

AIR POLLUTION CONTROL TECHNIQUES & A CASE STUDY OF INDUSTRIAL AIR EMISSIONS

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Air pollutants are the most dangerous type of pollution and they effect our environment the worst. The main air pollutants are CO₂, CO, NO_x, SO_x and particulate matter. These pollutants are causing some major environmental and health concerns. There are number of techniques to control these emissions to the atmosphere. The flue gas data of boilers and generators from ICI polyester industry is also included in this paper. The techniques in use to control the pollutants are discussed. One of the most common techniques is the switching of the fuel. The Natural gas emits almost 30 percent less carbon dioxide than oil, and just under 45 percent less carbon dioxide than coal. Emissions of particulates from natural gas combustion are 90 percent lower than from the combustion of oil, and 99 percent lower than burning coal. Natural gas emits virtually no sulfur dioxide, and upto 80 percent less nitrogen oxides than the combustion of coal. Similarly, use of compressed natural gas in vehicle reduces the amount of these emissions considerably. The other methods for the control and reduction of these emissions are combustion control techniques, Flue gas treatment and Fuel re-burning. NO_x can be reduced considerably by combustion control techniques like Low excess air, staged air combustion, staged fuel combustion, external flue gas recirculation, Fuel induced recirculation and steam/water injection. The flue gas treatments like selective non-catalytic reduction (SNCR) and selective catalytic reduction (SCR) are also used for reduction of NO_x.

Keywords: Air pollution, SNCR, SCR, NO_x, SO_x

1. Introduction

Fuel combustion produces large amounts of harmful air pollutants which are the biggest sources of atmospheric pollution. The main pollutants are particulate matter, sulfur dioxide, nitrogen oxide, carbon monoxide and volatile organic compounds (VOCs), which are capable of causing health problems ranging from respiratory disorders to cancer. In addition, other byproducts of fuel burning are heavy metal pollutants, including lead, arsenic, and mercury

The effect of ambient air pollution is very different and much more significant in the pediatric population. Air pollutants are more harmful to children in comparison to adults as the developing lung is more susceptible to damage from such chemicals. This leads to increased risk of asthma, impaired lung function, and higher school absences.

The World Health Organization (WHO) estimates that urban air pollution contributes every year to about 800,000 deaths and 4.6 million healthy life-years lost worldwide. A large proportion

of this morbidity and mortality (about 66%) is seen in the developing world. A World Bank study recently reported that 22,000 deaths in Pakistan occur on a yearly basis because of air pollution [1].

In relation to health, ground level ozone and particulate matter ("fine dust") are the pollutants of most concern. Exposure can lead to impacts ranging from minor effects on the respiratory system to premature mortality. Ozone is not emitted directly but is formed through the reaction of volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of sunlight. Particulate matter can be emitted directly to the air (so called primary particles) or be formed in the atmosphere as "secondary particles" from gases such as sulfur dioxide (SO₂), nitrogen oxides and ammonia (NH₃).

Ecosystems are also damaged by (1) the deposition of the acidifying substances – nitrogen oxides, sulfur dioxide and ammonia – which lead to loss of flora and fauna; (2) excess nutrient nitrogen in the form of ammonia and nitrogen oxides can disrupt plant communities, leach into freshwaters

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leading in each case to a loss of biodiversity (called "eutrophication"); and (3) ground level ozone that results in physical damage and reduced growth of agricultural crops, forests and plants. Air pollution also causes damage to materials leading to a deterioration of buildings and monuments [2].

