CHAPTER 1

INTRODUCTION

1.1. Background

1.1.1. Sustainable Development

Sustainable development was first introduced in 1972 in the United Nations (UN) Conference on Human Environment at Stockholm, Sweden. The UN was aware that the rapid development of human population had to sustain in limited resources. Without a good management, resources such as food, energy and water could be gone which, in the end, would move towards a global crisis. This conference triggered the establishment of environment protection organizations, and the most important was the involvement of politicians, government institutions and international organizations as the power behind the movement (*United Nations, 2018*). Afterwards, International Union for the Conservation of Natural Resources (IUCN) issued World Conservation Strategy (WCS) in 1980, which was the pioneer of sustainable development concept (*IUCN, 1980*).

World Commission on Environment and Development (1983) was established, and the year after, it was legalized into an independent body by the United Nations General Assembly with its job was to formulate '*A Global Agenda for Change*'. Through its report, '*Our Common Future*', or well-known as the Brundtland Report issued in 1987, WCED formulated the definition of sustainable development as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'. WCED stated that environment and development were two inseparable things: environment was the place where all of us lived; and development was the things that we all did in order to fix our fate in our living place (*WCED, 1987*).

The first international conference that promoted sustainable environment theme was held by the UN at Rio de Janeiro, Brazil on June 1992 about United Nations Conference on Environment and Development (UNCED). Specifically, this conference adopted the agendas of environment and development in the 21st century or also known as Agenda 21, i.e. an action program for sustainable development that contained Rio Declaration on Environment and Development. This declaration strictly acknowledged the rights of every nation to pursue social and economical advancement and gave countries responsibilities to adopt the model of sustainable development (*United Nations, 1992*).

UNCED for the first time mobilized Major Groups and legitimized their participation in sustainable development process. The leaders of countries in the world then strictly and widely acknowledged the importance of basic change in consumption and production patterns in achieving sustainable development. Ten years after Rio Declaration, the World Summit on Sustainable Development (WSSD) was held in Johannesburg, South Africa, to renew the global commitment on sustainable development. The conference agreement was stated in Johannesburg Plan of Implementation (JPOI), as well as assigned Commission on Sustainable Development (CSD) to follow up the implementation of sustainable development (*United Nations, 1992*).

The progress of contemporary sustainable development was marked by the United Nations Conference on Sustainable Development (UNCSD) or also known as Rio+20 as the third international conference held in Rio de Janeiro in 2012, and had three objectives, i.e. securing the renewal of political commitment for sustainable development, assessing the implementation progress and gap in fulfilling the previous commitment, and discussing new challenges emerging in sustainable development implementation. The results of the assembly were stated in a document entitled '*The Future We Want*', which contained, among others, acknowledgement that basic change in people's consumption and production patterns was very necessary to achieve global sustainable development (*UNDP, 2012*).

1.1.2. Sustainable Concept in Mining Industry

There are two problems generally asked in discussions on sustainable concept in mining sector, i.e. how to apply sustainable concept in mining operations which someday will end due to its non-renewable resources; and how to apply sustainable concept in operations that go against the characteristics of sustainable development. The first question is a generally known thing, that resources, both minerals and coals, no matter how plenty they are, someday will be gone to be mined considering their nature as non-renewable resources. Furthermore, project timeline that is no more than 10 years is often found in middle- and small-scale mines with very limited resources. The second question is that mining operations naturally go against what sustainable development practitioners are fighting for: their main operation is to move and take without replacing, and their activities have big impacts on the surrounding environment, not to mention the possible impacts on the people around the mine. Sustainable theme in mining industry is derived from sustainable development concept that is contemporarily campaigned in various sectors. Especially in mining field, sustainable concept has a unique position because the ore materials are not renewable resources (*Hendrix, 2006*).

International Institute for Sustainable Development (IISD) and World Business Council for Sustainable Development (WBCSD), through the final project report of Mining, Mineral and Sustainable Development (MMSD) issued in 2002, designed a framework of sustainable development in mineral sector. In the report, it was explained that what was meant by sustainable development concept implementation in mining industry was not an effort to create a new mine to replace other mine that had been closed down, but it was to see mining sector as a whole in contributing to current human's wealth without reducing the potential for future generations to do similar things. Therefore, sustainable mining approach must be comprehensive and future-oriented. Comprehensive means to measure the whole mining system starting from exploration stage to mine closure, including mine's products and results distribution, while future-oriented means to define short-term and long-term objectives consistently and collectively (*IIED, 2012*).

Furthermore, Johannesburg Plan of Implementation (JPOI) identifies three priority fields to maximize the sustainable potential at mining sector:

1. Analyzing social, health, economic and environmental impacts and benefits during mining operation cycles, including workers health and safety;

2. Improving participation of stakeholders, including local as well as female community;
3. Growing sustainable mining practices through technical support provision, capacity and finance development to developing and poor countries.

