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Review Article

AIR POLLUTION CONTROL TECHNIQUES

[a]Peter Osei Boamah, [a]Jacqueline Onumah, [b]Mohammed Takase, [c]Prince Osei Bonsu & [d]Tayari Salifu

[a]Department of Ecological Agriculture, Bolgatanga Polytechnic, Ghana, West Africa.
[b]Evangelical Presbyterian University, Ghana, West Africa.
[c]Department of Agricultural Engineering, University of Cape Coast, Ghana, West Africa.
[d]Department of Agricultural Engineering, Bolgatanga Polytechnic, Ghana, West Africa.
Current address: [a,c,d]School of Chemistry and Chemical Engineering, Jiangsu University, Zhenjiang, Jiangsu, 212013, China.

ABSTRACT
Air pollution is the introduction of chemicals, particulate matter (PM), or biological materials that cause harm or discomfort to humans and other living organisms, or cause damage to the natural environment. The substance that is solid, liquid or gas in the air that cause harm to humans and the environment is known as pollutants. These pollutants are classified into primary and secondary. This review mentioned sulphur dioxide, nitrogen oxides, carbon monoxide, carbon dioxide, volatile organic compounds, ammonia, odours, radioactive pollutants as primary pollutants whiles particulate matter, ground level ozone and peroxyoxyacetyl nitrate were mentioned as secondary pollutants. The effects of these pollutants on health and the environment were also not left out of this review. Furthermore, adsorption, absorption and incineration processes were mentioned as the three basic techniques for controlling gases. Finally, this review revealed that air borne particles could only be removed physically using equipment such as cyclones, scrubbers, electrostatic precipators and bag house filters for collecting the fine particulates.

KEYWORDS: Air pollution, sources, health, environment, controlling techniques.

INTRODUCTION

Air is an important natural resource providing the basis of life on earth. The air in the atmosphere provides oxygen to plants and animals by virtue of which they are able to live. It is therefore important to have good quality air for various activities. However, this is becoming increasingly difficult in view of large scale pollution caused by the industrialization of society, intensification of agriculture, introduction of motorized vehicles and explosion of the population. These activities generate primary and secondary air pollutants which substantially change the composition of air. Kaifu (2011) therefore defined air pollution as the introduction of chemicals, particulate matter (PM) or biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural environment or built environment into the atmosphere. Some of the primary and secondary air pollutants include sulphur dioxide, nitrogen oxides, carbon monoxide, carbon dioxide, volatile organic compounds (VOCs), ammonia, odours, radioactive pollutants and particulate matter, ground level ozone, peroxyoxyacetyl nitrate respectively (Kaifu, 2011). He further indicated that these pollutants are dispersed throughout the atmosphere in concentrations high enough to gradually cause serious health and environmental problems. The effects are often first noticed as wheezing, coughing, shortness of breath and a worsening of existing respiratory and cardiac conditions particularly in sensitive portions of the population including the very young, old or those with existing medical conditions such as asthma. Pollutants also have harmful effects on the environment through damage to plants, buildings and a reduction invisual amenity from smoke or haze. At the community level, reductions in air pollutants can be achieved by actively choosing to walk, cycle or take public transport rather than drive a car (DEHP, 2011). Motor vehicles should be kept in good condition and driven correctly to minimise emissions. Good urban design and planning can also reduce pollution by having cleaner, greener choices for the public. These may include increasing walking and cycling paths and by creating a space in the urban cities where people can work, play and shop which will reduce the need to travel. Purchasing items that have low energy requirements from their manufacture and use, or that can be recycled, also reduce the energy that needs to be generated (DEHP, 2011). Besides the community level approach having a clean air, it is essential to devise techniques to control air pollution. To control gaseous criteria pollutants as well as volatile organic compounds (VOCs) and other gaseous air toxics, absorption, adsorption, and incineration have been identified by ICMA (2007) as the three basic techniques employed to control gaseous pollutants. These techniques may be employed singly or in combination depending on the type of pollutant. Moreover, some pollutants are usually absorbed in the atmosphere. Absorption in the context of air pollution control involves the transfer of a gaseous pollutant from the air into a containing liquid such as water. The liquid should be able to serve as a solvent for the pollutant or to be captured by means of chemical reaction. In addition, gas adsorption is a surface phenomenon where gas molecules are sorbed, that is attracted to and held on the surface of a solid. Gas adsorption methods are used for odour control at various types of chemical-manufacturing and food-processing facilities in the recovery of a number of volatile solvents (e.g. benzene) and in the control of VOCs at industrial facilities. Again, incineration or combustion is a very rapid way to convert VOCs and other gaseous hydrocarbon pollutants to carbon dioxide and water (ICMA, 2007).