The major sources of air pollution in Pakistani cities are combustion of fossil fuels from vehicles, factories and power plants. However, there are no emissions inventories that show the estimated air pollutant emissions from these sources. The Government does not conduct regular emissions inventories in the cities. The air pollution problem is aggravated by the aging fleet of vehicles in poor mechanical condition and low levels of fuel efficiency. The increasing number of diesel trucks has further added to the problem. According to the Pakistan Environmental Protection Agency (EPA), a major share of the emissions loads from motor vehicles, although not quantified, can be attributed to a relatively small number of smoky diesel and 2-stroke vehicles found in many Pakistani cities. The high levels of sulfur in automotive diesel (0.5%–1%) and furnace oil (1%–3.5%) is seen as a major contributor to Sulfur dioxide (SO₂) and particulate matter (PM) in ambient air. Emissions from large-scale facilities, such as cement, fertilizer, sugar, steel, and power plants, many of which use furnace oil; and a wide range of small- to medium-scale industries (including brick kilns, steel re-rolling, steel recycling, and plastic molding) cause a disproportionate share of pollution through their use of dirty "waste" fuels, such as old tires, paper, wood, and textile waste. Industrial emissions are further compounded by the widespread use of small diesel electric generators in commercial and residential areas in response to the poor reliability of electricity supplies [3].

Table 1: Hourly average ambient concentrations of air pollutants in pakistani cities in 2000.

Pollutant (Hourly average data)	Lahore	Rawalpindi	Islamabad
PM ₁₀ (µg/m ³)	895.00	709.00	520.00
SO ₂ (ppb)	44.60	30.70	28.50
CO (ppm)	2.82	1.83	1.55
NO _x (ppb)	156.60	74.70	148.50
O ₃ (ppb)	8.50	17.00	10.00

The most recent study on the impacts of PM on health in Pakistan conducted by the Pakistan EPA and the World Bank showed that it causes 22,000

premature deaths in adults and 700 in children annually. The total health costs is estimated between Rs. 62 billion to Rs. 65 billion (about US\$1.09 billion) or approximately 1% of the gross domestic product [3].

2. Results and Discussion

2.1. Results

The flue gases data of the boilers and generators used in polyester industry was taken. The emission data of boilers is tabulated in Table 2. The emission data of generators is given in Table 3.

Table 2. Emission from industrial boilers.

Pollutants	Emission from Furnace oil-fired Boiler	Emission from Gas-fired Boiler
SO ₂ (ppm)	235	12.4
NO _x (ppm)	160	45
CO (ppm)	400	140

Table 3. Emission from industrial generators.

Pollutants	Furnace oil-fired Generator-I	Furnace oil-fired Generator-II	Furnace oil-fired Generator-III	Furnace oil-fired Generator-IV
SO ₂ (ppm)	220	350	230	200
NO _x (ppm)	250	300	300	290
CO (ppm)	1250	1000	1000	1500

2.2. Discussion

The emissions from gas-fired boilers are considerably lower than furnace oil-fired boiler. The SO₂ emission is 95% lower for gas-fired boiler as compared to furnace oil-fired boiler. The NO_x emissions are 28% for natural gas as compared with furnace oil. Similarly the CO emissions are 35% for natural gas as compared with furnace oil.

The SO₂ emissions are greater for generators as compared with boiler for the similar fuel. The CO produced in generators is considerably higher than that of boilers. The CO emission in case of generator is 2.5-4 times higher than that of boiler

3. Air Pollution Control Techniques

There are number of techniques to control the air pollution from any source. The major concern are Carbon Dioxide (CO₂), Nitrogen Oxides (NO_x), Sulfur Oxides (SO_x), Volatile Organic Compound (VOC) and Particulate Matter (PM). The major emphasis is given on these pollutants. Most of the

secondary pollutants are taken care of by treating these pollutants.

3.1. Switching fuel

One of the most common techniques to reduce the quantity of these pollutants is to switch the fuel. By using the environmental friendly fuels these amount of emissions can be reduced considerably. Natural gas is the cleanest of all the fossil fuels. Composed primarily of methane, the main products of the combustion of natural gas are carbon dioxide and water vapor, the same compounds we exhale when we breathe. Coal and oil are composed of much more complex molecules, with a higher carbon ratio and higher nitrogen and sulfur contents. This means that when combusted, coal and oil release higher levels of harmful emissions, including a higher ratio of carbon emissions, nitrogen oxides (NO_x), and sulfur dioxide (SO₂). Coal and fuel oil also release ash particles into the environment, substances that do not burn but instead are carried into the atmosphere and contribute to pollution. The combustion of natural gas, on the other hand, releases very small amounts of sulfur dioxide and nitrogen oxides, virtually no ash or particulate matter, and lower levels of carbon dioxide, carbon monoxide, and other reactive hydrocarbons.

