CHAPTER 2

LITERATURE REVIEW

2.1. Underground Mine

Block caving method is a method in undergrounds mine where ore body is taken by undercutting with drilling and blasting methods. Then, with the effect of gravitation force, the emergence of stress, power from the rock mass and power from discontinue field in the rock mass, may causes the rock block to fall.

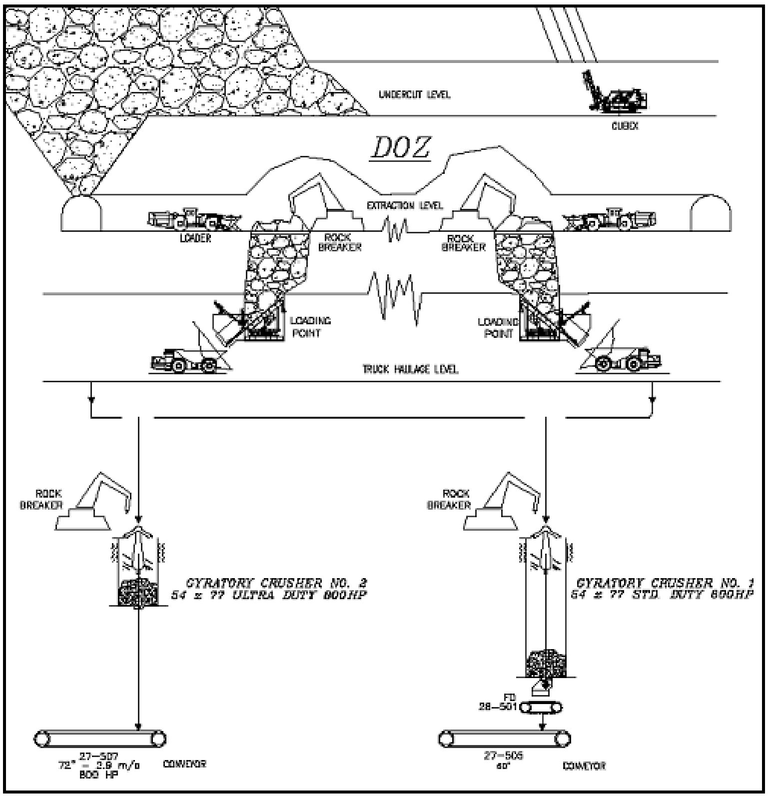

Figure 2.1. Block caving method

Source: PTFI, 2013.

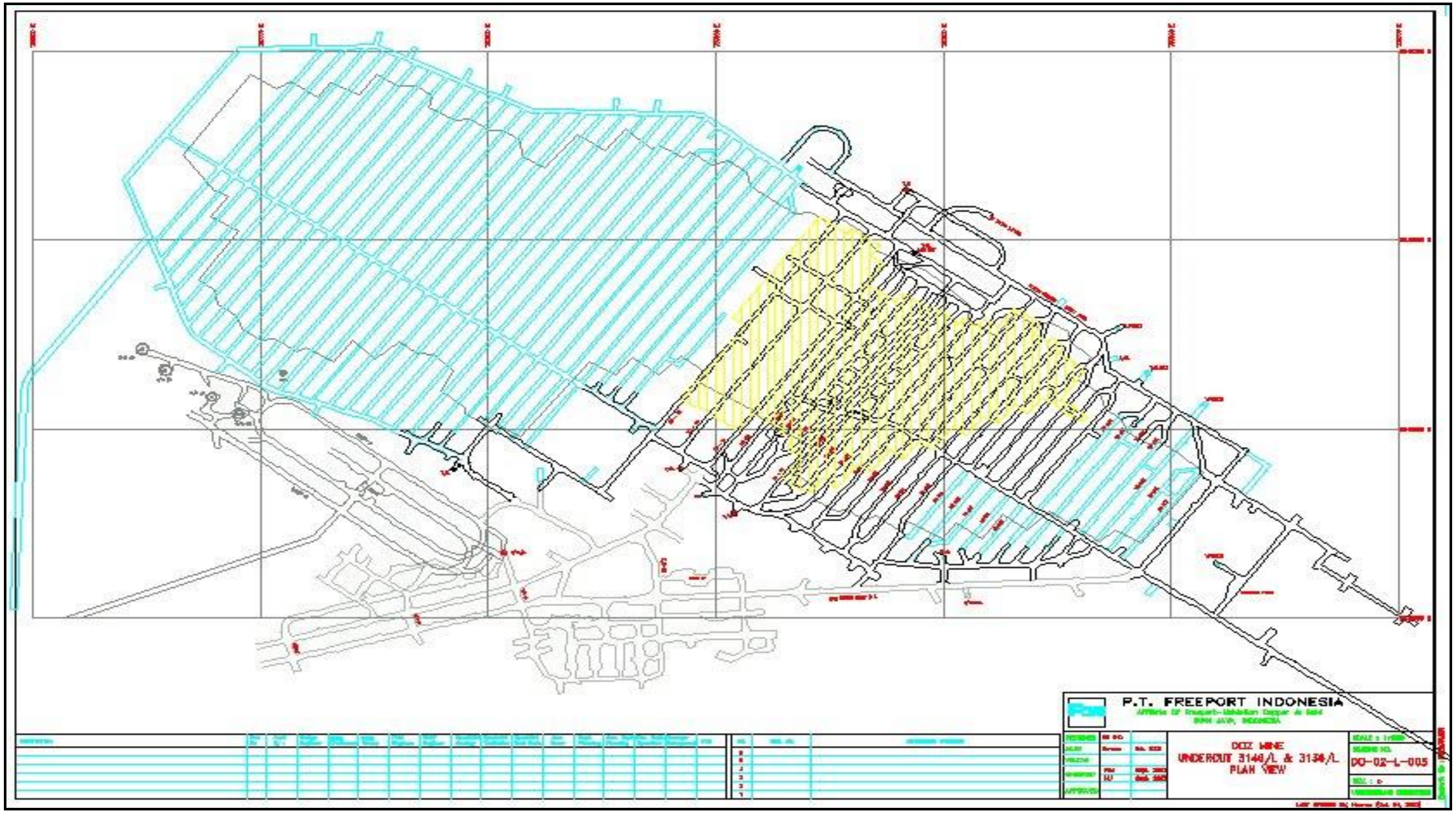

Figure 2.2. Undercut level

Source: PTFI, 2013.

The concept of block caving method is to tear down the ore body on top of the undercut level massively. Broken ore from undercut level is pulled down through drawbell located on extraction level, and then is transported through drawpoint by using Load Haul Dump (LHD) as shown in figure 2.1.

