Journal of Sustainability Science and Management
Volume 17 Number 1, January 2022: 281-301
eISSN: 2672-7226

EFFECTS OF EXHAUST EMISSIONS FROM DIESEL ENGINE APPLICATIONS ON ENVIRONMENT AND HEALTH: A REVIEW

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Submitted final draft: 29 April 2020 *Accepted: 03 June 2020* http://doi.org/10.46754/jssm.2022.01.019

Abstract: Recent achievements in Diesel Engine Applications (DEAs) have accomplished a very satisfactory level speeding up work, saving cost as well as energy. Tremendous research on its work mechanism have led to sustainable and renewable energy. DEAs significantly boost the economy and industrial sectors, which in turn provide comfort and improved lifestyle. Previous studies focused on the creative and innovative methods in diesel engine combustion process to reduce poisonous exhaust emissions. Looking beyond it advances, the exhaust emissions from DEAs contribute to climate change and global warming. The highlighted emitted gasses are oxides of nitrogen (NOx), carbon monoxide (CO) and hydrocarbon (HC), all of which are known to be among the greenhouse gasses (GHG). Particulate matter (PM) from DEA exhaust is also taken into consideration in the study. Exhaust emission mainly comes from the fossil fuel combustion and may come from natural sources. This study explores the effects of exhaust emission on the environment and health. Adverse effects of exhaust emissions on health are mostly related to cardiovascular and respiratory diseases. Climate change and global warming resulting from exhaust emissions also have disastrous consequences. Excessive and uncontrollable exhaust emissions increases global temperature and create a cycle of disasters, such as drought, fire and rising seawater level, causing floods in lowland areas. Although DEAs simplify our work and give a lot of benefits, they also adverse have implications on humans and the environment.

Keywords: Exhaust emission, diesel engine applications, health, environment, global warming.

Introduction

The development of the diesel engine was started by Rudolph Diesel in the 1890s. His creation of the internal combustion engine, which bears his name to this day, has powered the world's transportation and construction on a massive scale in recent years. The internal combustion engine is the most effective choice for vehicles as it emphasizes fuel-saving. In 1897, the diesel engine was considered to be successful, with 26% efficiency compared with 10% efficiency of the steam engine (Dietsche, 2014). In 1929, the United States had its first diesel car, known as Packard, which was powered by the Cummins engine. Cummins is the premier diesek engine brand being manufactured today. Today, diesel engines have reached 51% efficiency for large sea ships as well on experimental heavy-duty diesel engines (HDDE) (Koeberlein, 2011; Guinness World Record, 2017).

The world's population is predicted to reach about 9 billion in 2040 from the current 7.2 billion (Exxon Mobile, 2018). Thus, to accommodate the increasing population, sufficient energy is needed to cater to the demand and consumption. High energy consumption is needed to rapidly grow the economy and major industries. Indirectly, it also causes an excessive a Greenhouse Gasses (GHG) released to its surroundings. The concern for sustainability arose as economic growth increased energy consumption and demand, which led to more pollution emissions (Li & Lin, 2019). For example, the gross domestic product (GDP) of China has expanding thirtyfold in 2015 compared to 1978. With the rapid economic growth in the previous four decades, China has turned out to be the largest energy consumer and carbon dioxide (CO_2) emitter. Sulfur dioxide (SO_2) and dust emissions also increased tremendously, to about 26% and 30% respectively, of the world's total emission in 2012 (Li & Lin, 2016). The Energy Information Administration, EIA (2015) also predicted that energy consumption would increase to around 56% by 2040. Parallel to increasing energy consumption, CO_2 emission had also increased 3.5 times from 1961 to 2010 (Marland *et al*., 2007).

While the world's population and energy demand continue to grow, GHG emissions especially from diesel engines, keep rising and this has led to several issues. The combustion in the diesel engine emits less GHG and CO_2 than spark engines because of its great properties. (Yasar *et al*., 2013; Zachariadis, 2013; Ibeto and Ugwu, 2019). As comparison, diesel fuel contains 15% more energy, more carbon and higher compression ratio than gasoline fuel (Andre, 2019). Furthermore, an observation-based study by Andre (2019) showed that diesel engines produce more exhaust gas emissions compare with gasoline engines over their life cycle. His findings are supported by reports from campaign group Transport and Environment, the German Federal Office of the Environment and the French Agency for Environmental and Occupational Health Security. Researchers agree that common exhaust emissions from diesel engines are NOx, CO, HC and PM (Anderson *et al*., 2016; Yilmaz *et al*., 2017; Larsson *et al*., 2018; Liu *et al*., 2018; Wang *et al*., 2018; Walheer, 2018; Yusri *et al*., 2019; Karmaker *et al*., 2020). The level of energy consumption and pollutant release of diesel engines are the highest in the transportation industry compared with other industries worldwide (Motasemi *et al.*, 2014). Each common exhaust emission from diesel engines has several adverse impacts on health, mostly related to cardiovascular and respiratory disease. Generally, the main source of GHG emissions that increase global warming comes from the combustion of fossil fuel. Global warming and climate change caused by excessive exhaust generate a continuous cycle of disastrous phenomena.

The complications arising from undesirable emissions have alarmed academia, especially from automotive researchers. They claim that combustion of conventional fuels is a major contributor to high levels of exhaust emission and energy demands (Yilmaz & Atmanli, 2017; Hombach *et al*., 2018; Lv *et al*., 2018). Precautions and prevention methods from the public sector and academia should be applied to reduce the exhaust emissions on massive scale to protect the environment. There are countless investigations on DEAs emission to the environment. The authors here provide a review of the effects of exhaust emissions from diesel engines. Generally, the scope of this study covers all purposes of diesel engines usage, such as light-duty, heavy-duty, non-road, in locomotives and the marine sector. This study investigates the effects of diesel engine applications on the environment and health, and aimed to gather as much information as possible to tackle the aforementioned matters.

