Combined System for Reduction of Oxides of Sulphur, Nitrogen and Particulate Matter

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***Abstract*—Combined system for the reduction of oxides of Sulphur, oxides of Nitrogen & Particulate matter is the confederate system for the Reduction of the above air pollutants. SO_X, NO_X & PM are the pollutants which are being exhaust from the various sources like vehicles, industries, ships, Diesel generator sets etc. But we are focusing more on the Diesel generator sets as it is mostly the stationary air pollution sources. We would like to reduce the NO_X by the Copper tubes, SO_X by the use of scrubber & Particulate matters with the help of the Filter beds. We are also interested to find out the various scrubbing liquid for the reduction of the oxides of sulphur as we want to keep it as cheap as possible and as efficient as possible and we also finding the different types of the filter beds for the reduction of the particulate matters. Finally, we would be reducing the oxides of Sulphur, oxides of Nitrogen and Particulate matter with respect to the concentration & the efficiency of the system from the Diesel Generator set.**

Index Terms— Filter media, Isokinetic Condition, Oxides of Nitrogen, Oxides of Sulphur, Particulate Matter, Scrubber, Scrubbing Liquid

I. INTRODUCTION

Before the introduction of air quality regulations the use of air pollution control technology is to satisfy the demands of good engineering practice. At present the purpose of applying or developing a control technology is to meet the ambient air quality standards and other source related to regulations. A control technology can only be applied to a controllable source. So, it will be difficult to think of controlling emissions.

The cost of removing or reducing pollutants from the source is generally increases gradually with the percentage of control efficiency.

Application of control system requires the knowledge of source of air pollution regulations and waste generated from the system. Sometimes it is possible to develop a successful air pollution control system which tends to the problem of disposing the waste generated after using it.

There are mainly two methods for controlling air pollution can be either without an air pollution control device or with air pollution control equipment. The general methods for without an air pollution control device include process change, change in fuel, improve dispersion, good operating practices, and plant shutdown or relocation. Control equipment removes the pollutant, convert to less harmful contaminant or recover a valuable material for further use from it.

Air pollutants are substances that are introduced into the atmosphere through the anthropogenic activities. Air pollution occurs as gaseous and particulate forms which, when present in excess, are harmful to human beings, buildings and environment also.

With accelerated industrialisation and urbanisation, the standard of living is changing with change in the surrounding environment. Use of fossil fuels like petrol, gasoline, diesel etc., possess intimidation like degradation of air quality, increase in toxic air pollutants, rigorous change in the climate, increase in greenhouse gas emissions, increase in global warming, etc. With greater emission of SOx & NOx, it is necessary to find a solution for reduction/removal of them. Because they create a lot of problem in environment and also affect the human health. There are several methods are available to remove/reduce the concentration of SOx & NOx but mostly they are long steps reactions and require different equipment for both. So we are going to develop such a combined system from which we can efficiently remove/reduce the concentration of PM, SOx & NOx.

A) Particulates Matters:

1) Sources:

Particulate matter (PM) consists of majorly solids and liquids such as smoke, dust, aerosols, mists, fumes and condensed vapours that are suspended in the air for longer period of time. An important share of PM sources is from human (anthropogenic) activities and small share of natural activities. Human (anthropogenic) activities include Industrial pollution, Agriculture, combustion of fuel and wood, construction etc. Natural activities includes windblown and wildfires. PM10 is associated with dust as it has larger suspended particles and PM2.5 is associated with fuel burning, combustion processes and vehicle emissions as it has smaller suspended particle size. Particulate air pollution originates from different sources. One major source of primary particle emissions is fuel combustion, including mobile sources such as diesel and gasoline-powered vehicles. They are subdivided according to diameter: coarse particles >2.5 μm, fine particles <2.5 μm. A further it is to classify particles as primary or secondary, according to their origin. Particles that are emitted directly into the atmosphere are termed primary particles, whereas secondary particles form during atmospheric reactions. The primary particles contain dust and other solid materials, which are primarily formed during combustion processes. The increasing awareness about Particulate Matters Monitoring is mainly due to its effects on human health as well as environment. It is part of air quality monitoring which include process of monitoring harmful gases, Wind speed and its Direction etc. Particulate matter affects respiratory and cardiovascular systems. Because of smallest

size of fine particles it can go deep down in lungs and access gas exchange regions of the lungs through the dispersion. Particulate Matters can affect environment, such as change in the radiation balance of the planet, change in process of cloud formation, reduced visibility and global warming. It is necessity to monitor fine particulate matter at industrial sites as dust and air monitoring is becoming regular.

2) Health Effects:

The size of particles is directly proportional to their potential for causing health problems. Small particles less than 10 micrometres in diameter cause the greatest problems, because they can get deep into the lungs, and some may even get into the bloodstream. Exposure to such particles can affect both the lungs and the heart. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing. People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure. Many researches are performed to detect the impact of PM emissions on environment and human health. In these researches, it is noted that inhaling of these particles may cause human health problems such as untimely death, asthma, lung cancer, and other diseases.

