PHENOL DEGRADATION USING MOVING BED BIOFILM REACTORS

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Abstract: Phenol may enter the environment from oil refinery discharges, coal conversion plants, municipal waste treatment plant discharges, or spills. It released as a vapor from natural or human made sources contaminated by or containing phenol. It is also found naturally in animal wastes and decomposing organic material. It is used as a general disinfectant, as a reagent in chemical analysis and for the manufacture of artificial resins, medical and industrial organic compounds and dyes. It is also used in the manufacture of fertilizers, explosives, paints and paint removers, drugs, textiles and coke. It is produced in large volume, mostly as an intermediate in the production of other chemicals.
MBBR is performed in biofilm system with relatively large carriers. Contrary to most biofilm reactors, MBBR utilizes the whole tank volume for biomass growth. It also has a very low head-loss. It does not need any sludge recycle as compared to activated sludge reactor. This is achieved by having the biomass grow on carriers that move freely in the water volume of the reactor.
A cylindrical MBBR was used in this study. The reactor had an internal diameter of 10 cm and effective depth of wastewater in the reactor was about 60 cm. Reactor was filled with polyethylene floating biofilm carriers which is similar to corrugated cylinder. Reactor was working in upflow stream conditions. The circulation of the biofilm carriers inside the reactor was caused by aeration.
In this paper, treatment of phenolic wastewater using MBBR is presented. However researches show that phenol acts as an inhibitor in biological systems, but MBBR has had suitable removal. In this study COD from 500 to 3000 mg/L were investigated. COD of 700 mg/L had the best efficiency of about 60 percent during 24 hours; however it had acceptable COD removal till COD of 2500 mg/L.

Introduction

The removal of toxic phenolic compounds from industrial wastewater is an important issue to be addressed. Phenolic compounds such as phenol, hydroquinone and pyrogallol are used in different industries which end into their wastewaters. They are considered as priority pollutants because of their high toxicity at low concentrations. Phenol is an important raw material in petrochemical, pharmaceutical, plastic, pesticide production industries. It is a common component of oil refinery wastes and is produced in the conversion of coal into gaseous or liquid fuels and in the production of metallurgical coke from coal. It may enter the environment from oil refinery discharges, coal conversion plants, municipal waste treatment plant discharges, or spills. It released as a vapor from natural or human made sources contaminated by or containing phenol. It is also found naturally in animal wastes and decomposing organic material. It is used as a general disinfectant, as a reagent in chemical analysis and for the manufacture of artificial resins, medical and industrial organic compounds and dyes. It is also used in the manufacture of fertilizers, explosives, paints and paint removers, drugs, pharmaceuticals, textiles and coke. It is produced in large volume, mostly as an intermediate in the production of other chemicals.

The presence of these pollutants in water and soil has become significant problems. Effective methods for the removal or treatment of them need to be pursued. Many efforts have been made for the biological treatments of wastewater rich in phenolic compounds.

Common commercial wastewater treatment methods utilize the combination of physico-chemical and biological treatment. Both chemical and biological processes were used for many years to treat phenolic wastewater. Activated sludge, fluidized and packed bed reactors and recently moving bed biofilm reactors (MBBR) were studied as biological treatment processes [10, 11 and 13]. Chemical processes like advanced oxidation methods by ozone, hydrogen peroxide and fenton like process [7, 9] and reduction by electrode reactor [6] were also studied for degradation of phenol. Laboratory experiments are done on adsorption of phenol on carbonaceous adsorbents as an effective advanced process to treatment phenolic wastewater [5].

The Moving Bed Biofilm Reactor (MBBR) process (European Patent no.0, 575,314, US Patent no. 5,458,779) was developed in Norway in the late 1980s and early 1990s. In 1988, the Norwegian State Pollution Control Authority made recommendation on design of small wastewater plant [2]. These recommendations include design of biological/chemical treatment plants based on low loaded biofilm process with a large tank (sludge separator) serving both as pretreatment unit, sludge holding and equalization tank. A Norwegian company (Kaldnes Miljøtekonlogy A/S), which was developing the so-called MBBR at the time initiated construction of small treatment plants according to these recommendations.

The MBBR has been a commercial success. There are presently more than 400 large-scale wastewater treatment plants based on this process in operation in 22 different countries all over the world. In addition there are several hundred small, on-site treatment units based on the MBBR—most of these in Germany.

More than 50 MBBR plants are in operation at commercial fish farms, in addition to several hundred small MBBR systems for ornamental fish.