The Effects of Diesel Engine Applications on Environment

The United Nations Framework Convention on Climate Change (UNFCCC) had drafted a global policy known as the Paris Agreement in 2015. The agreement directs 195 signatory countries on managing low-carbon development, and to plan and manage GHG emissions (UNFCCC, 2015). A significant goal of the Paris Agreement regarding climate change is to reduce GHG emissions through Nationally Determined Contributions (NDCs). The main purpose of the Paris Agreement is to find ways to limit global temperature rise to 1.5ºC above pre-industrial levels. The agreement is on the management of climate change risks – including environmental health, accessible energy and economic growth (Ciplet *et al*., 2015). Chancel and Piketty (2015) shared found out there was more potential to lower GHG emissions by by regulating household pollution. Otto *et al.* (2019) added that the richest households contributed more GHG emissions than economic classes. However, global GHG emissions' concentration is increasing rapidly (Tilman *et al*., 2011; Richter *et al*., 2016; Maria *et al*., 2018; Lucas *et al*., 2019).

GHG emissions are currently at an alarming level, which has led to drastic changes to the environment (Abas *et al*., 2017). Heidari and Pearce (2016) summarized that the effects from GHG towards the climate include rising temperatures, crop failures, power outages, increasing sea levels and shoreline erosion. They also listed flooding, saltwater intrusion, frequency of storm formation, drought and fire formation. Anderson *et al*. (2016), based on Earth System Models (EMSs), predicted that the temperature in the 21st century could rises between 1 and 3.7ºC. Lee *et al.* (2019) calculated a country's temperature rise from 2010 to 2099 based on a CO_2 concentration increase of 100 parts per million (ppm) They project that the average temperature rise will largest in Canada (1.16 ºC/100 ppm) and Finland (1.14 ºC/100 ppm) while the smallest recorded in Ireland (0.62 ºC/100 ppm) and Argentina (0.63ºC/100 ppm). They also calculated the percentage increase of CO_2 concentration for every 1ºC temperature rise. Highest CO_2 concentration percentage increase for every 1ºC temperature rise is in Vietnam (10.34%/ºC) and the Philippines (8.18%/ ºC), the lowest is in Ireland (-0.92%/ºC) and Australia (-0.32%/ºC).

A World Meteorological Organization report, (WMO, 2018) stated that the previous two decades were the warmest since the measurement of global temperature started in 1850. Dale *et al.* (2001) stated that the effects of climate change include drought, fire and sea level rise, and these disasters may be related to each other. Droughts have a profound effect on ecosystems in temporary or permanent scenarios. A permanent scenario denotes either long recovery periods or the recovery to the initial state is not possible. Drought is defined as a period lacking water accessibility, which leads the ecosystem to cross the threshold of vulnerability (Crausbay *et al*., 2017). Omerkhil *et al.* (2020) found that over 80% of deteriorated land caused by conflict, unsustainable management and soil erosion due to climate change.

Figure 1 shows the climate change triggers of drought. Global warming also causes

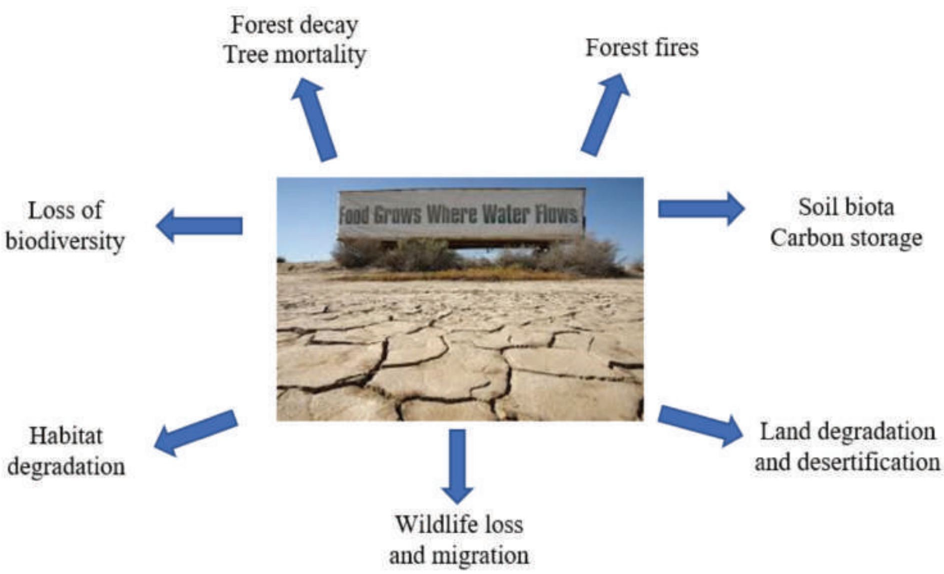

Figure 1: General effects of environmental drought

drought which affect numerous systems, such as soil, vegetation, forest and wildlife. A study by Bandyopadhyay *et al.* (2020) found out that Gujerat is major drought-prone area, and experiences a disaster every 3 to 4 years due to extreme temperature and heatwaves. Insufficient water and lack of food stocks in the chronically arid area adds stress to the limited groundwater sources. Five study areas, including Rajasthan, Gujarat and Maharashta with 2, 2 and 1 study areas, respectively recorded number of deaths rate range from 4.3 to 7.7 based on the population of each study area (Sarma *et al*., 2019).

