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THE ADVERSE EFFECTS OF FLUE-GAS EMISSION AND CARBON-SOOT FROM COMBUSTION OF FOSSIL FUEL LEADING TO THE PHASE-OUT CAMPAIGN OF COAL – A REVIEW

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Abstract—This paper reviews the effects of some flue gas and carbon-soot released into the environment by combustion of fossil fuel, and how to stop/reduce their emission. Although fossil fuels like coal, oil and natural gas are extremely useful important sources of energy, but when burned in either a limited or excess air, the environment does pay a price by the emission of some polluting (harmful) gases like carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon-soot. The review shows that the continues emission of these anthropogenic gases (greenhouse gases) in large volumes into the environment results into negative health effects, global dimming, global warming, greenhouse effect and acid rain formation. Carbon dioxide even though a major gas for photosynthesis process and chemical industry; it is most commonly released and has the highest volume in the environment that contribute immensely to global warming. It is ideal for all countries to have regulatory bodies to control the emission of harmful flue gases through policies such as command-and-control (which mandates the amount of pollution or the technology used), economic incentives, or voluntary programs, etc.

Keywords—pollution, flue gas, emission, carbon-soot, combustion, fossil fuel, environment

I. INTRODUCTION

Fossil fuel is of great importance because they can be burned (oxidized) to carbon dioxide and water, producing significant amounts of energy per unit weight. Some of the major uses of fossil fuels are in combustion for generating electricity, automobile transport, domestic energy source and as feedstock for the petrochemical industry, which releases flue gas (mixture of gases) containing carbon monoxide, sulfur oxide, hydrocarbons, nitrogen oxide, etc that pollute the environment and make life uncomfortable. Most of these gases are important feed-stocks in the chemical industries, but if release into the environment they become harmful to ecological existence or ecosystem (McCormac, 1992). Combustion of fossil fuel generates sulphuric, carbonic, and nitric acids, in the atmosphere which falls down as acid rain, affecting the environment negatively. In fact, the major disadvantage of using hydrocarbons (fossil fuels) as fuel or raw material is their potential to pollute the environment both through their harvesting, processing and consumption.

Fossil fuel is the major primary energy source in the world, and its consumption and utilization varies from country to country, depending on the technological advancement (Figure 1and 2). The Energy Information Administration (EIA) estimates that in 2007, the primary sources of energy consisted of petroleum 36.0 %, coal 27.4 % and natural gas 23.0 %, amounting to an 86.4 % share for fossil fuels in primary energy consumption in the world (EIA, 2010). Non-fossil sources in 2006 included hydroelectric 6.3 %, nuclear 8.5 %, and others (geothermal, solar, tidal, wind, wood, waste) amounting to 0.9 %. The world energy consumption trend has shown that it is growing at about 2.3 % per annum (IEA, 2005).

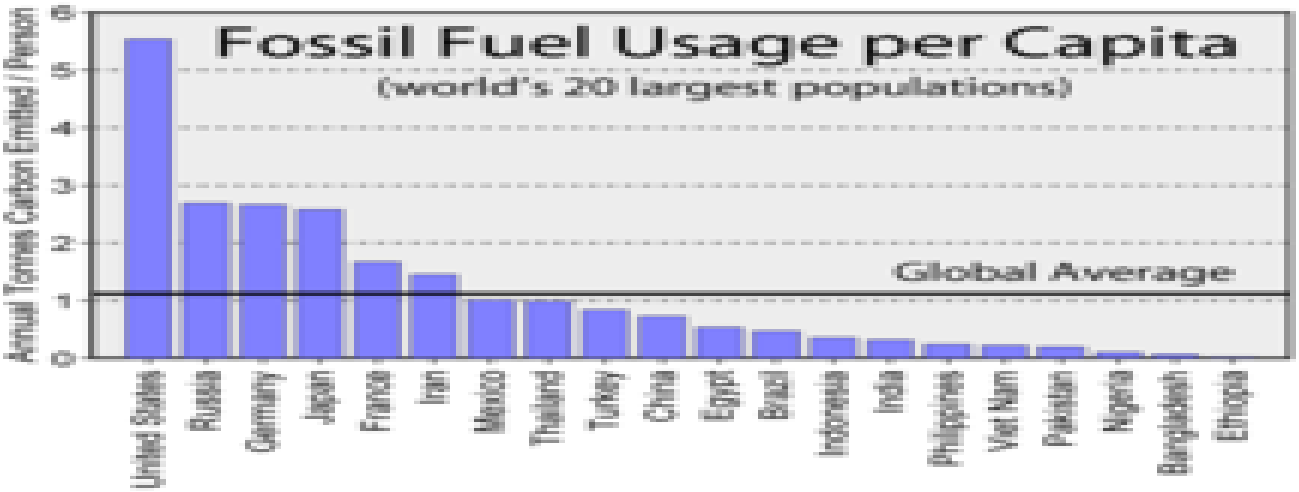

Figure1: Fossil fuel consumption per capita for the countries with the twenty largest populations (The World Fact-book, 2014)

