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Effects of Primary Air Pollutants on Human Health and Control Measures-A Review Paper

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Abstract:
Air pollution is one of the major health problems confronting humans today. The accumulation of air pollutants in the atmosphere in large quantities and of longer duration poses harm to human health, affect man-made structures as well as change the patterns of weather and climatic systems. This paper discusses the effects of air pollution upon human health with emphasis on primary air pollutants. It also looked at historical background of air pollution problem, various sources of primary air pollutants, nitrogen oxides (NOx), Carbon monoxide (CO), Particulate material(PM), Sulphur dioxide (SO_2), Volatile organic compounds (VOCs), Radon (Rn) and Lead (Pb) and their upon human health that range from cardiovascular diseases, cancer, emphysema, asthma and so on. Control of air pollutants is likewise discussed from legislative view points and by use of instruments that lessen the quantities of pollutants released by motor vehicles, industries and so on.

Keywords: *Air pollution, health, industries, control, primary, air index*

1. Introduction

Air pollution both indoors and outdoors is a main threat to human health, man-made structures, plants and animals and to the general environment at large in both developed and developing nations (Turk and Kavraz, 2011).

Air pollution could be defined as the release of harmful substances, chemicals, particulates, biological materials and gases with varying constituents based on the origin and weather conditions into the atmosphere that can cause diseases, discomfort or death of humans as well as damage other living things such as food crops and the natural environment at large (Sharma *et al.,* 2013). Air pollutants are material and gases that have adverse effects on humans, animals, plants and structures (Kampa and Castanas, 2008). ‘‘Air pollutant refers to any agent that spoils air quality’’ (Turk and Kavraz, 2011). Air pollutants are categorised into primary and secondary air pollutants on the basis of health problems they caused. However, this paper focuses on primary air pollutants. Sources of air pollutants are both natural and anthropogenic. However, humans have substantially contributes to more air pollution problems nowadays. This pollution affects atmospheric natural systems and as such affects public health gravely (Turk and Kavraz, 2011).

Primary air pollutants refer to harmful substances and gases released into the atmosphere having direct effects human health, animals and the general environment. Examples of such primary air pollutants are sulphur dioxides (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), particulate matter (PM), volatile organic compounds (VOCs), and lead (Pb) (Bernstein, 2004; Wright, 2005, p.578). The atmosphere which consists of complex and dynamic system of gases is important in supporting life on planet earth. Depletion of ozone layer of the stratosphere has long been understood as a great threat to human health and the earth’s ecological systems (Sharma *et al*., 2013). Air pollution is a menace to human health, structures, plants and the entire environment (European Environment Agency, 2013).

The key sources of air pollution include industrial processes, burning of solid waste, heat and power generation and the transportation engines. The burning of petrol, gasoline and other hydrocarbons fuels in trucks, automobiles and aeroplanes release numerous primary air pollutants such as nitrogen oxides, carbon monoxide, sulphur dioxide and a large quantities of particulates notably lead. Under the influence of sunlight, nitrogen oxides react (combine) with hydrocarbons to forming secondary type of pollutants, the photochemical oxidants inclusive are ozone and the eye-irritating peroxyacetyl nitrates (PANs) (Sharma *et al.,* 2013). Nitrogen oxides likewise combine with oxygen in the atmosphere forming nitrogen dioxide a fowl-smelling brown gas. In big cities like Los Angeles in the

United States, transportation is the chief cause of atmospheric pollution where nitrogen dioxide darkens the air, mixing with other pollutants and the atmospheric water vapour to produce brown smog (Sharma *et al.,* 2013). Despite the fact that vehicular fitting of catalytic converters has helped reduced smoke producing compounds in motor vehicle exhaust pollutants, scholarly findings have shown that the catalytic converters produce nitrous oxide which significantly contributes to global warming (Sharma *et al*., 2013).

1.1. General Overview of primary Air Pollutants

History of air pollution dates back to the Great Smog of London of 4th and 9th December 1952, in which the experienced stagnant air and solar radiant energy could not penetrate the cloud cover due to high concentration of pollutants with a consequent humidity of about 80% and temperature dropped to 1°C. In that incidence, an estimated 4000-8000 persons died mostly infants and aged persons as a result of respiratory and other diseases related to breathing polluted air (European Environment Agency, 2013). For details, see figures one and two below.