Wildfires have numerous affects on forests, such as mortality of trees, loss of soil seed sources and volatilization of earth nutrients. Anthropogenic fires are caused by land clearing for agriculture and human settlement (Cammeli & Angelsen, 2019; Trauernicht, 2019), and are worsened in warm temperatures where the amount of particulate matter (PM) suspension is higher (Abdullah *et al*., 2017). In Malaysia, smoke-haze caused by the fires in Indonesia affect the whole country during the 2015 El Nino phenomenon. PM_{10} concentrations were 45.0 $\mu g/m^3$ and 47.0 $\mu g/m^3$ in semi-urban (Muar) and urban sites (Cheras), respectively. During the smoke-haze phenomenon, PM_{10} concentrations were 358 $\mu g/m^3$ and 415 $\mu g/m^3$ respectively for the two sites, indicating a very unhealthy air quality. Local and transboundary smoke-haze has afflicted Malaysia for many years (Che Samsuddin *et al*., 2018). Farmers use fire as a cheap method for pest control and soil mineralization of grasslands and croplands (Nepstad *et al*., 2001).

Satellite and ground-based observations have measured the acceleration of sea level rise (Legeais *et al.,* 2018). Findings by Kulp and Strauss (2019) state that the sea level might rises more than two meters due to extreme global warming by 2100. The Danish Meteorological Institute (2019) also reported that increasing sea level is due to extreme global warming, which melted 197 billion tons of Greenland ice sheet in July 2019 alone. Nearly 99% of freshwater ice in the world is in two gigantic ice sheets in Antarctica and Greenland. It is predicted that the complete melting of the Greenland ice sheet will cause the sea level to increase by about 6 meters, while the melting of the Antarctic ice sheet may cause 60 meters of sea level rise. Worryingly, the melting of the Antarctic ice sheet at the current rate might raise the sea level to 15 meters by 2500 (DeConto & Pollard, 2016). Church *et al.* (2011) and Schaefer *et al.* (2020) described the ocean thermal expansion and water melting stored in glacier and ice-caps as the consequence of sea level rise. They observed that the sea level rise has exceeded projections because of climate change and anthropogenic activities, such as temissions and land-use change.

Oo *et al*. (2018) listed several major effects of sea level rise, such as coastal flooding and erosion, saltwater intrusion and increased salinity of agricultural water sources. Massive populations in low-elevation coastal areas are at high risk due to the sea-level rise. Because of these dangers, coastal populations are migrating inland. Sea level rise not only affect coastal population, but also the world over. The sea level rise has already destroyed coastal zones. Numerous population centres are in coastal zones, including major cities such as New York, Sydney and California. Kulp and Strauss (2019) found that several cities in Malaysia, such as Alor Setar, Kuala Terengganu and Kuching will be turned into islands, while Muar, Pekan and Port Klang risk being under water in 2050. Some 70% of Asian regions are exposed to the consequences of rising sea levels, such as Bangladesh, China, India, Indonesia, Japan, Philippines, Thailand and Vietnam. Cheng and Chen (2017) listed several river deltas in China that are below the high mean tide level, which regions are densely populated and possess high economic growth. The areas include the Beilunhe, Haihe, Minjiang, Luanhe and Yalujiang Rivers. Figure 2 shows the measured and predicted sea level on the Yangtze delta from 1880 to 2010, where the sea level is estimated to rise to a maximum of 110 cm and a minimum of 31 cm (Jevrejeva *et al*., 2016; Cheng and Chen, 2017).

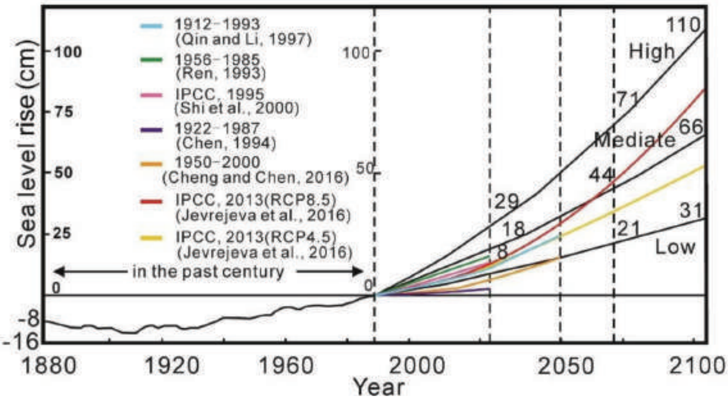

Figure 2: Measured and predicted sea level rises from various researches (Jevrejeva *et al*., 2016; Cheng & Chen, 2017)

Discussion on the negative effects of global warming have never stopped as the emission of GHG keeps rising day by day, and the fast-expanding transport industry is a significant contributor. The following subtopic will review the effects of gasses emit from DEAs on health.

The Effects of Diesel Engine Applications on Health

As energy consumption increases, health problems will also increase (Gao *et al*., 2019). Study on environmental degradation has strongly linked energy consumption and economic growth (Wang *et al*., 2019). These findings are also strongly supported by other research (Akadiri *et al*. 2019; Charfeddine & Kahia, 2019; Pandey & Rastogi, 2019; Raza *et al*., 2019). Harmful GHGs are pollutants and can be deposited in human tissues and organs *via* the respiratory system, which causes health to decline. Among the detrimental diseases are lung cancer, cardiopulmonary deaths, bronchitis and pneumonia (Sadeghinezhad *et al*., 2013; Mohd Noor *et al*., 2018). Cesar *et al.* (2015) reported that there were deaths recorded due to exposure to air pollutants. The number is significant, with 61% more cardiovascular disease cases, and those who suffered health conditions such as diabetes, cancer and hypertension, could be prone to the short-term effects. The ensuing discussion will analyze the adverse effects on health of common gasses released from DEAs.