Furthermore, the new collapse will occur when there is enough space where the rock mass fall and be collected. This type of mining is the location of the research, i.e. Deep Ore Zone (DOZ). This starts with the making main tunnels in the main levels:

1. Undercut Level

   This is a level of collapse with undercutting as the main activity (figure 2.2), i.e. drilling and blasting in drill drift area by using fan drilling pattern and Cubex Drill equipment so a cave is built. The distance among the drill drifts are ±7.5 m with various length following the ore body shape and its position is parallel with the panel underneath (*production level*). The size of the open hole from the drill drift is 3.6 x 3.6 m, which is the standard open hole based on the purpose of its making and the rock condition.

2. Production Level or Extraction Level

   This is an open hole located exactly below undercut level, functioning as a place for drawing out the broken ore from undercut level. Two important open holes in this level are:

   a. Drawpoint

      These are holes of ore drawing holes that move left and right in every panel for loading broken ore place from undercut level by using LHD equipment.

Drawpoint (figure 2.3) made consists of two types, i.e. single drawpoint, consisting of one hole from one side of panel, and double drawpoint, consisting of one hole that connects two panels. The layout of drawpoint is designed so that it can take broken ore load. The angle between panel and drawpoint is made 45^o with a distance between the drawpoint is 18 m. one drawpoint represents one block for one caving.

Figure 2.3. Draw point

Source: PTFI, 2013.

b. Panel

This is an open hole (figure 2.4) as a transportation route for broken ore from drawpoint to broken ore spill point completed with rock breaker to reduce big-sized broken ore so that it can escape from grizzly.

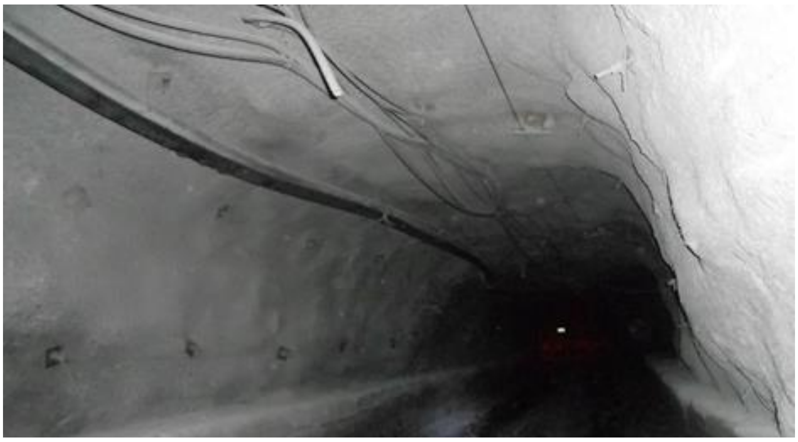

Figure 2.4. Panel

Source: PTFI, 2013.

There are 27 panels with a distance between panels is 30 meters. Grizzly station is made in each panel. The dimension of the open hole in the panel used is a standard open hole, i.e. 4.4 x 4.0 m. Rock bolt, weld mesh, shotcrete are installed on the floor, wall and roof of panel area, and with strengthening by concrete. In some areas, steel set is used mainly in the areas located in the weak rocks. The strengthening is meant to secure every activity in production panel from the danger of falling rocks (figure 2.5).

Broken ore that goes down from production level (figure 2.6) directly falls down through grizzly 50 meters high and compiled in a loading point (LP). Then, the broken ore is transported by using a truck (figure 2.7) to DOZ Crusher (*Gyratory Crusher Types*). There are two Gyratory Crusher-type crushers in Truck Haulage level at DOZ. Crusher-1 with 4,000 ton/h capacity and Crusher-2 with 2,500 ton/h capacity will reduce the size of the rocks and then be sent down to 10 m-diameter ore bin and forwarded through 3 m-diameter ore pass to the feeder.

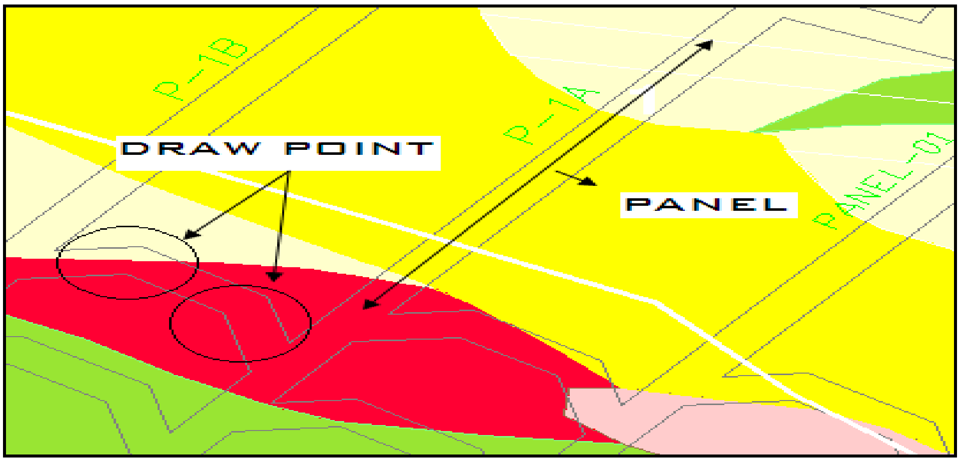

Figure 2.5. Draw point and panel

Source: PTFI, 2013.

4. Exhaust (Gallery) level

   Exhaust level (figure 2.8) is a level located between transportation level and production level that functions to channel fresh air toward undercut level, production level and transportation level. It also functions to release dirty air through 800m vertical raise that directly goes to the surface where vent point is installed.

5. Conveyor level

   This is the lowest level in block caving system, in a form of placing area for belt conveyor to channel broken ore coming from production level toward stockpile.