Therefore, it can be understood that the sustainability concept in mining does not mean that the operation has to be done continuously, and if assumed simply by creating a new mine to continue another mine that has been closed down. Sustainability concept in this industry is directed towards the efforts to maximize the benefits of mining development and at the same time and to be able to improve the environmental and social sustainability. This means that the sustainability concept on the mineral and coal extraction sector is emphasized on the optimization of the positive impacts resulted from the operations by emphasizing on the acculturation of economic, social and environmental pillars (the triple bottom-line) (TBL) (*Slaper & Hall, 2011*).

Nevertheless, in reality the implementation of sustainable mining practices still has to be seen fully and integrated, by Australian Centre for Sustainable Mining Practices argues that the triple bottom-line concept fails to consider the two very important and inseparable technical elements in sustainable mining operations: safety and resource efficiency. The integration of these important areas is a valuable input and can be regarded as a development of the concept that has been developed by MMSD (*Laurence, 2011*).

1.1.3. Sustainable Mining in Indonesia

In line with the global campaign on sustainable development, researches on this topic also starts to grow in Indonesia. Besides that, several mining companies consciously try to make sustainable mining practices as company program internalized as corporate needs. For example, PT Newmont Nusa Tenggara specifically develops Sustainable mining Bootcamp, an educational program for general community to directly see the mining process and the activities of the community around Batu Hijau mine area in West Sumbawa, West Nusa Tenggara. Another example is PT Freeport Indonesia, an affiliate of Freeport-McMoran Copper & Gold Inc which is a founding member of International Council on Mining and Metals (ICMM), which commits to implement ICMM's sustainable development framework in its whole operations (*PTFI, 2016*).

The slow pace of sustainable mining implementation in Indonesia is suspected to be caused by how weak the understanding of sustainable mining concept is. Several parties tend misinterpret sustainable mining as an effort for environmentally-oriented mining (*green mining*) or even socially-orientede and environmentally-oriented mining (*responsible mining*). In principle, sustainable mining is more on both concepts, or to combine both concepts with community economic development independently through proper fiscal balancing between mine company, workers and consumers, including local community. Thus, the big idea of sustainable mining is less satisfactory if it is still considered as corporate internal needs or managed partially by each institution. Once again, the approach has to be integrated and holistic, i.e. all stakeholders must be given a space of proportional involvement, including community involvement effort as part of corporate activity. On community involvement, specifically, this program has to be conducted seriously on every stage of mining operation, starting from mine exploration, production, to rehabilitation and closure. Public consultation must be done intensively and transparently so the community socio-economic needs can be defined clearly, which later on can be designed as part of corporate work plan (*Hojem, 2014*).

Basically, the purpose of Sustainable Development is to create a balance between development dimensions, such as economy, socials and environment. In mining industry field, it is definitely related and or stakeholders are to implement this sustainable development concept. Then, the industrial production process of the mine that implements the sustainable development concept must do industrial ecology. Industrial ecology is a system used to manage energy or material flow so high efficiency can be gained and less pollution is resulted. The main objective is to organize industrial system so that a type of eco-friendly and sustainable operation can be gained. There are four main elements in the strategy to implement industrial ecology: optimizing resources usage, creating a closed material cycle and minimizing emission, dematerialization process and reduction and omission of dependency on non-renewable energy source (*Garner, 1995*).

Mining industry that implements Sustainable Development must guarantee that there is a balance spread for current and future generations, in a form of balancing the distribution of land resources, production factors as well as sustainable economy in a form of welfare for all community levels. Sustainable development concept also uses integrative approach, i.e. natural diversity that becomes a pre-requirement to ensure that the natural resources are sustainably available for current and future time. Cultural diversity conservation will encourage equal treatment for each person and create knowledge on the traditions of various communities can be more understood by societies (*Tabara and Pahl-Wostl, 2007*).

1.1.4. Underground Mines Air Pollution

Pursue principles of sustainable development in continual improvement of health and safety performance, and environmental performance where PT Freeport Indonesia (PTFI) operate, assess negative and positive, direct nor indirect, cumulative environmental impacts of mining are needed to mitigate or ameliorate adverse environmental and health impacts.

Air has a very important meaning in the life of all living creatures and other materials. Therefore, air is natural resources that have to be protected for life, human and other creatures' life. In addition, in order control environmental pollution and or damage, to keep the sustainability of environmental functions, and to comply the regulations on environmental quality standards and/or the standard criteria of environmental damage have been stated in Article 68 of *Indonesian Act Number 32, 2009 on Environmental Protection and Management*. There is also to create healthy environment quality is the main part in the effort of health field which is stipulated in *Act Number 36, 2009 on Health*, such as the need for work environment.