The Effects of NOx Gasses on Health

Experiment by Gaskin *et al*. (2019), concluded that the absorption of NOx gasses through the skin is not a main contributor to health problems. However, off-gassing post-exposure from the surroundings, such as clothing and other items, are the greatest concern for possible sources of respiratory irritants that cause asthma. NOx gases include nitric oxide (NO), nitrous oxide (N_2O) and nitrogen dioxide (NO_2) including nitrogenous compounds associated with NO_2, which have oxidizing characteristics in solution and biological tissue (Cheng *et al*., 2010; Boningari & Smirniotis, 2016). NOx emissions combining with SO_2 gas has recently gained attention as a major precursor if gasses and contributes to the formation of smog, eutrophication and acid rain in the atmospheric chemistry. Soils and water acidification, and hastening of the corrosion process in building and monuments are among the effects of acid rain on the environment (Rd *et al*., 2012).

The source of NOx gasses is mainly by the combustion of fossil fuel and also caused by natural phenomena. Figure 3 shows the classification of NOx gasses by category of sources in (a) the United States and (b) Europe (Klingstedt *et al*., 2006; Roy & Baiker, 2009). Figure 3(a) shows that transportation is a major contributor to the total NOx emission, where fuel combustion and transportation accounted for 54.6% and 40.9% of NOx emissions in the

United States, respectively. Industrial processes make up 3% and other factors 1.5%. In Europe, traffic, including road traffic, contributes 46%, followed by agriculture (20%), biogenic (14%), power plants (10%), and 5% for both industry and residential fuel combustion for the total NOx emissions. As a consequence, the U.S. Federal Clean Air Act in 1990 amended the standards for light duty vehicles. Since the enforcement of regulation on Low Emission Vehicles II in 2004, California has the most stringent emission regulations, as shown in Figure 4(a). In Europe, the latest standards for gasoline and diesel for NOx emissions allow only 0.175 and 0.08 g/km for Euro V and Euro VI, respectively as shown in Figure 4(b).

In the past few years, NO_2 gas levels in China remained static or saw slight increase despite urbanization and the increasing number of vehicles (Richter *et al*., 2005). An increase in NOx concentration in the short-term was revealed to increase the risk of the respiratory system disease (Jo *et al*., 2017; Dabass *et al*., 2018), where the permeability of induced bronchial epithelial cells with inflammatory mediators were observed in patients demonstrating chronic diseases (Bayram & Dikensoy, 2006). Respiratory

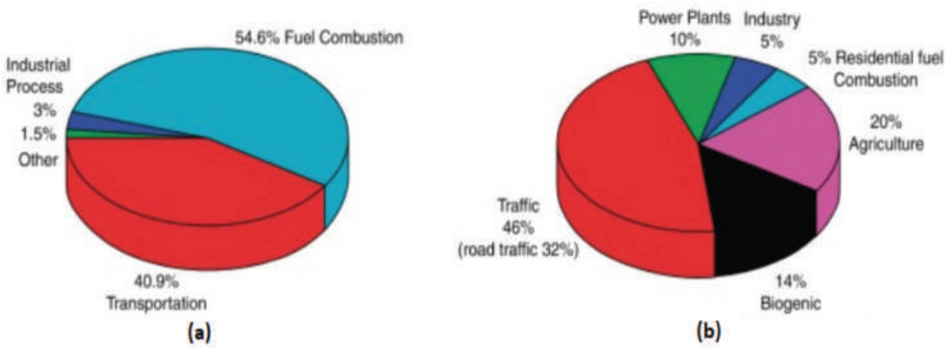

Figure 3: Classification of NO_x gases by source category in (a) the United States and (b) European Country (Klingstedt *et al*., 2006; Roy & Baiker, 2009)

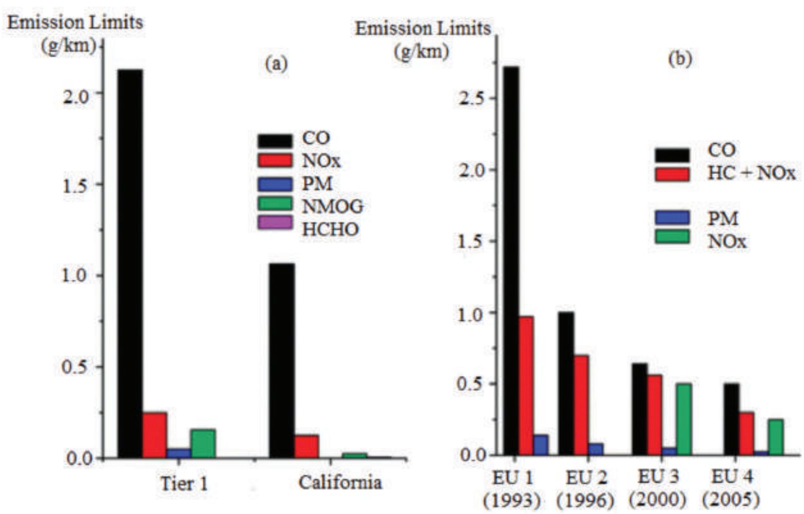

Figure 4: Emission limits for passenger cars powered by diesel in (a) the U.S. and California and (b) the European Country [PM = particulate matter, NMOG = non methane-organic-gases, HCHO = formaldehyde] (Klingstedt *et al*., 2006; Roy & Baiker, 2009)