Figure 1: Heavy Smog in Piccadilly Circus, London (December 6, 1952)
Source: (Photo by Central Press/Hulton Archive/Getty Images in Rosenberg, 1997)

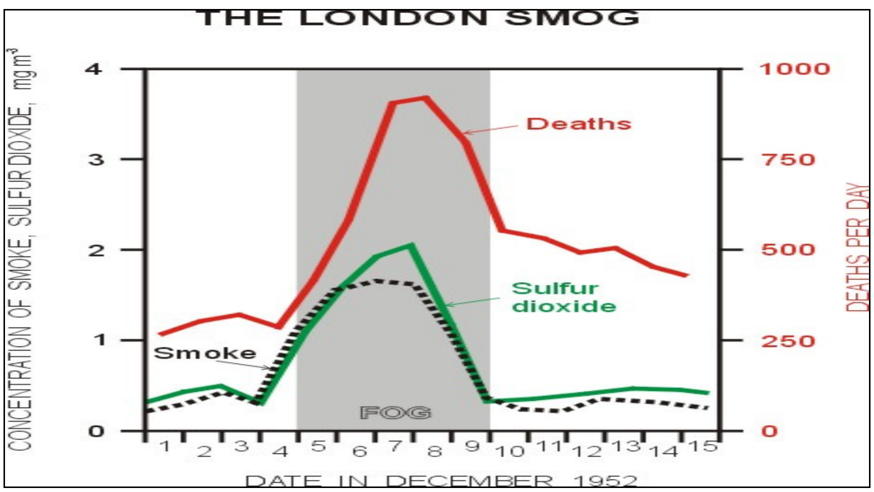

Figure 2: Death toll resulted from the Great London Smog episode.
Source: (Skyscrapercity.com)

Considering the human health effects of air pollution which range from cardiovascular (heart) attacks, lung cancer and other respiratory problems are more common in areas people are exposed to polluted air (dirty air due to contaminants) when compared to those people living in a clean environment (Nuruddeen, Abubakar and Umoru, 2013). It has been reported that air pollution episode is worse in the United States, China and some big cities around the world where large number of motor vehicles and industrial activities emit huge amount of pollutants into the atmosphere (William, 2007 in Nuruddeen, Abubakar and Umoru, 2013). The United Nation has estimated that 1.3 billion people around the globe are exposed to hazardous air pollutants (Nuruddeen, Abubakar and Umoru, 2013). Studies have shown that indoor air pollutants are often higher with serious human health effect than outdoor air pollutants for the fact that people spend more time indoor, also high concentration of air pollutants from cigarette smoking indoor is a serious problem among smokers in the western world. In the developing nations like Africa, Latin America and Asia, the use of firewood, kerosene stoves, room lanterns with diesel, use of charcoal and agricultural waste for cooking in households with less ventilation are serious indoor air pollution problems (Nuruddeen, Abubakar and Umoru, 2013).

1.2. Descriptions and Sources of Primary Air Pollutants

1.2.1. Carbon Monoxide (CO)

This is a colourless, tasteless, odourless as well as non-irritating but a very poisonous and most abundant gas in the lower atmosphere resulting from partial combustion of hydrocarbons (Prockop and Chickova, 2007; Handa and Tai, 2005). Other prevalent sources of CO are vehicle exhaust gas, industries, environmental tobacco smoke, partial fuel combustion from generators and heaters in poorly ventilated homes (Prockop and Chickova, 2007). CO can be endogenously produced by the breakdown of haemoglobin to bile pigments catalysed by haemoglobin oxygenases which is essential in cellular activities (Prockop and Chickova, 2007). CO stays in the atmosphere for about 1-2 months and moves for a long distance away from its source (Akimoto, 2003 in Curtis *et al*., 2006).

1.2.2. Sulphur Dioxide (SO_2)

SO_2 is a colourless and water soluble gas with a strong smell which can be perceived at about 0.5ppm (Gurjar; Molina and Ojna, 2010, p.113). Sources of SO_2 are combustion of fossil fuels like coal, heavy oils, plus smelting of sulphur-containing ores (Kampa and Castanas, 2008). Oceans and volcanoes are natural sources of SO_2 (Kampa and Castanas, 2008).

1.2.3. Nitrogen Oxides (Nox)

These are category of very reactive gases consisting of nitrogen dioxide and nitric oxide (United State Environmental Protection Agency, 1998; DEFRA, 2010). Majority of nitrogen oxides are odourless and colourless, but nitrogen dioxide (NO_2) together with other particles form reddish-brown blanket above several cities (US EPA, 1998). The primary sources of NOx are mobile and static combustion sites, vehicles, electric generators, industries and domestic fuel uses (US EPA, 1998; Kampa and Castanas, 2008). NOx is a precursor in the production of ground level ozone along with volatile organic compounds (Kampa and Castanas, 2008). In the UK, the major sources of NO_X are power stations, industries and vehicles (DEFRA, 2010). Road traffics contribute to long-term ground-level concentrations of NOx, and in UK cities, the highest concentration of NOx is at kerbside and street canyons due to poor dispersion (DEFRA, 2010). The limit value of nitrogen dioxide concentration set by the European Union that protects human health is 40µg/m³ (DEFRA, 2010).