Air pollution control is done for complying *Act Number 1, 1970 on Occupational Safety*, i.e. article 3(1) point (g) and (h) that says in order to prevent and control the emergence or spread of temperature, humidity, dust, dirt, vapor, gas, wind blows, weather, light and radiation, voice and vibration, as well as to prevent and control the emergence of diseases because of work, both physically and psychologically, poisons, infection and contagiousness.

Air is an environmental media that needs to be concerned and target of the which area, especially work environment. The existence of industrial sector growth per year is still a potential sector in triggering economic growth and business field equity, but on the other hand, it also gives negative impacts on the environment if it is not well handled. The negative impacts can be in the form of air pollution both indoor and outdoor, that can endanger human's health and contagious disease as well as the occurance of environmental pollution.

The indoor air quality is a problem that needs attention because it will affect human's health. According to the National Institute of Occupational Safety and Health (NIOSH) 1997, indoor air quality problem is generally caused by several things, i.e. lack of air ventilation 52 %, the existence of indoor contaminant source 16 %, outdoor contaminant 10 %, microba 5 %, construction materials 4 %, and others 13 % (*Decree of Indonesian Minister of Health Number 1407, 2002*).

Air pollution is defined as the decrease of air quality, having quality decrease in its usage, which finally cannot be used anymore by its function. In air pollution, it is always related to the source resulting air pollution, i.e. mobile sources (*generally vehicles*) and static sources (*generally industrial activities*) while the control is always related to various control activities coming from air quality standard threshold. With the existence of air quality standard parameter, we can set up and define air pollution control activity (*Indonesian Government Regulation Number 41, 1999*).

Act Number 4, 2009 on Mineral and Coal Mining stated that mining business is an activity in mineral or coal cultivation that covers the stages of general investigation, exploration, feasibility study, construction, mining, processing and smelting, transportation and sales, and post-mining. The *Decree of Minister of Mining and Energy Number 555.K/26/M.PE/1995 on General Mining Occupational Safety and Health*, article 80 explains about protection on health risks caused by air pollution.

Underground mine is a mining system to obtain minerals by making tunnels towards the mineral location. Various metals can be taken through this method such as gold, copper and silver. There are two main stages in underground mine method, i.e. development and production. In the development stage, everything to be digged is not valuable rocks. Development stage includes the making of entry way and the digging of other underground facilities, while the production stage is digging the ore itself. In underground mining, transportation of ore uses heavy equipment such as loader as well as other equipments that use diesel engine. Besides loader, haul truck, development jumbo machine, truck and other mine equipments that use diesel engines.

Heavy equipments are specific emission source, which do not have references for control effort both in national and international levels. The use of these specific emission sources still has to consider the environmental management of industry (*Indonesian Government Regulation Number 41, 1999*). It also refers to article 9(b) and (c), i.e. the execution of environment management and occupational health stated in the *Regulation of*

Indonesian Minister of Energy and Mineral Resources Number 38, 2014 on *The Implementation of Mineral and Coal Mining Safety Management System.*

Many of the ancillary activities associated with mining and beneficiation also impact air quality. Exhaust produced by diesel and other vehicles, emissions from a variety of onsite equipments, and air pollutants produced during equipment maintenance and cleaning are included. The United State Environmental Protection Agency (EPA) has promulgated National Ambient Air Quality Standards (NAAQS) for certain 'criteria' pollutants. The criteria air pollutants generally associated with mining include particulates, sulfur oxides (SOx), nitrous oxides (NOx), and carbon monoxide (CO). Mining releases varying quantities of other pollutants, including carbon dioxide (CO_2), volatile organic compounds (VOCs), methane, lead, and other hazardous air pollutants (HAPs), including radiological constituents. Certain of these criteria pollutants may increase the incidence and seriousness of a number of diseases, especially those related to respiratory tract, as well as impact the physical environment. Environmental impacts may include effects on visibility, acid deposition, and global climate.

There are two types of NAAQS, described as primary NAAQS and secondary NAAQS. Primary NAAQS prescribe maximum allowable concentrations of a criteria pollutant in the ambient air, leaving an 'adequate margin of safety' to protect human health. Secondary NAAQS are set at maximum level of a criteria pollutant that will protect the public welfare (not related to human or health). Most significantly, primary NAAQS are set to protect not only the major of the popolation, but sensitive subgroup as well. Protection of human health is the sole factor upon which primary NAAQS are based, and factors like cost and technical feasibility of attaining a primary standard are not to be considered when the standards are developed and periodically reviewed by EPA (*Marcus, 1997*).

