OVERVIEW OF VOC REMOVAL TECHNICS FROM AIR EMISSIONS OF CHEMICAL PROCESS INDUSTRIES

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Abstract: The emission of Volatile Organic Compounds (VOCs) from chemical process industries poses significant environmental and health concerns. This paper provides an overview of various techniques utilized for the removal of VOCs from air emissions in these industries. The methods discussed include adsorption, absorption, catalytic oxidation, thermal oxidation, biological treatment, and membrane separation. Factors influencing the selection of suitable removal techniques, such as VOC concentration, flow rates, cost-effectiveness, and regulatory compliance, are highlighted. The importance of employing efficient VOC removal methods for reducing environmental pollution, complying with regulations, and ensuring improved air quality for communities near industrial sites is emphasized. Overall, this paper serves as a comprehensive guide for understanding the basic of VOC removal techniques in chemical process industries to address emissions and environmental challenges effectively.

Index Terms: **VOCs, VOC removal techniques**

I. INTRODUCTION

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. [17]

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. Selection of applicable control techniques for point source organic emission abatement is made for the most part on the basis of stream specific characteristics and the desired control efficiency.

A key stream characteristic that affects the applicability of a particular control technology is the concentration of organics in the gas stream.[10]

II BASIC PRINCIPLES

In-plant gaseous stream sources (air/nitrogen) are often too numerous for collection and treatment by a central facility/process. In-plant liquid sources are also numerous; however, these streams are usually collected for centralized cleanup.

Additionally, when gaseous streams are treated, aqueous streams are often produced (and vice versa); thus a clear-cut distinction between treatment of gaseous and liquid streams is not always possible.

The proper selection depends on various factors

- ✓ Kinds of solvents (water soluble or low water soluble)
- ✓ Composition of solvents (single component or mixture)
- ✓ Solvent concentration
- ✓ Air flow rate
- ✓ Solvent price
- ✓ Energy cost
- ✓ Local conditions
- ✓ Production mode

Industrial Waste Gas Treatment Technologies

Table 2.1 Industrial Waste Gas Treatment Technologies [10]

physical	chemical	Biological
Condensation Adsorption-Activated Carbon Absorption Membrane Technology	Chemical Scrubber Thermal Oxidation Catalytic Oxidation Ozonation UV Oxidation	Biofilter Biotrickling Filter Bioscrubber Activated Sludge Reactor Membrane Bioreactor

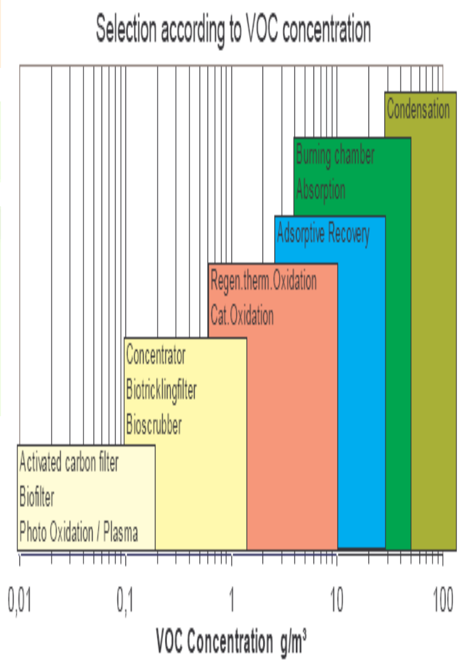

Figure 1 Schematic for Gross Guidelines For The Selection Of The Technique[10]

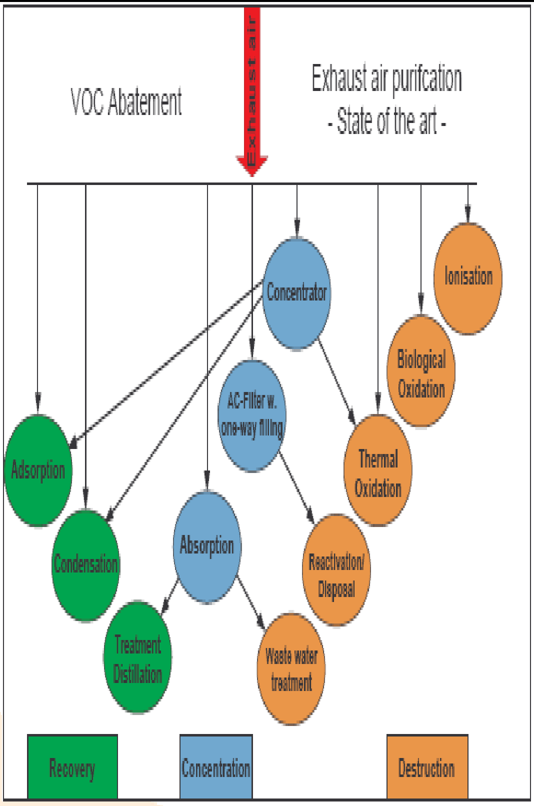

Figure 2 Different state of the art VOC abatement systems for exhaust air purification[10]

CONTROL TECHNIQUES FOR VAPOR-PHASE SYSTEMS [10]:

Gas-phase VOC recovery is typically accomplished using phase change processes (e.g., distillation or condensation) or mass separating agent-based processes, including equilibrium based processes (e.g., adsorption, absorption, and membrane-based absorption) and rate governed membrane processes (e.g., vapor permeation). Generally, however, most processes are hybrid processes, consisting of at least two separation techniques

1. Adsorption and Regeneration Processes: –

Activated carbon, synthetic resin beads (styrene divinyl benzene polymers), zeolite, and aerogels (which are regenerable at 50°C) are among the different types of adsorbents available for VOC recovery Furthermore, activated carbon has poor stability, humidity control problems, and is chemically reactive with certain contaminants (e.g., causing bed fires from ketones, aldehydes, etc.). When adsorption is used for VOC removal, the adsorbent can be regenerated using thermal regeneration, pressure swing adsorption (PSA), or with purge gas. A variety of thermal regeneration processes are available, including steam, hot nitrogen 1450 degrees Fahrenheit, microwave, infrared (for fixed beds), rotary wheels (for traveling beds), and fluidized beds.