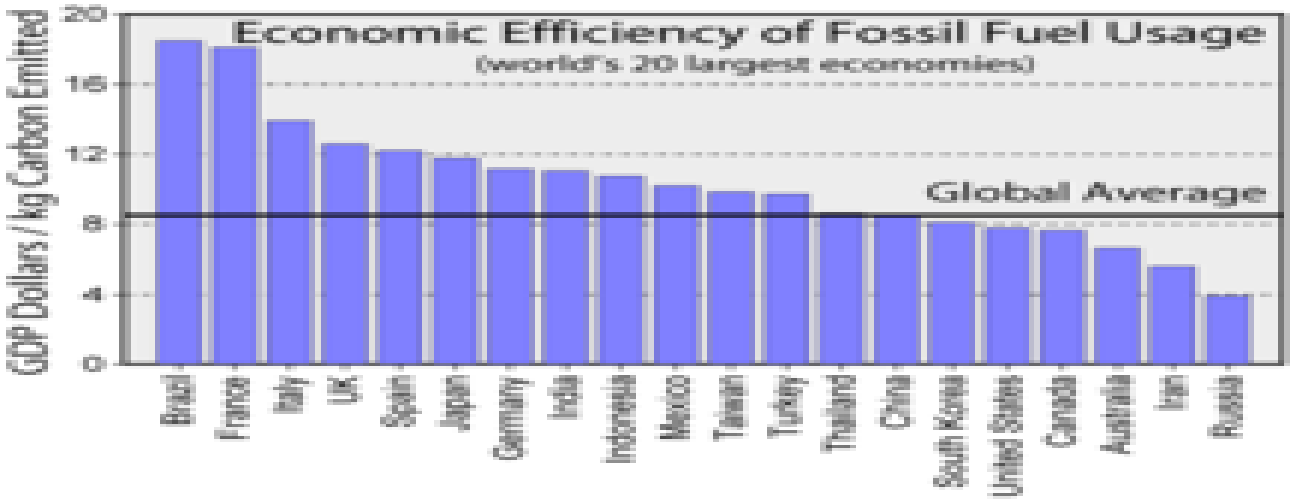

Figure 2: Ratio of gross domestic product (GDP) to kilograms of fossil fuel carbon consumed, for the world's 20 largest economies (The World Fact-book, 2014).

Figure 2, depicts how well a country is able to utilize the fossil fuel for economic growth. The two countries (Brazil and France) with the highest GDP per kilogram carbon ratios produce large amounts of hydroelectric and nuclear power from use of fossil fuel **(**The World Fact-book, 2014).

The burning of fossil fuels produces around 21.3 billion tonnes of carbon dioxide (CO_2) per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tonnes of atmospheric carbon dioxide per year (NEIC, 2004). A global movement towards the generation of renewable energy is therefore under way to help reduce global greenhouse gas emissions for cleaner air.

Fossil fuel also contains radioactive materials (mainly uranium and thorium); heavy metals like lead, mercury, copper, cadmium, etc and varieties of metallic substance which are released into the atmosphere on combustion. In 2000, about 12,000 tonnes of thorium and 5,000 tonnes of uranium were released worldwide from burning coal (Gabbard, 1993). It is estimated that in 1982, United States (US) coal burning released 155 times as much radioactive substances into the atmosphere from the Three Mile Island nuclear plant incident (Aubrecht, 2001). Burning coal also generates large amounts of bottom ash and fly ash. Harvesting, processing, and distributing fossil fuels can also create environmental concerns.

Carbon dioxide (CO_2) is a colourless and odourless gas that is released into the environment as a bye-product of animal respiration. Its heat-absorbing ability is what makes life possible on Earth. CO_2 has some very important and beneficial effect, but it meets the legal and encyclopeadic definition of a pollutant, and has to be regulated because of its harmful effect on the ecology. It is a primary greenhouse gas that causes the greatest amount of global warming. Human activities that involve combustion and industrial processes of fossil fuel have added more of the CO_2 than the atmospheric requirement and the level has been on the increase (Figure 4 and 5).

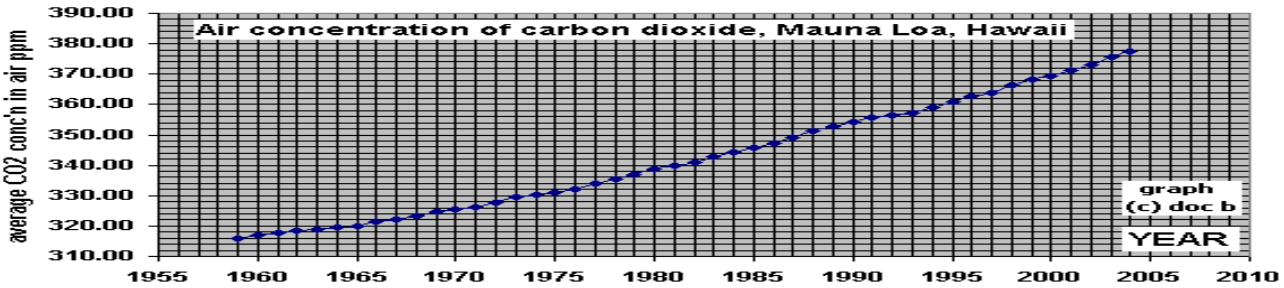

Figure 4: Graph showing rising carbon dioxide (CO_2) level from 1959 – 2004 (Brown, 2015).

The graph shows the steady yearly rise in the concentration of carbon dioxide in the atmosphere from 1959 – 2004 as measured at top of mountain Mauna Loa (on the Pacific island) of Hawaii, USA by a renowned scientist, Charles D. Keeling of the Institute of Oceanography (Brown, 2015). The followings can be deduced from the graph:

- It shows the reliable amount of carbon dioxide in the atmosphere because mountain Mauna Loa of Hawaii, is a good base-line for our planet analysis of the gas since it is well away from any industry involving fossil fuel burning.
- The concentration of CO_2 is in ppm (parts per million): one ppm means one in 10^6 of air molecules is CO_2. In percentage volume terms, one ppm = 1/100 x 10^6 = 0.0001 %. The graph shows that the CO_2 has risen from 0.0316 % (316 ppm) in 1959 to 0.0378 % (378 ppm) in 2004. This doesn't seem much of an increase, but on a global scale, it could have drastic consequences.