By far the most ubiquitous concern to the mining industry is particulate matter, which is emitted in relatively large amounts in almost all aspects of mining operations. In addition to mining, major sources of particulate matter include stationary fuel combustion, various industrial processes, road construction and use, and other. Particulate can affect human health adversely. At high enough levels, particulates can contribute to chronic respiratory illness such as emphysema and bronchitis and have been associated with increased mortality rates from some diseases. In addition, particulate matter may cause irritation of the eyes and throat, and it can impair visibility.

The majority of issues associated with the sulfur oxide are emitted by diesel vehicles and onsite fuel combustion at mining operations. Expsoure to high levels of sulfur oxides and their transformation products can interfere with respiratory tract. Nitrous oxide are emitted when fuel is burned at high temperatures. At high levels cause lung damage and exacerbate some respiratory diseases. Carbon monoxide is poisonous gas produced by the incomplete burning fuels , and is emiited primarily from fuel combustion process. Carbon monoxide can combine with nitrous oxide to produce smog. At high levels, carbon can impair the blood’s ability to transport oxygen, affect cardiovascular, nervous and pulmonary systems. In addition, it can cause eye and lung irritation, and as smog can produce an offensive odor and haze that impairs visibility (*Marcus, 1997*).

1.1.5. Diesel Fuel and Diesel Engine Exhaust

Indonesian Government Regulation Number 41, 1999 on air pollution control, covers activities mainly for regional air quality inventory by considering various criteria in air pollution control. The criteria defining ambient air quality standards and emission quality standards to used as the reference for air pollution control; defining quality in an area including the allocation planning of activity that pollutes the air. Air quality monitoring both ambient and emission followed with evaluation and analysis; supervision on regulation compliance and community involvement in the care of air pollution control.

Fuel policy followed with a range of integrated activities referring to clean and environmentally friendly fuel; defining basic both technical and non technical policies in air pollution control nationally. Counter measures of air pollution from mobile sources, among them, include supervision on managing emission threshold of exhaust gas, insection of exhaust gas emission for new and old type vehicles, ambient monitoring and purchasing of free lead oil fuel as well as low-sulphur diesel fuel based on the international standards.

The use of diesel fuel on diesel engines increases because of the reliability an efficiency of hydrocarbon fuel oxidation. However, there is a worry that the result of diesel engine oxidation is in the form of *diesel engine exhaust* (DEE), which is dangerous for people's health. The particles in DEE are *diesel particulate matter* (DPM) consisting of the center of carbon nucleus and absorbed organic compounds, and a small number of sulphate, nitrate, metal, and other elements. This worry is related to the small size of respirable *diesel exhaust particle* as well as its substantial content, i.e. polycyclic aromatic hydrocarbon, which is mutagenic in nature and in some cases, it is known to become human carcinogen, where miners and other workers around the diesel-powered equipment may have been exposed with DPM.

DPM is known as the job hazard for workers who operate diesel-powered equipment. DPM refers to the tiny carbon particle or *'soot'* in diesel exhaust smoke that can deeply go through the lungs and can result in serious health risks. DPM is a *diesel engine ehaust* (DEE) component, including soot particle, mainly consists of carbon, ash, abrasive metal particle, sulphate and silicate. Diesel soot particle has a solid nucleus consisting of carbon element, woth other element attached to the surface, including organic carbon compound known as aromatic hydrocarbon.

DPM is a significant component of PM (*Particulate Matter*). There is no unique marker for DPM, so measuring the outer level directly is difficult. DPM composition consists of hydrocarbon and O_2 that have two fractions, gas and vapor, with their main component (99 %) consisting of N_2, O_2, Ar, CO_2 and H_2O and minor component (1 %) consisting of CO, NOx, SO_2 complex that are mixed with hydrocarbon and attached to atom O, N, S etc. DPM is kept in lungs and its component can be absorbed in the body. The majority of DPM diameter is less than 1 µm ($^1/_{70}$ of human hair's diameter). Generally, the diameter of PM_{10} particle or less can be inhaled into the lungs (*USEPA, 2004*). The PM_{10} standards is considered a more accurate measure of particles that affect human health and welfare. Under this standard, particles with an aerodynamics diameter of 10 microns or less are regulated by the particulate matter NAAQS (*Marcus, 1997*).

Not all inhaled particles are deposited in the lungs, because many are exhaled. Particles with a diameter around 0.5 µm are kept in the air channel; with high deposition level for the second particle is smaller and bigger than 0.5 µm diameter. Chemical substances are absorbed in particles and can dissolve in liquid that covers the air channel, then absorbed into the body. The dissolved particles are wiped out by a more complex mechanism.

DPM exposure has been related to various acute short-term symptoms such as headache, queasiness, cough, hard to breathe, and irritation of eyes, nose and throat. Long-term exposure (*chronic*) can cause a more serious health problem such as heart disease and cardiopulmonary disease.