The use of fossil fuels for energy contributes to a number of environmental problems. As the cleanest of the fossil fuels, natural gas can be used in many ways to help reduce the emissions of pollutants into the atmosphere. Burning natural gas in the place of other fossil fuels emits fewer harmful pollutants into the atmosphere, and an increased reliance on natural gas can potentially reduce the emission of many of these most harmful pollutants.

One of the principal greenhouse gases is carbon dioxide. Although carbon dioxide does not trap heat as effectively as other greenhouse gases (making it a less potent greenhouse gas), the sheer volume of carbon dioxide emissions into the atmosphere is very high, particularly from the burning of fossil fuels. The most effective method to reduce the amount of CO₂ is by switching the fuel. The combustion of natural gas emits almost 30 percent less carbon dioxide than oil, and just under 45 percent less carbon dioxide than coal.

A study by the Union of Concerned Scientists in 1998 showed that the risk of premature death for residents in areas with high airborne particulate matter was 26 percent greater than for those in areas with low particulate levels. Natural gas emits virtually no particulates into the atmosphere: in fact, emissions of particulates from natural gas combustion are 90 percent lower than from the combustion of oil, and 99 percent lower than burning coal. Natural gas emits virtually no sulfur dioxide, and up to 80 percent less nitrogen oxides than the combustion of coal.

Table 4: Fossil fuel emission level (Pounds per BTU of energy input)

Pollutants	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxide	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

3.2. NO_x control

There are a number of oxides of nitrogen, including nitrous oxide (N₂O), nitric oxide (NO), nitrogen dioxide (NO₂), nitrogen trioxide (N₂O₃), and nitrogen pentoxide (N₂O₅), that are referred to collectively as NO_x. The two oxides of nitrogen that are of primary concern to air pollution are NO and NO₂. NO is a colorless gas that is a precursor to NO₂ and is an active compound in photochemical reactions that produce smog. NO₂ is a reddish brown gas that gives color to smog and can contribute to opacity in flue gas plumes from stacks.

The main techniques for controlling NO_x are

1. Fuel Switching,
2. Combustion Control,
3. Flue Gas Treatment,
4. Fuel Re-burning.

3.2.1. Fuel switching

Refined oils, generally, contain less than 0.05% fuel-bound nitrogen. Residual oils can contain upto 0.6% fuel-bound nitrogen. While natural gas contains some nitrogen, it is in the form of nitrogen gas, not the organic compounds that lead to fuel NO_x. Conversion to natural gas firing will significantly reduce NO_x emissions [4].

When firing fuel oils, NO_x formed by fuel-bound nitrogen can account for 20-50% of the total NO_x level. One method to reduce NO_x levels from boilers firing distillate oils is through the use of natural gas or low nitrogen fuel oil.

3.2.2. Combustion control techniques

A variety of combustion control techniques are used to reduce NO_x emissions by taking advantage of the thermodynamic and kinetic processes. Combustion control techniques reduce NO_x formation during the combustion process by controlling the flame temperature and/or oxygen concentration. They are generally more economical than flue gas treatment (post combustion) methods and are frequently utilized on industrial boilers.

3.2.3. Low excess air

As a safety factor to assure complete combustion, boilers are fired with excess air. One of the factors influencing NO_x formation in a boiler is the excess air level. High excess air levels may result in increased NO_x formation because the excess nitrogen and oxygen in the combustion air entering the flame will combine to form thermal NO_x.

