AIR POLLUTION CONTROL USING MEMBRANE TECHNIQUE: A REVIEW

[*1]Vanam Sudhakar, [2]Dr.Anil Kumar Kastala, [3]G.Shalini
[1,3]Project Assistant, [2]Assistant Professor
[1,3]Indian Institute of Chemical Technology, Hyderabad, India.
[2]Lords Institute of Engineering& Technology, Hyderabad, India.

Abstract*—*The state of the art of application of membrane techniques for air cleaning is presented. The most characteristic parameters of membrane separation of gases and vapours are described. Air pollution is most often affected by the emission of pollution generated by industry, power plants, vehicles emission, and agricultural and municipal waste VOCs are one of the main sources of photochemical reaction in the atmosphere leading to various environmental hazards; on the other hand, these VOCs have good commercial value. Growing environmental awareness has put up stringent regulations to control the VOCs emissions. In such circumstances, it becomes mandatory for each VOCs emitting industry or facility to opt for proper VOCs control measures. There are many techniques available to control VOCs emission (destruction based and recovery based) with many advantages and limitations. Therefore, deciding on a particular technique becomes a difficult task. This article illustrates various available options for VOCs control. The authors hope that this article will help in critically analysing the requirements and accordingly decide on the appropriate strategy to control VOCs.Separation of gases and vapours has been applied practically in the industry for the following areas: removal of volatile organics from the air and from industrial waste flows, oxygen enrichment of air and vice versa and the membrane absorption process.

Keywords--Air Pollution, Membrane Absorption, Gas Separation.

1. INTRODUCTION

Air pollution in India is quite a serious issue with the major sources being fuel wood and biomass burning, fuel adulteration, vehicle emission and traffic congestion [1]. In summer and winter months, large scale crop residue burning in agriculture fields – a low cost alternative to mechanical tilling is a major source of smoke, smog and particulate pollution [2- 4]. India has low per capita emissions of greenhouse gases but the country as a whole is the third largest after China and the United States [5]. In 2013 study on non-smokers has found that Indians have 30% lower lung function compared to Europeans [6].The Air (Prevention and Control of Pollution) Act was passed in 1981 to regulate air pollution and there have been some measurable improvements. However, the 2016 Environmental Performance Index ranked India 141 out of 180 countries [7].In 2015, Government of India, together with IIT Kanpur launched the National Air Quality Index [8]. Pollution is exceptionally hazardous when it involves the emission of so-called acid gases (SO_2, NO_X) and volatile organic compounds, mainly halogen-derived hydrocarbons and aromatic compounds which destroy the ozone layer and contribute to the creation of the greenhouse effect. The removal of volatile organic compounds can be carried out with the recovery of solvent or without it, although from environmental and economic viewpoints, the second solution is favoured. Another problem connected with pollution of the atmosphere is the generation of vast volumes of gases, which contributes to the creation of the greenhouse effect - carbon dioxide while burning carbon-derived fuels and simultaneous emission of methane and carbon dioxide from solid waste dumps. With respect to the latter case, it seems to be beneficial to recover methane since it is a valuable source of energy [9, 10] and is characterized by higher global greenhouse factor than carbon dioxide.In the 1980s the application of the membrane technique was initiated on an industrial scale for the treatment of gases. In this project work the accent will be on the objectives of atmospheric pollution control by pollution control device.

1.1. Air Pollutants

Air pollution is the introduction of harmful substances including particulates and biological molecules into Earth's atmosphere. It may cause diseases, allergies or death in humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution. Indoor air pollution and poor urban air quality are listed as two of the world’s worst toxic pollution problems in the 2008 Blacksmith Institute World's Worst Polluted Places report. According to the 2014 WHO report, air pollution in 2012 caused the deaths of around 7 million people worldwide, an estimate roughly matched by the International Energy Agency.

An air pollutant is a substance in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Primary pollutants are usually produced from a process, such as ash from a volcanic eruption. Other examples include carbon monoxide gas from motor vehicle exhaust, or the sulfur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground level ozone is a prominent example of a secondary pollutant. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

1.2. Major Primary Pollutants Produced By Human Activity Include

Carbon dioxide (CO_2)- This is by far the most emitted form of human caused air pollution. Although CO_2 is currently only about 405 parts per million in earth's atmosphere, billions of metric tons of CO_2 are emitted annually by burning of fossil fuels. CO_2 increase in earth's atmosphere has been accelerating.