On the other hand, airborne particles can be removed physically from a polluted airstream using equipment such as cyclones, scrubbers, electrostatic precipators and bag house filters for collecting the fine particulates (ICMA, 2007). This review provides recent literature on the above equipment, sources of air pollution, effect of air pollution on health and environment and techniques for controlling air pollution.

SOURCES OF AIR POLLUTION

Kaifu (2011) outlined the sources of air pollution to be the various locations, activities or factors which are responsible for the release of pollutants into the atmosphere. He defined a pollutant to be any substance (solid, liquid or gas) in the air that can cause harm to humans and the environment. Pollutants may be natural or man-made and can be further classified as primary or secondary. Usually, primary pollutants are directly emitted from processes such as ash from volcanic eruption, monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories. On the other hand, secondary pollutants are not emitted directly rather, they are formed in the air when primary pollutants react or interact. Besides, some pollutants may be both primary and secondary that is they are both emitted directly and formed from other primary pollutants. Kaifu (2011) discussed the details of primary and secondary pollutants as below.

Primary pollutants

These are major pollutants produced by human activity, they include the following:

Sulphur oxides (SOx) - Sulphur dioxide is a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulphur compounds their combustion generates sulphur dioxide. Also, further oxidation of SO_2 usually in the presence of a catalyst such as NO_2, forms H_2SO_4, thus acid rain. This is of great concern over the environmental impact of the use of these fuels as power sources.

Nitrogen oxides (NOx) **-** Nitrogen dioxide are emitted from high temperature combustion. Nitrogen dioxide is a chemical compound with the formula NO_2. It is one of the several nitrogen oxides. It is a reddish-brown toxic gas which has a sharp, biting odor characteristic and is one of the most prominent air pollutants.

Carbon monoxide (CO): It is a colourless, odourless, non-irritating but very poisonous 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.

Carbon dioxide (CO_2): Is a colourless, odourless, non-toxic greenhouse gas associated with ocean acidification, emitted from sources such as combustion, cement production, and respiration.

Volatile Organic Compounds (VOCs): VOCs are important outdoor air pollutant. They are often divided into separate categories of methane (CH_4) and non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to increasing global warming. Other hydrocarbon VOCs are also significant greenhouse gases via their role in creating ozone and in prolonging the life of methane in the atmosphere although their effect vary depending on local air quality. In addition, within the NMVOCs, the aromatic compounds such as benzene, toluene and xylene are suspected carcinogens and may lead to leukaemia through prolonged exposure. 1, 3-butadiene is another dangerous compound which is often associated with industrial uses.

Ammonia (NH_3): It is emitted from agricultural processes. Ammonia is a compound with the formula NH_3 and normally considered as a gas with a pungent odour characteristic. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Also, either directly or indirectly as a building block for the synthesis of many pharmaceuticals although it is known to be both caustic and hazardous.

Odours: Odours emanate from slaughterhouses, breweries, bio-industries, textile industries, coffee roasting plants, yeast and alcohol factories, sewage treatment works, solid waste composting works among others. VOCs and H2S have been identified as the major odour stimuli in sewer pipes and aerobic wastewater treatment plants (Smet and van Langenhove, 1998). Other odorous molecules include organic sulphides, mercaptans, ammonia, inorganic and organic amines, and organic acids, aldehydes and ketones.

Radioactive Pollutants: These are produced by nuclear explosions, war explosives and natural processes such as radioactive decay of radon.

Secondary pollutants

These are pollutants which are formed in the air when primary pollutants react or interact and they include particulate matter, ground level ozone and peroxyacetyl nitrate which have been elaborated below.

Particulate matter is formed from gaseous primary pollutants and compounds in photochemical smog. Smog is a kind of air pollution and the word ‘smog’ is derived from smoke and fog. Classic smog results from large amounts of coal burning in an area caused by a mixture of smoke and sulphur dioxide. Moreover, modern smog does not usually come from coal but from vehicular and industrial emissions which are acted on in the atmosphere by ultraviolet light from the sun to form secondary pollutants that also combine with the primary emissions to form photochemical smog.