Exposure for underground metal or non-metal miners is personal esposure. A miner for DPM cannot exceed 160 micrograms per cubic meter ($\mu g/m^3$) from total carbon (TC) when measured as 8 hours measured-time in average. Technique and administration of feasibility control are needed to reduce miner's exposure for or under the allowed threshold (PEL, *permissible exposure limit*).

In Indonesia, there are an underground mine for mineral metals. Besides *particulate matter*, DEE also consists of nitrogen gas mixture including nitrous oxide (NOx), sulfur oxide (SOx), carbon monoxide (CO), and organics that vapor easily (including aldehyde, benzene and polycyclic aromatic hydrocarbon). Other pollutants, too, such as carbon monoxide (CO), nitrogen dioxide (NO_2), hydrogen disulphide (H_2S) and sulphur dioxide (SO_2) as well as dust from mining process have exposed the underground miners.

Based on the above descriptions, a study related to exposure-response on underground miners by DEE needs to be conducted, where other gas pollutants and ash also exposed to these miners.

1.2. Research Problem Identification and Steps of Research

Based on the backgrounds above, the general problem statement in this research is: *'How Diesel Engine Exhaust (DEE) affects the environment and health, and how is the exposure response of the underground miners in PT Freeport Indonesia?'*

While the specific problem formulation in this research is:

1. Does DEE in Deep Ore Zone (DOZ) underground mine in PT Freeport Indonesia cause air pollution?
2. How is the distribution of DEE pollutant to the environment in DOZ underground mine of PT Freport Indonesia?
3. How is the effect of DEE exposure on the DOZ underground miners' health of PT Freeport Indonesia?
4. How to design the safety and environmental management model in underground mine of PT Freeport Indonesia?.

Based on the literature review in previous research, steps to solve the problems and answer the objectives of the study are defined as follows:

1. To obtain overview of DOZ underground mining operation characteristics generally and specifically.
2. Taking measurements of indoor pollutant concentration in DOZ mine for DEE consisting of CO gas; NO and NO2; and DPM concentration and characteristic of DPM morphology.
3. Mapping the concentration of pollutants in DOZ mine by geostatistical spatial interpolation method. The geostatic method chosen was the universal kriging method with flow of map generation.
4. To measure pulmonary function disorders and *chronic pulmonary obstructive disease* (COPD) on miners of DOZ mine by using reference of the GOLD classification.

1.3. Research Objectives

The general objective of this research is to answer research problems identification above and to know DEE exposure response on DOZ underground miners in PT Freeport Indonesia. The specific objectives of this research are:

1. To analyze if DEE in DOZ underground mine of PT Freeport Indonesia's causes air pollution

2. To analyze the distribution of DEE pollutants in the area of DOZ underground mine of PT Freeport Indonesia
3. To analyze the effect of DEE exposure on DOZ underground miners of PT Freeport Indonesia's respiratory health
4. To modelize safety and environmental management in other underground mines of PT Freeport Indonesia.

1.4. Originality and Novelties

Previous studies have applied the kriging method to map the air pollutant level, such as SO_2, O_3, and particulates (*Withworth et al., 2011; Shad et al., 2009*). Furthermore, the method also applies to GIS-based test of the spatial interpolation of the climate data (*Chiu et al., 2009*). Studies have also revealed the application of kriging in evaluating CO rate (*Potoglou and Kanaroglou, 2005*) and DPM (*Brauer et al., 2003*) in air ambient. However, only few studies have been devoted to the off-road research in the underground mining.

Results of the previous studies proved that the kriging method are also useful for identifying metallic (*Fonturbel et al., 2011*), particulate (*Gulliver et al., 2011; Brauer et al., 2003*), SO_2, NO_2 (*Briggs et al., 2000*) and TSP (*Sengupta et al., 1996*).

Previous research had been conducted by Attfield *et al* (2012). However, this research was done on non-metal underground miners in the United States. Furthermore, research on the effect of diesel exhaust exposure on the health was done by Parnia *et al*

(2014), Setton *et al* (2013), Lucking *et al* (2011), Lehman *et al* (2009), Li *et al* (2010), Robertson *et al* (2012), Löndahl*et al* (2012), Wu *et al* (2012), Nemmar *et al* (2013).

Liu *et al* (2013) stated that there is a strong association that hes been observed between ambient particle ($PM_{2.5}$) and the result of disadvantageous cardiovascular. Specifically, exposure related to $PM_{2.5}$ transportation has been related to the increase of left hypertrophy ventricle, which is a strong risk factor for mortality of cardiovascular. Xu *et al* (2013) stated that exposure on DE causes inflammation response. Previous study on controlled exposure was in concentration 300μg/m^3 by DE in 1 hour. Long-term and investigated exposure period seeks how fast DE can do induction the airway and systemic effect.