airways inflammation, breathing problems, asthma and cardiovascular health effects are among the results from the investigation on human exposure towards NOx emission gasses. Several factors were identified to measure the degree of harmful exposure to NOx gasses, such as hygroscopicity of the gasses, temperature fluctuation, relative humidity and ventilation (Gaskin *et al*., 2019). Cesar *et al.* (2015) found that the reduction of 3 $\mu g/m^3$ of NOx concentration leads to a 10% to 18% reduced risk of death. In contrast, a study in Brazil found that a 10 $\mu g/m^3$ of NO_2 rise resulted in increased hospitalizations, particularly among the elderly and children (Gouveia *et al*., 2006: Negrisoli & Nascimento, 2013). Death associated with low-level exposure to NOx concentration have been recorded. Chen *et al*. (2012) and Cesar *et al.* (2015) recorded a risk of mortality increase by 2.52% related to respiratory diseases at NO_2 concentrations between 26 $\mu g/m^3$ and 67 $\mu g/m^3$, involving mostly the elderly over 60 years old.

The Effects of CO Gasses on Health

Carbon monoxide (CO) is as a pollutant that threatens human health and widespread around the environment. Exposure to CO is related to high rates of cardiovascular disease (CVD) worldwide (GBD, 2016; Cohen *et al*., 2017; McRae *et al*., 2019). The characteristics of CO include it being colorless, tasteless and odorless, which causes death from unwitting poisoning. Direct contact with CO also leads to asphyxiation, fluctuations in blood pressure and myocardial ischemia (Chambers *et al*., 2008; Lee *et al*., 2017). The sources of CO gas had been identified from the household items, generally heating equipment, such as portable generators, charcoal grills and gas fires, and burning of fossil fuels like coal, oil and natural gas. Exposure to improper installation of exhaust vents is also a source of CO poisoning. Researchers have found that low levels of CO are produced by the human body (Brazier, 2017: Neto *et al*., 2008). Individuals normally are prone to CO gas exposure due to lack of awareness of CO's chemical characteristics and its high toxicity. CO gas were inhaled into the lungs through the respiratory system the same way as oxygen (O_2) and is directly transferred to the bloodstream. The transfer allows the diffusion of CO with hemoglobin (Hb), forming carboxyhemoglobin (COHb), transported and deposited to human tissues with affinity 250 times higher than O_2. Consequently, CO displaces O_2 in the tissue which causes reduced oxygen-carrying and storage capacity of Hb (Shah *et al*., 2013). The brain and heart are the main organs being affected due to lack of O_2 since they have high requirements of O_2 (Wu & Wang, 2005; Rose *et al*., 2017).

Table 1 shows the effects of possible of CO level in human blood. The effects can be detected at lowest concentration percentage less than 2%. However, symptoms that reduce productivity in the workplace are often assumed to be due to

Table 1: COHb effects at various level concentration percentage in blood (Neto *et al*., 2008)

COHb (%)	Effect
< 2	Minor reduction in work magnitude.
5	Oxygen intake and exercise routine declines; neurobehavioral role decrements.
10	Inadequacy breath in intense activity; conceivable forehead tightness; extension in cutaneous blood vessel.
20	Deficit breath on steady exertion; intermittent headache with trembles in joints.
30	Regular headache; irritable; easy to exhaust and weary; disturbed verdict; possible giddiness; duskiness in sight.
40 – 50	Constant headache and bewilderment; collapse; black out.
60 – 70	Unconsciousness; intermittent cramp; respiratory failure; death if longer exposure.
80	Promptly death.

lack of rest, improper diet and stress. The effects get worst as the CO concentration increases until 60 - 70 percentage of COHb, which could cause death if exposure is prolonged and treatment is delayed. Researchers' interest in the effects of CO to human condition and CVD hospitalizations is growing (Tian *et al*., 2015; Liu *et al*., 2018; Newell *et al*., 2018; Cheng *et al*., 2019; Dastoorpoor *et al*., 2019). A study over 24 hours mean was conducted on ambient CO gas of 0.88 mg/m^3. The result shows that 89,484 hospital outpatients were recorded to be afflicted with respiratory diseases such as asthma, bronchiectasis and pneumonia. Female patients and the elderly were the worst affected by CO gas due to respiratory diseases (Cheng *et al*., 2019; Zhao *et al*., 2019). In Lanzhou, China, a significant impact on CVD hospitalization due to CO concentration was recorded. Every increment of 1 mg/m^3 in CO concentration was allied with an 11% increase in total hospitalization because of CVD. The study identified CO gas to be responsible for 62,792 CVD cases. The effects of CO and CVD cause each patient to spend about 5% of their annual salary for treatment (Cheng *et al*., 2019). The limited number of studies on CO and CVD hospitalizations in high-income countries were inconsistent (Milojevic *et al*., 2014; Hashemi & Khanjani, 2016; Samoli *et al*., 2016; Dastoorpoor *et al*., 2019).