1.2.4. Lead (Pb)

This is a poisonous metal at low quantity which originates from burning of lead-containing fuels and solid wastes (Wright, 2005, p.578). Lead could also be emitted from vehicle exhausts, manufacture of non-ferrous metals, iron, steel and cement (EEA, 2012). Natural sources of lead are soil dust, sea spray and ash particles from volcanoes (EEA, 2012). Lead can also accumulate in the food chain thereby causing damage to the brain and death (Wright, 2005, p.578).

1.2.5. Particulate Matter (PM)

These are particulate air pollutants with different combinations and sizes suspended in the atmosphere derived from natural and human processes (Poschl, 2005 in Kampa and Castanas, 2008). PM is emitted from industries, fires, road traffics, construction and demolition sites, road and soil dust, power plants, incinerators as well as windstorms (Kampa and Castanas, 2008; Curtis et al., 2006). Particulate matter is of different sizes such as PM2.5 and PM10 with particles less than 2.5um and 10um respectively (DEFRA, 2007). There are other categories of PM like ultrafine particles less than 0.1um, fine particles <1µ as well as courser particles >1µm (DEFRA, 2007). The sizes of particles dictate the site they could be deposited in human's body; the smaller the particle the more dangerous it is and vice versa. PM10 chiefly affects the upper respiratory tract while PM2.5 can enter the lung alveoli (air sac) (Kampa and Castanas, 2008).

1.2.6. Volatile Organic Compounds (VOCs)

These are group of chemicals that can readily evaporate into the air (Curtis *et al*., 2006). Sources of VOCs are petroleum refineries, vehicle exhausts, natural gas fields, fuel stores, wastes, household products (deodorants, paints, and preservatives), pesticides, combustions and industrial activities and coniferous forests (Godish, 2003; Lerdu *et al*., 1997 in Curtis *et al*., 2006).

1.2.7. Radon Gas (Rn)

Radon gas is a colourless and odourless radioactive gas which occur naturally from the breakdown of radium and uranium from granites and soil (Wright, 2005, p.578; WHO, 2009). Radon gas has a half-life of 3.8 days and concentrates in closed areas such as underground mines and houses (WHO, 2009). Radon gas contributes greatly to the ionising radiation dose received by people (WHO, 2009). For details of primary air pollutants sources, see figures three, four and five below:

Figure 3: Emissions from a coal-burning electric power plant in Pleasant Prairie, Wisconsin, near Kenosha
Source: (Jordan, 2009) http://www.learnnc.org/lp/multimedia/14252

Figure 4: Bush burning releasing emissions indiscriminately into the atmosphere in an Indian village
Source: (TutorVistor.com) http://biology.tutorvista.com/environmental-pollution/air-pollution.html

Figure 5: Release of carbon monoxide, nitrogen oxides and other emissions by road traffics
Source: (SciTech Daily, 2015) http://scitechdaily.com/human-caused-air-pollution-results-in-over-two-million-deaths-annually/

1.3. Air Quality Standard

Air quality standard has been brought up by the United State Environmental Protection Agency (US EPA) in 1994 with a view to protecting the quality of the air as well as giving warming if air quality falls below standard due to release of pollutants excessively. Table one below explains the ranges and quality of air with likely human health effects. With reference to the index table, the public can determine if certain levels of pollution in a particular area are good, moderate, and unhealthy for sensitive groups or life threatening. Furthermore, local officials use the air quality index as a public information instrument with a view to advising the general public on the general health implications associated with several of air pollution as well as furnishing the public with the necessary precautionary measures if the pollution levels fall in range that poses possible health problems (US EPA, 1994) in Nuruddeen, Abubakar and Umoru, 2013).

AQI	**EPA Colour Scale**	**EPA Descriptor**	**Warning**
Range			
0 to 50	Green	Good	Green signifies good air people can go about their outdoor activities without health problems.
50 to 100	Yellow	Moderate	The air is safe for most people. However, some sensitive persons might react to ozone at this range, particularly those lung and heart diseases like asthma, and children are susceptible. People in these groups or people who develop symptoms when they exercise at "yellow" ozone levels should consider avoiding prolonged outdoor exercise during late afternoon or early evening when ozone is at its highest.
101 to 150	Orange	Unhealthy for sensitive people/ groups	In this level, the outdoor air is more likely to be unhealthy for more people. People and children who are sensitive to ozone and people with lung and heart diseases should avoid prolonged outdoor exercise in the afternoon and early evening when ozone level is highest.
151 to 200	Red	Unhealthy	In this level, more people will be impacted by ozone. People should restrict their outdoor activities to morning or late hours of the evening when ozone level is low, and should avoid exposure to high ozone.
201 to 300	Purple		At this range, more people will be increasingly affected by ozone. People should restrict their outdoor activities to morning and late evening hours when ozone level is low in order to avoid high exposure.
Over 300	Black		At this level, all people should avoid all outdoor activities

Table 1: EPA Air Quality Index and Clean Air Standard for outdoor Warning
Source: (US EPA, 1994 in Nuruddeen, Abubakar and Umoru, 2013).

