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RESEARCH ARTICLE

BIOLOGICAL METHODS FOR REMOVAL OF VOCS FROM AIR EMISSIONS OF CHEMICAL PROCESS INDUSRIES

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ABSTRACT

Air pollution became a real problem with industrial revolution. Today over two billion pounds of pollutants are released to the atmosphere each year. This paper focuses on different bio-technologies, which can be used to reduce the emissions of volatile organic compounds to the atmosphere from chemical process industries. The term volatile refers to the tendency of a compound to evaporate. By definition VOCs are emitted from a myriad of chemical industrial processes. As a consequence of the 1990 clean air act amendments more and more industries are being required to reduce their voc emissions. The control of emissions of VOCs has been a very prominent environmental issue. In the 1990s and will continue into the 21st century. There are different techniques are available to remove the VOCs from the air stream which is generated during various chemical process. Focus of this paper is on the various biological application for the removal of the VOCs from the air emission of process industries. This paper covers the most effective biological activities bio filtration, bio trickling filter and bio scrubber. Main emphasis has been given to their background, selection criteria, process description, its advantages as well as its limitations.

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INTRODUCTION

In the 21st century life become very modern and fast with the technologies developed. Due to the modernization and due to the population growth the industrial revolution the air pollution become a serious issue nowadays. There are so many contaminants plays very important role in the air pollution Volatile Organic Compound is the one of the compound which is considered as a pollutant. Large quantities of volatile and semi volatile compounds are emitted into the atmosphere because of both natural and anthropogenic activities.

Definition of VOC (http://www.npi.gov.au/index.html)

Any chemical compound based on carbon chains or rings (and also containing hydrogen) with a vapour pressure greater than 2mm of mercury (0.27 KPa) at 25°C, excluding methane. These compounds may contain oxygen, nitrogen and other elements. Substances that are specifically excluded are carbon dioxide, carbon monoxide, carbonic acid, carbonates salts, metallic carbides and methane.

Volatile organic compounds (VOCs) include mainly,

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- Chlorinated solvents
- Fuel components

Sources of Emission (http://www.npi.gov.au/index.html)

- Chemical Industry sources
- Diffuse sources, and process industry sources (included in diffuse emissions data)
- Consumer products which may contain TVOCs
- Transport sources
- Natural sources

VOC Recovery Technologies

Several different air pollution control technologies can be applied to sources of organic air emissions (once they are covered, enclosed, or vented) to recover or destroy the pollutants. In general, application of a particular Technology depends more on the emission (gas) stream under consideration than on the particular source type. A key stream characteristic that affects the applicability of a particular control technology is the concentration of organics in the gas stream.

The Proper Selection Depends On Various Factors

- Kinds of solvents

- Composition of solvents
- Solvent concentration
- Air flow rate
- Solvent price and Energy cost
- Local conditions and production mode

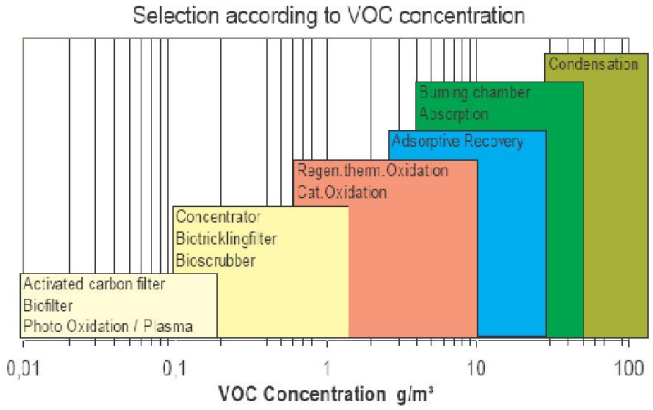

Fig. 1. Schematic for Gross Guidelines for the Selection of the Technique (Wang and Pereird)

Biological Techniques for the Removal of VOCS

Over the past three decades, there has been a rapid maturing and expansion of the use of biological techniques for the control of air pollution generated via various sources. A wide range of VOCs can be very effectively controlled using biofilters and bio trickling filters. The success of biological techniques for air pollution control can be attributed to several reasons:

- Bio treatment of gases works well, it is often very cost effective even at low concentrations of pollutants,
- Biological treatment does not require high temperatures, it does not generate secondary pollutants such as NOx, particulate matter, spent activated carbon, or additional CO_2,
- Bio treatment of gases is energy efficient and does not require additional fossil fuel,
- Bio treatment of gases is environmental friendly and is well perceived by the general public.