Miller *et al* (2013) stated that DEP exposure will increase and shake *lesiaterosklerotic diapolipoprotein E* lack (apoE-/-) on the rats. Robertson *et al* (2014) argue that inhaled DEP increases blood pressure and has deep side effect on myocardium, resulting in network damage, but also increae the vulnerability on ischemia related to aritmia and reperfusion injury. This effect is mediated through lung TRPV1 activation, sympathetic neural system and oxidative stress resulted locally.

Silverman *et al* (2012) stated that most studies are on simple relationship between DE exposure and lung cancer, but consistent on risk improvement. Li *et al* (2011) investigates the relationship between pathogenesis of chronic obstructive lung disease (COPD) and the mechanism of molecular which underpins the entry of Ca^{2+} into human’s epitel channel resulted by DEP.

Mills *et al* (2011) state that oxidation from nanoparticulate seems to be dominated mediating the vascular effect that is disadvantegous from DEE inhalation. This gives a reason for environmental health intervention examination targeted to reduce particulate emission of the traffic given.

Previous air pollutants researches that have been done in Indonesia and presented in table 1.1. Investigation of researches related to DEE is conducted at least 100 researches that have been done in and presented in table 1.2. In table 1.1 below, it shows the result of previous research studies conducted in Indonesia related to the air pollution and its effects on health.

Viewed from originality and novelties point of view, this research is different from the previous researches. There has been no research on DEE in Indonesia yet, mainly related to DEE exposure to the miners, especially to the underground miners of metal mineral mine. The results of previous studies show there are no special studies of DEE exposure, especially the influence of CO and DPM and its effect on respiratory health.

Table 1.2 is the result of a research investigation related to the response of gas pollutant and particulate matter exposure to respiratory health, but no studies have mapped the concentration of air pollutant in underground mines, particularly mines of mineral, copper, and gold. Based on the results of this study, it can be concluded that the originality of this study is that there is no similar or similar research on the response of DEE exposure on respiratory health in Indonesia.

Noveltties of this research are the use of geostatistical spatial interpolation method to map the concentration of DEE pollutant in underground mines. This method can be used as a model to map the concentration of DEE pollutant in other underground mines to predict the exposure of DEE responses to miners. Some of the advantages of this research are that the concentration of air pollutants in the underground mine can be mapped as ambient air concentration in open space by geostatistics method. The mapping results of the air pollutant concentration can be a reference and an estimation of the number of groups in the population that can be exposed to the pollutant so it can be predicted epidemiologically associated with the amount of incidence of illness and even death caused by the pollutant.

1.5. Research Benefits

This research is expected to become one of references that can give an overview on the effect of DEE on the environment and underground mineral miners' health and the estimation of its exposure response, in which there only few research has been done in Indonesia.

Besides that, this research is expected to become a reference related to DEE other than on underground mines, such as general traffic, urban air quality and the effect of DEE exposure on health especially on the decreasing function of lungs as well as estimation model of exposure response in other fields of study.

Table 1.1. Previous air pollutants researches

No.	Citation	Design	Location	Period	Sampel	Pollutants	Outcomes
1	Aditama. *Impact of haze from forest fire to respiratory health: Indonesian experience*. Respirology, 5:169-74; 2000.	Deskriptif (episode)	Indonesia 8 province	1997-1998	General population	Haze from forest fire	Respiratory health: data collected from pulmonologists, health offices and hospitals indicated a significant increase in respiratory conditions that the study attributed to air pollution haze.
2	Albalak, Noonan, Buchanan, *et al. Blood lead levels and risk factors for lead poisoning among children in Jakarta, Indonesia*. Sci Total Environ, 301:75-85; 2003.	Cross sectional	Indonesia Jakarta	-	397 children from 40 primary schools	Lead	Blood lead concentration: before the lead phaseout in Jakarta, 35% of children had blood lead concentrations >10 µg/dL and 2.4% had concentration > 20 µg/dL. Approximately 25% had concentrations of 10 to 14.9 µg/dL. In children who lived near a highway or major intersection were significantly higher than in those who lived near a street with litle or no traffic. Level of education was not included in the model.
3	Browne, Husni, Risk. *Airborne lead and particulate levels in Semarang. Indonesia and potential health impacts*. Sci Total Environ, 227:145-54; 1999.	Health impact	Indonesia Semarang	1996-1997	1.3 million adults and children	TSP, airborne lead	Mortality: increased TSP concentration near major roads resulted in an estimated 1.6% increase in total mortality and 7.9% increase in mortality from respiratory disease. Estimated blood lead concentrations indicated possible lead toxicity among Semarang children.
4	Duki, Sudarmadi, Suzuki, *et al*. *Effect of air pollution on respiratory health in Indonesia and its economic cost*. Arch Environ Health,	Cross sectional	Indonesia Jakarta Bandar Lampung	1996-1997	16,663 pairs of junior high school students	NO_2	The prevalence rate of respiratory symptoms was significantly associated with NO_2. It was estimated that the reduction of NO_2 to a proposed concentration of 25 ppb would yield