The Effects of HC on Health

A list of 16 representative polycyclic aromatic hydrocarbons (PAHs) released by the US Environmental Protection Agency (EPA) had been used for more than four decades. Popularly known as 16 US EPA PAHs, the name gained global recognition representing all non-polar (homocyclic) and polar (heterocyclic/substituted). PAHs are divided into two groups, light PAHs and heavy PAHs. Heavy PAHs are more dangerous compared to light PAHs (Kuppusamy *et al*., 2016; Li *et al*., 2016). Light PAHs contain up to four rings while heavy PAHs contain more than four rings. It is made up of carbon and hydrogen bond in simple to complex structures. The benzene ring arrangement on PAHs has widespread physical, chemical and toxicology physiognomies (Lawal, 2017). Figure 5 shows the chemical structure of commonly studied PAHs among all the 16 PAHs listed (Haritash & Kaushik, 2009). Exposure to PAHs mainly occurs through natural and anthropogenic sources, such as polluted air, food, petroleum products, sludge and sediments, coal, water, waste and plants, (Vignet *et al*., 2014; Wei *et al*., 2015). Classification of PAHs as persistent organic pollutants and have high-molecular-weight are detrimental to the environment and humans (Al-Saleh *et al.,* 2013; Lawal, 2017). Figure 6 shows the mechanism of PAHs action from the sources, both from vehicle and industrial emission to infect the human body and its consequences (Jia *et al*., 2018). Chen *et al.* (2019) studied the impact of temperature on PAHs accumulation in spinach (*Spinacia oleracea* L.). They found the root uptake was the dominating pathway and PAHs concentration to increase by 60.8 - 111.5% for every 5ºC increments. However, the result of PAHs accumulation in plants differ in various tissues.

The enormous growth vehicles production in developing countries creates other challenges, such as safety, increased fuel price and air pollution. Haworth (2012) stated that motorcycles are the main transportation mode in Asia countries as they are cheaper and represent 77% of the motorcycles worldwide in 2012 alone. In general, volatility of low-molecular-weight PAHs is higher than high-molecular-weight PAHs at lower temperature of condensation in gas state. The reactivity of lower-molecular-weight PAHs with other pollutants, such as ozone, NOx and SO_2 add to its significant effects which is forming diones, nitro- and dinitro- PAHs, and sulfuric acids, respectively (Park *et al*., 2001; Kameda, 2011). These compounds play their unique role in the environment and analytical sciences, which likely utilize many toxic compounds (Lawal, 2017). The exposure routes include ingestion, inhalation and eye absorption (Rengajaran *et al*., 2015). The effect of PAHs stimulates direct and indirectly oxidative stress and cellular nucleophile alkylation (Benigni & Bossa, 2011).

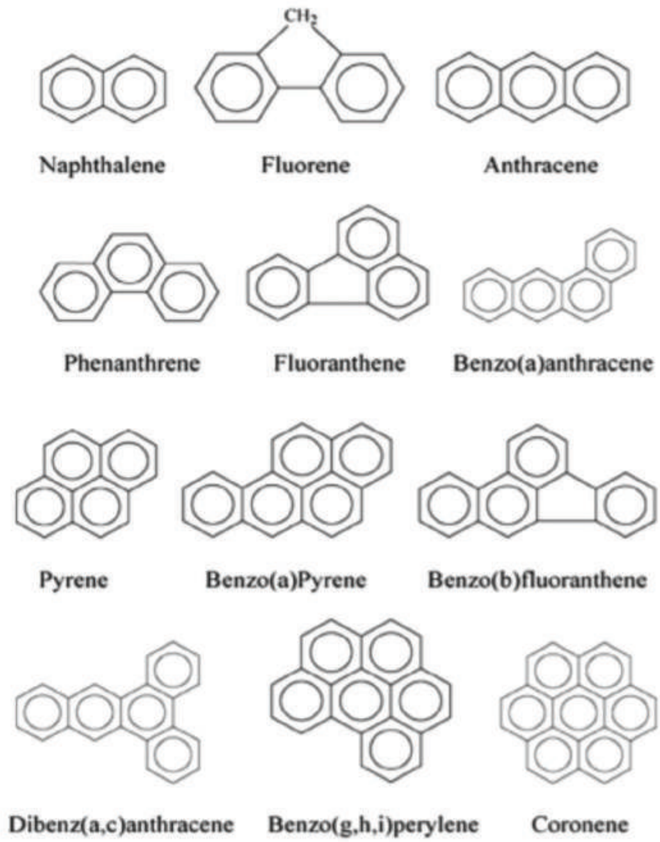

Figure 5: Common chemical structures of PAHs (Haritash & Kaushik, 2009)

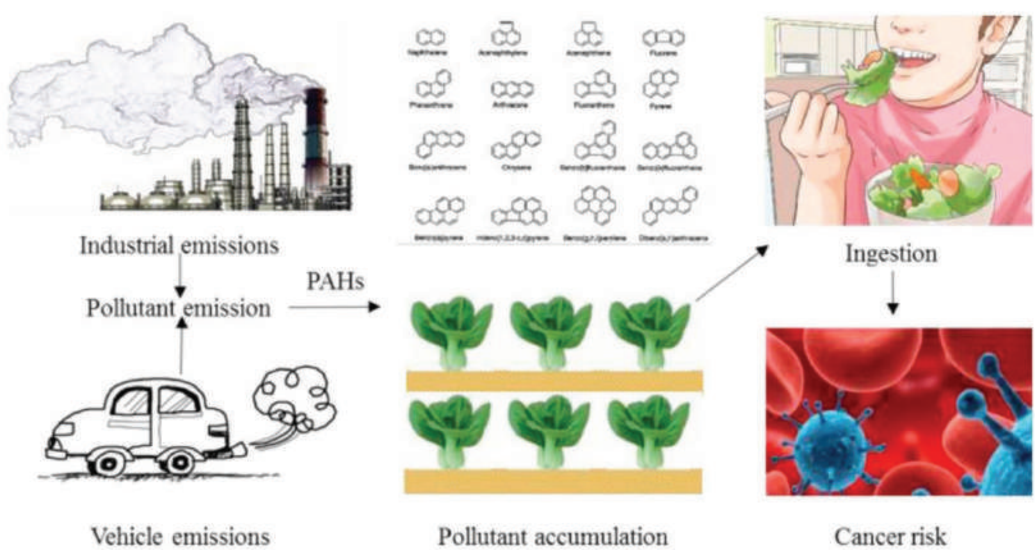

Figure 6: The toxicity absorption of PAHs from the sources to human body (Jia *et al*., 2018)