MBBR is performed in biofilm system with relatively large (0.1 to 5 cm) carriers. These are mixed with the wastewater and suspended in the reactor by the turbulence. The system located somewhere between an activated sludge and a fixed-bed biofilm system [2].

One important advantage of the moving bed biofilm reactor is that the filling fraction of biofilm carriers in the reactor may be subject to preferences. In order to be able to move the carrier suspension freely, it is recommended that filling fractions should be below 70% [1]. One may, however, use as much as needed below this. A number of different carriers have been developed. Those designed and developed in Norway, are two variants are called Kaldnes® and Natrix® [2]. These carries are small plastic tubes (1 to 5 cm diameter or length) made from polyethylene with density close to 1 g/cm^3. The inner part of the tubes is divided into several sectors to increase the total biofilm surface. This system is successfully used for treating of high-strength industrial wastewater. Also other kinds of carriers with differences in size and shape and, therefore, different specific surface area have used.

Investigations on the shape and size effect of carrier made it clear that the key factor in the design of a moving bed biofilm process for organic matter removal is the effective surface area where biomass may grow. The size and shape of carrier may have an influence on this effective area. The design of process should be based on organic surface area removal rate [3].

Methods and Materials

Three applied cylindrical MBBR reactors (Fig. 1) were made of Plexiglas. Each reactor had an internal diameter of 10 cm, a height of 70 cm and wall thickness of 4 mm. There were five sampling ports. The effective depth of wastewater in each reactor was 60 cm (70% of reactor volume) filled with plastic floating biofilm carrier (Fig. 2) described in Table1.

Batch reactors were working in upflow stream conditions in room temperature (24+/-2^{o}C). The circulation of the biofilm carriers inside the reactors was caused by aeration. In order to keep the carriers in the reactors, a sieve (with 5 mm opening) was placed at the outlet of the reactors. Filling ratio of plastic elements in the reactors is important due to the amount of biomass, which can be supported by carriers. The reactors used here were filled about 70%.

The synthesized wastewater has been prepared using phenol which was supplied by Merck, Germany. In order to have C/N/P= 100/5/1 and alkalinity, necessary nutrients (urea, KH_2PO_4, K_2HPO_4) was used to feed the reactor.

The parameters of pH, COD (soluble COD filtered through Vattman paper No.42) and dissolved oxygen (DO) were measured, daily. TSS, mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) was measured on alternative days. VFA and alkalinity were controlled weekly. Microscopic investigation was done regularly. All tests analysis procedure was done as outline in the Standard Method Handbook [4].

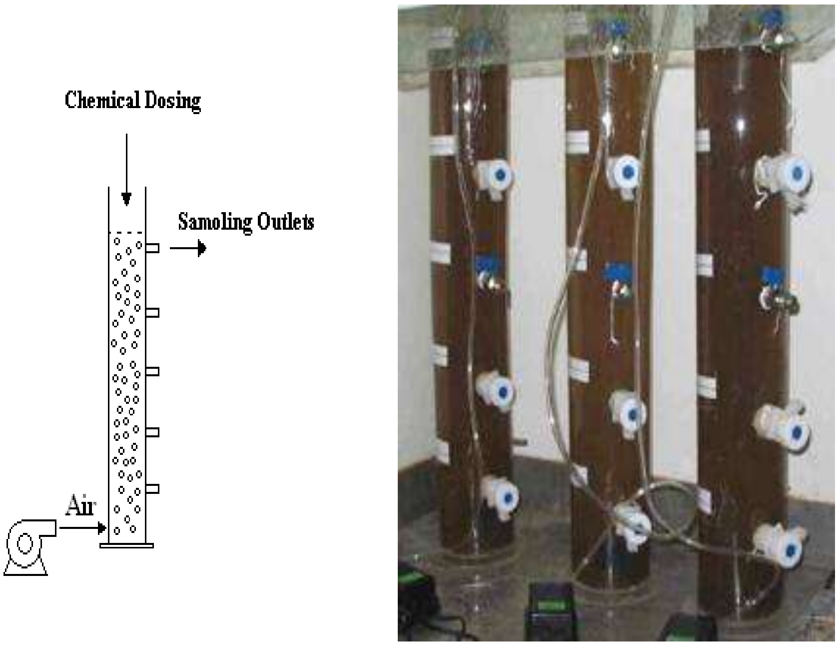

Figure 1 Schematic Diagram of the MBBR and the Reactors used in the Study

Figure 2 Biofilm carriers used in experiments

Table 1 Characteristic data for carrier used

Material	Polyethylene
Density (g/cm^3)	0.95
Shape	Corrugated cylinder
Length (mm)	120-150
Diameter (mm)	120
Specific Surface (m^2/m^3)	120
Filling Ratio (%)	70 %

Results and Discussion

After 20 days of starting up the reactor with sludge obtained from Ekbatan wastewater treatment plant as seed, solution of glucose and wastewater compound with COD of 1000 mg/l with different concentrations was used. In the adaptation step, the amount of Organic Loading Rate (OLR) was being increased stepwise within 60 days. In the beginning, the COD removal rate was very low but after 4 months of the study, it reached to 50%.