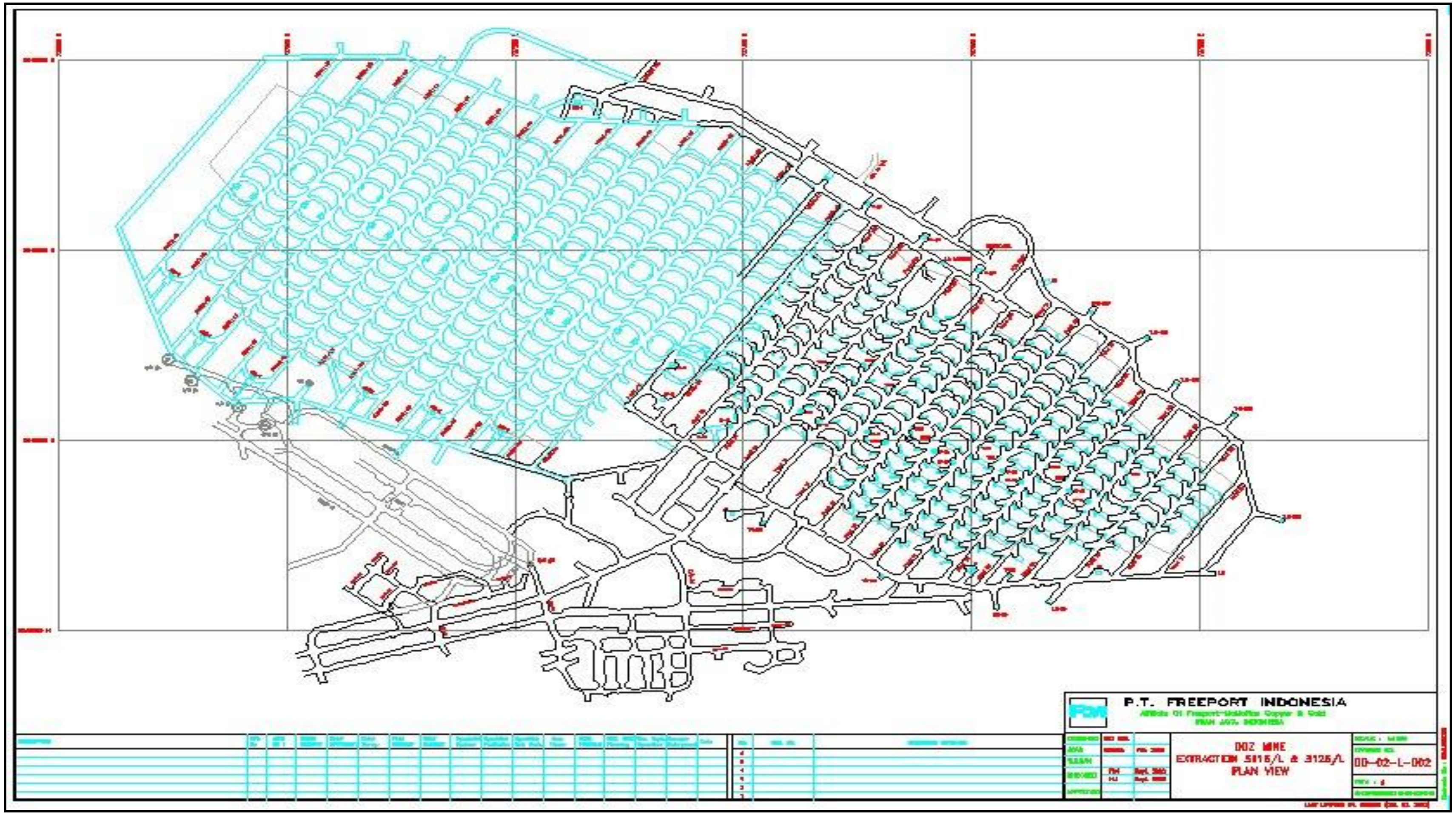

Figure 2.6. Production level

Source: PTFI, 2013.

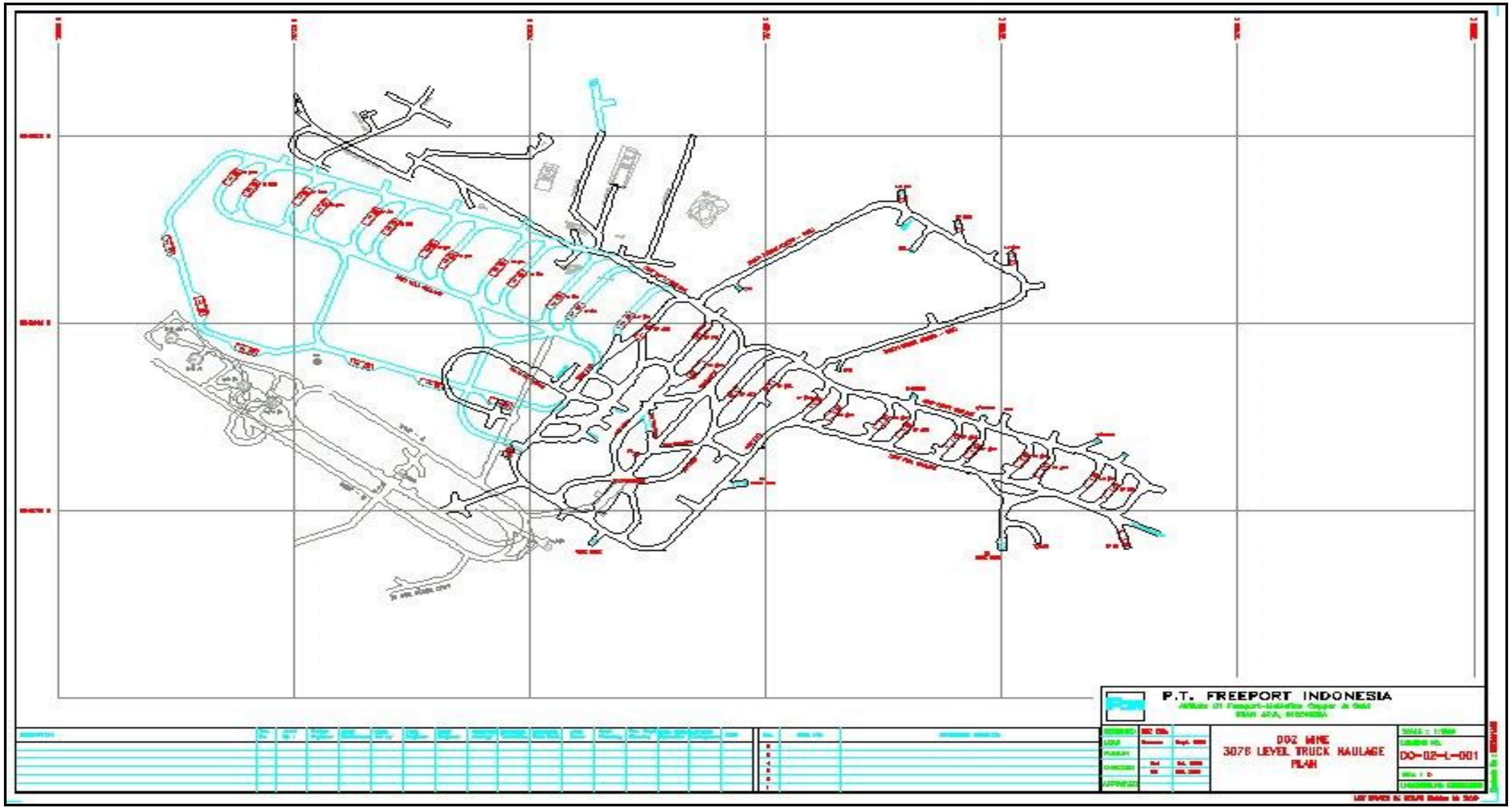

Figure 2.7. Truck haulage level

Source: PTFI, 2013.