2. Effects of Primary Air Pollutants upon Human Health

Air pollution has both acute and long-term effects upon human health. Health effects of air pollution ranges from slight inflammation of the eyes and the upper respiratory tract to serious respiratory infections, cardiovascular diseases, lung cancer and death (Minnesotans for Sustainability, 2003). Air pollution has been known to cause severe respiratory problems in children and chronic bronchitis and emphysema in adults (Minnesotans for Sustainability, 2003).

There had been growing evidence that indoor air pollution has effects on human health and that exposure to it increases the risks of severe lower respiratory infections in children, chronic obstructive lung diseases in adults as well as lung cancer due to excessive use of coal (WHO, 2002). Also, there is clear relationship between indoor air pollution and diseases like tuberculosis, asthma, otitis media, cataracts, perinatal mortality (stillbirths and deaths in the first week of life), respiratory cancer and low birth weight (WHO, 2002).

2.1. Sulphur Dioxide and Its Effects on Human Health

Turk and Kavraz (2011) reported that increased quantity of sulphur dioxide, ozone and other pollutants in the air causes elevated risk of asthma, bronchitis and pulmonary infections particularly in elderly persons and those with existing heart and lung problems. Inhaled sulphur dioxide in air reacts with the moisture of nose, nasal cavity and the oesophagus (windpipe) damages cells of the respiratory tracts (Turk and Kavraz, 2011). Sulphur dioxide has effects on the proper functioning of the lungs, causes inflammation of the eyes, coughing and worsening of asthmatic conditions in patients (Turk and Kavraz, 2011). Tunnicliffe *et al*., (2001) has reported that sulphur dioxide irritates respiratory system, constricts bronchioles as well as causes bradycardia (slowing heartbeat). Evaluations in cities across the Europe and Canada revealed that short-term sulphur dioxide exposure increases chances of cardiorespiratory morbidity and death (Chen *et al*, 2012). Sunyer *et al*., (2003 in Chen *et al*., 2012) reported statistical link between outdoor sulphur dioxide and cardiovascular admissions in hospitals, especially for ischemic heart diseases in Europe's seven cities. Subjection to high level of sulphur dioxide results in the inflammation of nose, throat, bronchioles and dysnoea in asthmatic persons (Barmes *et al*., 1987 in Kampa and Castanas, 2008). Sulphur dioxide vulnerability amongst people varies, however, short-term exposure for less than 1ppm results in reversible reduction in lung function (Badernhorst, 2007). Badernhorst (2007) also found that long-term exposure to sulphur dioxide leads to asthma and emphysema. Numerous researches have shown that less than 5ppm sulphur dioxide trigger permanent lung defect, possibly due to persistent broncho-constriction (Badernhorst, 2007). In an enclosed area, sulphur dioxide causes acute airway blockade, hypoxemia (inadequate blood oxygenation), lung oedema and death in few minutes (Badernhorst, 2007).Long-term exposure to SO2 induces irritation of respiratory system, coughing, secretion of mucus, worsening of asthma, severe bronchitis and renders people more vulnerable to respiratory tract infections (EEA, 2012). Death and admissions in hospitals increase due to heart and lung diseases with level of SO2 (WHO, 2008 in EEA, 2012).

2.2. Carbon Monoxide and Human Health

In the United States, carbon monoxide is one of the harmful gas causing death of hundreds and as such known as the unnoticed poison of the 21st century (Prockop and Chichkova, 2007). According to WHO, diesel exhaust from vehicles contains nitrogen oxide and carbon monoxide which cause lung cancer and bladder tumours particularly amongst miners, truck drivers and railway workers (WHO, 2004). Carbon monoxide decreases the blood ability of transporting oxygen to cells and tissues and long-term exposure to carbon monoxide results in heart diseases (Wright, 2005, p.587). Kampa and Castanas (2008) reported that inhaled carbon monoxide and benzene can cause haematological effects as well as cancer. Carbon monoxide reacts with blood haemoglobin, thus decreasing its ability to transmit oxygen to organs like the brain and heart which eventually affect their functions (Kampa and Castanas, 2008). Vehicular PM, nitrogen oxides and carbon monoxide were found to increase the risk of blepharitis (eyelid infection) even after many days of subjection (Malerbi *et al.,* 2012). Carbon monoxide exposure may result in weakness of the body, nausea, shock, abdominal discomfort, sight change, breathlessness as well as loss of conscience (Handa and Tai, 2005). Handa and Tai (2005) also added that subjection to carbon monoxide causes head ache, tiredness, dizziness and drowsiness. Currie, Neidell and Scmieder (2009) reported that pregnant women's exposure to carbon monoxide decreases the amount of oxygen conveyed to developing foetus; carbon monoxide easily enters the placenta and combines with foetal haemoglobin causing 10-15% concentration in foetal blood higher than in mother's blood. Carbon monoxide has greater effect than any other pollutant due to its capacity of entering the placenta and accumulates in the foetal blood (Currie, Neidell and Schmieder (2009). Carbon monoxide has been found to be the primary cause of hospital admissions for heart failure compared to NO_X, SO_2, and O_3 (Bernstein et al., 2008).