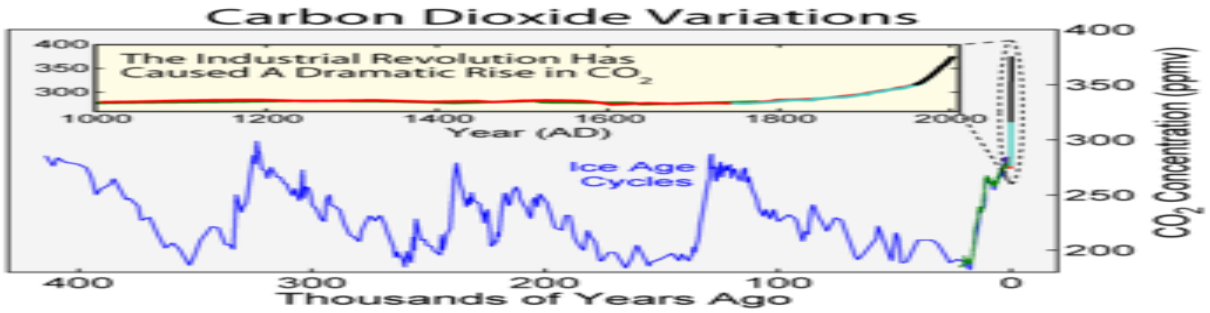

Figure 5: Carbon dioxide variations over the last 400,000 years, showing a rise since the industrial revolution (Casper, 2010).

The U.S. holds less than 5 % of the world's population, but due to large houses and private cars, it uses more than a quarter of the world's supply of fossil fuel (Gardnor *et al*., 2011). According to the National Energy Information Centre (NEIC), about 90 % of anthropogenic greenhouse gases emission comes from the combustion of fossil fuel in United States with carbon dioxide taking lead of 82 % (Figure 6).

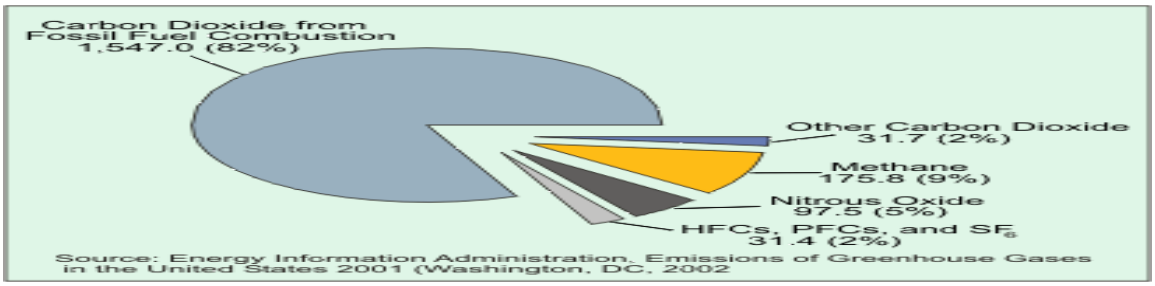

Figure 6: Greenhouse gases emission composition (NEIC, 2004).

II. COAL AND ITS PHASE OUT CAMPAIGN

Coal is a solid fuel that is widely posited to be the most polluting fossil fuel. It is one of the largest sources of energy that supplied 27 % of the world's primary energy in 2009. At least 40 % of the world's electricity comes from coal, and it is one of the largest worldwide anthropogenic sources of carbon dioxide emission (wikipeadia, 2015). According to an American scientist, the average coal power plant emits more than 100 times as much carbon dioxide per year than does a comparatively sized nuclear power plant, in the form of fly ash (Hvistendahl, 2007).

To decrease carbon emissions and thus possibly stop extreme climate change, some have called for coal to be phased out (Goodell, 2007). Some believe that coal should not be phased out, considering that longer-term global economic growth cannot be achieved without adequate and affordable energy supplies, and thus require continuous significant contributions from fossil fuels such as coal. In this phenomenon, IEA (2005) suggested the enforcement of clean coal technology to reduce greenhouse gas emissions. Some environmentalists and climatologists support a phase-out and criticise clean coal technology as not a solution to climate change (Worldwatch Institute, 2015), while entrepreneurs promote improved regulations and modernised technology (wikipeadia, 2015). Hanse *et al*. (2008) and, Kharecha and Hanse (2008) called for a moratorium and phasing out coal power completely by the year 2030 and 2050 respectively.

Fossil fuel phase out is the proposed energy transition that will gradually bring about the use of green energy source which are naturally replenished such as sunlight, wind, rain, tides, waves, and geothermal heat; and eventually replace the former through multiple means: including electrification, decommissioning of operating fossil fuel-fired power plants and prevention of the construction of new fossil-fuel-fired power stations. Its purpose is to reduce air pollution, mining tragedies and greenhouse gas emissions which cause climate change (IPCC, 2007). A move to the many forms of renewable energy is involved in shifting away from fossil fuels.