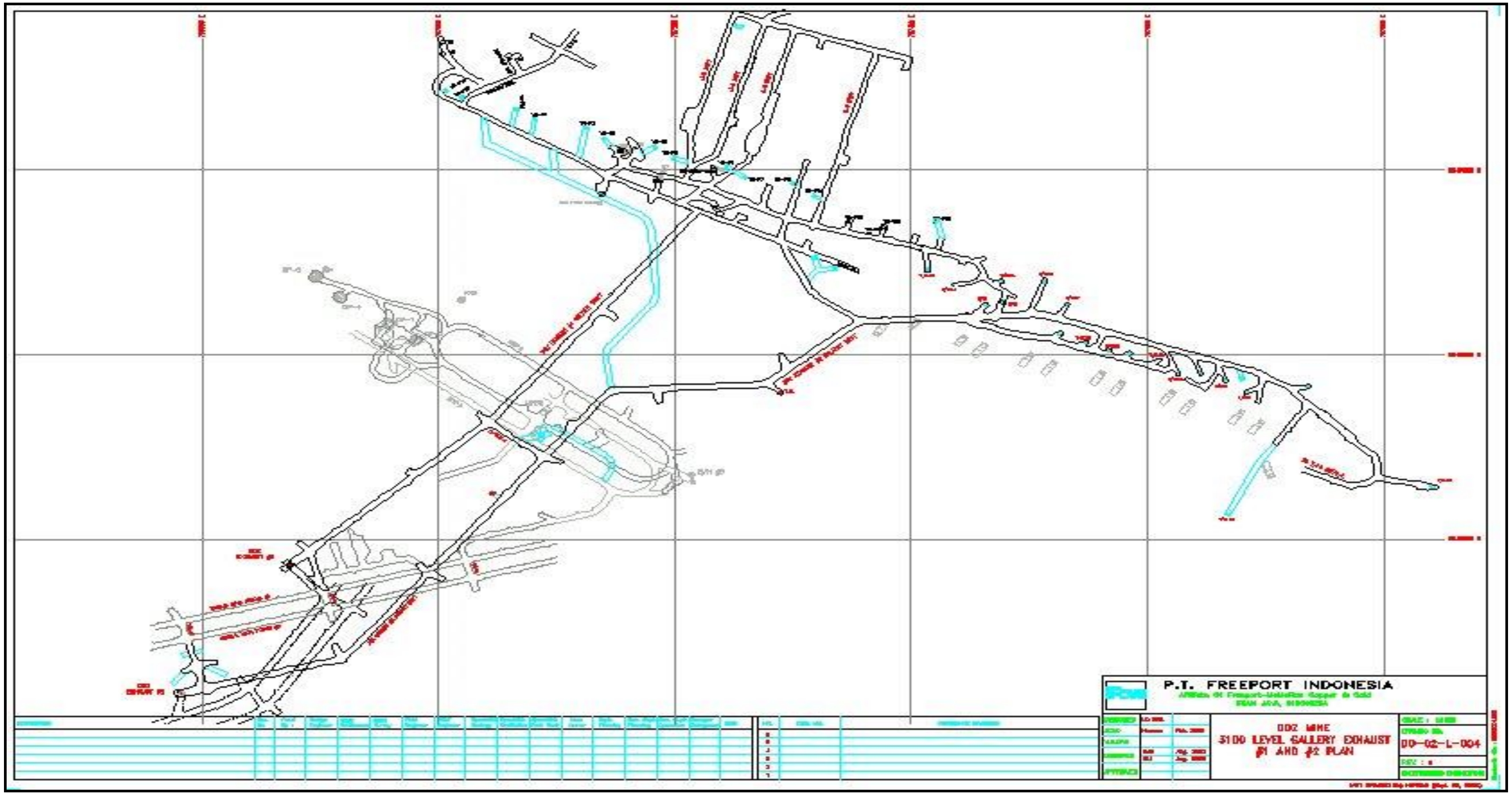

Figure 2.8. Exhaust (Gallery) level

Source: PTFI, 2013.

2.2. Ventilation System

Ventilation system for fresh air supply into the mine is very necessary based on the need for number of people and working equipment inside on each level. In order to get fresh and high qualified air, it is necessary to control the air inside the tunnels. This means the intake air and exhaust air must be balanced. The air must achieve all places mentioned in active working area category (*the intake must posses equivalent value with the exhaust*).

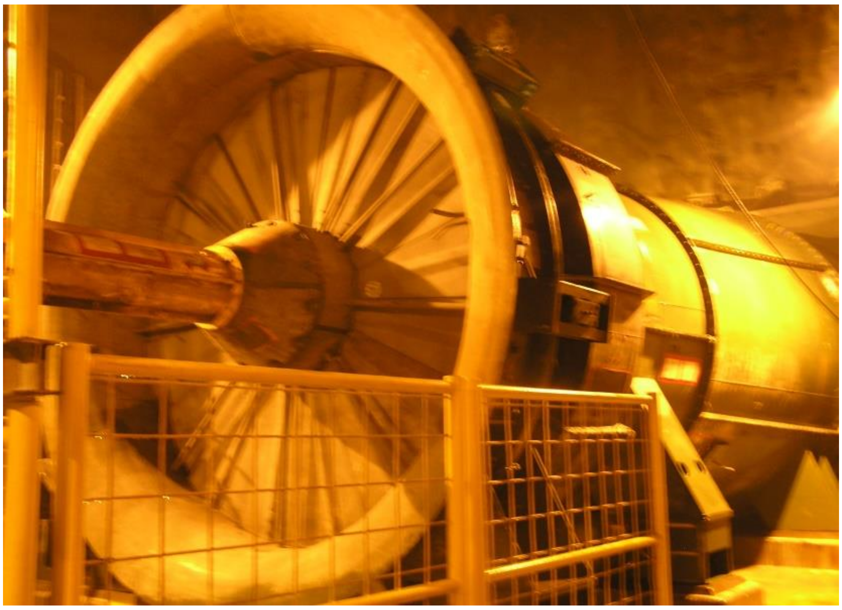

Figure 2.9. Main fan 2200 HP

Source: PTFI, 2013.