Detention Time Effect on COD Removal

During the study, the effect of different retention times was studied for each reactor. COD removal efficiency has measured after 24, 48 and 72 hr for every step increase in COD. At low phenol concentration (from 700 to 1000 mg/l) maximum efficiency was obtained. By further increasing in COD loading up to 3000 mg/l, a decrease in COD removal rate was occurred. Figure 3 indicates the removal rate for different COD and detention times.

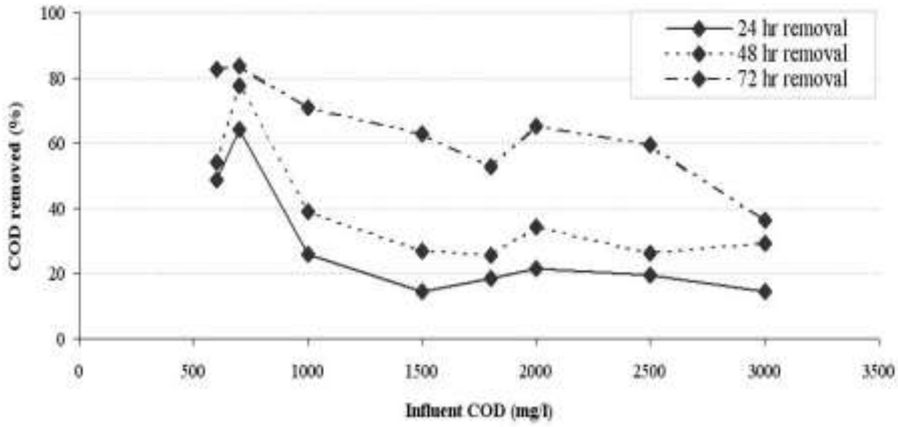

Figure 3 Variation of organic loading rate and COD removal for Phenol wastewater in different detention times

Comparing filling ratio effect on system efficiency

At the end of the study, the effect of packing amount with 50 and 30 percent filling ratios on efficiency were investigated. As an example, the results for COD of 2500 mg/L are given in figure 4. More efficiency for ratio of 30 and 50% can be related for more adaptation as it can be seen that 30% filling ration have proper removal.

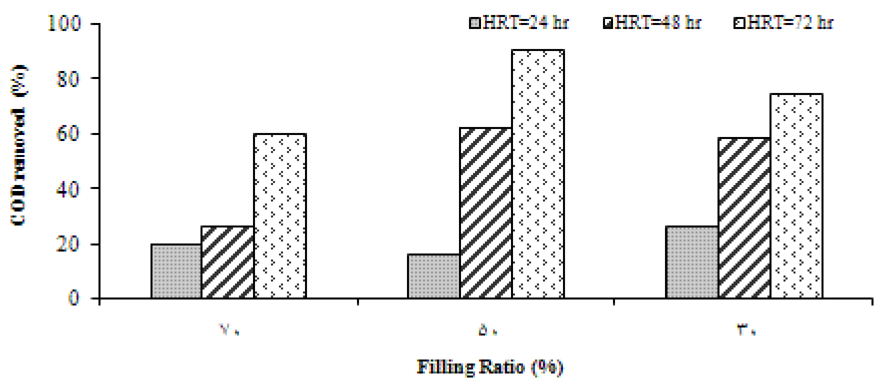

Figure 4 Phenol removal in different filling ratio (COD=2500 mg/L)

Attached microorganisms role in wastewater treatment

To investigate the role of suspended and attached microorganisms in wastewater treatment, phenol wastewater was slightly discharged from the reactors to minimize separation of attached microorganisms from the packing. Then the system was feeded with wastewater (COD 2000 mg/L). Results of this step showed that 80 percent removal efficiency were obtained after 72 hours. The removal difference between the previous experiments and this step was neglected that means suspended microorganisms had not main effect on COD removal.

Conclusion

Based on the experimental results obtained from pilot units testing the MBBR process behavior, it can be concluded that detention time as an operating parameter influenced COD removal efficiency and removal was improved with increasing retention time. This observed more obviously when influent COD increased and inhibitory of phenolic compound affect the biodegradation.

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