Limiting the amount of excess air entering a flame is accomplished through burner design and can be optimized through the use of oxygen trim controls. Low excess air firing can be used on most boilers and generally results in overall NO_x reductions of 5-10% when firing natural gas.

3.2.4. Staged combustion

Staged Combustion involves changing the air and fuel flow patterns in order to reduce the peak flame temperature and oxygen concentrations. Enlarging the flame results in lower flame temperatures and lower thermal NO_x formation which, in turn, results in lower overall NO_x emissions. The technology can be applied to most boiler types and sizes.

Staging can either be done internally within the burner body – these designs are frequently incorporated into “Low NO_x Burners” (LNB). Staging can also be done external to the burner through the separate introduction of fuel and/or air through different ports within the boiler furnace. [5]

3.2.5. Flue gas recirculation (FGR)

FGR involves recirculating a portion of relatively cool exhaust gases back into the combustion process in order to lower the flame temperature. Flue gas recirculation technology can be classified into two types:

1. External flue gas recirculation utilizes an external fan to recirculate the flue gases back into the flame. External piping routes the exhaust gases from the stack to the burner. A valve controls the recirculation rate, based on boiler input.
2. Induced flue gas recirculation utilizes the combustion air fan to recirculate the flue gases back into the flame. A portion of the flue gases are routed by duct work or internally to the combustion air fan, where they are premixed with the combustion air and introduced into the flame through the burner. New designs of induced FGR that utilize an integral FGR design are becoming popular because of their uncomplicated design and reliability.

3.2.6. Water/steam injection

By injecting water or steam into the flame, flame temperatures are reduced, thereby lowering thermal NO_x formation and overall NO_x levels. Water or steam injection can reduce NO_x upto 75% (when firing natural gas) and can result in lower reductions when firing oils. There is a practical limit to the amount of water or steam that can be injected into the flame before condensation problems are experienced. Additionally, under normal operating conditions, water/steam injection can result in a 3-10% boiler efficiency loss. Water or steam injection can be used in conjunction with other NO_x control methods such as burner modifications or flue gas recirculation. Some advanced designs of steam injection technology do not have as significant an impact on boiler efficiency.

3.2.7. Flue gas treatment methods

3.2.7.1. Selective non-catalytic reduction (SNCR)

Selective non-catalytic reduction involves the injection of a NO_x reducing agent, such as ammonia or urea, into the boiler exhaust gases at a temperature of approximately 1400-1600°F. The ammonia or urea breaks down the NO_x in the exhaust gases into water and atmospheric nitrogen. Selective non-catalytic reduction reduces NO_x up to 70%. [5].

3.2.7.2. Selective catalytic reduction (SCR)

Selective catalytic reduction involves the injection of ammonia in the boiler exhaust gases in the presence of a catalyst. The catalyst allows the ammonia to reduce NO_x levels at lower exhaust temperatures than selective non-catalytic reduction. Unlike selective non-catalytic reduction, where the exhaust gases must be approximately 1400-1600°F, selective catalytic reduction can be utilized where exhaust gasses are between 500°F and 1200°F, depending on the catalyst used. Selective catalytic reduction can result in NO_x reductions upto 90%, however, it is costly. [5].

3.2.8. Fuel re-burning

A second combustion zone after the primary flame zone can be established by adding additional hydrocarbon fuel outside of the primary flame zone. NO_x is reduced by reaction with hydrocarbon radicals in this zone.

This involves the injection of natural gas after primary fuel combustion. It is typically used only on large utility power plant boilers firing coal or residual oil. It is a three-stage combustion process based on fuel staging [6] [7].

Table 5 Summary of NO_x control techniques [5]

Technology	NO _x Removal efficiency
LNB	Up to 50%
Re-burning	39-67
SNCR	30-66
SCR	80-90+
Advance gas Re-burning (AGR)	68-76
Flue-Lean gas Re-burning (FLGR)	55-73

3.3. Volatile organic compounds (VOCs) control

Volatile organic compounds, or VOCs, are compounds containing combinations of carbon, hydrogen, and sometimes oxygen. VOCs vaporize easily once emitted into the air and are of concern because of their role in ground level ozone formation.