2. Fluidized Bed Systems:-

This process utilizes a separate adsorber and desorber and a highly abrasion resistant, macro porous, polymeric pellet called Bonopore. During operation, particles are pneumatically transported from the adsorber to the, desorber, where they are regenerated using steam-heated, air-based desorption. The recovered VOCs are condensed using cooling water.

These units typically treat 35,000 cubic meters per hour (m^3/hr) vapor streams, but have a 500 to 500,000 m^3/hr range. Additionally, special hydrophilic adsorbents can be used for streams containing water vapor for adsorbing formaldehyde

3. Absorption: -

Absorption processes should be selected based on the characteristics of the VOCs to be treated. Since water can act as an absorbent as long as an azeotrope is not formed, conventional towers should be used to treat hydrophilic VOCs. If hydrophobic VOCs requires treatment, membrane-based absorption and stripping using heavy hydrocarbon absorbents is probably appropriate.

4. Condensation:-

In condensation process gaseous contaminants are removed from a gas stream by causing them to change to a liquid. The ultimate efficiency of a condenser depends on the operating temperature. The condensation system generally operates at efficiencies greater than 90 percent.

5. Aqueous-Phase Systems:-

Aqueous-phase VOC recovery is typically accomplished using phase change processes, filtration processes, or mass separating agent-based processes. Appropriate mass separating agent based processes include equilibrium-based processes (e.g., adsorption and stripping) and rate governed membrane processes (e.g., pervaporation). Like gas phase systems, most processes are generally hybrid processes, consisting of at least two separation techniques. An aqueous VOC recovery which employed a combination of several processes like stripping, adsorption, etc.

5.1 Stripping

Air stripping is a full-scale technology in which volatile organics are partitioned from ground water by greatly increasing the surface area of the contaminated water exposed to air. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.

5.2 Pervaporation

Pervaporation processes are also used to remove organics from aqueous streams. This process is used to separate VOCs from the water. Surfactant enhanced aquifer remediation for surfactant recovery can also be employed during soil remediation.

5.3. Hybrid Process –

A Variety of hybrid processes can be used for wastewater treatment including:

1. Air-stripping followed by activated carbon adsorption of the stripping air;
2. Steam-stripping followed by condensation;
3. Activated carbon adsorption followed by steam-stripping; and
4. Solvent extraction followed by distillation.

Additionally, wastewater from stream-stripping can be treated by reverse osmosis and concentrated for recovery by Pervaporation.

III NEW APPLICATIONS OF EXISTING TECHNOLOGY

1. Membrane Separation –

During membrane separation, contaminants are recovered from waste process streams using permeable membranes. Membrane separation has been used in the past for water quality management and has recently been used for air management, particularly VOC recovery. Membrane separation is used to recover compounds that are not efficiently recovered using adsorption and condensation, Membrane separation is increasingly being used for halogenated solvents and is a good alternative for recovering expensive solvents.

2. Photochemical Destruction Technologies –

Photochemical destruction technologies destroy VOCs using UV radiation and oxidants. In general, this technology has limited commercial application.

3. Biological Techniques

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. A wide range of VOCs can be very effectively controlled using biofilters and biotrickling filters.

The success of biological techniques for air pollution control can be attributed to several reasons:

- ✓ Biotreatment 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,
- ✓ Biotreatment of gases is energy efficient and does not require additional fossil fuel,
- ✓ Biotreatment of gases is environmental friendly and is well perceived by the general public.

a. Biofiltration

Biofiltration has been used frequently in Europe for odor control and is currently expanding into a number of other areas. During Biofiltration, VOCs are destroyed in biologically active filter beds. The technology has a 50% success rate for sustained operation and some success with gasoline and benzene, toluene, and xylenes (BTX) vapor streams. It also has low operating costs and energy usage.

b. Bio Scrubbing

A bioscrubber consists of two reactors. The first part is an absorption tower, where pollutants are absorbed in a liquid phase. This liquid phase goes to a second reactor, which is a kind of activated sludge unit. In the latter, microorganisms growing in suspended flocs in the water, degrade the pollutants. The effluent of this unit is recirculated over the absorption tower in a co- or countercurrent way to the flow of the waste gas.

c. Bio Trickling Filters

A biotrickling filter is very similar to a biofilter. In this case, pollutants are also transferred from the gas phase to a biofilm, which grows on a packing material. However, the packing materials are made of chemical inert materials, such as plastic rings. Because nutrients are not available in these materials, they have to be supplied to the microorganisms by recirculating a liquid phase through the reactor in co- or countercurrent flow.

IV SUMMARY

Various Volatile Organic Compounds (VOCs) are emitted into the atmosphere from chemical process industries, contributing to air pollution and environmental degradation. To mitigate these emissions, several techniques are employed in the removal of VOCs from industrial air emissions.

Each VOC removal technique has its advantages and limitations, and the selection of the appropriate method depends on various factors such as VOC concentration, flow rate, cost-effectiveness, and regulatory compliance. Often, a combination of these techniques may be employed in a treatment train to achieve optimal VOC removal efficiency.

Implementing effective VOC removal techniques is crucial not only for regulatory compliance but also for reducing environmental impact and ensuring cleaner air for communities surrounding chemical process industries. Ongoing research and advancements continue to improve these methods to make them more efficient, cost-effective, and environmentally friendly.

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