Ground level ozone (O_3) is formed from NOx and VOCs. Ozone (O_3) is a key constituent of certain regions of the stratosphere commonly known as the ozone layer. The layer undergoes photochemical and chemical reactions which drive many of the chemical processes that occur in the atmosphere by day and night. More importantly, high concentrations at abnormal level brought about by human activities largely through the combustion of fossil fuel constitute a pollutant and hence a smog, Peroxyacetyl nitrate (PAN) is similar to NOx and VOCs as described above.

TYPES OF AIR POLLUTION

Air pollution can be classified into accidental air pollution, Industrial air pollution, Transport related air pollution and

Dwelling related air pollution (Tutor Vista, 2010). Accidental air pollution is pollution due to forest fires, accidents to petroleum mass transport vehicles, leakage and blasts in industries. Air pollution due to accidents is occasional and they may be dangerous to emit large quantity of pollutant at a time. Industrial air pollution is pollution from thermal power plants, chemical fertilizers, food, pesticide and pharmaceutical industries, cement, steel, paper, sugar industries, textile and textile related industries, petroleum and other industries and atomic units. Transport related air pollution can be pollution due to all types of terrestrial transport system, urban transport system and other modes of transport. Dwelling related air pollution is the type of air pollution due to the use of aerosols, high density of population and waste disposal system. Dwelling related pollution is more correlated to wide spread use of advanced technologies like computers, refrigerators, air conditioners among others as well as mis-handling or non-handling of waste disposal systems in urban agglomeration. Among the aforementioned types of air pollution, industrial pollution and transport related pollution contribute greatly to air pollutants because industrial activity and transport are continuously operative (Tutor Vista, 2010).

EFFECT OF AIR POLLUTION ON HEALTH

Pollutants in the air cause health defects ranging from unnoticeable chemical and biological changes to troubled breathing and coughing. The ill effects of air pollution primarily attack the cardiovascular and respiratory systems. However, the severity of health to pollution depends on a number of factors including the composition of the pollution, degree and length of exposure and genetics. The effect of air pollution on health is discussed under the following headings respiratory effects, cardiovascular effects and asthma as portrayed by Mission (2012).

Respiratory effects

The respiratory system is extremely susceptible to pollutants. Ozone, metals, and other pollutants from the air enter the lungs and can cause damage. Ozone has been known to attack the alveoli, an integral piece of the respiratory system responsible for filtering in oxygen and out carbon dioxide. Pollutants are also able to cause secondary damage to lung tissue by reacting with airway enzymes to cause inflammation or infection of the lungs.

Cardiovascular Effects

Once toxic substances reach the cardiovascular system, a number of reactions do occur. These include physical changes, degeneration, and inflammation of the heart and other areas of the cardiovascular system. Pollutants can also cause heart arrhythmias, which when severe enough can prove fatal.

Asthma

Perhaps the most well-known health defect caused by air pollution is asthma, a disease that can be both chronic and incapacitating. Ozone, sulfur dioxide, particulate matter like dust and ash, and nitrogen oxide have all been known to exacerbate or even trigger asthma. About 30 percent of asthma cases in children are as a direct result of environmental pollution (Mission, 2012).

EFFECT OF AIR POLLUTION ON THE ENVIRONMENT

The environment is made up of the world around us, including both living organisms and non-living material. The atmosphere contains many gases necessary for life. However, human activities release pollutants into the atmosphere that contribute to air pollution. Air pollutants are substances present in earth's atmosphere at a concentration capable of causing harm to people, other animals, materials and vegetation. The most notable and potentially dangerous effects of air pollution come from the greenhouse gas effect or "global warming" (Marla, 2010). Carbon pollution traps heat in the atmosphere increasing temperatures like in a greenhouse. These warming temperatures destroy many ecosystems as some species depend on a stable climate (Marla, 2010). In addition, nitrogen or sulphur containing rain also called acid rain damages plants and buildings. The details of the effect of air pollution on the environment are discussed below.

Photochemical smog

Smog is formed when pollutants like hydrocarbons and nitrogen oxides combine in the presence of sunlight. It is a mixture of gases mainly composed of ozone (O_3), peroxyacetyl nitrate (PAN) and NO_x and it is formed by photochemical reactions hence the name photochemical smog. The word 'smog' is derived from the two words - smoke and fog. Smog forms a yellowish brown haze especially during winter and hampers visibility. It is also known as brown air when solar radiation is intense. In addition, during seasons of lesser solar radiation or areas, smog formation is incomplete and the air is referred to as grey air. Smog is known to cause many respiratory disorders and allergies as it contains polluting gases.