If an area, due to its distance and location, causes fresh air cannot achieve the area naturally because of the pressure from outside air decreases, then the auxiliary ventilation is badly needed in this mentioned area. Besides as fresh air supplier into the mine, the other function of the ventilation system is as the dissolver for pollutant and hazardous gas both toxic and explosive and as the remover for the ash resulted from blasting inside the mine.

Ventilation system is categorized into two parts based on their function:

1. Main Ventilation System

   This is the main ventilation system that uses either exhaust or intake high-powered (HP) fan.

2. Auxiliary Ventilation System

   This is an auxiliary ventilation system that also uses fan and is used in locations that need additional pressure as a result of the decrease of main fan pressure in certain distance or location that is impossible for fresh air to enter an area without auxiliary fan. Generally it has power (HP) that is not too big if compared to the main fan and the one that is used also exhaust in nature.

Ventilation system in an underground mine has various objectives, as follows:

1. To provide and channel fresh air into the mine for respiratory and comfort for the miners. In Mine Safety and Health Administration (MSHA) standards, the airflow minimum level needed for every one miner is 70 cubic feet meter per worker (cfm/worker).
2. Dilution on pollutant particles comes from both smoke from oxidation result of heavy equipment (*diesel engine*) that works in mine area and dust from blasting and drilling process. In MSHA standard, the minimum level of velocity of airflow in drift area (non-conveyor) is 60 fpm, while airflow’s

MSHA standards used by PT Freeport Indonesia in diluting the smoke of diesel engine in heavy equipment is 125 cfm/HP at minimum.

3. Dilution on both toxic and explosive gases in the mine area.

   In MSHA standards, the approved values of gases are: Oxygen (O_2) >19.5 %; Carbon Dioxide (CO_2) Time Weight Average (TWA) 0.5 %; Carbon Monoxide (CO) TWA 50 ppm; Hydrogen Sulfide (H_2S) TWA 10 ppm; Sulfur Dioxide TWA 2 ppm; Short Term Exposure Limit (STEL) 5 ppm; Nitrogen Dioxide (NO_2) STEL 5 ppm; and Methane (CH_4) TWA 0.25 %.

2.3. Diesel Engine Exhaust (DEE)

DEE, which is generally known as ‘diesel smoke’ is a mixture of gas, vapor, liquid aerosol and substance consisting of particles. They contain oxidation products including: carbon (*soot*), nitrogen, water, carbon monoxide, aldehyde, nitrogen oxide, Sulphur oxide, polycyclic aromatic hydrocarbon. The content of carbon particles or soot varies from 60 % to 80 % depending on the fuel used and the type of engine. Most contaminants are adsorbed to the soot. Gasoline engine results more carbon monoxide but soot is less than diesel engine.

The number and composition of diesel smoke at workplace can vary, depending on: quality of diesel fuel used, type of engine (e.g. standard, turbo or injector), engine tuning status, fuel pump setup, workload demand in engine and engine temperature. Diesel engine is a product of oxidation. Vehicles at workplace can result three types of smoke, two of which show the engine problem.

Figure 2.10. Diesel smoke

Source: PTFI, 2013.

These three types are: blue smoke (mainly oil and unoxidized fuel) which shows that the engine needs more setup; black smoke (soot, oil and unoxidized fuel) that shows mechanical error in engine; and white smoke (water drops and unoxidized fuel) resulted when the engine starts from cool temperature and disappears as the engine gets warmer. In older engine, white smoke produced has strong smell that can cause irritation on upper respiratory system.

DEE is a mixture of thousands of different gases and small particles. These small particles are the most important because they belong to *polycyclic aromatic hydrocarbon* (PAH) and metal like nickel and arson (this is the well-known cause of human cancer). Most diesel particles are small enough to be inhaled far deep into the lungs, where they cause the biggest hazard. Diesel exhaust contains 20 times more particles than the engine that uses gasoline. Some toxic gases that are mainly in diesel smoke are nitrogen oxide, sulphur oxide, and carbon monoxide.

Diesel particulate matter (DPM) is a component of diesel exhaust (DE) that belongs to soot particle especially consisting of carbon, ash, abrasive metal particle, sulfate and silicate. Diesel soot particle has solid nucleus that consists of carbon element, with other substance attached to the ground, including organic carbon compound known as aromatic hydrocarbon.

2.3.1. DEE Composition

DEE is a complex mixture of constituents both in gases or particles. Gas component of DE (*diesel smoke*) includes carbon dioxide, oxygen, nitrogen, water vapor, carbon monoxide, nitrogen compound, Sulphur compound, and many molecules of low heavy hydrocarbon.

Among the gas hydrocarbon component of DE known individually, the one which becomes toxicology relevance is aldehyde (e.g. formaldehyde, acetaldehyde, acrolein), benzene, 1, 3-butadiena, and PAH and nitro-PAH. Particles appear in DE (i.e. DPM), which consists of carbon element nucleus center and absorbed organic compound, and a small number of sulfate, nitrate, metal and other elements.

DPM consists of fine particles (fine particles have <2.5 µm diameter), including subgroup with a large number of ultrafine particles (ultrafine particles have <0.1 µm diameter). Collectively, these particles have big surface area which makes them appropriate media to absorb organics. Furthermore, their small size makes them very inhaled and able to achieve the lungs deeply. Some organic compound on particles relevantly has toxic potentials.

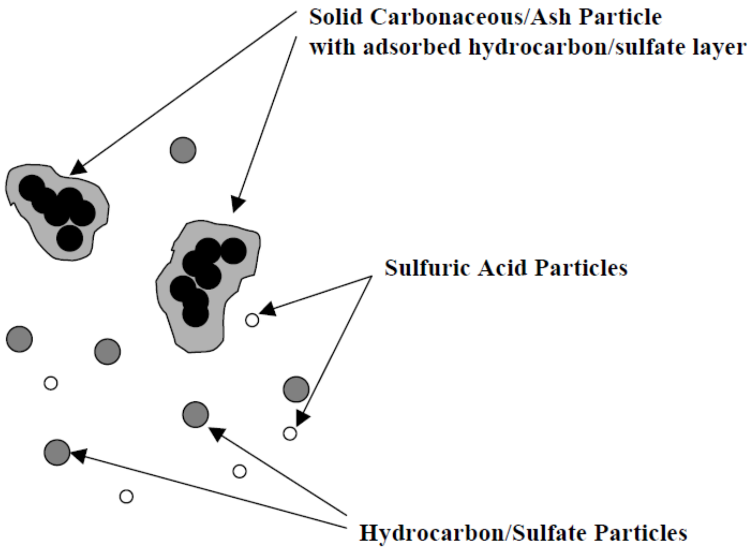

Figure 2.11. DEE schematic diagram

Source: modified from Kittelson, 1998.