Separation processes are used as a means of air pollution control for both particulate matter and gas. These processes essentially remove the pollutant from the carrier gas resulting in a cleaned gas stream. If the pollutant content of the cleaned stream meets the effluent emission standards, the cleaned stream can be discharged to the

atmosphere. Absorption and adsorption are both diffusion separation processes that can be used to collect hazardous air pollutants. In the case of absorption, the pollutant is transferred to the solvent which then may need further treatment. Recovery of the solvent might be undertaken by distillation or by stripping the absorbed material from the solvent. The problem of treating the waste material in the stream separated from the solvent remains. If the pollutant material has a value, adsorption may provide the means for the material to be more readily recovered. In the case of particulate matter, wet scrubbing collects the particles primarily through the mechanism of inertial impaction. Gaseous contaminants such as sulfur oxide, nitrogen oxide, or hydrochloric acid, if present alongwith the particulates, may be collected simultaneously by absorption.

Many organic materials may be removed by condensation, which is essentially a diffusion operation. If a suitable coolant is available and the pollutant concentration is high enough, condensation can be very effective in recovering material that may be used again. For organic pollutants when the concentration is low or recovering the material is not desired, incineration can be used to convert the pollutant to carbon dioxide and water. For large emissions such as would be found in petroleum refineries the pollutant may be flared. [4].

3.4. VOC control in boiler

In reference to boiler performance, they are often referred to as hydrocarbons and generally are divided into two categories - methane and non-methane. Formation of VOCs in commercial and industrial boilers, primarily result from poor or incomplete combustion due to improper burner set-up and adjustment. To control VOC emissions from commercial and industrial boilers, no auxiliary equipment is needed; properly maintaining the burner/boiler package will keep VOC emissions at a minimum. Proper maintenance includes keeping the air/fuel ratio at the manufacturer's specified setting, having the proper air and fuel pressures at the burner, and maintaining the atomizing air pressure on oil burners at the correct levels. An improperly maintained boiler/burner package can result in VOC levels over 100 times the normal levels [7].

Table 6. Summary of NO_x Control Techniques [4].

Device	Inlet Conc. (PPMV)	Efficiency
Absorption	250	90%
	1000	95%
	5000	98%
Adsorption	200	50%
	1000	90-95%
	5000	98%
Condensation	500	50%
	10,000	95%
Thermal incineration	20	95%
	100	99%
Catalytic Incineration	50	90%
	100	>95%
Flares		>98%

3.5. SO_x control

The largest source of sulfur is sulfur dioxide. Sulfur dioxide is a primary source of acid rain. The other forms of sulfur emissions are H₂S, SO₃, and sulfuric acid mist.

The primary reason sulfur compounds, or SO_x, are classified as a pollutant is because they react with water vapor (in the flue gas and atmosphere) to form sulfuric acid mist. Airborne sulfuric acid has been found in fog, smog, acid rain, and snow. Sulfuric acid has also been found in lakes, rivers, and soil. The acid is extremely corrosive and harmful to the environment.

The combustion of fuels containing sulfur (primarily oils and coals) results in pollutants occurring in the forms of SO₂ (sulfur dioxide) and SO₃ (sulfur trioxide), together referred to as SO_x (sulfur oxides). The level of SO_x emitted depends directly on the sulfur content of the fuel. The level of SO_x emissions is not dependent on boiler size or burner design. Typically, about 95% of the sulfur in the fuel will be emitted as SO₂, 1-5% as SO₃, and 1-3% as sulfate particulate. Sulfate particulate is not considered part of the total SO_x emissions.

Historically, SO_x pollution has been controlled by either dispersion or reduction. Dispersion involves the utilization of a tall stack, which enables the release of pollutants high above the ground and over any surrounding buildings, mountains, or hills, in order to limit ground level SO_x emissions. Today, dispersion alone is not enough to meet more stringent SO_x emission

requirements; reduction methods must also be employed.