Atherosclerosis development from oxidative stress might promote inflammatory process due to increase pro-inflammatory effectors influx level which later accelerate atherogenic effects from PAHs exposure (Jeng *et al*., 2011; Hou *et al*., 2018). Acceptance of oxidative stress and inflammation trigger endothelial dysfunction, as they are the precursors to atherosclerosis development (Siti *et al*., 2015). Holme *et al.* (2019) also added PAHs exposure exacerbates CVDs, such as hypertension, thrombosis and myocardial infarction. Meanwhile, PAHs also can be detected in food prepared in various ways, such as frying, drying, smoking, grilling, refining and barbecuing (Que *et al*., 2019). Tongo *et al*. (2017) studied human health risk assessment of common PAHs in four types of smoked fish species collected from three major markets in Southern Nigeria. *Scomber scombrus* recorded the highest dietary daily intake value for total PAHs (3.585 mg/kg) while *Ethmalosa fimbriata* and *Clarias gariepinus* recorded the highest value of total carcinogenic PAHs at 0.467 mg/kg and 0.446 mg/kg, respectively. A study was conducted in a southern Israel industrial park with 20 km radius which hosts 70 types of chemical substances, including volatile organic compounds (VOCs), PAHs and inorganic substances. The findings highlighted that exposure to these pollutants at early life increases the risk of respiratory illness at later ages (Nirel *et al*., 2015).

The Effects of PM to Health

The widespread pollution of particulate matter (PM) caused by rapid industrialization and urbanization contributed to the decline of human health. Besides, PM tends to amass several harmful substances such as heavy metals, PAHs and viruses when inhaled. Inhaled heavy metal particles *via* the respiratory system such as Copper (Cu), Nickel (Ni), Lead (Pb) and Cadmium (Cd) causes a range of diseases (Cheng *et al*., 2013; Kim *et al*., 2015; Underwood, 2017). PM comes from various sources such as coal combustion, biomass incineration, fossil fuel burning, fugitive dust, road and construction dirt, cement and oil (Abdullah *et al*., 2019; Liu *et al*., 2019). Extreme exposure to PM-associated heavy metals noticeably worsens lung infections (Rastogi *et al*., 1991), and also causes symptoms of asthma, emphysema and lung cancer (Kuo *et al*., 2006). Indoor and outdoor experiments showed that the researchers are concerned with the high exposure risk even with low concentration of air pollutants.

Table 2 and Figure 7 show the basic comparison with respect to the size of $PM_{2.5}$ and

Table 2: Basic evaluation properties of PM regarding to particle dimensions: fine ($PM_{2.5}$) versus coarse (PM_{10}) mode particles (Kim *et al*., 2015)

Characteristics	Fine Mode Particles ($Pm_{2.5}$)	Coarse Mode Particles (Pm_{10})
Diameter	Less than 2.5 μm	Less than 10 μm
Composed of	Sulfate, SO_{2-4}; nitrate, NO_{-3}; ammonium, NH_{+4}; hydrogen ion, H+; elemental carbon, C; organic compounds; PAHs; metals, Pb, Cd, V, Ni, Cu, Zn; particle-bound water, and biogenic organics.	Resuspended dust, soil dust, street dust; coal and oily fly ash; metal oxides of Si, Al, Mg, Ti, Fe, $CaCO_3$, NaCl, sea salt; pollen, mold spores and plant parts.
Sources	Combustion of coal, oil, gasoline; transformation product of NOx, SO_2, and organics including biogenic organics, e.g. terpenes; high temperature processes; smelters and steel mills.	Resuspension of soil tracked onto roads and streets; suspension from disturbed soils, e.g. farming, mining; resuspension of industrial dusts; construction, coal and oil combustion, and ocean spray.
Lifetimes	Days to weeks	Minutes to hours
Travel distance (KM)	Up to 1000	Up to 10

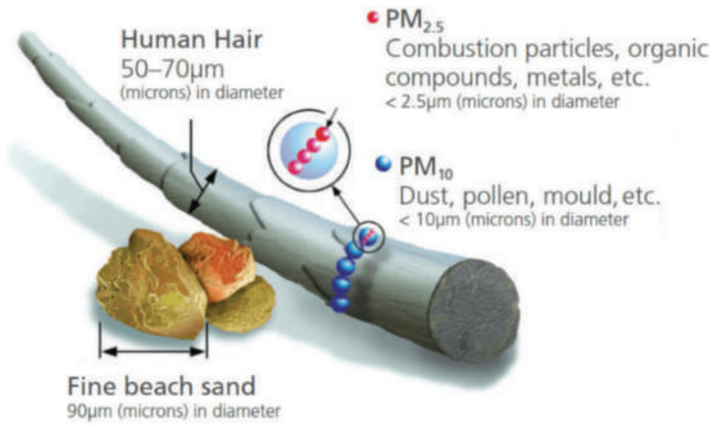

Figure 7: Size evaluation of $PM_{2.5}$ and PM_{10} with the average diameter of human hair (~70 µm) and fine beach sand (~90 µm) (Guaita *et al*., 2011)

