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# Application-Economical Investigation of various Bioreactors for Removal of Air Pollutants

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## Abstract

*In recent years, due to increase of industries activities and industrial technologies, air pollution has a significant increase. As you know, daily growth of industrial factories next to cities, along with other air pollutant agents such as vehicles, led to increase of air pollutants emissions. By considering this condition in issue of air pollution due to industrial activities, it is reasonable to take fundamental decisions for air purification by selecting appropriate and economical methods and prevent the entry of pollutants into the air as possible. One of air purification tools in the field of industry and other sections such as treatment of emissions from composting units and wastewater treatment plants, are biofilters. Basically biofelters are used for treatment of gases containing odor compounds and other volatile organic compounds. The aim of this study is assessment and investigation of biofilters as one of air purification method compared with other methods, in order to apply more useful and economical option among so many different tools. In this research, biofilters were compared with adsorption and catalytic oxidation methods in terms of application and economical and initial investment costs was determined, and based on the results of the study, the advantages of biofilters relative to other methods was determined. Also, biofilters were investigated in terms of improvement of efficiency and applicability in various industries.*

**Keywords:** Air purification, biofilter, adsorption, air pollution, catalytic oxidation.

## Introduction

It is more than half a century that Europeans have started using bioreactors for purification of polluted air. Especially for purification of emissions from wastewater treatment plants, composting units, abattoirs and... Which containing odor and VOC compounds. One of the most common types of bioreactors are biofilters. Basically biofilters containing odor and other volatile organic compounds[1]. Application of biofilters is economical and it doesn't have any harmful environmental effects. By considering the characteristics of gas which should be treated, economical issues and required level of purification required for various types of biofilter will be determined.

## Biological Reactions

By using bacteria to consume pollutants, treatment of polluted air flow is done in the biofilters by means of a bed or environment which is usually a natural organic matter [2]. These beds can provide the required nutrients for microorganisms. Burning of any fuel produces nitrogen oxides, fine particles, sulfur dioxide and carbon monoxide, while water and carbon are the products of biological reactions[3,4].

So, biological methods are not suitable when polluted gases containing high concentrations of volatile, valuable and recyclable compounds. Figure 1 shows a magnified cross section of biofilter which clearly describes the mechanism of VOC removal.

**Schematic of odor removal by biofilter:** Biofilters are able to remove odor from gases according to figure 2 and described mechanism. Polluted air is passed within the biofilter filled by media from the bottom-up. The function of the system is so that water enters into the biofilter from top and generated moisture creates a biofilm layer, and finally passing of gas is associated with odor removal along with occurrence of interactions.

**Bed material:** Bed material has a significant role in removal mechanism of bioreactors. Various types of these materials according to their nutrition, can be an important source of nutrition for microorganisms[5]. There are aromatic and aliphatic volatile organic compounds in entrance air flow into the biofilters that according to tables 1 and 2, allocate different removal capacity to itself through passing from different materials of the bed.

**Research and studies:** Normally there are some parameters in bioreactors like other systems that influence on system performance. According to table 3, variables that have an impact on bioreactors performance are temperature, moisture, care and feeding, pH, and microbial populations.