Greenhouse Effect

Greenhouse effect refers to another type of air pollution formed by contamination of gas with oxygen. When greenhouse pollutants move upward in the air and eventually return to earth, they can destroy plants, crops and livestock. Ozone gas is one of the six major types of gases that create the greenhouse effect and can create "holes" in the atmosphere. This type of air pollution can ultimately affect weather by burning layers of the earth's atmosphere that normally filter radiation and heat from the sun.

Ozone Layer Depletion

Ozone, a gas occurring naturally in the atmosphere comprises the ozone layer, a region of the stratosphere located several miles above Earth's surface (National Oceanic and Atmospheric Administration, 2011). The ozone layer protects living creatures from the sun's ultraviolet rays. However, human activities have produced chemicals such as chlorofluorocarbons (CFCs) that have depleted the ozone layer in recent years (NOAA, 2011). This depletion allows more ultraviolet light to reach the planet's surface which causes health problems such as cancer, from extended exposure to the light (EPA, 2012).

Vegetation Damage

A variety of air pollutants including ozone, fluorides, sulfur dioxide, carbon monoxide and nitrogen oxides cause damage to vegetation. A study conducted by EPA US identified three types of plant injuries caused by air pollutants. These are collapse of leaf tissue, changes in growth, yellowing and other color changes. EPA US also discovered ozone as the major plant pollutant as ozone interferes with the ability of some plants to produce and store food, damages the leaves of plants and trees and reduces crop yields and forest growth (EPA, 2012).

Land and Water Pollution

Harmful particles are been carried by air currents over long distances. These particles settle in water or on the ground to contaminate soil and water sources in the area. Particulate accumulation in water makes streams and lakes more acidic, and changes the nutrient balance in rivers and coastal waters (EPA, 2012). Besides, particulates on the ground leach nutrients from the soil and damage trees and crops. In addition, acid rain which occurs when emissions from fossil fuels react with water, oxygen and other chemicals in the atmosphere to form acidic compounds makes lakes and streams more acidic and damages trees and forest soils (EPA, 2012).

Acid Deposits

Acid deposition occurs when a combination of dry, acidic particles and precipitation falls to the Earth's surface. Acid corrodes metals such as bronze and causes paint and stone such as limestone or marble to deteriorate (EPA, 2010). Also acid deposition damages cars, buildings and objects such as monuments and statues and the destruction to buildings and other structures such as bridges leads to increased maintenance costs.

TECHNIQUES FOR CONTROLLING AIR POLLUTION

The best way to protect air quality is to reduce pollutant emissions by changing to fuels and processes that are less polluting. Pollutants that are not eliminated in this way must be collected or trapped by appropriate air-cleaning devices as they are generated and before they can escape into the atmosphere (ICMA, 2007). Many types of air-cleaning devices exist for removing particulate and gaseous air pollutants. They are applicable to both air toxics and criteria pollutants. Below are items commonly used as pollution control devices by industry or transportation devices. They can either destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere.

Control of particulates

Airborne particles can be removed from a polluted airstream by a variety of physical processes. The common types of equipment for collecting fine particulates include cyclones, scrubbers, electrostatic precipitators and bag house filters. Once collected, particulates adhere to each other forming agglomerates that can readily be removed from the equipment and disposed off usually in a landfill. Each air-pollution control project is unique and it is usually not possible to decide in advance what the best type of particle collection device (or combination of devices) may be and so control systems must be designed on a case-by-case basis. More importantly, particulate characteristics that influence the selection of collection devices include corrosivity, reactivity, shape, density, and

Scrubbers

especially size and size distribution (the range of different particle sizes in the airstream) (ICMA, 2007). Other design factors include airstream characteristics (e.g., pressure, temperature, and viscosity), flow rate, removal efficiency requirements, and allowable resistance to airflow. In general, cyclone collectors are often used to control industrial dust emissions and as precleaners for other kinds of collection devices. Again, wet scrubbers are usually applied in the control of flammable or explosive dusts or mists from sources such as industrial and chemical processing facilities and hazardous-waste incinerators. They can also handle hot airstreams and sticky particles. Electrostatic precipitators and fabric-filter bag houses are often used at power plants and the principles behind cyclones, scrubbers, electrostatic precipitators and bag houses as air-cleaning equipment described by ICMA (2007) are presented below.

