from Low Strength Effluent

COD of the MSE was reduced to 16 and 22 mgL^{-1} by P. tenue and O. acuminata, respectively (Figure 7) from an initial amount of 416 mgL^{-1}.

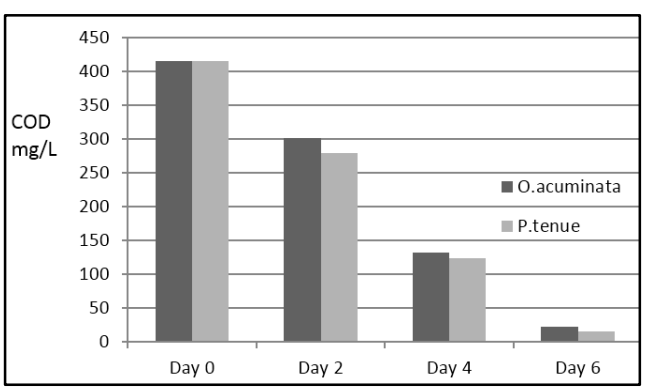

Figure 7. Removal of COD from Medium Strength Effluent

Dissolved chemicals from the effluent could effectively be utilised by the organisms, which resulted the reduction of COD of the synthetic effluent. Reduction in total dissolved solids from petrochemical effluent was reported using Oscillatoria quadripunctulata (Joseph V and Joseph A, 2001). Removal efficiency of 100% of COD was obtained for LSE within 48 hrs. Hydrocarbon degradation has been widely reported in laboratory scale batch studies (Mohanty G and Mukherji S, 2007). A Chlorella sp. showed a high tolerance in removal of Polybrominated Diphenyl Ethers (PBDEs) from wastewater (Deng and Tam, 2015). Maximum phenol degradation of 97% could be achieved with microalgae Chlorella pyrenoidosa having concentration of 4 g/L, phenol concentration of 0.8 g/L and reaction time of 4 days (Priyadharshini D S and Bakthavatsalam K A, 2016). Although, microalgae can serve as an appropriate alternative feedstock for biofuel production, the high microalgal cultivation cost has been a major obstacle for commercialising such attempts (Wang 2016). Since, the organism was belonging to filamentous cyanobacteria, biofilms were detached from the attached surface after 3 weeks of growth, which in turn reduces the harvesting cost. The biofilms were removed from the reactor at regular time intervals and dried for fatty acid production.

CONCLUSION

Photobioreactor technology is a new approach for the treatment of waste water from various industries. Phormidium tenue and Oscillatoria acuminata are tolerant strains of Cyanobacteria isolated from refinery effluent. Phenolic compounds are very toxic to most unicellular and higher organisms. However, some microorganisms are able to utilise them as carbon and energy source since they possess remarkable ability to adapt to unfavourable environmental conditions. The present results confirmed that Cyanobacteria can effectively utilise the dissolved substances in the petrochemical effluent. PBR with Phormidium tenue is no doubt, a novel efficient appliance, which can be adopted for treatment of waste water containing phenol and sulphides. A careful considerations of various design parameters of PBR with immobilised cyanobacteria promises greater efficiency even in high concentrations of phenol and sulphides. Photosynthetic organisms aerate the systems, which in turn increases the degradation rate. It is necessary to develop cost-effective technologies that would permit efficient biomass harvesting and oil extraction. Since, microalgae production is regarded as a feasible approach to mitigate global warming, this technology definitely provide significant benefits to the refinery industries by treating the waste water and utilising the biomass as biofuel resource. Therefore, more efficient designs should be developed to enhance the capability of these organisms.

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