3) Visibility detriment:

Fine particles (PM2.5) are the major cause of reduced visibility (haze) in parts of the United States (US), including many of our treasured national parks and wilderness areas.

Environmental damage: Particles can be carried over long distances by wind and then settle on the ground or water. Depending on their chemical composition, the effects of this settling may include: making lakes and streams acidic, changing the nutrient balance in coastal waters and large river basins, decreasing the nutrients in soil, damaging sensitive forests and farm crops, affecting the diversity of ecosystems, contributing to an acid rain effects.

4) Materials damage:

PM can stain and damage stone and other materials, including culturally important objects such as statues and monuments. Some of these effects are related to acid rain effects on materials like the Taj Mahal.

B) SO_X and NO_X:

The emission of NOx and SOx has different consequences for the atmosphere: The primary air pollutants sulphur dioxide and nitrogen oxides undergo chemical transformations as they are dispersed in the atmosphere, forming sulphuric acid and nitric acid respectively, which may be deposited downwind as acid rain.

SO_X:

1) Sources:

The main sources are the combustion of fuel containing sulphur mostly coal and oil. It is also produced during metal smelting and other industrial processes.

SO_2 is oxidised to SO_3 and at last forms sulphuric acid, which contributes to acid rain and provides cloud condensation nuclei by forming secondary particles.

2) Health Effects:

Sulphur Dioxide (SO_2) with the high concentration can result in breathing problems with asthmatic children & adults. Sulphur dioxide is also associated with asthma, eye irritation, and heart failure. Short term exposure has been linked to chest tightness & shortness of breath. Long Term exposure has been affected in conjunction with high levels of particulates soot, include respiratory illness, alteration in the lung defenses. It causes coughing and aggravates conditions such as chronic bronchitis.

3) Environmental Effects:

Sulfur dioxide is the major pathfinder of acid rain, which has acidified soils, lakes and streams, accelerated corrosion of buildings and monuments and reduced visibility. Sulfur dioxide also is a major precursor of fine particulate soot, which poses significant health problems. When Sulphur dioxide combines with water and air, it forms Sulfuric acid, which is the main component of acid rain. It can cause deforestation, corrode building materials and paints.

4) Air quality standard:

The recommended air quality standards for sulphur dioxide are:

- 0.20 parts per million (ppm) for a 1-hour exposure period
- 0.08ppm for a 24-hour exposure period
- 0.02ppm for an annual exposure period.

NO_X:

Nitrogen oxides (NOx) are a very interesting and important family of air polluting chemical compounds. NOx is involved in production of ground level ozone but it also reacts with tropospheric ozone thus help in the depletion of the ozone layer.

1) Sources:

Nitrogen dioxide (NO_2) is not usually released directly into the air. Nitrogen dioxide forms when nitrogen oxide (NO) and other nitrogen oxides (NOx) react with other chemicals in the air to form nitrogen dioxide. The main source of nitrogen dioxide resulting from human activities is the combustion of coal, gas and oil especially fuel used in the cars. It is also produced from making nitric acid, welding and using explosives, refining of petrol and metals, commercial manufacturing, and food manufacturing. Natural sources of other nitrogen oxides include volcanoes and bacteria.

2) Need to Control NO_X:

NOx represent a family of seven compounds. EPA regulates only nitrogen dioxide (NO_2) as a surrogate for this family of compounds because it is the most prevalent form of NOx in the atmosphere that is generated by anthropogenic activities. NO_2 is not only an important air pollutant by itself, but also reacts in the atmosphere to form ozone (O_3) and acid rain. It is important to notice that the ozone that we want to minimize is tropospheric ozone; that is, ozone in the ambient air that we

breathe. Stratospheric ozone in the upper atmosphere that we cannot breathe. Stratospheric ozone protects us and the troposphere from ionizing radiation which is coming from the sun. EPA has established National Ambient Air Quality Standards (NAAQS) for NO_2 and tropospheric ozone. The NAAQS define levels of air quality which are necessary, with a reasonable margin of safety, to protect public health at primary standard and public welfare at secondary standard from any known or anticipated adverse effects of pollution on the environment. The primary and secondary standard for NO_2 is 0.053 parts per million (ppm), annual arithmetic mean concentration. Tropospheric ozone has been and continues to be a very important air pollution problem in the United States and is the primary constituent of smog. Large portions of the country don't meet the ozone NAAQS and thereby expose large portions of the population to unhealthy levels of ozone in the air. NO_2 reacts in the presence of air and ultraviolet light (UV) in sunlight to form ozone and nitric oxide (NO). The NO then reacts with free radicals in the atmosphere, which are also created by the UV acting on volatile organic compounds (VOC). The free radicals then recycle NO to NO_2. In this way, each molecule of NO can produce ozone multiple times 40. This will continue until the VOC are reduced to the short chains of carbon compounds that cease to be photo reactive (a reaction caused by light). A VOC molecule can usually do this about 5 times. In addition to the NO_2 and Ozone NAAQS concerns, NOx and sulphur oxides (SO_X) in the 2 atmosphere are captured by moisture to form acid rain. Acid rain, along with cloud and dry deposition, severely affects the certain ecosystems and directly affects some portions of our economy. All of these facts indicate that an obvious needs to reduce NOx emissions.