The 20 leaders of the world's top industrialized nations, as well as key countries with developing economies, have agreed to phase out their subsidies for fossil fuels, including coal. In a concluding statement from the Group of 20 (G20) Summit – held in Pittsburgh, Pennsylvania, on September 24 and 25, 2009 – the nations' leaders agreed to phase out and rationalize over the medium term inefficient fossil fuel subsidies. The G20 leaders also called for targeted support for poor people that would be impacted by higher prices for fossil fuels. The leaders noted that inefficient fossil-fuel subsidies encourage wasteful consumption, reduce our energy security, impede investment in clean energy sources, and undermine efforts to deal with the threat of climate change (wikipeadia, 2015). The positions of some countries toward the use of coal for energy generation are as below:

The Australian Greens party has proposed to phase out coal power stations. Australia is one of the coal largest exporter and consumption per capita. The proposal is strongly opposed by industry, unions and the main Opposition Party in Parliament (wikipeadia, 2015).

The single greatest coal-consuming country is China and currently there are no plans to phase out coal burning power stations at the national level. China’s share of the world coal production was

28 % in 2000 and rose to 48 % in 2009. China's exceedingly high energy demand has pushed the demand for relatively cheap coal-fired power. Coal supplies about 80 % of China's energy needs today, and that ratio is expected to continue, even as overall power usage grows rapidly. Serious air quality deterioration has resulted from the massive use of coal and many Chinese cities suffer severe smog events. China has huge investments in coal power but due to the consequence, the region of Beijing has decided to phase out all its coal-fired power generation by the end of 2015 and switch to renewable sources (Singapore, 2013).

India is in no way phasing out coal or fossil fuels in general. The annual report of India's Power Ministry has a plan to grow power by about 80 GW as part of their 11th 5-year plan, and 79 % of that growth will be in fossil-fuel fired power plants, primarily coal (Annual Report, 2009). India plans four new ultra mega coal-fired power plants as part of that growth, each 4000MW in capacity (Wikipeadia, 2015).

In 2007, Germany announced plans to phase out hard coal-industry subsidies by 2018, a move which is expected to end hard coal mining in Germany (Newsletter, 2007). Coal is still a major source of power in Germany, but is gradually being replaced by renewable energy such as solar and wind.

In October 2007, the Clark Labour government in New Zealand introduced a 10-year moratorium on new fossil fuel (coal) thermal power generation. The ban was limited to state-owned utilities, though an extension to private sector was considered (Wikipeadia, 2015).

South Africa's power sector is currently the 8th highest global emitter of carbon dioxide (CO_2). Around 77 % of South Africa's energy demand is directly met by coal and when current projects come online, this ratio will increase in the near term. There are no plans to phase out coal-fired power plants in South Africa, and indeed, the country is investing in building massive amounts of new coal-fired capacity to meet power demands, as well as modernizing the existing coal-fired plants to meet environmental requirements (Wikipeadia, 2015).

The United Kingdom (UK) announced that no new coal-fired power stations will be built in Britain from 2009 onwards unless they capture and bury at least 25 % of greenhouse gases immediately and 100 % by 2025 (Vidal, 2009). The UK decision is also subject to the European Union's Large Combustion Plant Directive covering even non-carbon dioxide (CO_2) emissions which is expected to bring many older plants to a close over the next few years as they are too expensive to upgrade (UK Environmental Agency, 2013).

In 2007, the United States of America (USA) proposed 154 new coal-fired plants in 42 states. By 2012, that had dropped to 15, mostly due to new rules limiting mercury emissions, and limiting carbon emissions to 1,000 pounds of CO_2 per megawatt-hour of electricity produced (Johnson, *et al*., 2012). In July 2013, US Secretary of Energy Ernest Moniz outlined Obama administration policy on fossil fuels: *"In the last four years, we've more than doubled renewable energy generation from wind and solar power. However, coal and other fossil fuels still provide 80 percent of our energy, 70 percent of our electricity, and will be a major part of our energy future for decades. That's why any serious effort to protect our kids from the worst effects of climate change must also include developing, demonstrating and deploying the technologies to use our abundant fossil fuel resources as cleanly as possible"* (Moniz, 2013). In the US, many of the fossil fuel phase-out initiatives have taken place at the state or local levels by the gradual introduction of various renewable energy sources (Figure 3).