Sulfur oxides (SOx) - particularly sulfur dioxide, a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Coal and petroleum often contain sulphur compounds, and their combustion generates sulfur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.

Nitrogen oxides (NOx) - Nitrogen oxides, particularly nitrogen dioxide, are expelled from high temperature combustion, and are also produced during thunderstorms by electric discharge. They can be seen as a brown haze dome above or a plume downwind of cities. Nitrogen dioxide is a chemical compound with the formula NO_2. It is one of several nitrogen oxides. One of the most prominent air pollutants, this reddish-brown toxic gas has a characteristic sharp, biting odor.

Carbon monoxide (CO) - CO is a colorless, odorless, toxic yet non-irritating gas. It is a product of incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.

Volatile organic compounds (VOC) - VOCs are a well-known outdoor air pollutant. They arecategorized as either methane (CH_4) or non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming. Other hydrocarbon VOCs are also significant greenhouse gases because of their role in creating ozone and prolonging the life of methane in the atmosphere. This effect varies depending on local air quality. The aromatic NMVOCs benzene, toluene and xylene are suspected carcinogens and may lead to leukemia with prolonged exposure.
Particulates alternatively referred to as particulate matter (PM), atmospheric particulate matter, orfine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to combined particles and gas. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols. Averaged worldwide, anthropogenic aerosols—those made by human activities—currently account for approximately 10 percent of our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer.

2. POLLUTION SOURCES

There are various locations, activities or factors which are responsible for releasing pollutants into the atmosphere. These sources can be classified into two major categories.

2.1 Anthropogenic (Man-Made) Sources

These are mostly related to the burning of multiple types of fuel. Stationary sources include smoke stacks of power plants, manufacturing factories and waste incinerators, as well as furnaces and other types of fuel-burning heating devices. Indeveloping and poor countries, traditional biomass burning is the major source of air pollutants; traditional biomass includes wood, crop waste and dung Mobile sources include motor vehicles, marine vessels, and aircraft. Controlled burn practices in agriculture and forest management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest. Fumes from paint, hair spray, varnish, aerosol sprays and other solvents Waste deposition in landfills, which generate methane. Methane is highly flammable and may form explosive mixtures with air. Methane is also an asphyxiant and may displace oxygen in an enclosed space. Asphyxia or suffocation may result if the oxygen concentration is reduced to below 19.5% by displacement. Military resources, such as nuclear weapons, toxic gases, germ warfare and rocketry.

2.2 Natural Sources

Dust from natural sources, usually large areas of land with little or no vegetation Methane, emitted by the digestion of food by animals, for example cattle Radon gas from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking. Smoke and carbon monoxide from wildfires Vegetation, in some regions, emits environmentally significant amounts of Volatile organic compounds (VOCs) on warmer days. These VOCs react with primary anthropogenic pollutants specifically, NOx, SO_2, and anthropogenic organic carbon compounds to produce a seasonal haze of secondary pollutants. Black gum, poplar, oak and willow are some examples of vegetation that can produce abundant VOCs. The VOC production from these species result in ozone levels up to eight times higher than the low-impact tree species. Volcanic activity, which produces sulfur, chlorine, and ash particulate.

3. EFFECTS OF AIR POLLUTION

3.1 Health Effects

Air pollution is a significant risk factor for a number of pollution-related diseases and health conditions including respiratory infections, heart disease, COPD,(chronic obstructive pulmonary disease) stroke and lung cancer [2].The health effects caused by air pollution may include difficulty in breathing, wheezing, coughing, asthma and worsening of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency room visits, more hospital admissions and premature death. The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics [11]. The most common sources of air pollution include particulates, ozone, nitrogen dioxide, and sulfur dioxide. Children aged less than five years that live in developing countries are the most vulnerable population in terms of total deaths attributable to indoor and outdoor air pollution [12].

3.2 Agricultural Effects

In India in 2014, it was reported that air pollution by black carbon and ground level ozone had cut crop yields in the most affected areas by almost half in 2011 when compared to 1980 levels [13].