3) Health effect:

The major health effect of nitrogen dioxide is on the respiratory system. Inhalation of nitrogen dioxide by children increases their risk of respiratory infection and may cause poorer lung function in later life. There is also an association between nitrogen dioxide concentrations in the air and increases in mortality and hospital admissions for respiratory disease. Nitrogen dioxide can decrease the lungs defences against bacteria making them more receptive to infections. It can also cause asthma. Nitrogen dioxide can damage the lungs and lower resistance to respiratory infection.

4) Effects on ecosystems:

Nitrogen dioxide is toxic to plants in short-term concentrations of 120 µg/m3. It reduces the plant growth. When sulphur dioxide and ozone are also present, the effects on vegetation are worse. With sulphur dioxide, nitrogen dioxide can also cause acid rain. Acid rain is not a problem in New Zealand.

5) Effects on buildings:

Nitrogen dioxide forms acids in the presence of moisture and these can be corrosive to building materials at high concentrations.

6) Effects on visibility:

Nitrogen dioxide can form secondary particles which are called nitrates that can cause haze and reduce the visibility. Nitrogen dioxide is the gas that makes summer smog look brownish in colour.

II. Methods for removal of SO_X, NO_X and PM

There are several methods are available for reduction of Oxides of Sulphur & Nitrogen and Particulate Matter like scrubbers, plasma Pyrolysis, electro plasma Pyrolysis, filter bed, cyclone separators, electrostatic precipitators etc. But the problem is that the pollutants will be removed in different units. The design of such equipment is like that through which one can remove pollutants only in one unit i.e. combine system for removal of Oxides of Sulphur & Nitrogen and Particulate Matter.

[1] Researches Stationary, 2000; Andersson and Winnes, 2011; Lamas and Rodriguez, 2012; Lamas et al., 2013 showed the possibility of achieving NOx emissions reduction. After studying different technologies they found selective catalytic reduction and sea water scrubbing was one of the best technique for reductions of NOx and PM. They had also suggested that instead of conventional fuels we can also use alternative fuels or natural gas in its liquid state. This method was investigated at a high speed craft operating in the red sea area between Egypt and Kingdom of Soudi Arabia. The result obtained was a very conciliatory from the point of view of environment and economics. They had used one of the old methods that used was adding water to the liquid fuel (Genesis Engineering Inc., 2003). Using the puri NOx product additives with liquid fuels to formed a stable product they achieved reduction of about 20% & 50% for NOx and P.M respectively.

[2]Zhitao Han, Bojun Liu, Shaolong Yang, Xinxiang Pan, and Zhijun Yan has found NO*x* removal by wet scrubbing using NaClO solution was studied based on a spraying reactor in a cyclic mode. The results showed that when NaClO concentration was higher than 0.05M and initial solution pH was below 8, NO*x* removal efficiency was relatively stable, which was higher than 60%. The coexisting CO2 (5%) had little effect on NO*x* removal efficiency, but the solution pH began to decrease with the proceeding of cyclic scrubbing process when initial pH was higher than 6. NOx removal efficiency increase with little increase in absorbent temperature.

[3] Francesco Di Natale, Claudia Carotenuto, Luca D'Addio, Amedeo Lancia, Teresa Antes, Michal Szudyga, Anatol Jaworek, Donald Gregory, Michael Jackson, Procolo Volpe, Radu Beleca, Nadarajah Manivannan, Maysam Abbod, Wamadeva Balachandran, they communicated two innovative techniques for cleaning of marine diesel engine i.e. the Electrostatic Sea Water scrubbing and Electron Beam/ microwave non-thermal plasma. The DEECON (Diesel Engines Emission Control) projects aims to develop a new integrated unit aimed to reduce SO_2, NOx, VOC and PM in marine diesel exhaust gases. The main processes, involved in the DEECON unit, are new concepts of 365 electrified seawater scrubber (ESWS) and Electron Beam/Microwave induced non-thermal plasma system (EBMW-NTPR). Preliminary experimental and modelling analyses showed that the two processes may be suitably used to achieve the project

objectives. The ESWS unit is able to remove SO_2 with an overall efficiency above 98 % (data not shown), while PM levels can be reduced by more than 90 % in terms of numerical concentration; the EBMW-NTPR is very promising in terms of NOx and SO_2 removal, and pertinent literature indicates that they may be suitable for a reduction of VOC compounds as well.