	58:135-43; 2003.				and their mothers		savings of US $6.8-$7.9 in mead direct 'out of pocket' expense/capita for treatment of respiratory symptoms and would decrease average work or school days lost/capita by 3.1-5.5 days.
5	Frankenberg, McKee, Thomas. *Health consequences of forest in Indonesia*. Demography, 42:109-29; 2005.	Cross sectional (episode)	Indonesia	1997	Men and womwn in 30-55 year, $\geq$ 56 year	Haze from forest fire	1993-1997, individuals exposed to haze experienced greater increases in difficulty performing activities of daily living than did their counterparts in non-haze areas. Results suggested that haze had a negative effect on respiratory and general health.
6	Hong, Chia, Widjaja, *et al. Prevalence of respiratory symptoms in children and air quality by village in rural Indonesia*. J Occup Environ Med, 46:1174-79; 2004.	Cross sectional	Indonesia Kerinci SP 7 Pelalawan	2001	382 children	PM_{10}, NO_2, CO, hydrocarbo n	Prevalence of respiratory symptoms: higher PM_{10} and hydrocarbon concentrations were associated with a higher prevalence of respiratory symptoms in children in two of the villages studied.
7	Kunii, Kanagawa, Yajima, *et al. The 1997 haze disaster in Indonesia: its air quality and health effects*. Arch Environ Health, 57:16-22; 2002.	Cross sectional	Indonesia Jakarta Jambi	1997	543 adults and children	PM_{10}, NO_2, CO, O_3, PAHs	Respiratory symptoms, lung function: questionnaire interviews and spirometry indicated respiratory symptoms in more than 90% of participants exposed to PM_{10} and CO at very low versus hazardous concentrations and to PAH concentrations 6-14 times higher than those in an unaffected area. Gender, asthma and wearing a mask were associated with severity of symptoms.
8	Ostro. *Estimating the health effects of air pollutants, a method with an application to Jakarta*. The World Bank,	Health impact	Indonesia Jakarta	-	-	PM, SO_2, NO_2, O_3, lead	Health benefits: a method for quantifying the benefits of reduced air pollution was proposed and applied to data from Jakarta.

	Washington. Policy Research Working Paper 1301; 1994.						
9	Tri-Tugaswati A and Yasuo K. *Effect of air pollution on respiratory symptoms of junior high school students in Indonesia*. Southeast Asian J Trop Med Public Health, 27:792-800; 1996.	Cross sectional	Indonesia Jakarta and sourrounding cities.	1994	16,187 junior high school students	NO_2	Respitaory symptoms: when a self-administered was used it was found that the prevalence of persistent cough was 7.3-10.8% and that of persistent phlegm 4.5-5%. A significant relation was found between NO_2 exposure and the prevalence of cough, phlegm and wheezing.

Source: Health Effect Institute, 2016.

Table 1.2. Previous studies of PM and gaseous pollutants related to lung function

No.	Citation	Design	Location	Period	Sampel	Pollutants	Outcomes
1	Aekplakorn, Loomis, Vichit-Vadakan, *et al. Acute effect of SO_2 from a power plant on pulmonary function of children, Thailand*. Int J Epidemiol, 32:854-61; 2003.	Panel	Thailand Mae Moh district	1997	175 children (6-14 year)	PM_{10}, SO_2	Lung function: decline in lung function among asthmatic children were associated with increases in particulate air pollution but not with increases in SO_2.
2	Aekplakorn, Loomis, Vichit-Vadakan, *et al. Heterogenecity of daily pulmonary function in response to air pollution among asthmatic children*. Southeast Asian J Trop Med	Panel	Thailand Mae Moh district	1997	83 children	PM_{10}, SO_2	Lung function: FVC, FEV_1, PEFR, FEF_{25-75}: as association was found between the short-term exposure if children to SO_2 and PM and inter-individual variance in subject specific change in FVC, FEV_1 and PEFR even with low daily concentrations of these

