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Air Filtilization: A Review-based Approach to Air Filtration and Residue Utilization

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***Abstract*— The present status of air highly concerns every responsible citizen. It is a need of time to take action for a higher sustainable society that breathes clean air. Various methods are suggested for the purpose such as cutting emissions, plantation, artificial photosynthesis etc. This study, in particular, focuses on one such method that is filtration of the air. Though there are strong interlinkages between the classification done in this context, the classification of this study is based on gaseous and particulate filtration. The study discusses various mechanisms for filtration and further utilization of the residue at the macroscopic level through the study of researches that have been accomplished or are in the process of completion hitherto. Flue-gas desulfurization, dry and wet scrubbing, carbon capture etc. are the popular technologies that are already in trend. Further, recent studies have coined up some new methods such as the deployment of slug flow capillary microreactor for metal extraction, two-dimensional chromatography, Sludge Humic Acid-Sodium (SHA-Na) based SO_2 absorption etc. All these concepts have been discussed in the study. This article, in general, aims at spreading awareness and providing the framework for air filtration and residue utilization which is referred to here as Air Filtilization.**

***Keywords*- Air Filtration, Residue Utilization, Air Filtilization, Flue-Gas Desulfurization, Capture Technologies**

I.INTRODUCTION

The present status of the atmosphere raises high concerns about sustainability. As per the ref. [26] smokestacks of power plants, factories, waste incinerators, vehicular emissions, chemical dust etc. have caused huge depletion of air around us. This requires an immediate response for the control of air pollution. One of the various mechanisms of this is extracting pollutants from the air as a part of the cleansing of air. Further, proper management of the extracted pollutants also becomes essential. One of the several approaches to this is to separate the components of the residue and deploy them as raw materials in different industries as per the need or simply preparing a stock of the material for long term use. This approach has been emphasized in this study. Firstly, a general classification of filtration methods have been discussed and then particulate and gaseous filtration techniques have been discussed separately through the rigorous review of the available literature. The techniques which have the potential to obtain useful products through the separation processes have been emphasized concerning the resource management perspective.

II.METHODS OF AIR FILTRATION

Based on the two major types of emission particulate and gaseous, there are two types of filtration techniques which are classified as follows as per ref. [1]:

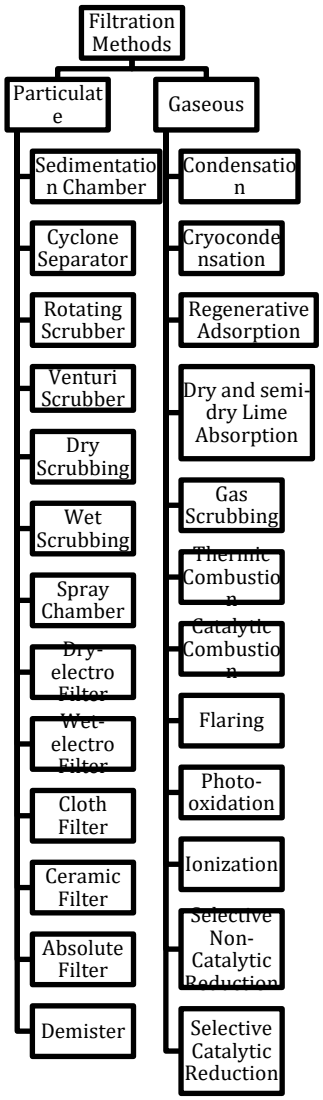

Figure.1: Classification of Filtration Methods [1]

The above-suggested methods are used as per the need and utility purposes in the different industrial areas. Also, more methods are being continuously explored and invented such as the self-powered air filter revealed in the ref. [9] and a transparent air filter mentioned in ref. [10]

III.PARTICULATE FILTRATION

Firstly, discussing the particulate filters is of crucial importance. Most of the filters provide residues in different chambers, portions or as deposition comfortably. As described in ref. [2] and ref. [3], Dry and Wet Scrubbers are of utmost importance in the context of this paper as they provide impure gypsum as output which after appropriate concentration has the probability,

according to ref. [4], to be used as construction material. The schematic diagram adapted from ref. [3] is shown below:

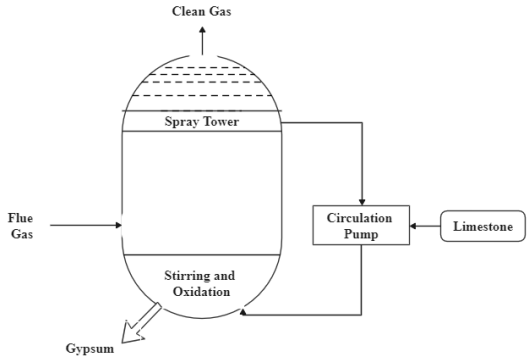

Figure2: Dry and Wet Scrubber [3]

Further, in the case of other methods, it is essential to discuss macro-level residue utilization. Since the major components of air particulates include metals, organic compounds, sulphate, nitrate and ammonium ions, a specific discussion on these is essentially needed.

A. Metal Extraction

It has been well identified in the ref. [5] that the metals present in the air cause respiratory issues, cardiovascular effects, cancer, genotoxicity, neurotoxicity, immunotoxicity, mental health issues, toxic effects in the eye, and many more such impacts on health. But of course, metals are of great utility. Therefore, their systematic extraction may be beneficial from resource management perspectives if done at the macroscopic scale. According to ref. [6] Pb, Zn and Cd are the most common toxic metal contaminant in the air particulates due to their wide utility at industrial scale. Continuous flow extraction is a promising method for industrial deployment to extract metals from air particulates as mentioned in ref. [7] Significant data of deposition amount have been shown in the ref. [7]. Overview of system design for continuous flow extraction is as follows:

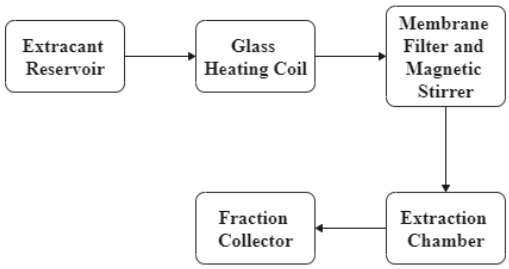

Fig.3: Continuous Flow Extraction System [7]

Further, a very recent study mentioned in ref. [8] identifies the method for intensified extraction of Zinc from Cadmium and Manganese by a slug flow capillary microreactor.

B. Organic Compound (OC) Extraction

In this aspect, the study by Craig Fairbaugh mentioned in ref. [11] is very crucial which, in general, talks about a system to separate volatile organic compounds and semi-volatile organic compounds with two-dimensional gas chromatography with time to flight mass spectrometry and two-dimensional liquid chromatography with mass spectrometry. These techniques increase the

efficiency and functionality of chromatography to a large extent as the effluent is flown from one dimension to another. Since the present discussion is of particulates, the obtaining of secondary organic aerosols is of utmost importance. The study separated and characterised a diverse range of organic aerosols which on further concentration in a long term may have the capability to be used at a significant scale.

C. Sulphate and Nitrate Aerosol Extraction

The wet and dry deposition has been perceived to be the most important processes from these perspectives as revealed in the ref. [12] and ref. [13]. As per the ref. [24]

The process of removing particles or gases from the atmosphere through the delivery of mass to the surface by non-precipitation is defined as ''dry deposition''.

The process of dry deposition consists of the following steps:

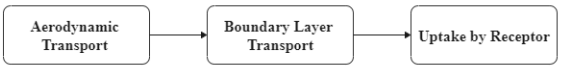

Figure 4: Dry Deposition [24]

Whereas, wet deposition means according to ref. [25] *the transfer of pollutants from the atmosphere to the earth by the inclusion or solution in precipitation.*

These processes have been in use for a long time and also remain essential in the present context.