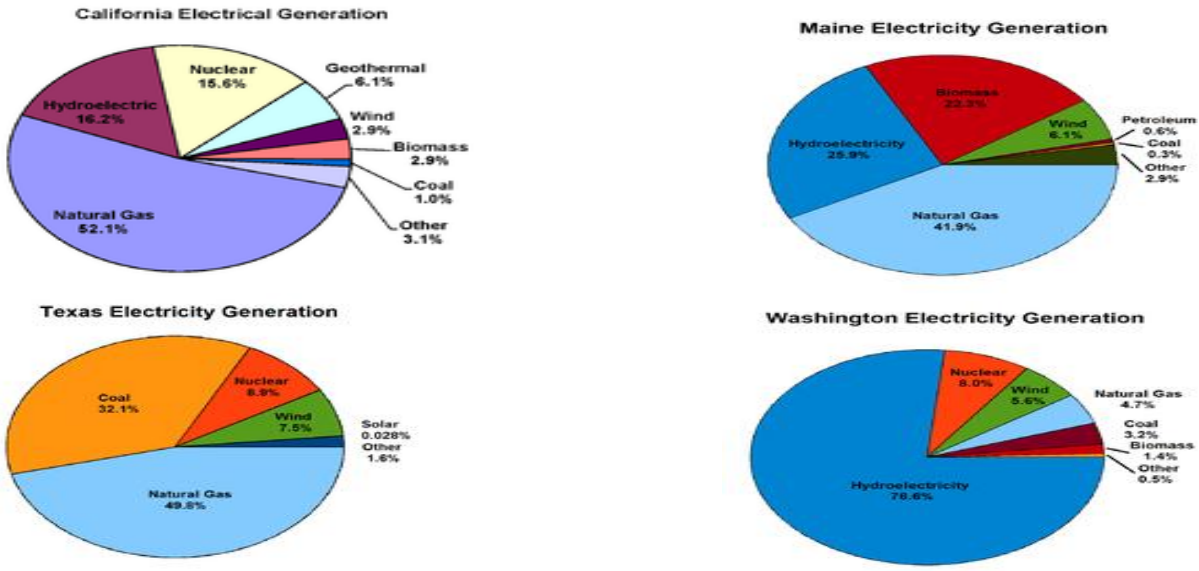

Figure 3: Sources of electricity generation in California, Maine, Texas and Washington (US-EIA, 2010).

Chemistry of some Fossil Fuel Combustion and the Pollutant

Fossil fuel varies in cost of harvesting, efficiency and cleanliness on combustion. Generally, as regards cleanliness, the order is methane (natural gas) > alkanes in petrol > coke > heavy oil > coal (Brown, 2015). When it is burned efficiently in an excess supply of air/oxygen, complete combustion occurs and the carbon is oxidised to carbon dioxide while the hydrogen is oxidised to water, releasing heat energy. Example of complete combustion for natural gas, petrol and coal is as below:

$CH_{4(g)}$ (methane) + $2O_{2(g)}$ (oxygen) ==> $CO_{2(g)}$ (carbon dioxide)+ $2H_2O_{(l)}$ (water)

$(C_3H_4)n_{(s)}$ (coal) + $O_{2(g)}$ (oxygen) ==> $nCO_{2(g)}$ (carbon dioxide)+ $nH_2O_{(l)}$ (water)

$C_{(s)}$ (coke) + $O_{2(g)}$ (oxygen) ==> $CO_{2(g)}$ (carbon dioxide)

$CO_{2(g)}$ (carbon dioxide) + $C_{(s)}$ (coke) ==> $2CO_{(g)}$ (carbon monoxide)

When the fossil fuel is burned in a limited supply of air, incomplete combustion occurs causing fuel inefficiency and pollution by forming other products like carbon monoxide and/ or carbon soot. There is also less heat released in incomplete combustion compared to complete combustion, since not all the carbon atoms of the fuel are fully combined with the amount of oxygen. Example of incomplete combustion is as below equation:

$CH_{4(g)}$ (methane) + $O_{2(g)}$ (oxygen) ==> $C_{(s)}$ (carbon-soot) + $2H_2O_{(l)}$ (water)

$2CH_{4(g)}$ (methane) + $3O_{2(g)}$ (oxygen) ==> $2CO_{(g)}$ (carbon monoxide) + $4H_2O_{(l)}$ (water)

$2NO_{(g)}$ (nitrogen monoxide) + $2CO_{(g)}$ ==> $N_{2(g)}$ (nitrogen) + $2CO_{2(g)}$ (carbon dioxide)

Fossil fuel also burns and generates sulphuric, carbonic, and nitric acids which are deleterious substances. For instance, the sulphur compound in the fuel burns and release sulphur dioxide and when it reacts with rain water and oxygen (in air), it forms a very dilute solution of sulphuric acid – the origin of acid rain. The overall change is represented by the equation below.

$S_{(s)}$ (sulphur) + $O_{2(g)}$ (oxygen) ==> $SO_{2(g)}$ (sulphur dioxide)

$S_{(s)}$ (sulphur) + $H_{2\,(g)}$ (hydrogen) ==> $H_2S_{(g)}$ (hydrogen sulphide)

$2SO_{2(g\text{-}air)}$ + $O_{2(g\text{-}air)}$ + $2H_2O_{(l\text{-}rain)}$ (water) ==> $2H_2SO_{4(aq\text{-}rain)}$ (sulphuric acid)

The Adverse Effect of the Pollutant

The explosion of industrial growth that prompted us into the combustion of unprecedented heavy quantity of solid, liquid and gaseous fuel to obtain energy has let various gases and

hydrocarbon compounds flying in the environment. This development has aggravated our ecological challenges in the following ways:

Health Implication

Carbon-soot, a fine black powder-dust is potentially harmful and readily formed during incomplete combustion. It is classically produced by smoky yellow flames when burning fossil fuel and inefficient motor vehicle engines. The carbon soot is harmful as follows:

- The soot, like any fine solid dust is harmful when absorbed on the sensitive tissue of the lining of the nose, throat and lungs, causing coughing, irritation and sore throat, and are ejected from your body through sneezing, coughing, and nose blowing.
- Soot is also a 'carrier' of polycyclic aromatic hydrocarbons (PAH's) which are carcinogenic (unburned carcinogenic hydrocarbons). Carbon monoxide, a by-product of the fossil fuel incomplete combustion is a colourless and odourless gas, and can be fatal even in very low concentrations by the following ways:
- Oxygen is carried around the body by a complicated protein molecule in red blood cells called haemoglobin.