4. APPLICATION OF MEMBRANE ABSORPTION PROCESS

Polymeric membranes have also found a new application possibility as separation surface of two phases. For example two flowing liquids, or flowing gas and liquid can be separated by means of a porous hydrophobic membrane. Since the membrane is porous, the contact between two liquids is possible in for Air Treatment Polymeric membranes spite of the fact that it forms a separating barrier between both phases. In order to separate water phase from gas phase or from another water phase the membrane must have hydrophobic character. Due to the above it is possible to carry out a process similar to extraction, and the absorption of gases with the use of membrane units. By the application of capillary membranes for that purpose we can obtain high phase contact surfaces (over 1000 m^2/m^3). Such compact installations are cheaper than classical absorbers having a contact surface of about 100 m^2/m^3. A membrane can form a permeable barrier between the liquid and gas phase.

When the membrane is porous, gas impurities diffuse through the pores and are absorbed by the liquid passing on itsother side, and in the case of nonporous membrane the impurities dissolve in the material of the membrane and then diffuse through it. The contact surface between gas phase and liquid phase depends solely on the type of membrane, and not on the flux volume of flowing media. Absorption in the liquid phase can be effected by physical separation or chemical reaction, and the separation selectivity only depends on the type of absorbent. With the application of capillary modules, very efficient contactors of the gas-liquid type can be constructed. Most of the absorbents applied in the conventional absorption process can be also used in membrane absorbers. During the utilization of membrane gas absorbers it must be ensured that the liquid phase is not mixed with the gas phase. This means that with respect to porous membranes, the absorption liquid should not be allowed to penetrate inside the pores. It depends on the size of pores, pressure difference on both sides of membrane and the affinity of absorption liquid with the membrane material, and it is connected with the wet ability in the system solid body (membrane) liquid.

Membrane pores do not get wet when the wetting angle is higher than 90 and pressure difference on both sides of the membrane is limited by the size of pores. For water absorption liquids there are suitable membrane materials such as polypropylene and Teflon. Since surface tension is decreasing along with temperature, the breakthrough pressure decreases along with the increase of temperature. For nonporous membranes, the permeation of liquid depends on pressure difference and affinity between polymer and absorption liquid since the liquid must first of all penetrate the inside of the matrix. When there are fast chemical reactions taking place in the presence of membranes, the transport of matter is limited by diffusion stage in gas phase and therefore it depends on hydrodynamic conditions over the membrane surface, its properties (porosity, thickness, morphology) and transport properties. The values of mass transfer coefficient in such conditions range from 0.001 to 0.1 m/s [14].

The application of membranes for gas absorption has a lot of advantages over the conventional solutions where columns with filling are used:

- Operation of contact unit does not depend on the volume of gas flux or liquid flux,
- Such phenomena as snatching up of liquid drops by gas, column flooding, formation of channels or foaming do not occur,
- The units are compact due to the application of membranes from capillary fibers.