IV.GASEOUS FILTRATION

As per the ref. [14] the major gaseous pollutants are Sulphur Dioxide, Carbon Monoxide and Dioxide, Ozone and other gaseous photochemical oxidants, etc. Here, the focus will be mainly on the Carbon and Sulphur Capture technologies.

A. Carbon Capture Technologies

The term carbon capture refers to the capturing of Carbon dioxide before it is released into the atmosphere as per the ref. [15]. This process in the forms of various types of technologies has been in existence for about 100 years as per ref. [16]. The same reference discusses several general classifications of Carbon capture at an industrial scale such as chemical and physical solvent-based methods, membrane-based capture, oxy-fuel combustion etc. In the present context, an emerging technology regarding the same is Bio-Energy and Carbon Capture and Storage (BECCS), a detailed analysis of which has been provided in the ref. [17], schematic flow diagram of which is shown below:

Figure 5: BECCS Strategy[17]

This process can produce negative emissions which is a highly appreciable perspective from the environmental point of view. Direct air capture is also a useful process but the process is highly expensive and energy-intensive as revealed in the data of ref. [18]. Carbon mineralization is another technique regarding the same which is utilizable as the ref. [19] suggests. Some minerals have a natural tendency to react with CO_2 gas to form a solid substance. This process is visualized as follows as suggested in the ref. [23]-

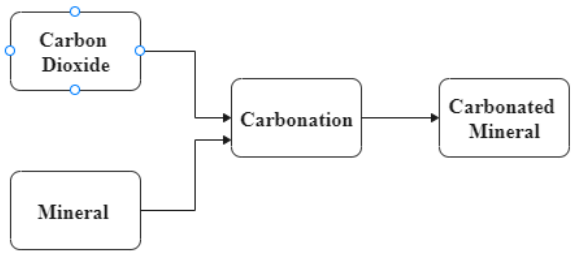

Figure 6: Carbon Mineralization [23]

This property can be deployed in the removal and storage of Carbon dioxide from the air.

B.Sulphur Dioxide Capture

Flue gas desulphurization (FGD) techniques are essentially considerable in this regard as mentioned in ref. [2], ref. [20] and ref. [21]. There are various types of FGD systems such as wet scrubber, limestone/gypsum system, sodium (hydroxide) scrubbing etc. which are discussed in the ref. [20]. The most important aspect concerning this study is that it yields marketable elemental sulphur which is one of the best examples of residue utilization. This process has also achieved more than 98% efficiency in recent times. A recent specific technique for flue-gas desulfurization in which sludge humic acid with sodium (SHA-Na) absorbs SO_2 as shown in the ref. [22] the process of which is shown in the figure below:

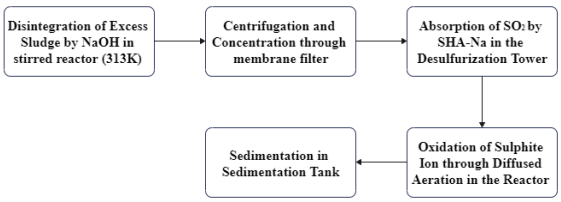

Figure7: Mechanism of SHA-Na Based Flue-gas Desulfurization [22]

V.CONCLUSION

In this study, firstly, a classification of the air filtration methods known to date in the contexts of particulate and gaseous filtration has been presented. Further, there is an attempt made to explore those methods specifically which may lead to the utilization of the residues obtained in the process of filtration. Hence, the study focuses on air filtration and then residue utilization which is here referred to as 'Air Filtilization'. The various methods which are found to be of extreme importance are the use of dry and wet scrubber, continuous-flow extraction system, deposition methods, BECCS strategy, mineralization techniques, two-dimensional gas chromatography and FGD. The study has tried to frame a strategy for adapting to the right filtration methods which induce utilization of the residues. Such an approach is the need of the time because the increasing

population has resulted in vast demands of industrial materials, production of which is leading to a high level of emissions. This approach may help future generations to manage resources in an enhanced manner.

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