Cyclones

A cyclone (see figure 1) removes particulates by causing the dirty airstream to flow in a spiral path inside a cylindrical chamber. Dirty air enters the chamber from a tangential direction at the outer wall of the device forming a vortex as it swirls within the chamber. The larger particulates because of their greater inertia move outward and are forced against the chamber wall. Slowed by friction with the wall surface, they then slide down the wall into a conical dust hopper at the bottom of the cyclone. The cleaned air swirls upward in a narrower spiral through an inner cylinder and emerges from an outlet at the top and accumulated particulate dust is periodically removed from the hopper for disposal. Cyclones are best at removing relatively coarse particulates. They can routinely achieve efficiencies of 90 percent for particles larger than about 20 µm (0.0008 inch). However, cyclones are not sufficient to meet stringent air quality standards. They are typically used as precleaners and are followed by more efficient air-cleaning equipment such as electrostatic precipitators and baghouses.

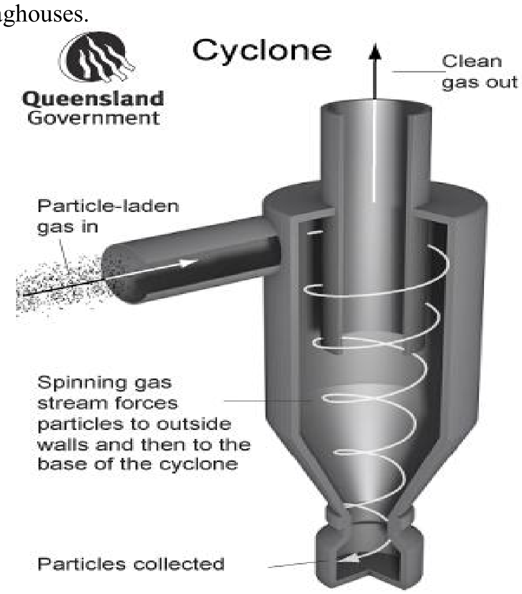

FIG 1: Diagram of a cyclone (Adapted from DEHP, 2011)

Wet scrubbers trap suspended particles by direct contact with a spray of water or other liquid. In effect, a scrubber washes the particulates out of the dirty airstream as they collide with and are entrained by the countless tiny droplets in the spray.
Several configurations of wet scrubbers are in use. In a spray-tower scrubber, an upward-flowing airstream is washed by water sprayed downward from a series of nozzles. The water is recirculated after it is sufficiently cleaned to prevent clogging of the nozzles. Spray-tower scrubbers can remove 90% of particulates larger than about 8 μm (0.0003 inch).
In orifice scrubbers and wet-impingement scrubbers, the air and droplet mixture collides with a solid surface. Collision with a surface atomizes the droplets reducing droplet size and thereby increasing total surface contact area. These devices have the advantage of lower water-recirculation rates and they offer removal efficiencies of about 90 percent for particles larger than 2 μm (0.00008 inch).
Venturi scrubbers are the most efficient of the wet collectors achieving efficiencies of more than 98% for particles larger than 0.5 μm (0.00002 inch) in diameter. Scrubber efficiency depends on the relative velocity between the droplets and the particulates. Venturi scrubbers achieve high relative velocities by injecting water into the throat of a venturi channel (a constriction in the flow path) through which particulate-laden air is passing at high speed.

Electrostatic precipitators

Electrostatic precipitation is a commonly used method for removing fine particulates from airstreams. In an electrostatic precipitator (see figure 2), particles suspended in the airstream are given an electric charge as they enter the unit and are then removed by the influence of an electric field. The precipitation unit comprises baffles for distributing airflow, discharge and collection electrodes, a dust clean-out system and collection hoppers. A high DC voltage (as much as 100,000 volts) is applied to the discharge electrodes to charge the particles, which then are attracted to oppositely charged collection electrodes on which they become trapped.
In a typical unit, the collection electrodes comprise a group of large rectangular metal plates suspended vertically and parallel to each other inside a boxlike structure. There are often hundreds of plates having a combined surface area of tens of thousands of square metres. Rows of discharge electrode wires hang between the collection plates. The wires are given a negative electric charge whereas the plates are grounded and thus become positively charged.