Methods of SO_x reduction include switching to low sulfur fuel, desulfurizing the fuel, and utilizing a flue gas desulfurization (FGD) system. Fuel desulfurization, which primarily applies to coal, involves removing sulfur from the fuel prior to burning. Flue gas desulfurization involves the utilization of scrubbers to remove SO_x emissions from the flue gases.

Flue gas desulfurization systems are classified as either non-regenerable or regenerable. Non-regenerable FGD systems, the most common type, result in a waste product that requires proper disposal. Regenerable FGD converts the waste by-product into a marketable product, such as sulfur or sulfuric acid. SO_x emission reductions of 90-95% can be achieved through FGD. Fuel desulfurization and FGD are primarily used for reducing SO_x emissions for large utility boilers. Generally the technology cannot be cost justified on industrial boilers [4].

3.6. Boilers

For users of industrial boilers, utilizing low sulfur fuels is the most cost effective method of SO_x reduction. Because SO_x emissions primarily depend on the sulfur content of the fuel, burning fuels containing a minimal amount of sulfur (distillate oil) can achieve SO_x reductions, without the need to install and maintain expensive equipment.

Many facilities in that industry use wet limestone scrubbers that have a relatively high capital cost in order to utilize inexpensive limestone reagent, although other systems sometimes are used. Smaller, industrial-scale facilities typically use more expensive reagents in systems with lower equipment costs. [7].

3.7. SNOX process

The SNOX process is an innovative and patented process removing up to 98% of SO₂ and SO₃ and up to 95% NO_x and essentially all particulates from flue gases. The SNOX process is a combined SO_x and NO_x removal process which removes 95- 98% of SO₂ and SO₃ and 90-95% of the content of NO_x in flue gases, depending on the bypass in the gas-gas heat exchanger and the

amount of catalyst installed. The sulfur is recovered as commercial grade concentrated sulfuric acid with a concentration of 93-96% H_2SO_4 , depending on the content of excess water in the flue gas. NOx is catalytically reduced to N_2 . At the same time, essentially all dust and particulates are removed from the flue gas. The heat produced in the process and by cooling the flue gas to 100° C is recovered as steam and preheating of combustion air thus increasing boiler efficiency and compensating for the power consumption of the flue gas and air blowers.

The process generates no secondary sources of pollution such as waste water, slurries or solids. It consumes no water or materials, except for ammonia for the catalytic NOx-reduction, some support heat upstream of the catalytic reactors and a very small amount of a chemical used for acid mist control.

The process consists of the following steps:

- Dust removal in ESP (or bag filter) to ≤ 5 mg/Nm³ of non-combustible dust
- Heating of the flue gas to 390-400°C
- Catalytic reduction of NOx by NH_3 added to the gas upstream of the NOx-reactor
- Catalytic oxidation of SO_2 to SO_3 in the subsequent oxidation reactor
- Cooling of the gas to 250-260°C
- Further cooling of the gas to about 100°C in air-cooled glass tubes in the "WSA
- Condenser" whereby the SO_3 and H_2SO_4 vapor is condensed and drawn off as concentrated sulfuric acid from the bottom chamber of the condenser.

The process is in particular suited for retrofit on boilers burning high sulfur refinery residuals such as petroleum coke, heavy oils and sour gases. [8]

3.8. Carbon monoxide (CO) control

Carbon monoxide is a pollutant that is readily absorbed in the body and can impair the oxygen-carrying capacity of the hemoglobin. Impairment of the body's hemoglobin results in less oxygen to the brain, heart, and tissues. Even short-term over exposure to carbon monoxide can be critical, or fatal, to people with heart and lung diseases. It may also cause headaches and dizziness in healthy people.

During combustion, carbon in the fuel oxidizes through a series of reactions to form carbon dioxide (CO_2). However, 100 percent conversion of carbon to CO_2 is rarely achieved in practice and some carbon only oxidizes to the intermediate step, carbon monoxide.