	Public Health, 35:990-98; 2004.						pollutants in the study area.
3	Agarwal, Jayaraman, Anand, Marimuthu. *Assessing respiratory morbidity through pollution status and meteorological condition of Delhi*. Environ Monit Assess 114:489-504; 2006.	Ecologic	India Delhi	2000-2003	Residents of Delhi	SPM, RSPM, SO_2, NO_2	Respiratory morbidity, COPD, asthma, emphysema: significant positive correlations of SPM and RSPM were observed with COPD but not with asthma.
4	Bell, Levy, Lin. *The effect of sandstorms and air pollution on cause specific hospital admissions in Taipei, Taiwan*. Occup Environ Med, 65:104-11; 2008.	Time series	Taipei China	1995-2002	6909 admissions for ischemic heart diseass; 11,466 for cerebrovascular disease; 10,996 for pneumonia; 10,231 for asthma	NO_2, CO, O_3, SO_2, PM_{10}, $PM_{2.5}$ (as indicators of pollutants and sandstorms)	Hospital admissions related to ischemic heart disease were 16-21% higher on sandstorm days than on other days. Asthma admissions rose 4.48% per 28mg/m^3 increase in PM10 concentrations and 7.6% per 10ppb increase in O_3, cerebrovascular disease were associated with PM_{10} and CO but not with SO_2.
5	Chang, Pan, Xie, *et al. Time-series analysis on the relationship between air polution and daily mortality in Beijing (in China)*. J of Hygiene Research, 32:564-68; 2003.	Time series	China Beijing	1998-2000	Risidents of 8 districts in Beijing	TSP, PM10, SO2, Nox, CO	Airborne concentrations of PM10, SO2, Nox and CO each correlated significantly with mortality, especially from respiratory, cardiovascular, cerebrovascular, coronary heart disease and COPD and TSP concentrations were associated with respiratory disease.
6	Chattopadhyay, Mukherjee, Mukherjee, *et al. Exposure to*	Cross sectional	India Kolkata	-	505 residents	PM_{10}, VOCs (in	Changes in lung function: higher traffic load in the areas studied was associated

	vehicular pollution and assessment of respiratory function in urban inhabitants. Lung, 185:263-70; 2007.					motor vehicle exhaust)	with increased deterioration of respiratory function, itt was found that 3.6% of the subjects had restrictive impairement, 3.17% had obstructive impairement and 1.88% had both.
7	Jang, Kim, Lee, *et al. Hospitals visits and admissions in patients with asthma, COPD and cardiovascular diseases according to air pollutants*. J Asthma Allergy Clin Immunol, 26:233-38; 2006.	Ecologic	South Korea Bucheon	1992-1993, Jan-Aug, 2003	Hospitalized patients (>10 year)	PM_{10}, SO_2, NO_2, O_3	COPD, asthma, cardiovascular disease: significant associations were found between monthly change in PM_{10} concentrations and emergency-department visits for women with asthma as well as outpatient visits for men with asthma. Significant associations were also found between monthly change in O_3 concentrations and outpatient visits for COPD and angina pectoris. SO_2 and NO_2 concentrations were not significantly associated with any diseases outcome.
8	Jones, Lam, Dean. *Respiratory health of bus drivers in Hong Kong*. Int Arch Occup Environ Health, 79:414-18; 2006.	Cross sectional	China Hong Kong	2003-2004	358 drivers of air conditioned buses, 129 drivers of non air conditioned buses	PM_{10}, CO_2, CO (measured in inside buses)	Lung function, respiratory symptoms: compared with drivers of air conditioned buses, drivers of non air conditioned buses reported frequent productive cough, dry cough and sore throat. Measured lung function (FVC, FEF and max ventilatory volume) was lower than that of the drivers of the air conditioned buses and of a university cohort.
9	Ko, Tam, Womg, *et al*. *The temporal relationship between air pollutants and hospital admissions for COPD in Hong Kong*.	Ecologic	China Hong Kong	2000-2004	119,225 emergency hospital admissions	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3	All five pollutants were significantly associated with increased admissions for COPD. For every 10mg/m^3 increase in SO^2, NO_2, O^3, PM_{10} and $PM_{2.5}$ concentrations, the relative risk (RR)

	Thorax, 62:780-85; 2007.						admission was 1.007, 1.026, 1.034, 1.024 and 1.031. in multipollutant model O^3, SO_2 and $PM_{2.5}$ were significantly associated with increased associated with increased admissions for COPD.
10	Sekine, Shima, Nitta, *et al. Long term effects of exposure to automobile exhaust on pulmonary function of female adults in Tokyo, Japan*. Occup Environ Med, 61:350-57; 2004.	Cohort	Japan Tokyo	1987-1994	5682 women	SPM, NO_2	Lung function: subjects living in areas with high concentrations of air pollution showed higher prevalence rates of respiratory symptoms and a larger decrease in FEV_1 than those living in areas with low concentrations of air polution.
11	Yu, Womh, Liu. *Impact of air pollution on cardiopulmonary fitness in schoolchildren*. J Occup Environ Med 46:946-952; 2004.	Cross sectional	China Kwun Tong Shatin (district in Hong Kong)	-	821 primary schoolchildren (8-13 year)	RSP, SO_2, NO_2	Lung function: children in high-pollution district had significantly lower max oxygen uptake than those in a low pollution district.

Source: Health Effect Institute, 2016.