Compared to the traditional VOC removal technologies bio technologies are more reliable and cheap. More importantly, biodegradable VOCs can be degraded to non hazardous products such as carbon dioxide and water without the generation of other secondary waste. This biological degradation process occurs by oxidation, and can be written as follows:

$$Organic\ Pollutant + O_2 \Rightarrow CO_2 + H_2O + Heat + Biomass$$

Following techniques are most effective biotechnology for the removal of VOCs.

Biofiltration

Biofiltration is a relatively new pollution control technology. It is an attractive technique for the elimination of malodorous gas emissions and of low concentrations of volatile organic compounds (VOCs).

Process Description

The most common style biofilter is just a big box. A bio filter's main function is to bring microorganisms into contact with pollutants contained in an air stream. The box that makes up this biofilter contains a filter material, which is the breeding ground for the microorganisms. The microorganisms live in a thin layer of moisture, the "biofilm", which surrounds the particles that make up the filter media. During the biofiltration process, the polluted air stream is slowly pumped through the biofilter and the pollutants are absorbed into the filter media. The contaminated gas is diffused in the biofilter and adsorbed onto the biofilm. This gives microorganisms the opportunity to degrade the pollutants and to produce energy and metabolic byproducts in the form of CO_2 and H_2O.

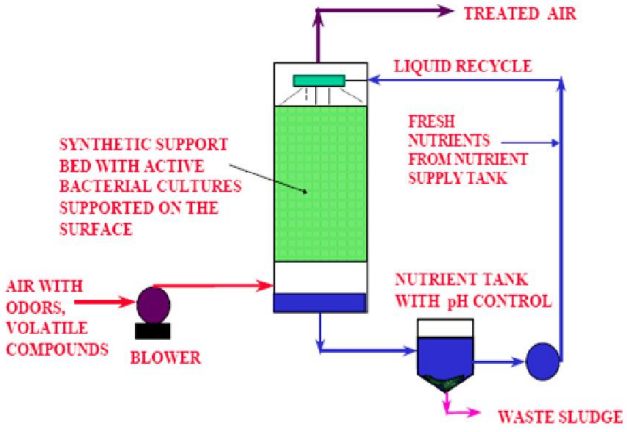

Fig. 2. Schematic Representation of Biofiltration (Govind)

Biofilter Media (Govind)

Major considerations when determining the appropriate filter material include:

- Ability to retain moisture to sustain bio film layer;
- Large surface area, both for contaminant absorption and microbial growth;
- Ability to retain nutrients and supply them to microbes as required;
- Low resistance to air flow (minimizes pressure drop and blower power requirements);
- Physical characteristics, such as physical stability and ease of handling

Types of Biofilter Support Media (Devinny and Govind)

Support media used in biofilters are classified into two major groups:

- Natural media
- Synthetic media

The Desired Features of a Good Support Media Are As Follows (Govind)

- High void fraction,
- High surface area per unit volume of the biofilter bed.
- Low gas-phase pressure drop.

- Hydrophilic surface, to allow good water wet ability.
- Low overall density.
- Low cost.