2.3. Nitrogen Oxides and Human Health

Nitrogen oxides are very reactive gases. Long-term exposure to nitrogen oxides damages lung activity, affect the body immune system making the lungs vulnerable to viral and bacterial infections (Wright, 2005, p.587). Lee et *al.,* (2011) found that carbon monoxide and nitrogen oxides emitted by vehicles affect lung activities in children particularly boys. Nitrogen oxides have remarkable effects on respiratory system and reach deeper sites of the respiratory area (Wichman *et al*. 2005). New reliable evidence suggests that children, infants and female adults are most vulnerable to respiratory risks of NO2 exposure (Bernstein et al., 2008). Short-term exposure to 10ppm nitrogen dioxide or above can cause fluid entry into the lungs plus other symptoms of lung oedema (Wichman et al. 2005). At lower concentrations, nitrogen dioxide alters lung activity, reduces the strength body defence and affects lung structure. Persistent exposure to nitrogen oxide causes fibrotic alterations and emphysema (Wichman *et al*. 2005). Mortality and hospital admission survey showed that asthmatic and bronchitic patients are mostly affected by short-term nitrogen dioxide exposure (Wichman *et al*. 2005). Short-term exposure to PM, CO, NO2, SO2, NO2 and benzene aggravates asthma condition in children (Curtis *et al*. 2006). Nitrogen dioxide increases the risk of respiratory disorders (Kampa and Castanas, 2008). Epidemiological findings have indicate that bronchitis symptoms in children increase due to long-term subjection to NO2 (Gurja, Molina and Ojna, 2010, p.2). Long-term exposure to a yearly mean of less than 40µg/m³ NO2 leads hospital admissions for respiratory infections, Otitis media and ultimately death (Latza, Gerdes and Baur, 2009).

2.4. Particulate Matter (PM) and Human Health

Particulate matters are primary air pollutants having effects on human health especially the respiratory system derived from natural and human activities (Poschl, 2005 in Kampa and Castanas, 2008). Short-term subjection to PM causes irritation of the lung, cardiovascular system and ultimately death (WHO, 2004). In children and adults, PM do reduces lung activity, causes diseases of the lung and eventually decreases life expectancy due to cardiovascular death and lung cancer (WHO, 2004). According to Gurjar, Molina and Ojna (2010, p.2) PM exposure is a leading cause of health effects to rural and urban dwellers of developed and developing nations. Risk of contracting heart and respiratory diseases and lung cancer is common due to long-term exposure to particulate matter (Gurjar, Molina and Ojna, 2010, p.2). PM2.5 and PM10 exposure can cause ventricular ectopy (a heartbeat due to an impulse generated in the ventricles) amongst smokers (Liao et al. 2009 in Polichetti *et al*., 2009). A research in Chile has shown a strong link between elevated ambient PM2.5 concentration and higher wheezing bronchitis in children (Pino *et al*. 20*04 in* Bernstein *et al.,* 2008). There has been report that particulate matter affects developing foetus, but has no placental effect (Currie, Neidell and Schmieder, 2009).

Particulate air pollution was one of the pollution type shown to have severe health effects due to both short and long-term exposure in the United States and the United Kingdom (Harrison, 2001, p.275). There are clear evidences that short alterations in hospital admissions, death and lung activity are related to outdoor concentrations of particulate matter; also common symptoms and death as a result of respiratory infections are link to outdoor particulate matter concentrations (Harrison, 2001, p.275). Asthma and other respiratory infections in Birmingham hospitals were shown to have related to ambient PM10 and smoke well below outdoor air quality standards (Harrison, 2001, p.275).

2.5. Volatile Organic Compounds (Vocs) and Human Health

Volatile organic compounds are chemicals which could easily evaporate into the air from vehicle exhausts, petrochemicals, household products, pesticides and so on. VOCs have effects upon human health when inhaled. Human exposure to VOCs can cause severe and chronic poisoning (Tanyanont and Vichit-Vadakan, 2012). VOCs cause acute health effects to human which include inflammation of the eyes, nose, throat, skin as well as nausea, dizziness, body weakness, headache and breathlessness (United State Environmental Protection Agency, 2007 in Tanyanont and Vichit-Vadakan, 2012). Exposure to VOCs induces severe respiratory tract irritation, visual defects and memory abnormality (Chang et al. 2013). Chang *et al.,* (2013) also added that VOCs cause impairment of the kidney, liver and the central nervous system. A number of VOCs are notable carcinogens while others impact the brain, liver and the body immune system (Wu *et al*., 2012). Several findings have shown links between atmospheric VOCs and harmful health effects like asthma (Wichman *et al*., 2009 in Wu *et al*., 2012). See figure six below for primary air pollutants effects on human health:

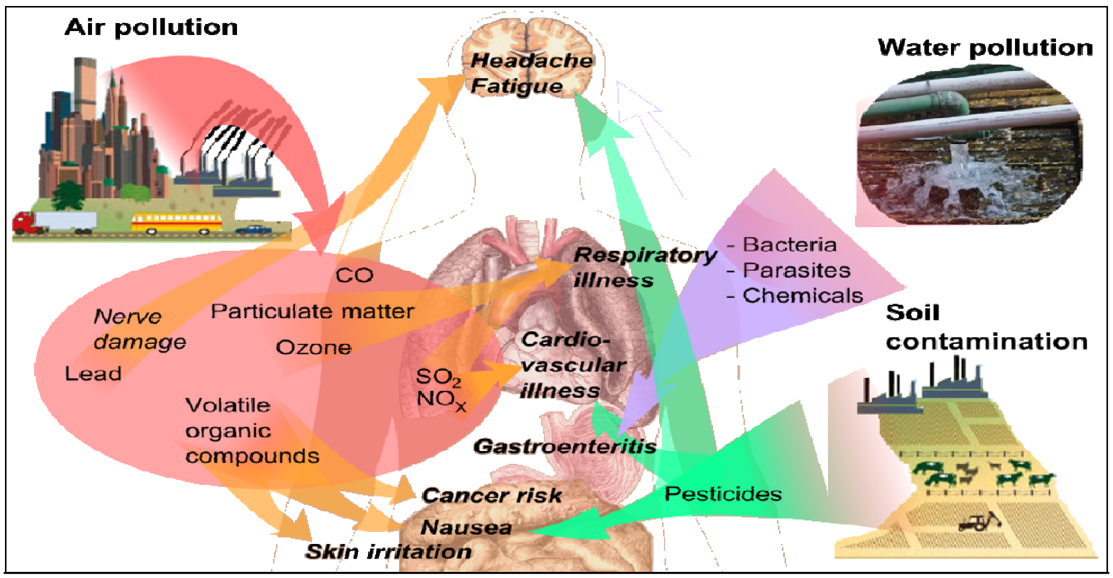

Figure 6: Overview of main health effects on humans from some common types of pollution
Source: (Mikael, 2014)

3. Control of Primary Air Pollutants

3.1. Air Pollution Control through Legislation

Various measures have been put in place for the control of air pollutants due to the fact that their concentrations have exceeded the natural cleansing capacity of the atmosphere (Wright, 2005, p.592). The Clean Air Act of 1970 has been the basis of the U.S. air pollution control measures. The act identified the key air pollutants (CO, NOx, SO2, particulates), set standards and devised control measures to protect human health and the environment (Wright, 2005, p.592).

The National Emissions Ceilings Directive 2001/81/EC (NECD) have been enacted within European countries to regulate the four key air pollutants SO2, NOx, NH3 and VOCS. The NECD aims at protecting the environment and human health effects resulting from eutrophication, acidification as well as ground level ozone associated with air pollution (EEA, 2011).

The Gothenburg Protocol (1999) to the United Nations Economic Commission for Europe's Convention on trans-boundary air pollution (LRTAP) controls regional emissions of SO2, NOx, NH3 and VOCs in the Europe through setting standards (European Environment Agency, 2012).

The Geneva Protocol (1991) which was in effect in 1997 regulates volatile organic compounds pollution. The protocol mandated 30% VOCs emissions reduction across the Europe as of 1999 (EEA, 2011). The Vapour Recovery Directives regulate the emissions of VOCs from stored petrol terminals within Europe (EEA, 2012). The Solvents Directive (1999/13/EC) monitors industrial emissions of VOCs from various processes and installations, comprising of printing, pharmaceutical companies, surface cleanings, dry cleanings, and so on (EEA, 2012). The Paint Directive controls VOCs in paints, vanishes as well as vehicle-refinishing products (EEA, 2012). The Directive on Integrated Pollution Prevention and Control (96/61/EC) which came into effect in 1999 regulates air pollution, water and land by industries within the Europe (EEA, 2011). The EU Directive 91/441/EC mandated fitting of three-way catalysts in new petrol cars within Europe in an effort to reducing emissions of CO, VOCs, PM and NOx from road traffics (EEA, 2012).