Older boilers generally have higher levels of CO than new equipment because CO has only recently become a concern and older burners were not designed to achieve low CO levels. In today's equipment, high levels of carbon monoxide emissions primarily result from incomplete combustion due to poor burner design or firing conditions (for example, an improper air-to-fuel ratio) or possibly a leaky furnace. Through proper burner maintenance, inspections, operation, or by upgrading equipment or utilizing an oxygen control package, the formation of carbon monoxide can be controlled at an acceptable level [7].

4. Particulate Matter (PM)

Emissions of particulate matter (PM) from combustion sources consist of many different types of compounds, including nitrates, sulfates, carbons, oxides, and any un-combusted elements in the fuel. Particulate pollutants can be corrosive, toxic to plants and animals, and harmful to humans.

Particulate matter emissions generally are classified into two categories, PM and PM_{10} . PM_{10} is a particulate matter with a diameter less than 10 microns. All particulate matter can pose a health problem. However, the greatest concern is with PM_{10} , because of its ability to bypass the body's natural filtering system.

A variety of particulate removal technologies, with different physical and economic characteristics, are available.

4.1. Inertial or impingement separators

Rely on the inertial properties of the particles to separate them from the carrier gas stream. Inertial separators are primarily used for the collection of medium-size and coarse particles. They include settling chambers and centrifugal cyclones (straight-through, or the more frequently used reverse-flow cyclones). Cyclones are low-cost, low-maintenance centrifugal collectors that are typically used to remove particulates in the size range of 10–100 microns (mm). The fine-dust-removal efficiency of cyclones is typically below

70%, whereas electrostatic precipitators (ESPs) and bag houses can have removal efficiencies of 99.9% or more. Cyclones are, therefore, often used as a primary stage before other PM removal mechanisms [9].

4.2 *Electrostatic precipitators (ESPs)*

Remove particles by using an electrostatic field to attract the particles onto the electrodes. Collection efficiencies for well-designed, well-operated, and well maintained systems are typically in the order of 99.9% or more of the inlet dust loading. ESPs are especially efficient in collecting fine particulates and can also capture trace emissions of some toxic metals with an efficiency of 99%.

4.3 *Filters and dust collectors (bag houses)*

Collect dust by passing flue gases through a fabric that acts as a filter. The most commonly used is the bag filter, or bag house. The various types of filter media include woven fabric, needled felt, plastic, ceramic, and metal. The operating temperature of the bag house gas influences the choice of fabric. Accumulated particles are removed by mechanical shaking, reversal of the gas flow, or a stream of high-pressure air. Fabric filters are efficient (99.9% removal) for both high and low concentrations of particles but are suitable only for dry and free-flowing particles. Their efficiency in removing toxic metals such as arsenic, cadmium, chromium, lead, and nickel is greater than 99%.

4.4 *Wet scrubbers*

rely on a liquid spray to remove dust particles from a gas stream. They are primarily used to remove gaseous emissions, with particulate control a secondary function. The major types are venturi scrubbers, jet (fume) scrubbers, and spray towers or chambers. Venturi scrubbers consume large quantities of scrubbing liquid (such as water) and electric power and incur high pressure drops. Jet or fume scrubbers rely on the kinetic energy of the liquid stream. The typical removal efficiency of a jet or fume scrubber (for particles 10 μ m or less) is lower than that of a venturi scrubber [10].

4.5 *PM Control of automobile engine*

Diesel fuel is a major contributor to particulate matter (PM). Diesel particulate emissions are of increasing concern as they are small, often less than 2.5 microns in size, and consist of a complex

mix of engine oils, sulfates and inorganic materials. These particles have been identified by health experts as contributing to a variety of lung related illnesses including asthma, emphysema and bronchitis.

To date, most of the diesel PM reduction efforts have focused on either new engine replacements or retrofitting existing engines with post combustion emission control equipment. Of primary interest are diesel oxidation catalysts and diesel particulate filters [11].