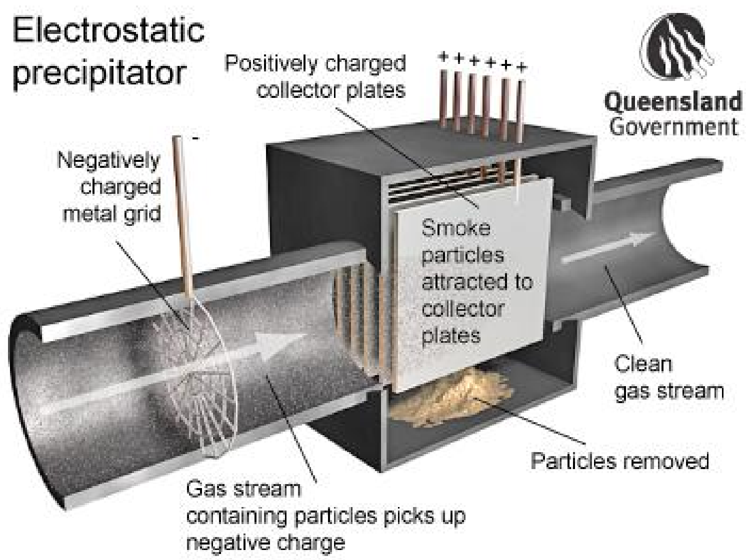

FIGURE 2. Diagram of an electrostatic precipator (Adapted from DEHP, 2011)

Particles that stick to the collection plates are removed periodically when the plates are shaken, or "rapped." Rapping is a mechanical technique for separating the trapped particles from the plates which typically become covered with a 6-mm (0.2-inch) layer of dust. Rappers are either of the impulse (single-blow) or vibrating type. The dislodged particles are collected in a hopper at the bottom of the unit and removed for disposal. An electrostatic precipitator can remove particulates as small as 1 μm (0.00004 inch) with an efficiency exceeding 99 %. The effectiveness of electrostatic precipitators in removing fly ash from the combustion gases of fossil-fuel furnaces accounts to their high frequency of use at power stations.

Bag house filters

One of the most efficient devices for removing suspended particulates is an assembly of fabric filter bags commonly called a bag house. A typical bag house (see figure 3 below) comprises an array of long, narrow bags—each about 25 cm (10 inches) in diameter—that are suspended upside down in a large enclosure. Dust-laden air is blown upward through the bottom of the enclosure by fans. Particulates are trapped inside the filter bags while the clean air passes through the fabric and exits at the top of the bag house.

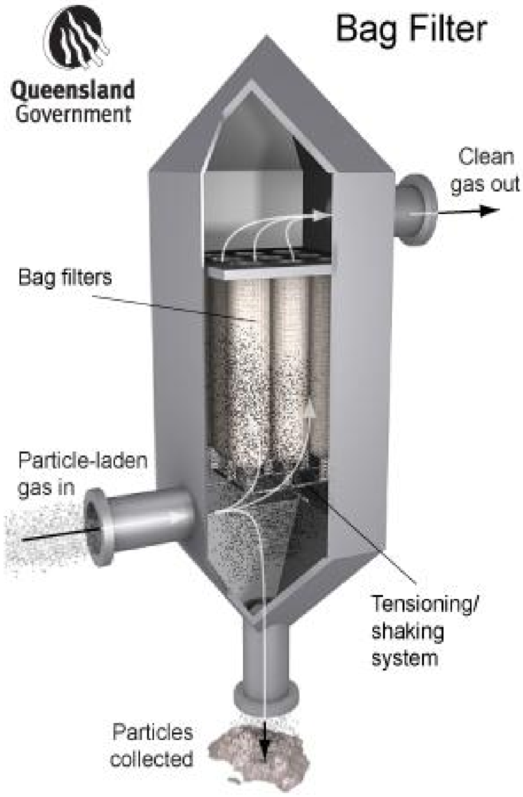

FIGURE 3. Diagram of typical bag filter (Adapted from DEHP, 2011)

A fabric-filter dust collector can remove nearly 100% of particles as small as 1 μm (0.00004 inch) and a significant fraction of particles as small as 0.01 μm (0.0000004 inch). Fabric filters however, offer relatively high resistance to airflow and they are expensive to operate and maintain. Additionally, to prolong the useful life of the filter fabric the air to be cleaned must be cooled (usually below 300 °C or 570 °F) before it is passed through the unit and cooling coils are needed for this purpose which add to the expense. Also, certain filter fabrics for example those made of ceramic or mineral materials can operate at higher temperatures.

Several compartments of filter bags are often used at a single bag house installation. This arrangement allows individual compartments to be cleaned while others remain in service. The bags are cleaned by mechanical shakers or by reversing the flow of air and the loosened particulates are collected and removed for disposal.

Control of gases

Gaseous criteria pollutants, VOCs and other gaseous air toxics are controlled by three basic techniques which are absorption, adsorption, and incineration (ICMA, 2007). These techniques can be employed singly or in combination and are detailed below.