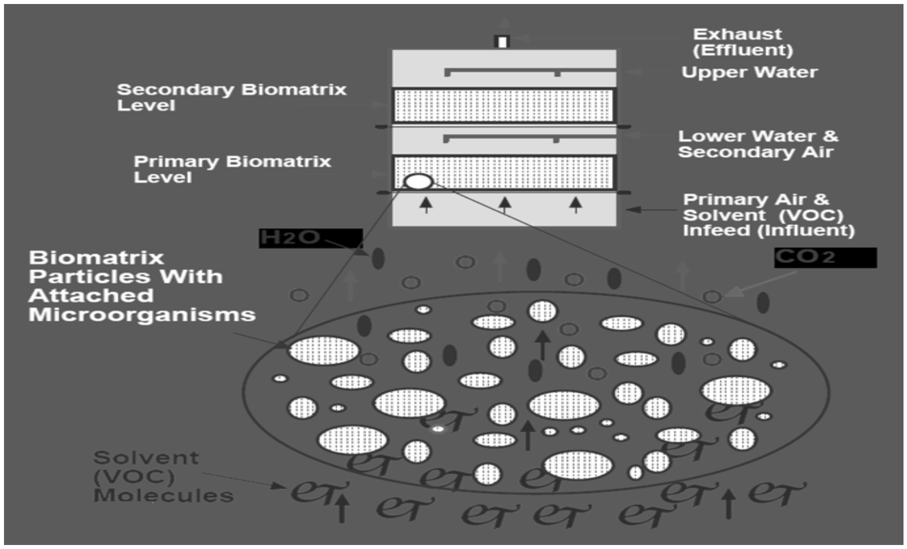


**Figure-1**
**VOC removal by biofilter**

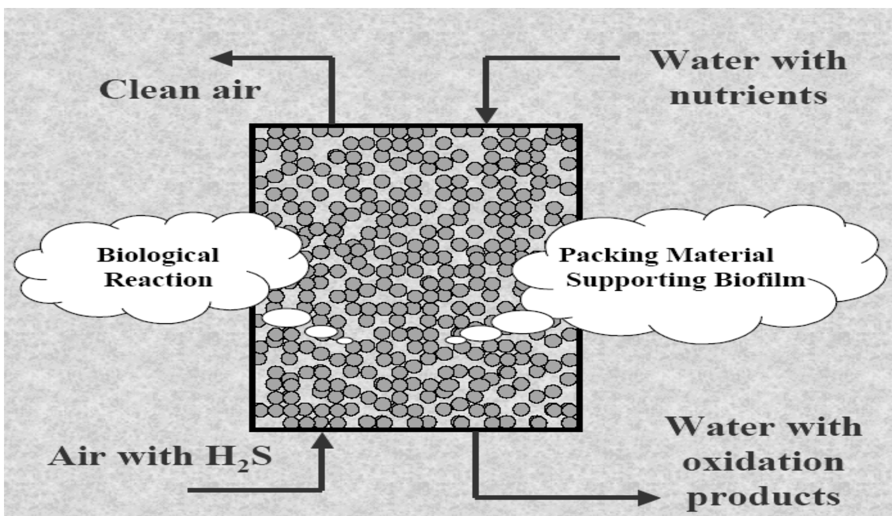


**Figure-2**
**Odor removal by biofilter**

**Table-1**
**Removal of aromatic volatile organic compounds from polluted air**

| Bed | Compounds/microorganism | Removal capacity |
|---|---|---|
| Soil | BTEX/intercropping | 5 |
| mixture of peat and compost | TX/ intercropping | 40 |
| Compost | Xylene and Toluene | 20 and 20 |
| Mixture of compost and activated carbon | Toluene | 44 |
| Mixture of compost and bark | Styrene | 120 |
| Mixture of peat and glass beads of pearl stone (2 to 1) | Phenol/TEX/ intercropping | 70 |

**Tables-2**
**Removal of aliphatic volatile organic compounds from polluted air**

| Bed | Compounds/microorganism | Removal capacity |
|---|---|---|
| activated carbon | Ethanol/intercropping | 53-219 |
| peat and pearl stone (2/3) | Methanol/mixture of bacteria | 112/8 |
| Mixture of compost and pearl stone | DCM/ mixture of bacteria and fungi | - |
| Mixture of compost and peat and additives | Ethyl acetate/ intercropping | 36 |
| Mixture of compost and bark | Ethyl acetate/ intercropping | 175 |
| Mixture of compost and limestone | Methyl ethyl ketone | 39/8 |
| bark | Butane/intercropping | 90 |

**Table-3**
**Influential variables on biofilter performance**

| | |
|---|---|
| **Temperature** | It is the most important parameter that affect on the performance of biofilters (influence on growth and living of microorganisms) If the gas is too hot, it will pass through a moisturizer, and if the gas is too cold, it must be heated to increase the performance. |
| **Moisture** | Microorganisms need moisture to survive. Moisture creates a biofilm that remove pollutants from gas stream and makes them available for microorganisms. Optimum moisture of bed must be around 40 to 60 %. |
| **Care and feeding** | Essential Nutrients for growth and activity of microorganisms are nitrogen, phosphor, potassium and also low values of sulphur, magnesium, calcium, sodium and iron. Nitrogen, phosphor and potassium can be supplied by adding manure into the bed environment . |
| **pH** | Most of the bioreactors have the best performance at pH around 7. |
| **microbial populations** | It can be determined in the laboratory that which microbial species has the best performance for a particular pollutant. Then, the bed can be inoculated with that particular species . |

In this study, the biofilters have been investigated in terms of modification and improvement of efficiency, economic benefits and elimination of pollutants in various industries and other advantages and disadvantages of the system. Like other systems, biofilters have some disadvantages, so that their modification can affect on inefficiency and cost of the system[6,7,8].