5. METHODOLOGY

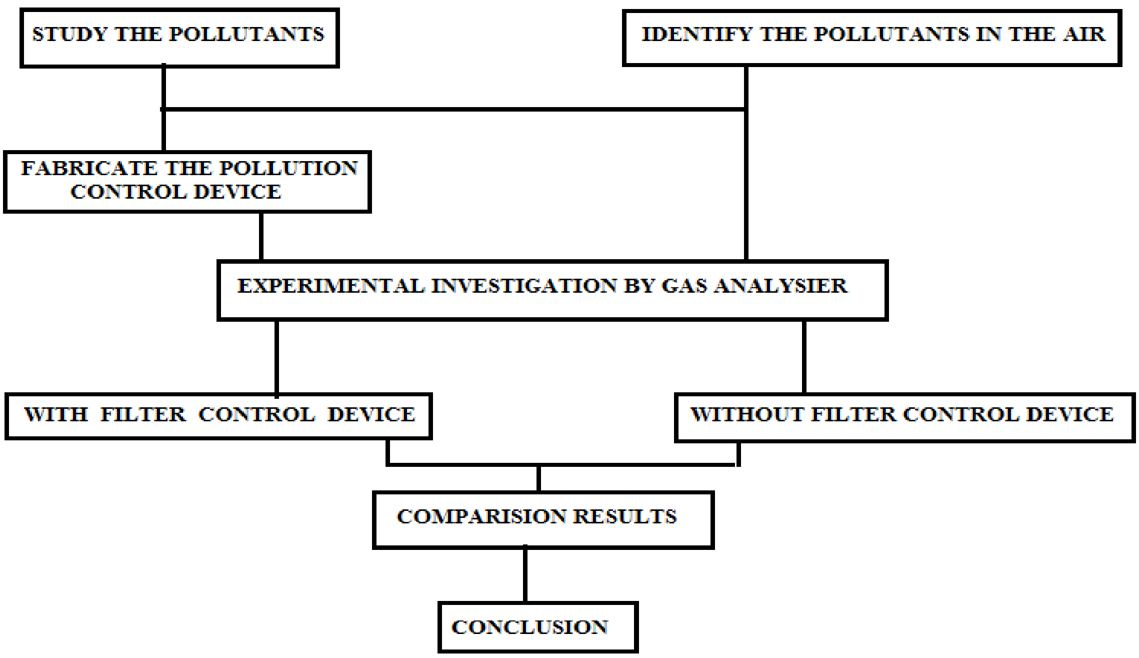

Fig: 1 Air Pollution Control Methodology

6. CONCLUSION

Owing to huge amount of the CO_2, chemical absorption may be more suitable than physical absorption purpose. However, chemical absorption is an energy intensive process in which more than 60% of total energy consumed in stripper for thermal regeneration of CO_2- rich chemical absorbents. Various methods like chemical looping combustion (CLC) and rotating packed bed method use many sophisticated apparatus to absorb carbondi- oxide. Other methods include the use of cryogenics or solvents which require very strict conditions perform an efficient absorption. To make absorption as practical application, the future research could be focused on the improvements of absorbent formulation and process efficiency.

To achieve the purpose, the following approaches are suggested:

i. To use absorbents with less corrosion, less viscosity, low vapour pressure, rapid reaction rate with CO_2, high CO_2 absorption capacity, and less regeneration energy, a compromised formulation is needed because all the mentioned properties may not be satisfied in the meantime,

ii. To enhance high gas-to liquid mass and heat transfer rates in absorber and stripper,

iii. To reduce equipment volume and capital cost,

iv. To prevent the negative effects of SOx, NOx, and oxygen on absorbent.

v. To develop a more suitable model for the scale up purpose.

REFERENCES

[1] "Reports". Worstpolluted.Org. Archived From The Original On 11 August 2010. Retrieved 2010-08-29.

[2] "7 Million Premature Deaths Annually Linked To Air Pollution". Who. 25 March 2014. Retrieved 25 March 2014.

[3] World Energy Outlook Special Report 2016 Energy And Airpollution.Pdf

[4] "Study Links 6.5 Million Deaths Each Year To Air Pollution". New York Times. 26 June 2016. Retrieved 27 June 2016.

[5] "Air Pollution Causes, Effects, And Solutions". National Geographic. 9 October 2016.

[6] Vaidyanathan, Climatewire, Gayathri. "The Worst Climate Pollution Is Carbon Dioxide". Scientific American.

[7] Johnson, Keith ,"How Carbon Dioxide Became A 'Pollutant'". Wall Street Journal, 18 April 2009.

[8] Barbalace, Roberta C. "Co_2 Pollution And Global Warming: When Does Carbon Dioxide Become A Pollutant?". Environmentalchemistry.Com. November 7, 2006.

[9] Rautenbach R., Ehresman H., Upgrading Of Land Fill Gas By Membranes - Process Design And Cost Evaluation, Aiche.Symp.Ser., 85 (272), 48, 1989.

[10] Rautenbach R., Welsch K., Treatment Of Landfill Gas By Gas Permeation - Pilot Plant Results And Comparison To Alternatives., Desalination, 90, 193, 1993.

[11] Daniel A. Vallero. "Fundamentals Of Air Pollution". Elsevier Academic Press.

[12] "Air Quality And Health". Www.Who.Int. Retrieved 2011-11-26.

[13] India Air Pollution 'Cutting Crop Yields By Almost Half' The Guardian, 3 November 2014.

[14] Jansen A.E., Klaassen R, Feron P.H.M., Hanemaaijer J.H., Meulen B., Membrane Gas Adsorption Processes In Environmental Applications, In: "Membrane Processes In Separation And Purification" (Crepso J.G., Bod Deker K.W., Eds.), Kluwer Academic Publishers, Dor Drecht-Boston-London, Pp. 343-356, 1994.