Advantages

- Ambient temperature and pressure technology
- Produces no toxic by products
- Capable of treating both organic and inorganic odorous compounds;
- Does not require handling of corrosive chemicals
- Minimal operating cost, when compared with chemical oxidation and thermal destruction methods
- Robust, and can operate reliably with minimal operator intervention.
- Substantial cost saving
- No emission of by product
- Saves chemical cost
-

Commercial Applications (http://www.rpi.edu/dept/chemeng/BiotechEnviron/MISC/biofilt/biofiltration.html)

VOC applications to date have included the following industries:

- Waste and wastewater treatment
- Soil and Groundwater remediation
- Chemical and petrochemical industry
- Oil and gas industry
- Synthetic resins
- Paint and ink
- Pharmaceutical industry

Bio Trickling Filter (Devinny; Shareefdeen and Singh)

A bio-trickling filter consists of columns filled with packing, on the surface of which a biofilm develops. The packing can be activated carbon, glass or ceramic beads, stoneware rings, and other materials. Nutrient-rich water trickles down from the upper side of the column. Contaminated gas is supplied either co-current or counter current to the water direction. The major difference between bio trickling filters and biofilters is the presence of continuous water flow in the reactor. The water phase carries nutrients for the micro organisms, and is usually neutralized before recirculation, for pH control purposes. Microbial oxidation takes place in the water phase as well as in the immobilized bio films attached on the media particles.

Process Description (Devinny; Shareefdeen and Singh)

Bio trickling filters work in a similar manner to biofilters, except that an aqueous phase is trickled over the packed bed, and that the packing is usually made of some synthetic or inert material, like plastic rings, open pore foam, lava rock, etc. The trickling solution contains essential inorganic nutrients and is usually recycled. Bio trickling filters are more complex than biofilters but are more effective, especially for the treatment of compounds that generate acidic by-products, such as H_2S. They can be built taller than biofilters. Bio trickling filters are more recent than biofilters, and have not yet been fully deployed in industrial applications.

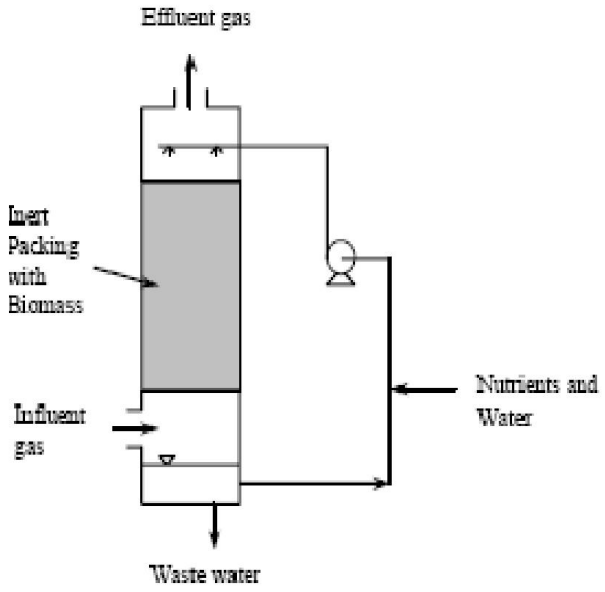

Fig. 3. Schematic Representation of Bio Trickling Filter (Devinny)

Advantages

- Increased operator control over key parameters such a nutrient concentrations and pH, as well as the opportunity to wash degradation by products out of the reactor
- Higher gas velocity
- Minimal gas residence time
- Uniform distribution of gases and water within the media bed
- Rapid response to sharp fluctuations in contaminant loadings
- Ability to treat higher concentrations of H_2S and other odorous compounds
- Biological decomposition of components; no VOCs as rest products
- Applicable for decomposition of acid forming components
- pH control and correction are possible within certain limits
- Low pressure drop
- Average investment- and functioning costs

Applications Include Treatment Of (Devinny; Shareefdeen and Singh)

- Aromatic hydrocarbons – benzenes, toluene, xylenes
- Organics - aldehydes, amines, ketones, alcohols
- Inorganics – hydrogen sulfide, ammonia
- Reduced sulfur compounds - mercaptans, disulfides
- Unidentifiable odor

Bio Scrubber

The bio scrubber is a bioreactor process in which contaminated exhaust air is scrubbed in an absorber with a scrubbing liquid. The discharge effluent from the bio scrubber is collected in an

activation tank (sump) where the absorbed constituents are degraded by micro organisms.