## Modification and improvement of efficiency in biofilters

**Recirculation in biofilter system:** One method of biofilter modification is creation of recirculation system. According to figure 3, recirculating a portion of output into the biofilter can led to increase of contact time between gas and bacteria. Increase of contact time will lead to better air purification and removal of contaminants[9].

**Linearization of biofilters:** Another method that can increase the contaminants removal efficiency of biofilters is placing some biofilters in series, according to figure 4. Linearization of biofilters for improvement of efficiency can be done in two ways of horizontal or vertical (if land is not available). It should be mentioned that implementation of this method requires a lot of land.

**Economical benefits:** Usually, economic cost and investment should be assessed before application of any system in various activities, to select the best option in terms of economical benefits[10,11]. In the previously done studies, a comparison between three systems of adsorption, catalytic oxidation and biofilter was done and their results are presented in table 5. These study was conducted according to the criteria of air flow rate and the results show that the initial investment cost against the flow rate in biofilters is less and economical than adsorption, catalytic oxidation. So that any increase of inlet air flow rate into the system increases the investment cost of various methods according to their increased efficiency, and this value in biofilter is less than other methods.

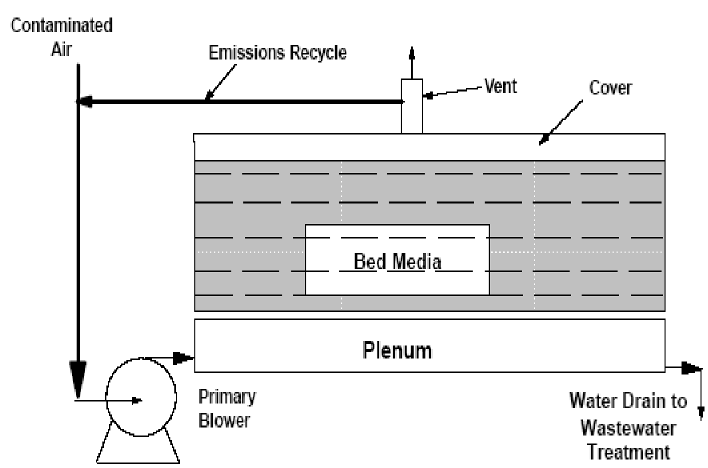


**Figure-3**
**Recirculation in biofilter**

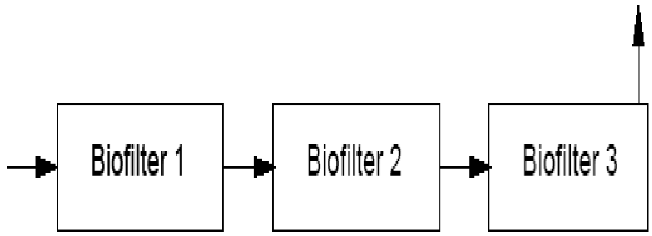


**Figure-4**
**Linearization of biofilters**

**Applications of biofilters in various industries and amount of contaminant removal:** Along with other air purification systems, biofilters are applicable in various industries. According to studies, this result is obtained that biofilters have different contaminates removal efficiency in various industries, which is depends on the type of removed contaminant and its concentration[12,13]. It should be mentioned that the inlet air flow rate into the biofilter is different in various studies (table 4).

## Advantages and disadvantages of biofilters

**Advantages of biofilters:** The benefits of this system are low cost of construction and installation, low cost of operation and maintenance according to the required amount of pre-treatment, being ideal system for purification of gases containing low concentrations of contaminants and high volume, no need to fuel[14-16], and no need for chemical additives.

## Disadvantages of biofilters

Disadvantages of this system are: i. its traditional designs requires high-field, ii. inlet flow of adjusting pH or adding nutrients is discontinuous, iii. its traditional designs have no caps, which result in some problems in sampling from output flow and determination of removal efficiency, iv. depending on the performance, the substrate material should be replaced after each period of 2 to 5 years. According to previous studies, two methods of recirculation and linearization of biofilters are mentioned to eliminate these disadvantages.