In an effort for controlling air pollution, there have been low emission zones established for couple of years in Sweden, Greater Tokyo Area, and recently in London and some cities in the Netherlands. In these zones, more polluting vehicles are not allowed through placing emissions standards and other criteria (DEFRA, 2009). The UK government employed several measures for controlling vehicular nitrogen oxides and particulate matter through prohibition of old vehicles in some areas, consideration of alternative fuel technology like hybrid vehicles, biofuels, renewable fuels as well as fuel consumption efficiency of vehicles (DEFRA, 2007). Air pollutants reduction could also be achieved via regulatory controls and other strategies in industries, homes and the transport spheres e.g. use of gas in power stations instead of coal, pollutants trapping or transformation (fitting catalytic converters into vehicles); behaviour change like using public transport systems also reduce emissions (DEFRA, 2010).

3.2. Air Pollution Control through Devices/Equipment

Technological devices are used industries, power plants and in vehicles for the removal of harmful substances from emissions or convert them to less harmful substances (Chiras, 2009, p.418). Devices employed by industries and vehicles to control air pollution include bag filters, cyclones, catalytic converters, electrostatic precipitators and scrubbers (Chiras, 2009, p.418).

3.2.1. Cyclone

This is a device used in industries for trapping particulates usually in small operations. Cyclones are effective in removing 50-90% of large particles, but are not suitable for ultra-fine particles (Chiras, 2009, p.418). Figure 7 below:

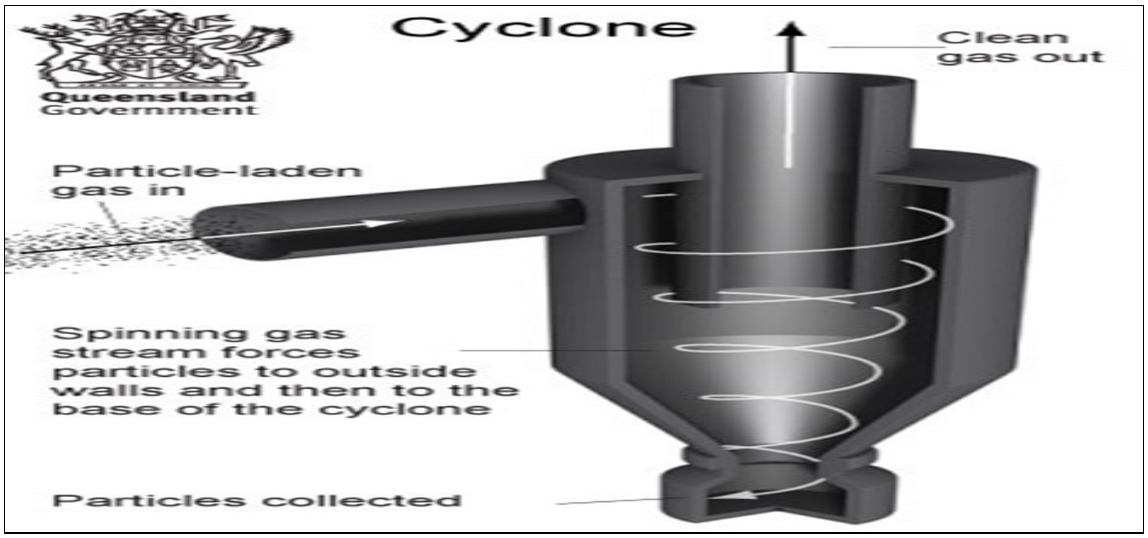

Figure 7: A cyclone
Sources: (Queensland Government, Department of Environment and Heritage Protection, 2011) (QGDEHP)

3.2.2. Electrostatic Precipitator

This is also used in industries for removal of particulates; it is effective and can remove about 99% of particles. It is being used in many US coal plants (Chiras, 2009, p.418). Figur**e** eight below shows an electrostatic precipitator