Process Description

Unlike Biofiltration, bio scrubbing is carried out in two successive steps: first, the pollutant to be removed undergoes sorption, second they are degraded. A bio scrubber works like an absorber followed by degradation of the substances to be abated.

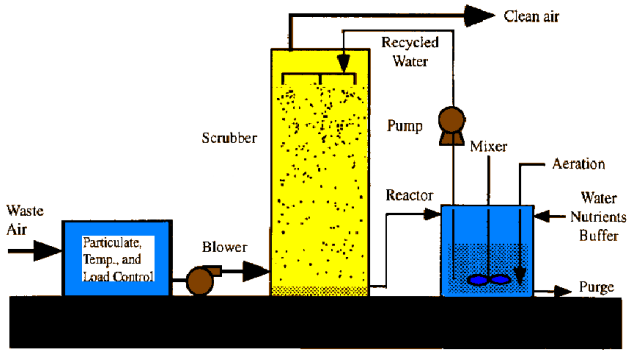

Fig. 4. Schematic Representation of Bio Scrubber (Devinny)

In the absorption stage, the pollutants are taken up by an absorbent. This process is performed in absorber, in which the waste gas to be cleaned is brought into contact with the absorbent. The laden scrubbing liquid is then fed to a reactor containing micro organisms, in which subsequent degradation of the pollutants is performed.

Treatable Compounds (www-dfiu.wiwi.uni-karlsruhe.de/abgeschlossen/ Platform/website/Guidelines/ Abatement/IFARE_bioscrubber.PDF)

The following VOCs and their mixtures can be biologically degraded

- Alcohols: ethanol, iso propanol, methanol
- Phenols,
- Glycols: ethylene glycol
- Glycol ether
- Esters: acetic acid methyl ester
- Ketones: acetone, methyl ketone

Aldehydes: formaldehyde

Advantages (Devinny; Shareefdeen and Singh; www-dfiu.wiwi.uni-karlsruhe.de/abgeschlossen/Platform/website /Guidelines/ Abatement/IFARE_bioscrubber.PDF)

- Smaller equipment volume, which is generally appreciated by the industry even if slightly higher capital and operating costs are involved
- No clogging problems of packing material
- Better process control of nutrient and pH
- Suitable for elimination of eater soluble compounds such as H_2S, SO_2, alcohols, aldehydes, and fatty acids where pH control is important
- Capable of handling large gas flow rates and high pollutant concentration
- More reliable, predictable and stable operation
- Lower concentration of toxic by products generated in the reactor, due to capability of removing reaction products by washing
- Good adaptation capacity of microbial biomass in response to the gas composition

Application (Devinny; Shareefdeen and Singh)

Similarly to the Biofiltration process, bio scrubbing has been implemented mainly for the removal of odors. Nowadays, bio scrubber are applied in,

- Foundries
- Chipboard of animal corpses
- Coating
- Printing industry: flexography and screen printing
- Manufacturing of the printing inks
- Electronics industry

Conclusion

Biotechnology is very cheap and eco friendly for the removal of VOC. All these technologies are ambient temperature and relatively low pressure technologies. They are relatively cost effective and no other chemicals are required. They don't produce any toxic byproducts. But no technologies are ideal technology. Though it is very effective and cost effective there are some limitations are there. Biofiltration cannot successfully treat some organic compounds, which have low adsorption or degradation rates. This is especially true for chlorinated VOCs. Similarly the bio trickling filter cannot handle, such as very high concentrations of pollutants (1,000 parts per million or more). Clogging of the pore surface is the problem during the operation. In case of bio scrubber, requirement to dissolve the gaseous pollutants during the short residence time in the absorption column, therefore, less suitable for less water soluble compounds. These are the main limitations of these bio technologies. The research work is going on to overcome these limitations. Although, biotechnology is the future for the VOC removal technology because of its cost effective and eco friendly solution to the air pollution problem and more and more chemical process industries are moving towards this biotechnical solution to prevent air pollution emission from various process stream.

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