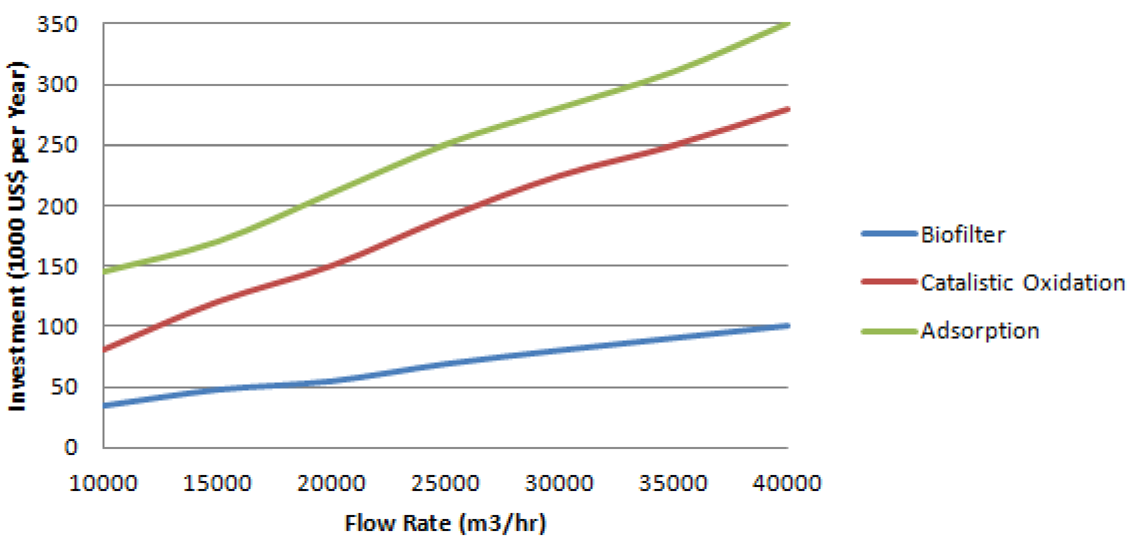


**Figure-5**
**Comparison of investment cost in three methods**

**Table-4**
**Application of biofilters in various industries**

| Industry | Gas flow rate ($m^3$/hr) | Type of removed contaminant | Concentration of material(mgr/$m^3$) | Efficiency |
|---|---|---|---|---|
| Gelatine production | 35000 | Odorous gas | - | 70-93 |
| Chocolate and cacao production | 10000 | Odorous gas | - | 99 |
| Fish meal production factory | 40000 | Odorous gas | 230 | 50-90 |
| Tobacco production factory | 30000 | Odorous gas, Nicotine | 3.5 | 95 |
| Wastewater treatment plant | 10000 | Odorous gas | 10 | 90-95 |
| dye works | 11700 | Solvent | 1800 | 90 |
| Film production | 140000 | Organic solvents | 400 | 75 |
| Iron foundry | 40000 | Benzene | 9 | 80 |

## Conclusion

The results of the study showed that some systems are enhanced for better performance and higher efficiency of biofilters. In this regard, conventional biofilter is enhanced to trickling biofilter, bioscrubbers and other supplementary systems.

Trickling biofilter: This is a form of enhanced biofilter (figure 6) to overcome the problem of acid accumulation. Trickling biofilter is very similar to trickling filter, except that inlet contaminants into trickling biofilter are in the gas phase. Contaminants should be resolved in the liquid phase to be prepared for microbes. Because of continuity of the liquid flow, formed acids are neutralized spontaneously. And additional biological mass is removed and disposed from reservoir at certain intervals.

Bioscrubber: Bioscrubbers are used to solve two problems in trickling biofilter: i. increase of contaminants uptake in liquid, ii. increase the time in which microbes consumes the contaminants through the submerging of bed in the liquid phase which led to increase of contaminants uptake capability (figure 7), because when gas is in contact with bed, fine bubbles formed which increases the interface between the gas and liquid. Also, to increase the contact time, the output of scrubbers is collected in an reservoir (collector wells) before recirculation. Collector wells act as a storage for the liquid phase and provides additional times for microbes to consume the contaminants. Depending upon the recirculation rate of liquid phase and size of collector wells, this time can be added for a hour or more. In biosrubbers, wetting of polluted gas before purification is not necessary. This issue can cause to save the installation costs of moisturizer. Bioscrubbers requires less space than other types of bioreactors. This is an important issue that we can concentrate the facilities in a limited space and also make them available. Since monitoring of pH and nutrients can be done automatically, so bioscrubbers need less maintenance than other types of bioreactors and this process is ideal for gas emissions during the acid treatment, because acid exits as a liquid stream. bioscrubbers are able to purify the contaminated gases containing fine particulates.