PM_{10} by Kim *et al*. (2015) and Guaita *et al*. (2011). Table 2 summarizes the comparison of $PM_{2.5}$ and PM_{10} from different characteristics, such as size, chemical and compound compositions, possible sources, maximum travel period and lifetimes. It is stated that $PM_{2.5\ is}$ able to suspend in the environment for weeks and travel up to 1000 km compare to PM_{10}, which persists in the air only for hours and disperses about 10 km only. SO_2 gas has been shown to be assimilated with mineral dust and recorded high mass fraction of between 10 - 20%, which is a discrete feature of $PM_{2.5}$ in most of the region (Huang *et at*., 2014: Usher *et al*., 2003). Figure 7 compares the size of PM to fine beach sand and human hair. PM_{10} is one fifth the diameter of human hair while $PM_{2.5}$ is a quarter of PM_{10} size. A study in China from 2001 – 2011 on PM_{10} included long-term trend, spatial and temporal distribution and the impact on health. It was found that although the level of PM_{10} pollutants decreased, the concentration level remained higher than WHO guidelines. Inversely, the reduction of PM_{10} can still see life-threatening impacts (Cheng *et al*., 2013). Premature birth, CVD, respiratory hospital admission and fatality are among the effects of PM to human health (Cheng *et al*., 2013; Kim *et al*., 2015). The association of heavy metals with PM pollution was found to be well-correlated and lead to health degradation (Cheung *et al*., 2011; WHO, 2013). Figure 8 illustrates the possible route and accumulation of PM in various sizes in human organs through the respiratory system (Londahl *et al*., 2006). The figure indicates the smaller the size of PM being inhaled, the deeper and further the deposition site in the respiratory system that triggers the cancer formation.

Studies on mortality and outdoor $PM_{2.5}$ at low concentrations (< 35 µg/m^3) were limited compared to the global exposure range (Cohen *et al.* 2017). This deficit motivated the Integrated Exposure Response (IER) model, which associates both indoor and outdoor information. The IER model has predicted a total of 4 million deaths in 2015 related to PM pollutants in the global scenario. From the number of deaths, ischemic heart disease recorded the highest percentage at 39%, followed by stroke (20%), chronic intrusive pulmonary disease (19%), respiratory infection (16%) and lung cancer (7%) (Burnett *et al*., 2014). In 2017, a predicted number of people dying from outdoor pollution is 3.4 million, representing 6% of global deaths. Egypt recorded 114 deaths per 100,000 individuals, more than ten times higher than Sweden, Finland and New Zealand, with a death rate of less than 10 per 100,000 individuals. The findings also found that middle-income countries had high death rates, especially in Asia and Central Europe, including Egypt, Bangladesh, China, India and Pakistan. Consequences of improved indoor air quality, the global death

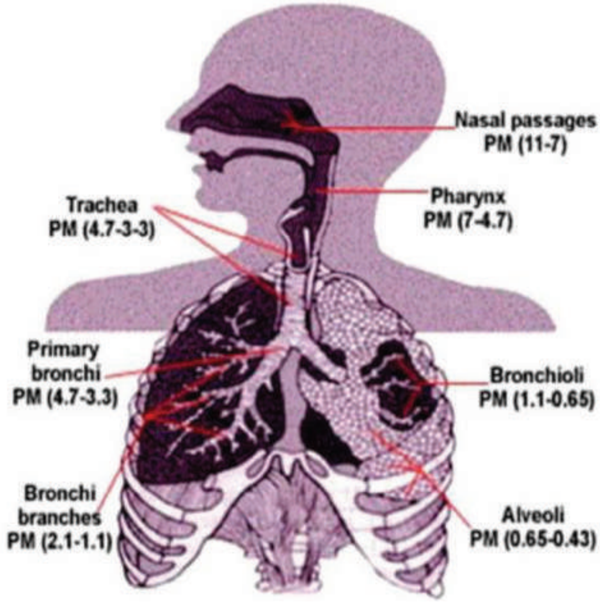

Figure 8: Deposition of possible particulate matter of varying sizes (Londahl *et al*., 2006)

rates caused by air pollution decrease in recent decades. The death rates per 100,000 individuals linked to PM declined from 44 to 38, and ozone from 11 to 6 since 1990 (Ritchie & Roser, 2020).

Conclusion

Various studies agree that DEAs have a huge impact on boosting the economies and industrial sectors, which in turn improves comfort and modern life. However, DEAs have long-term adverse effect. The outcome of the previous studies has indicated that the DEAs contributed to harming the environment and health. The exhaust emissions released t at uncontrollable rates form Greenhouse Gasses (GHG), which is the main contributor to climate change and global warming. The cycle of disasters caused by global warming and climate change include drought, fire and the rise of sea levels. The catastrophes are related and i may create another disaster. For instance, drought happened due to extreme heat waves and the high temperature makes grassland and cropland an easy target for fires. The heat from fires and global warming together can accelerate Greenland and Antarctic ice sheets melting rate, which in turn will increase the sea level. Thus, some regions will completely sink or form an island. The highlighted gasses are NOx, CO and HC, while PM is also emitted from DEAs. It will affect human health, especially the respiratory system, and lead to increased risk of cardiovascular diseases. The elderly, women, children and respiratory-related patients are the most affected group. Therefore, the Paris Agreement which involves a majority of the world's government leaders should fulfill the global policies to minimize the causes of climate change and global warming rising to 2ºC in the 21st century. Governments, international lobby groups and health organizations are able to inspire and inform the public the effects of exhaust emissions on global warming and climate change. Last but not least, the authors strongly believe that c green technology will be able to manage and reduce the adverse effects of DEAs.

Acknowledgements

The authors gratefully acknowledge the financial support from the Fundamental Research Grant Scheme for Research Acculturation of Early Career Researchers by the Malaysian Ministry of Education Vot No. RACER/1/2019/WAB09/UMT//2 and UMT Vot: 59554.

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