Absorption

In the context of air-pollution control, absorption involves the transfer of a gaseous pollutant from the air into a contacting liquid such as water. The liquid must either be able to serve as a solvent for the pollutant or to capture it by means of a chemical reaction. Wet scrubbers similar to those employed to control suspended particulates may be used for gas absorption. Gas absorption can also be carried out in packed scrubbers, or towers, in which the liquid is present on a wetted surface rather than droplets suspended in the air. A common type of packed scrubber is the counter current tower. After entering the bottom of the tower, the polluted airstream flows upward through a wetted column of light which is chemically inactive packing material. The liquid absorbent flows downward and is uniformly spread throughout the column packing thereby increasing the total area of contact between gas and liquid. Thermoplastic materials are most widely used as packing for counter current scrubber towers. These devices usually have gas removal efficiencies of 90–95%.

Cocurrent and cross-flow packed scrubber designs are also used for gas absorption. In the cocurrent design, both gas and liquid flow in the same direction—vertically downward through the scrubber. Although not as efficient as counter current designs, cocurrent devices can work at higher liquid flow rates. The increased flow prevents plugging of the packing when the airstream contains high levels of particulates while cocurrent designs also afford lowered resistance to airflow and allow the cross-sectional area of the tower to be reduced. The cross-flow design in which gas flows horizontally through the packing and liquid flows vertically downward can also operate with lower airflow resistance when high particulate levels are present. In general, scrubbers are used at fertilizer production facilities to remove ammonia from the airstream, at glass production plants to remove hydrogen fluoride, at chemical plants to remove water-soluble solvents such as acetone and methyl alcohol and at rendering plants to control odours. Sulfur dioxide in flue gas from fossil-fuel power plants can be controlled by means of an absorption process called flue gas desulfurization (FGD). FGD systems may involve wet scrubbing or dry scrubbing. In wet FGD systems, flue gases are brought in contact with an absorbent which can be either a liquid or slurry of solid material. The sulphur dioxide dissolves in or reacts with the absorbent and becomes trapped in it. In dry FGD systems, the absorbent is dry pulverized lime or limestone and once absorption occurs, the solid particles are removed by means of bag house filters. The dry FGD systems, compared with wet systems, offer cost and energy savings and easier operation, but they require higher chemical consumption and are also limited to flue gases derived from the combustion of low-sulphur coal. FGD systems are also classified as either regenerable or non-regenerable (throwaway), depending on whether the sulphur that is removed from the flue gas is recovered or discarded. Non-regenerable FGD systems produce a sulphur-containing sludge residue that requires appropriate disposal but regenerable FGD systems require additional steps to convert the sulphur dioxide into useful by-products like sulphuric acid.

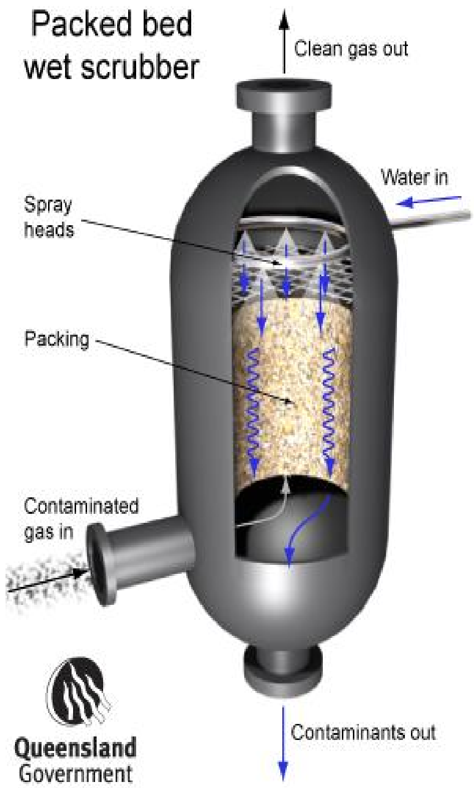

FIGURE 4 . Diagram of packed wet scrubber(Adapted from DEHP, 2011)

Adsorption

Gas adsorption as contrasted with absorption is a surface phenomenon. The gas molecules are sorbed i.e. attracted to and held on the surface of a solid. Gas adsorption methods are used for odour control at various types and stages of chemical-manufacturing and food-processing facilities in the recovery of a number of volatile solvents (e.g., benzene) and in the control of VOCs at industrial facilities.

Activated carbon (heated charcoal) is one of the most common adsorbent materials, it is very porous and has an extremely high ratio of surface area to volume. Activated carbon is particularly useful as an adsorbent for cleaning air-streams that contain VOCs and for solvent recovery and odour control. A properly designed carbon adsorption unit can remove gas with an efficiency exceeding 95% (ICMA, 2007).