  The bonding between haemoglobin and carbon monoxide is approximately 200 times stronger than that with oxygen (New York State Department of Health, 2015), and so the oxygen is easily replaced by carbon monoxide to form carboxy-heamoglobin and blocks normal respiratory cell thereby reducing the capacity of blood to carry oxygen. According to the equation below, the equilibrium shifts to the right towards the carboxy-heamoglobin side

  $Hb_{(aq)}$ (heamoglobin)+$4CO_{(g)}$(carbon monoxide) ==> $Hb(CO)_{4\,(aq)}$ (carboxy-heamoglobin)

  The consequence is reduced blood-oxygen concentration leading to unconsciousness and eventually death! (Brown, 2015). It takes about 320 minutes to reverse the effects of carbon monoxide as long as no further carbon monoxide is breathed in. This is done by introduction of pure oxygen to the body which will then react with carboxy-heamoglobin to produce the properly oxygenated haemoglobin alongside gaseous carbon monoxide which dissipates when exhaled (New York State Department of Health, 2015):

  $Hb(CO)_{4\,(aq)} + 4O_{2\,(g)}$ (oxygen) ==> $Hb(O_2)_{4\,(aq)}$ (oxygenated haemoglobin) + $4CO_{(g)}$

It would appear that the hydrogen in the fossil-hydrocarbon fuel is more easily burned than carbon when there is lack of oxygen for complete combustion, and usually form water, carbon-soot and deadly carbon monoxide.

Nitrogen dioxide is a lung and eye irritant. The Nitrogen dioxide and nitrogen monoxide do involve in the complex chemistry of photochemical smog, which can also produce harmful chemicals in the air.

Sulphur dioxide is a harmful gas and lung irritant, and contributed to 5000 extra deaths in the great 'London Smog' in the 1950's as well as being a major acid-rain gas (Brown, 2015). The formation of acid rain has several bad effects on the environment, e.g. it lowers soil pH (potential of hydrogen) and thereby causing plant damage.

Global Dimming

This makes the prediction about global warming even more uncertain. As the earth warms up; more water vapour, carbon dioxide is released as a result of fossil fuel combustion and other pollutants from industrial activities can exist in the atmosphere. The more concentration of these pollutants that are formed in the upper atmosphere, the more sunlight is reflected, so less radiated energy reaches the Earth's surface, leading to the opposite of global warming. The effect of global dimming was prominently noticed in the aftermath of the 9/11 terrorist attack on New York's World Trade Center Twin Towers in 2001 because of the concentration of the flue gases and fine solid particles like carbon-soot or flying ash in the atmosphere. These pollutants led to global dimming

that drastically decreased the sunlight intensity reaching the Earth's surface. And consequently, all aircraft were grounded in USA and many parts of the world for several days after the attack (Brown, 2015). It is ironic that the vapour trail of aircraft, resulting from the use of fossil fuel, contributes to global dimming as well as to global warming at the same time! The basic difference between them is the operational period: global dimming effect is usually within few hours or days while global warming is a continual process.

Ozone Layer Depletion

Ozone layer**,** also called ozonosphere is a region of the upper atmosphere between roughly 15 and 35 Km above Earth's surface, containing relatively high concentrations of ozone molecules (O_3). The ozone layer effectively blocks almost all solar radiation of wavelengths less than 290 nanometers from reaching Earth's surface, including certain types of ultraviolet (UV) and other forms of radiation that could injure or kill most living things (Wuebbles, 2015). The ozone forms there by the action of sunlight on oxygen:

$$\text{Sunlight} + 3O_{2(g)}\ (\text{oxygen}) \implies 2O_{3(g)}\ (\text{ozone})$$

This action has been taking place for many millions of years, and naturally occurring nitrogen gas in the atmosphere apparently kept the ozone concentration at a fairly stable level. Ozone is a special form of oxygen, made up of three oxygen atoms rather than the usual two oxygen atoms. The ozone layer of the atmosphere protects life on earth by absorbing harmful ultraviolet radiation from the sun. In the 1980s scientist discovered that industrial pollutants such as chlorofluorocarbon (CFC) used as refrigerant and as aerosol spray were damaging or depleting the ozone layer and that holes had appeared in it, especially over the Antarctic (Casper, 2010). When released into the atmosphere, this chlorine and fluorine containing chemical (CFC) rises into the upper stratosphere and is broken down by sunlight, whereupon the chlorine reacts with ozone and destroys its molecules up to 100,000 per CFC molecule (Ola, 2009). The use of CFCs in aerosols has been banned in the United States and elsewhere. Other stratospheric ozone-depleting gases result exclusively from human industrial processes are halocarbons e.g. hydrofluorocarbons (HFCs), methyl chloroform (CH_3Cl_3), carbon tetrachloride (CCl_4), perfluorocarbons (PFCs), hydrochlorofluorocarbons (HCFCs), etc. Thinning of the ozone layer is predicted to cause increases in skin cancer and cataract, damage to certain crops: plankton and the marine food web, and an increase in atmospheric carbon dioxide.

Global Warming or Climate Change

Global warming means the measurable increase in the average temperature of Earth's atmosphere, caused by buildup or accumulation of greenhouse gases. The United Nations Environment Programme and the World Meteorological Organization jointly established Intergovernmental Panel on Climate change (IPCC) in 1988, consisting of 2,500 scientists that assess scientific and technical information related to the issue of climate change (Casper, 2010). Based on some facts, these scientists believe that the Earth is currently facing a period of rapid warming brought in by combined action of rising levels of heat-trapping gases, known as greenhouse gases and ozone depletion by some organic substance. The scientists in recent time also buttressed their argument with the continues ice-melting at the polar region, most especially that the Antarctica is now losing about 160 billion tonnes of ice in a year to the ocean – twice as much as when the continent was last surveyed (www.bbc.com/…-270465050).