Diesel oxidation catalysts (DOCs) are relatively inexpensive and are robust enough to be used in many non-road applications such as construction and mining equipment. They are not overly sensitive to fuel sulfur content and can achieve PM reductions of 25 percent or more. Diesel particulate filters (DPFs) also offer retrofit opportunities. DPFs work best with newer engines that achieve higher sustained engine exhaust temperatures. DPFs also require the use of ultra-low sulfur diesel. Although DPFs cost two to three times more than oxidation catalysts, they can achieve PM removal efficiencies in excess of 90 percent [12].

Low sulfur diesel fuels or alternative fuels can also provide PM control. Reducing the sulfur content of diesel fuels provides a direct fuel related reduction in particulate matter emissions. More importantly, low sulfur fuel allows the use of emission control technologies that have been proven effective in providing significant PM control. As a result, most diesel PM control programs also include a low sulfur diesel component.

Other fuels and fuel technologies that can provide PM benefits include bio-diesel, natural gas, diesel/water emulsions and diesel/electric hybrids. Bio-diesel and water/diesel emulsions are direct fuel substitutes that can be used with little or no modifications to an existing diesel engine. For most bio-diesel applications, a B20 blend is used, which consists of 80 percent diesel, 20 percent bio-diesel. PM emission reductions are estimated at about 10 percent or more for B20. Water/diesel emulsion fuels blend about 20 percent water with diesel. A surfactant and additives make up about 1 percent of the mix and maintain the emulsion. For the most part this is a proprietary fuel marketed under the name PuriNOx. PM reductions of 40 percent or more have been reported for PuriNOx.

In boilers, PM emissions are primarily dependent on the grade of fuel fired in the boiler. Generally, PM levels from natural gas are significantly lower than those of oils. Distillate oils result in much lower particulate emissions than residual oils [11].

4.6. PM control in boiler

When burning heavy oils, particulate levels mainly depend on four fuel constituents: sulfur, ash, carbon residue, and asphalenes. These constituents exist in fuel oils, particularly residual oils, and have a major effect on particulate emissions. By knowing the fuel constituent levels, the particulate emissions for the oil can be estimated.

Methods of particulate control vary for different types and sizes of boilers. For utility boilers, electrostatic precipitators, scrubbers, and bag houses are commonly utilized. For industrial and commercial boilers, the most effective method is to utilize clean fuels. The emission levels of particulate matter can be lowered by switching from a residual to distillate oil or by switching from distillate oil to a natural gas. Additionally, through proper burner set-up, adjustment and maintenance, particulate emissions can be minimized, but not to the extent accomplished by switching fuels [7].

5. Conclusion

Air pollution is not only affecting the human health but also causing damage to our environment. The flue gas data from polyester plant's boilers and generators shows that natural gas is far better environment friendly fuel than furnace oil. The emissions from generator are greater than that of boiler. The major concern for air pollution is the primary pollutants, which are dangerous not only as individual but also participate in the formation of dangerous secondary pollutants like ozone and acid rain. The easiest way to reduce pollution is by using environment friendly fuels like natural gas and biologic fuels like ethanol and bio-diesel. There are number of techniques available for removing the pollutants generated. NO_x are controlled by combustion control techniques and flue gas treatment. The flue gas treatment like SCR is the most effective method to reduce the NO_x . New technologies like Hybrid-Selective Reduction (HSR) are amongst the other technologies that are

very effective for removal of NO_x . Multi pollutants control technologies like SNOX and NOXSO are very effective for removal of NO_x and SO_x . SO_2 removal, as high as more than 98%, could be achieved by using NOXSO. VOCs are effectively removed by Absorption, Adsorption and thermal incineration. The removal efficiency achieved by these techniques could be as high as 99%. PM could be controlled by using techniques like ESPs and filters. The efficiency obtained by these processes could be as high as 99.9%.

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