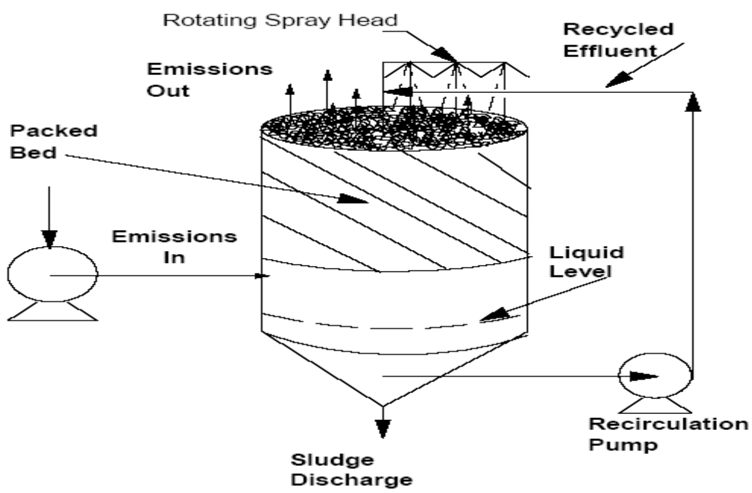


**Figure-6**
**Trickling biofilter**

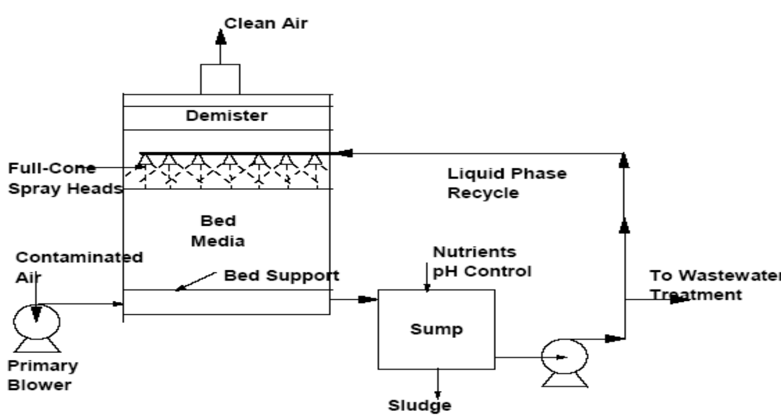


**Figure-7**
**Bio scrubber**

Comparison of biofilter method with other enhanced methods: Based on the results of this study, the differences between the characteristics of three technologies of biofilter, bioscrubber and trickling filter is investigated and presented according to the table 5. The difference between these three methods is on the presence or absence of carrier material and mobile phase. Also in biorector method unlike two other methods, there is not any carrier and active live mass isdispursed.

**Table-5**
**Comparison of biofilter method and other enhanced methods**

| Reactor | Carrier | Mobile Phase | Active Biomass |
|---|---|---|---|
| bioscrubber | - | Liquid & GAS | Dispersed |
| Trickling biofilter | Synthetic | Liquid & GAS | Fixed |
| biofilter | Organic Synthetic | Gas | Fixed |

To purify the contaminated gases, at first, the need for pretreatment must be investigated according to the characteristics of considered gas. If considered gas is too hot or cold, acidic or very contaminated, proper pretreatment should be performed on it to be suitable to entry into the biofilter. Then, according to the economical issues and level of required purification, proper option of gas treatment by using biofilter should be selected. If gas flow containing pollutants that produce acid, trickling biofilter or scrubbers can be suitable methods of purification. While if gas stream doesn't produce acid and enough space be available, conventional biofilter can be used. Also, in the cases that high efficiency of removal is required, bioscrubber is an appropriate option. Although there is a liquious mobile phase in trickling filters, but biofilter system should be kept wet, because there is not liquious mobile phase in it. Application of these methods is more economic than common methods of controlling of air pollutants and contaminants removal rate will be more than 95% if operations be carried out effectively. Head lost in treatment units before and after biofilter can lead to high pressure differences and may units that work with negetive pressure be crumbled due to high vacuum. The experience showed that filter efficiency increases if the particles being charged before entry into the filter, this issue lead to production of hybrid devices of filter-electrostatic.

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