Naturally occurring greenhouse gas like carbon dioxide retain or trap the radiant energy (heat) emitted to the Earth surface by the sun thereby insulating and warming the planet in a process known as the green house effect. Without the thermal blanketing of the natural greenhouse effect, Earth's climate would be too cold for most living organisms to survive (Casper, 2010). A greenhouse gas is any gaseous compound in the atmosphere that is capable of absorbing infrared radiation, thereby trapping and holding heat in the atmosphere. Some green house gases are water vapour,

methane, ozone, nitrous oxide, fluorinated compounds and carbon dioxide which is the most abundant gas (Figure 7 and 8). Since the beginning of the industrial revolution which started in Britain in the mid-1700s, however, human activities have added more and more of these gases into the atmosphere. For example, level of carbon dioxide (a powerful greenhouse gas), has risen by 35 percent since 1750s (Casper, 2010; Pickering and Owen, 1995), largely from the burning of fossil fuels such as coal, oil, and natural gas. With more greenhouse gases in the mix, the atmosphere act like a thickening blanket and traps more heat resulting into global warming or climate change which has the following negative effect: flooding at polar region, suppression of immune system, reduced crop yield, etc.

These gases vary in their ability to absorb and hold heat in the atmosphere, a phenomenon known as the "greenhouse effect." HFCs and PFCs are the most heat-absorbent, but there are also wide differences between naturally occurring gases. For example, nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide, and methane absorbs 21 times more heat per molecule than carbon dioxide (file:///C:/Users/...Greenhouse%20Gases.htm) giving it a high global warming potential (GWP) rating, even though it stays in the atmosphere for only about 12 years while that of the CO_2 is about 100 years (US Center for Climate and Energy Solutions, 2014). These gases also vary in GWP based on their level of emission in to the environment. GWP is a measure of how much a given mass of house gas is estimated to contribute to global warming. It indicates the warming effect of a greenhouse gas. It is a relative scale, which compares the gas in question to that of the same mass of carbon dioxide whose GWP is equal to one. Three factors affect the degree to which any greenhouse gas will influence global warming: Its abundance in the atmosphere, how long it stays in the environment (atmospheric lifetime) and its global-warming potential. According to the Environmental Protection Agency (EPA), carbon dioxide has a significant impact on global warming partly because of its abundance in the atmosphere and long atmospheric lifetime (Lallanilla, 2015).

The major non-gas contributor to the Earth's greenhouse effect is cloud, which also absorb and emit infrared radiation and thus has an effect on radiative properties of the greenhouse gases. Cloud is water droplet or ice crystal suspended in the atmosphere (Kiehl and Kevin, 1997). Oxygen (O_2) is the second most abundant gas in our atmosphere and does not absorb thermal infrared radiation. Some of the major atmospheric constituents that are non-greenhouse gases are nitrogen (N_2) and argon (Ar). This is because molecules containing two atoms (diatomic) of the same element and monoatomic molecules such as argon have no net change in their dipole moment when they vibrate and hence are almost totally unaffected by infrared radiation. Although molecules containing two atoms of different elements such as carbon monoxide (CO) or hydrogen chloride (HCl) absorb infra red, these molecules are short-lived in the atmosphere owing to their reactivity and solubility. Because they do not contribute significantly to the greenhouse effect, they are usually omitted when discussing greenhouse gases (Wikipeadia, 2015).

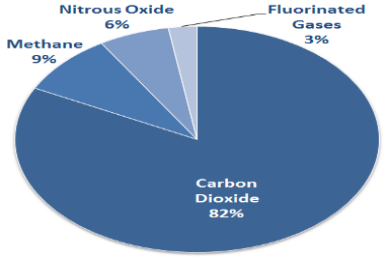

Figure 7: Overview of greenhouse emission (EPA, 2015)

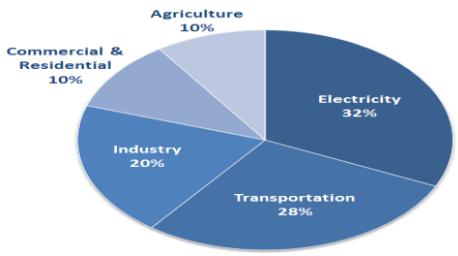

Figure 8: Sources of greenhouse gas emission (NEIC, 2004)

III. METHOD FOR DETERMINATION OF POLLUTANTS

Analysis of a sample is commonly based on a chemical reaction of the constituent that produces an easily identifiable quality such as colour, heat or insolubility as well as the quantity. The

environmental pollutant can either be determined through gravimetric, titrimetric or instrumental method of analysis depending on its nature and type.

IV. MANAGEMENT OF FLUE-GAS EMMISSION

The harmful effect of fossil fuel usage to the ecosystem has let to clean fuel technology. Clean fuel technology is a marketing term used to describe technologies being developed that aim to reduce the negative environmental impact of fossil fuel in energy generation. Clean coal technology seeks to reduce harsh environmental effects by using multiple technologies to clean coal and contain its emissions. It implies that it is possible to make fossil fuel an energy source that is free of (or very low in) carbon dioxide and other pollutant emissions. Some of the techniques that would be used to accomplish this and some control measures include:

The use and design of more efficient automobile engines as well as the improvement on the efficiency of catalytic converter system can reduce environmental pollution. The converter uses transition metals like platinum and rhodium, to convert nitrogen monoxide that is harmful to the environment into harmless nitrogen (N_2) and carbon dioxide which have no direct negative effect, by its reaction with carbon monoxide (a deleterious gas too) in the system.