[4] Chen and Schirmer; Wang et al. and Zheng and Banerjee were found that the diesel engines have high efficiency, reliability and durability with their low operating cost. This important characteristics makes them most preferred engines especially from heavy duty vehicles. But, also they are responsible for polluting the environment by emitting different polluted gases like CO2, SOx, NOx, VOC etc. Out of different technologies the researchers discussed 3 methods of reduction of Sox, NOx and PM. They also studied the effect of emitted gases on the human health and on the environment. They combined DPFs (Diesel Particulate Filter) with DOC (Diesel Oxidation Catalyst) to eliminate PM emissions from diesel exhaust gas. They are typically constructed of SiC structure which acts as a mechanical filter and removes PM from diesel exhaust gas by 100%.

[5] A new permanganate-impregnated alumina media provides for improved control of NO_2. Application of this and other dry-scrubbing media types into a nonwoven fiber matrix provide higher removal efficiencies and lower pressure drops than traditional air cleaning systems and can also be produced with integral particulate filtration. Chris Muller has used different absorbent solution to absorb the NOx from the polluted gases. Researchers Muller and England found that Granular Activated Carbon (GAC) does a good job in removing aldehydes, hydro carbons, organic acids and nitrogen dioxide because of its high surface area to volume ratio. It is not as much effective against oxides of sulfur, lower molecular weight aldehydes and organic acids. Chris Muller found out that Granular activated carbon is the dry-scrubbing medium of choice for the control of many hydrocarbons and testing has shown that a new PIA(permanganate impregnated alumina) medium containing 12% NaMnO4 shows a much higher removal capacity for NO2 than PIA containing KMnO4. Add to these a KOH-impregnated activated carbon-alumina medium and one can effectively control the majority of the primary gaseous contaminants of concern found in automobile and diesel exhaust.

[6]Hu Zhang, Huling Tong, Sujuan Wang, Yuquon Zhuo, Change Chen and Xuchang Xu has done experiment in fixed bed scrubber containing KMnO4, at low temperature they found enhance adsorbent ability to capture NO. It is also found that increase in temperature improve the SO2 capturing. They studied optimum condition for simultaneous removal of SO2 and NO removal including reaction temperature, O2 concentration and relative humidity.

[7]Masanori Sakai, Caili Su and Eiji Sasaoka used fix bed reactor in coal combustion plant for simultaneous removal of SOx & NOx. The result showed that SO_2 was absorbed by $Ca(OH)^2$ in the presence of NO and in the absence of NO it absorbed $(SO3)^2$ salt. They had been also found that NO could not be absorbed by slacked lime without SO_2 at low temperature.

[8] Pilot scale project for removal of SO_x & NO_x from Boiler emission, Toshiaki Yamamoto, Hidekatsu Fujishima, Masaaki Okubo and Tomoyuki Kuroki used two different methods i.e. radical injection and chemical hybrid process. The NOx removal efficiency was found to be 90% and NO_2 was further reduced to N2 and nontoxic & water soluble Na_2SO_4 by Na_2SO_3 solution. The removal efficiency of SO_2 was in the range of 85-90%.

[9] Tsung-Wen Chien, Hsin Chu were used $NaClO_2$ solution to remove SO_2 and NO from flue gases. They performed experiment in a bench-scale spraying sieve tray wet scrubber in a continuous mode. The individual study of NOx removal found to be in the range of 3-13% and combine study for removal of SO_x found in the range of 89-100% and NOx removal found to be 37-72%.

[10] Wessel Pluim Kaj vd Valk Niels Prinsen Wouter Fontijn were used different method for reduction of SOx and NOx like SCR, hydride propulsion, plasma technology, Dimethyl ether (DME), scrubbers and exhaust gas recirculation. They compared all methods and concluded that combination of DME (Dimethyl ether) and SCR (Selective Catalytic Reduction) is the best method for about 80% NOx removal and 100% SOx reduction.

[11] Copenhagen, March 2004 has found out Tier III 80% NOx reduction requirement can only be met by the use of external engine methods such as SCR (Selective Catalytic Reduction). However, by development and research, MAN Diesel has been able to achieve a NOx reduction of 70% by means of such internal methods as SAM and EGR (Exhaust Gas Recirculation).

III. Conclusion

There are many methods for reduction of Oxides of Sulphur and Nitrogen and Particulate Matters individually or by integrated units. This Combine System will tend to reduce the Oxides of Sulphur and Nitrogen and Particulate Matter effectively & there is further scope of research on this system which can increase the efficiency of the system and make it more economical as small scale users can also implement it.

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