Adsorption systems are configured either as stationary bed units or as moving bed units. In stationary bed adsorbers, the polluted airstream enters from the top, passes through a layer or bed of activated carbon and exits at the bottom while moving bed adsorbers, the activated carbon moves slowly down through channels by gravity as the air to be cleaned passes through in a cross-flow current.

Incineration

The process called incineration or combustion can be used to convert VOCs and other gaseous hydrocarbon pollutants to carbon dioxide and water. Incineration of VOCs and hydrocarbon fumes is usually accomplished in a special incinerator called an afterburner. To achieve complete combustion, the afterburner must provide the proper amount of turbulence and burning time and it must maintain a sufficiently high temperature. Sufficient turbulence or mixing, is a key factor in combustion because it reduces the required burning time and temperature. A process called direct flame incineration can be used when the waste gas is itself a combustible mixture and does not need the addition of air or fuel.

An afterburner typically is made of a steel shell lined with refractory material such as fireclay brick. The refractory lining protects the shell and serves as a thermal insulator. Given enough time and high enough temperatures, gaseous organic pollutants can be almost completely oxidized with incineration efficiency approaching 100 %. Also, certain substances, such as platinum can act in a manner that assists the combustion reaction. These substances are called catalysts which allow complete oxidation of the combustible gases at relatively low temperatures.

Afterburners are used to control odours, destroy toxic compounds or reduce the amount of photo chemically reactive substances released into the air. They are employed at a variety of industrial facilities where VOC vapours are emitted from combustion processes or solvent evaporation (e.g., petroleum refineries, paint-drying facilities, and paper mills).

CONCLUSION

Air pollution has become a major environmental issue due to rapid population growth, intensification of agriculture and industrialization. Air pollution is caused by a variety of different substances that include liquid, solid and gas particles. The effect of these pollutants on our health and the environment is enormous. The best way to achieve good air quality is to reduce pollutant emissions by changing to fuels and processes that are less polluting. Also, pollutants that are difficult to be eliminated by the aforementioned processes must be collected or trapped by appropriate air-cleaning devices such as cyclone, electrostatic precipitator, packed wet scrubber and bag filter before they can escape into the atmosphere.

Cyclones are used as precleaners and are followed by electrostatic precipitators and bag houses which are more efficient air-cleaning equipment. Furthermore, gaseous criteria pollutants as well as VOCs and other gaseous air toxics should be controlled by employing singly or in combination three basic techniques such as absorption, adsorption, and incineration.

REFERENCES

Department of Environment and Heritage Protection DEHP (2011) Controlling air pollution. http:// www. ehp. qld.gov.au/air/pollution/controlling.html. Accessed on August, 22, 2012

Environmental Protection Agency EPA US (2012) Health Effects. http://www.epa.gov/air /ozonepollution/ health. html. Accessed on August, 22, 2012

Environmental Protection Agency EPA US (2012) Particulate Matter: Health and Environment. http://www.

epa.gov/air/particlepollution/health.html. Accessed on August, 22, 2012.

Environmental Protection Agency EPA US (2010) Acid Rain: Effects of Acid Rain-Materials http://www.epa. gov/ acidrain/ effects/materials.html Accessed on August, 22, 2012.

Inkomati Catchment Management Agency ICMA (2007) Techniques for controlling air pollution. http://www .inkomaticma.co.za. Accessed on August, 22, 2012.

Kaifi, M.A. (2011) Role of Agriculture in Air Pollution. PIMS Arid University, Rawalpindi,16pp.

Marla, L. S. (2010) The effect of air pollution on the environment. http://www.livestrong.com/article/172211-the-effects-of-air-pollution-on-the-environment/ Accessed on August, 22, 2012.

Mission, C. (2012) The effects of air pollution on human health.http://www.ehow.com/about_5397380_effects-air-pollution-human-health.html Accessed on August, 22, 2012.

National Oceanic and Atmospheric Administration NOAA (2011) The Ozone layer. http://www.oar.noaa.gov/ climate/ t_ozonelayer.html. Accessed on August, 22, 2012.

Smet, E. and H. Van Langenhove (1998) Abatement of volatile organic sulphur compounds in Odorous emissions from the bio-industry. *Biodegradation* ***9***, 273– 284.

Tutor Vista (2010) Types of air pollution. http://www. tutorvista.com. Accessed on August, 22, 2012.