Organic content, generally, ranges from about 20 to 40 % from particle's weight, even though higher and lower percentages are also reported. Many organic compounds appear in particle and gas, which are individually known to have mutagenic and carcinogenic characteristics. For example, PAH, nitro-PAH, and its derivative, oxidized PAH that appears in diesel particles, with PAHs and their derivatives consisting of around 1 % or less the DPM mass.

DPM effects on visibility occur in various scales, from big-scaled effect such as fog around continental area, to small-scaled effect that occurs from individual vehicle's exhaust. Diesel engine is only 5 % of vehicle's road. However, it can give contribution 10 to 75 % from visibility degradation in urban area, depending on the characteristics of the sources around (*Eldering and Cass, 1996*).

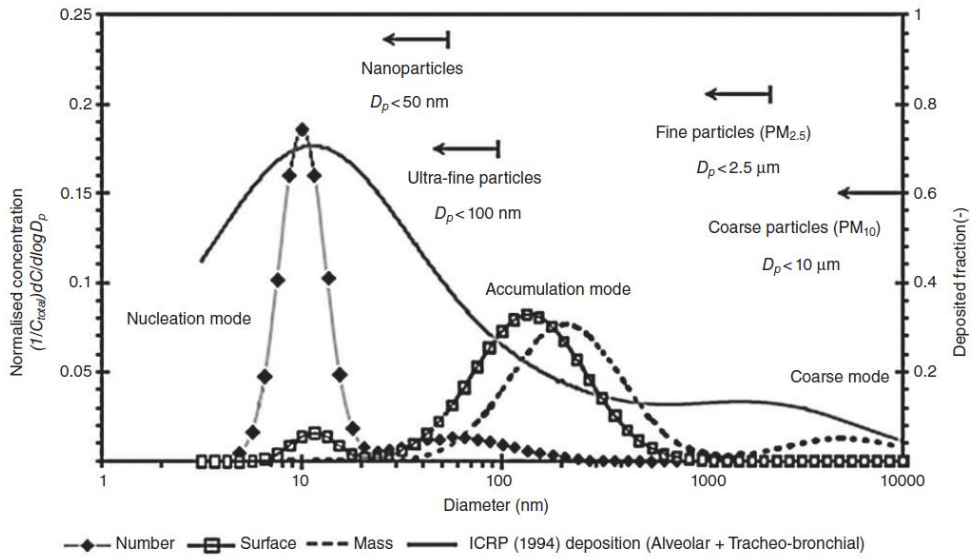

Figure 2.12. Deposition and particulate diameter

Source: modified from Kittelson, 1998.

DE's 'conventional' strange composition gives ability to reduce visibility almost twice as most other particle sources. The end result is that the visibility impact of available diesel armada, even though the variables in time and location are consistently far bigger than their proportional fraction of the vehicle's distance coverage. This is anticipated as significant visibility benefit which accompanies future reduction in DPM and NOx emission (*Kleeman et al., 2000*).

2.3.2. DEE as Indoor Air Pollutant Component

DEE is exposed from ‘on-road’ diesel vehicle engine or ‘non-road’ diesel engine (for example: locomotive, ship, heavy equipment, etc.) In 1998 in the United States, it shows that DE measured with DPM consist of around 6% of total measurement of $PM_{2.5}$ ambient (i.e. particle with aerodynamic diameter of 2.5 micrometer or less) and around 23 % of $PM_{2.5}$ measurement result if natural resources etc. are exceptional.

DE faces dilution as well as chemical and physical transformation on the atmosphere, and dispersion and transportation on the atmosphere. DPM is directly emitted from diesel engine (primary particulate) and can be formed from gas compound emitted by diesel engine (secondary particle). DPM’s mass exposure is stated in gram DPM/m^3, historically used as a replacing measurement of exposure for all DE. Even though there is an uncertainty on whether DPM is the most appropriate parameter to be related to human health effect. In surrounding environment, DE exposure comes from both on-road and non-road engine exhaust.

Carbonaceous Matter refers to the compound containing carbon related to the particles in DE. Carbonaceous Matter covers all compounds containing organic carbon and element found in particle phase. This term is sometimes used alternately to refer to the dissolved fraction of DPM or soot fraction.

Diesel Exhaust (DE) refers to the gas-phase emission and particle-phase resulted from diesel fuel oxidation in internal oxidation, compression-ignition. DE includes emission from diesel engine or vehicle’s diesel fuel (including *after treatment* equipment), but does not include emission from brake and tire wear.

Diesel Particulate Matter (DPM) refers to the particle-phase compound emitted in DE. DPM can refer to the primary and secondary emissions of particles formed by atmosphere process. DPM also refers to primary particles if it is considered fresh after being emitted and regarded old after receiving oxidation, nitration, or other chemical substances and physical change in the atmosphere.

Elemental Carbon (EC) refers to the carbon that has faced pyrolysis (i.e., after being stripped down by hydrogen). In its pure form, EC contains carbon atom only, even though EC, as available in the material oxidation particulate, may contain some hydrogen atoms.

Organic Carbon (OC) refers to carbon and molecule that contain hydrogen emitted in DE which are mostly a result of diesel fuel oxidation, in a lower level, from lubricant engine. OC compound can also contain oxygen, nitrogen, and Sulphur, as well as other elements in small number.

Soluble Organic Fraction (SOF) refers to organic part of DPM that can be extracted from particle matrix in solutions.

Soot refers to agglomeration of EC and OC particles. Soot is also often marked as DPM dissolved part.

2.3.3. Primary Emissions

Diesel engine got its patent in 1892 by Rudolf Diesel, which was regarded as a prime driver giving many benefits of improving fuel efficiency compared to engine's plug (SI). As of today, economically, diesel engine fuel remains one of the strongest selling value. In the United States, diesel engine is used mainly by trucks, buses, farming and other non-road equipment, locomotives and ships. Main advantage of diesel engine compared to gasoline engine is its economical and durable.