$2NO_{(g)}$ (nitrogen monoxide) + $2CO_{(g)}$ (carbon monoxide) ==> $N_{2(g)}$ + $2CO_{2(g)}$ (carbon dioxide)

Advancement of green technology: 'Green' alternative renewable energy resources which have no or little ecological problem in their production can be more exploited, but not without problems e.g. wind turbines – weather dependant; wave power – subject to storm magnitude; hydroelectric power – environmental and ecological effect; photovoltaic cell and solar power – depends on intensity of sunlight and varies from country to country, through the day and the seasons; etc. Renewable energy is energy that comes from resources which are naturally replenished such as sunlight, wind, rain, tides, waves, and geothermal heat. As of 2012, 17 % of global final energy consumption comes from renewable resources, with 8.5 % of all energy from traditional biomass, mainly used for heating, and 3.3 % from hydroelectricity. Other renewables (small hydro, modern biomass, wind, solar, geothermal, and bio-fuels) accounted for another 4.9 % and are growing rapidly. The share of renewables in electricity generation is 20 %, with 15 % of electricity coming from hydroelectricity and 5 % from other renewable (REN21, 2012).

Power station and chemical industries burning fossil fuel should be equipped with gas trapping facility, and the gas trapped can be stored and converted into harmless substances or useful chemical compounds. This will only reduce pollution because flue gas released by burning oil based fuel is more difficult to control than that produced by burning of coal and gas (e.g. methane). This is due to the fact that oil based fuels such as gasoline and diesel are burnt in moving vehicles as well as the factories and thermal plants. On the other hand coal and gas are burnt mainly in factories and thermal plants which cause pollution at a particular place. This pollution can be controlled more easily by installing chimney and equipment for trapping the emitted gas/gases, than the moving vehicles. It is worth noting that long road tunnels should be ventilated and never run a car engine in a closed garage!

Afforestation programme should be strengthened by government to encourage private organizations and individual in all countries to massively plant more trees and maintain for the CO_2 release by combustion of fossil fuel to be recycled via photosynthesis. Photosynthesis is a complex reaction which essentially uses energy from the sun, plants and algae to transform carbon dioxide and water into glucose and oxygen. In chemical terms:

$6CO_{2\ (g)}$ (carbon dioxide) + $12H_2O_{(l)}$ (water) + chlorophyll
+ Sun light ==> $C_6H_{12}O_{6(aq)}$ (glucose) + $6O_{2\ (g)}$ (oxygen) + $6H_2O_{(l)}$ (water)

All fossil fuel feed-stocks should be processed to reduce the concentration of sulphur compounds (i.e. desulphurization) and other harmful substances like fluorites, chlorite, radioactive materials, etc before usage. According to Singh *et al*. (2005), the introduction of sulphur fixation

agent into the feed-stock, otherwise known as desulfurizing agent (DSA) ensures that most of the sulphur content of the coal is fixed into the ash as a salt instead of being liberated into the atmosphere as a gas such as sulphur dioxide (SO_2). This implies that, by this technology, the pollution problems associated with burning of coal is to a great extent taken care of. Calcium hydroxide ($Ca(OH)_2$) and calcium oxide (CaO), are the common desulfurizing agent used for this purpose. For instance, when CaO is used, the reaction follows this equation:

$$CaO(s) + SO_2(g) + ½O_2(g) \Longrightarrow CaSO_4(s)$$

Carbon dioxide environmental pollution can also be reduced by passing the trapped emitting gas through the slaked lime or calcium hydroxide ($Ca(OH)_2$):

$$Ca(OH)_2(l) + CO_2(g) \Longrightarrow CaCO_3(s) + H_2O(l)$$

Hydrogen-fuel: Hydrogen gas can be used as a long-term possible alternative to fossil fuels. It burns with a pale blue flame in air, as it reacts with oxygen and oxidises to form water, releasing energy:

$$2H_{2(g)} \text{ (hydrogen)} + O_{2(g)} \text{ (oxygen)} \Longrightarrow 2H_2O_{(l)} \text{ (water)}$$

It is a non-polluting clean fuel since the only combustion product is water and so it is environmentally friendly. It is easily distributed in pipes like natural gas, but there are health and safety issues to do with storage and distribution since it is like natural gas, highly flammable and explosive. It would be ideal if it could be manufactured by electrolysis of water, using solar voltaic-cell.

V. CONCLUSION AND RECOMMENDATION

This review revealed that the major sources of anthropogenic polluting gases such as CO_2, NO, CH_4, etc, known as greenhouse gases from the fossil fuels and they have negative effects on the ecosystem.

Carbon dioxide is posited to be the most contributing green house gas to global warming because of its abundance and atmospheric lifetime. Lesser amounts of CFCs, HCFCs, PFCs, and SF6 are also emitted and their contribution to global warming is magnified by their high GWP, although their total contribution is still small compared to the most emitted gases.

The combustion of fossil fuel leads to by-products that have either drastic health or environmental threat.

Denaturalization of raw food for consumption through boiling is ideal more than roasting on direct fire which may result in the formation of carbon-soot a 'carrier' of polycyclic aromatic hydrocarbons (PAHs) which are carcinogenic, so as to avoid risk of cancer.

Those working in the fossil fuel industries should wear protective materials fully and go for medical check-up regularly to avoid any eventual health impairment or affliction.

Government in every nation should also come out with effective regulatory policies on the combustion and use of hydrocarbon substance(s) in order to drastically reduce the emission of these dangerous gases to the environment. In short, to avoid the global warming which is considered dangerous, we need to achieve major reductions in global CO_2 emissions in the next 10 years.

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