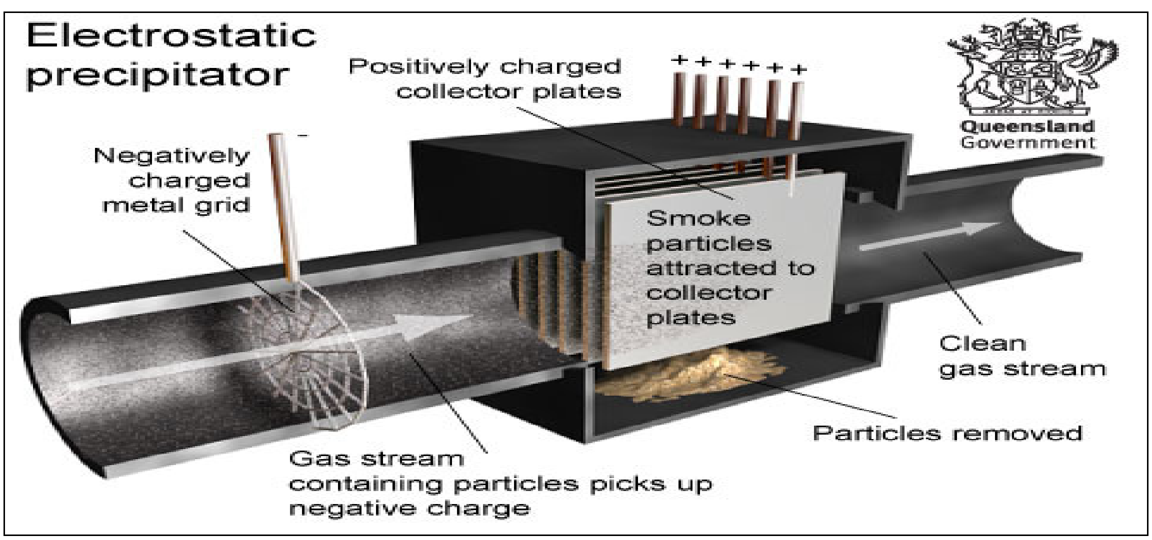

Figure 8: An electrostatic precipitator
Sources: (QGDEHP, 2011)

3.2.3. Scrubber
This device is used in industries for trapping particulates and sulphur dioxide gas in their operations. It traps over 99% of particulates as well as 80 to 95% sulphur dioxide. However, nitrogen oxide and carbon dioxide are not trapped by this equipment (Chiras, 2009, p.418). Figure ten below shows a scrubber:

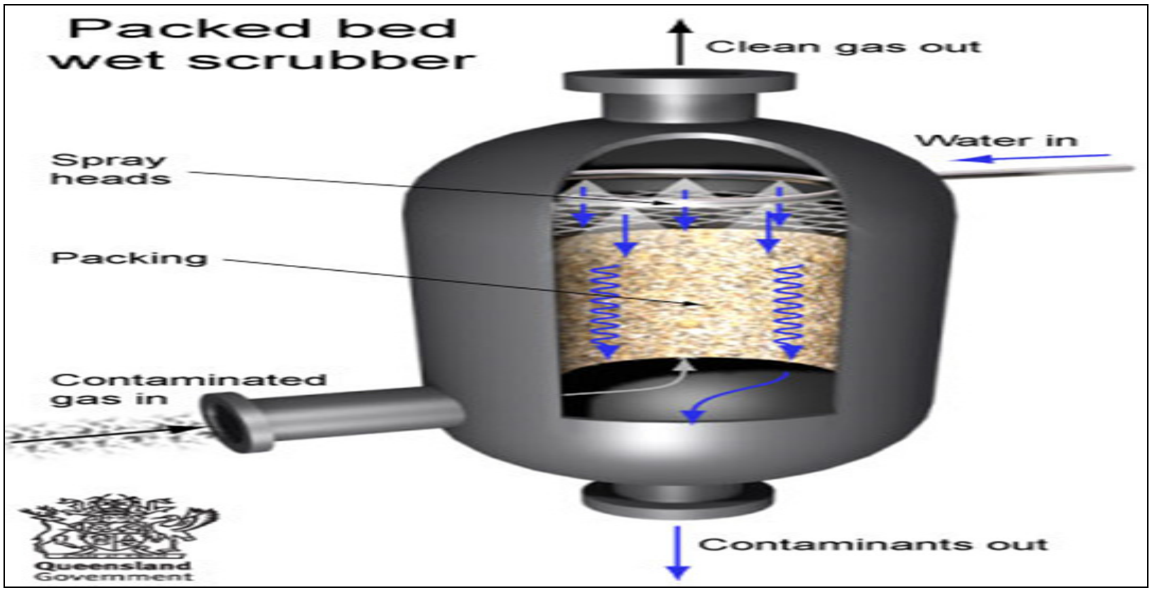

Figure 9: A scrubber
Sources: (QGDEHP, 2011)

Other devices used in industries in trapping dust, particles, primary pollutants include dust chamber, tube filter, jet chamber, venchuri washer and electrical separators. Trees are also helpful in trapping pollutants (Harrison, 2001).

3.2.4. Dust Chamber
This device make use of gravitational force in removing dust particles in power plants. It is efficient for trapping larger particles of about 5µm, however, it is not effective for ultra-fine particles removal (Chiras, 2009, p.18).

3.2.5. Tube Filters
These devices are used in vehicles for removing/trapping micro-particulates of less than 1µm (Chiras, 2009, p.18).

3.2.6. Venturi-Washers
These are equally employed in industrial operations for removal of particulate of less than 1µm; they are 90% effective for industrial particulate matter removal (Chiras, 2009, p.18).

4. Conclusion
This review discussed the effects of primary air pollutants on human health. It has been seen from various literatures that primary air pollutants have serious effects on human health such as cardiovascular problems like asthma, emphysema and other life-threatening ailment like cancer. In view of these problems, stringent legislations and enforcement of the use of emissions filtering devices by governments and world nations can help in minimizing air pollution effects to the minimum.

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