All diesel engines use hydraulic fuel injection in one form or another. The fuel system must fulfil four objectives if the diesel engine is to function well during the whole operation coverage. Diesel fuel is a mixture of many different hydrocarbon molecules from around C7 to C35, with boiling range approximately from 350 to 650 °F. Many fuel and property oil, such as certain energy contents (higher than gasoline), ignition quality, and density, related to hydrocarbon composition. Therefore, fuel and lubricant composition affects many aspects of engine performance, including the economy of the fuel and exhaust gas emission.

Perfect and unperfect oxidation results in diesel engine is formed from a mixture of gas complex (gas-phase hydrocarbon, CO, CO_2, NO, NO_2, SO_2) and particulate (carbon material element, sulfate, and trace element). Because of the worries on health effects related to DE, EPA started regulating emission from diesel engine in 1970 (for smoke) and the added gas emission regulations.

A basic understanding on diesel oxidation process can assist in understanding complex factors affecting DPM formation and other DE emission. Diesel oxidation is a quite homogenous process. Fuel is sprayed in high pressure to the content of compressed cylinder (mainly air with some oxidation of product residue) as piston approaches the peak of compression stage.

Turbulent mixture of fuel and air occurring is increased with injection pressure, port intake orientation (tangential intake-rotation inducement on cylinder wall), piston movement, and bowl-shaped piston. In some cases, fuel and air mixture are induced through fuel injection into turbulence generating of a pre-space or room rotation located close to the main room (especially in old engines, hi-speed engines and some Light Duty diesel engines).

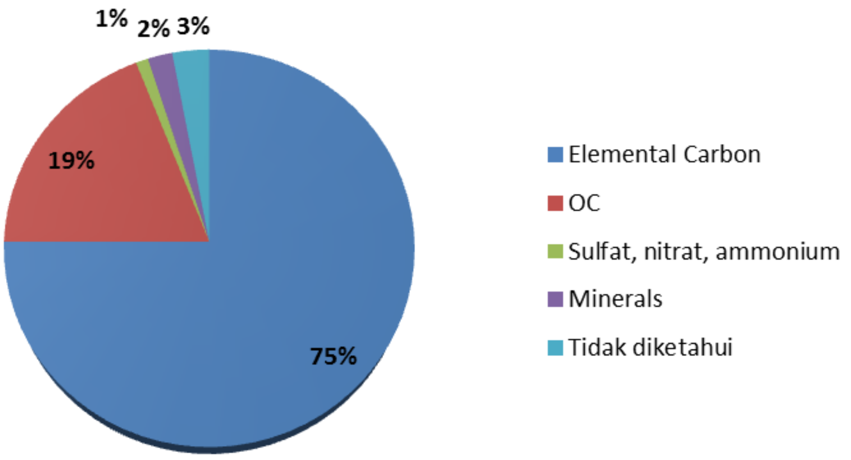

Figure 2.13. Specific chemical composition for DPM ($PM_{2.5}$) heavy duty diesel engine

Source: modified from Kittelson, 1998.

Emission from oxidation engine results in nitrogen oxide (NOx) mainly (at least at the beginning) as NO. High oxidation temperature causes a reaction between oxygen and nitrogen to form several NO and NO_2. Most NO_2 that is formed during oxidation is quickly decomposed. NO can also be unraveled into N_2 and O_2, but the level of decomposition is very slow (*Heywood, 1988; Watson and Janota, 1982*). Thus, almost all NOx emitted is NO.

Certain OC species is used to help differentiate DPM aerosol from other oxidation aerosols. Up to 90 % of organic fraction related to DPM is currently classified as completed complex materials. Ultrafine DPM (5 to 50 nm) contributes majority (50 to 90 %) of particle number but only 1 to 20 % of DPM mass.

A research by Gertler (1999) in Mount Tuscarora Tunnel shows an increase of 20 particle of nm diameter as diesel vehicle fraction in the tunnel from 13 to 78 %. Nuclei-mode particle contribution from highways in distribution of ambient aerosol size reported by Whitby and Sverdrup (1980). In sum, four characteristics of DPM are (1) high level of EC proportion, (2) Surface area related to carbon particle in 0.2 µ of many sizes, (3) enrichment of certain polycyclic organic compound, and (4) 50 to 90 % of DPM particles in diesel engines are in nuclei-mode in many sizes, with modus of 20 nm (*Imhof et al., 2006).*

2.4. Geostatistics

Geostatistics is a bridge between statistics and Geographic Information System (GIS), where Geostatistics analysis is a geostatistical technique focusing on spatial variable, i.e. the relationship between the variable measured in certain points with the same variable measured on the point with certain distance from the first point. Problems occur when solution of estimation problem has been defined, so that a method emerges to ease the task of completing the prediction, i.e. Kriging Method. This method was used by G. Matheron in 1960s, to feature a specific method in weighted moving average that minimized variance from estimation results.

Geostatistics data directs to samples in a form of points, both regular and irregular from a spatial continued distribution. Data from every point sample is defined by location and the weight of measurement value of the observed object. Every data value is related to its location. The Geostatistics basic principle is that area that is often adjacent will tend to have value weight that is not far different if compared to the area apart.

Geostatistics contains statistics definition that is applied in geology studies and geography generally. According to Cressie (1993), geostatistical data is not only limited to earth coverage, but also covers a more universal area, i.e. data related to statistics theory and its application with spatial continued index that creates a surface. Meanwhile, Isaaks and Srivastava (1989) state that Geostatistics offers a way to portray spatial continuity of natural phenomena. Three important components in Geostatistics are correlogram, covariance function and semivariogram or variogram used to describe spatial correlation of an observation.

2.4.1. Kriging

Kriging is one of the techniques or methods of data analysis that is often used in mining. Generally, kriging is a geostatistical data analysis to interpolate a value of mineral content based on the defined values. Kriging is an estimation method that gives Estimator BLUE (*Best Linear Unbiased Estimator*) from point values or block average. This estimation method considers factors affecting the estimation accuracy, i.e.: the number of samples, sample position, distance between samples and the points to be estimated, spatial continuity from the involved variables, etc. In other words, this method is used to estimate the characteristic values from estimator ($\hat{z}$) in un-sampled points based on the information of sampled points around.

According Olea (1999), estimator kriging $\hat{z}(x_0)$ with x_0 is a linear combination of random variable with xi, This can be seen from the following formula:

$$\hat{z}(x_0) - m = \sum_{i=1}^{k} \lambda_i [z(x_i) - m] \qquad \textbf{(2.1)}$$

Where:

m = mean value (scalar constant)

λi = weigh (xi) for estimation of location x.

Same value (xi) will have weigh coefficient that is different for the estimation of different location.

xi = vector of different location.

k = number of sampled data for estimation.

Random function of the above equation is a form of second order stationary, where there are two equations variation that does not affect spatial translation. The two equations are:

$$E\,[z(x)] = m$$

$$E\,[(z(x) - m)\,(z(x + h) - m)] = E\,[z(x)z(x + h) - m^2]$$

$$= Cov\,(x, x + h) = Cov\,(h)$$

where [.] works as expectation value, m is scalar constant that also known as mean, h is distance vector, and Cov[.] is covariant value from random function.

For example, $Y\ x$ is a result of (x) with its expectation value:

$$Y(x) = z(x) - E\,[z(x)] \qquad \textbf{(2.2)}$$

From above equation, expectation value will be defined from both sides, i.e.:

$$E\,[Y(x)] = E\,[z(x) - E\,[z(x)]]$$

because $E[z(x)] = m$ and m constant, so $E[z(x)]$ is also constant in nature, then:

$$E\,[Y(x)] = E\,[z(x)] - E\,[z(x)]$$

$$E\,[Y(x)] = 0$$

thus,

$z(x) - E[z(x)] = 0$

$E[z(x)] = z(x) = m$

it can be stated that value $z(x)$ is the same with its expectation $E[z(x)]$ and it is also the same with value m as scalar constant, from this development of equation (2.2) later on, it will be used to prove unbiased estimator in Universal Kriging.

The objective of kriging is to define the coefficient value of λi weighing that minimizes variance can be stated as follows:

$$\sigma^2 = Var\ [\hat{z}(x_0) - z(x_0)$$ **(2.3)**

with an estimation on each location is the difference between the real value from the estimator value $\hat{z}(x_0)$ with the value of $z(x_0)$ defined as:

$$\sigma^2(x_{0)} = Var\ [\sum_{i=1}^{k} \lambda i(x_{i)} - z(x_0)]$$

2.4.2. Universal Kriging

Universal kriging is the general form of simple kriging as one of the expansion ways of ordinary kriging method. Universal kriging is the kriging from data which has certain trend tendency. This method is appropriate if it is used in the values at sample points that, indeed, has certain tendency. For example, the thickness of layer increases with the change of direction or permeability value that decreases with the location stays away from the channel sand. By considering that (x_i) is k random variable part from coverage $d \supset D$ as its spatial area, universal kriging estimator $\hat{z}(x_{0)}$ for random function $z(x_i)$ is:

$$\hat{z}(x_0)^n = \sum_{i=1}^{k} \lambda_i z(x_{i)}$$

with the assumption that $E[z(x)]$ and $var[z(x)]$ exist, model $z(x)$ can be defined as follows:

z(x) + m(x) + ε(x)

(x) is equation of trend (drift), a result of linear combination with coefficient not zero, with

$[z(x)] = m(x)$

$[(x)]$ is expectation value of *z(x)*.

For trend (drift) of polynomial model $f1x$, it is presented as follows:

$$m(x) = \sum_{l=0}^{n} \alpha_l f_l(x) \quad \textbf{(2.4)}$$

where $f_0(x) = 1$ and $\varepsilon(x)$ is an error that fulfils intrinsic stationarity characteristics with $E[\varepsilon(x)] = 0$.

where:

α_l = trend coefficient

$f_l(x)$ = location coordinate

n = number of ordo in trend equation

Olea (1999) states that estimator $zx0$ works as unbiased estimator, if and only if:

$$\sum_{i=1}^{k} \lambda_i f_l(x_i) = f_l(x_0) \quad \textbf{(2.5)}$$

The above equation is often called as universality condition for l = 1, 2, …, n. If that equation is multiplied by α_l then equation n + 1 shall be given, i.e.:

$$\sum_{l=0}^{n} \alpha_l \sum_{i=1}^{k} \lambda_i f_l(x_i) = \sum_{l=0}^{n} \alpha_l \ f_l(x_0) \quad \textbf{(2.6)}$$

on the left-side equation, (*Olea, 1999*) double sum will have the same value with expectation value from $\hat{z}(x)$. Meanwhile, the right-side equation will have the same value with (x), and (x) = $[(x)]$. Thus, equation (2.6) will become:

$$[\hat{z}(x) - z(x)] = 0$$

from the above equation, later on it can be obtained

$$\hat{z}\ (x) = m = z(x)$$

Therefore, it can be stated that estimator from universal kriging is unbiased estimator. Then, in universal kriging, the first trend function $f_0(x)$ has constant value, with $f_0(x)$ = 1 thus based on universality condition, it can be obtained:

$$\sum_{l=1}^{k} \lambda_i = 1$$

in universal kriging, equation with value 1 is needed in a condition to obtain unbiased estimator.

2.5. Diesel Particulate Matter and Product of Combustion Gases

2.5.1. Diesel Particulate Matter (DPM)

It has been proven that there is danger on human health related to DEE exposure. The danger includes acute exposure-related symptoms, chronic exposure-related non-cancer respiratory effect, and lung cancer. DPM that is kept in lungs and their components can be absorbed in body. The majority of DPM diameter is less than 1µm and generally, particle diameter of PM_{10} or less can be inhaled into lungs (*USEPA, 2004*). Not all particles inhaled are deposited in the lungs, and many of them are exhaled. Particles with around 0.5 µm diameter are kept in airway, with high level of deposition for the second particle is smaller of larger than 0.5 µm diameters.

According to WHO, this compound is also proven to destroy DNA and is absorbed into blood flow after being exposed with DPM. Therefore, it is considered available for the damage of cells in these networks as lungs. Benzene, the first registered toxic air contaminant that causes cancer and as leukemia agent for human, has been reported exist not only in gas phase of DEE, but also in DPM itself (*USEPA, 2002*).

DEE is considered causing respiratory danger for human based on a wide study that shows that inflammation appears in DEE-exposed animals (*USEPA, 2002*). More than 30 human epidemiology studies have investigated the potential of DEE carcinogenicity. These studies, in average, find that long-term exposure of work is related to a 40 % increase in lungs cancer relative risks (*SRP*, *1998*).

IARC (1989) concludes that DEE is potential carcinogen towards human, and USEPA (2002) also concludes human carcinogen by inhalation exposure. The DPM impact on visibility occurs in various scales, from big-scaled impact such as fog close to continental area, small-sized impact occurring from individual vehicle's exhaust (*Eldering and Cass*, *1996*).

2.5.2. Nitrogen Oxide as Product of Combustion (POC)

Clean air contains approximately 78 % of nitrogen gas and 20 % oxygen gas. At high temperature (121 ^{o}C or 200 ^{o}F), the two gases will react to form NOx and NO_2. *American Lung Association* suggests that NOx sources are vehicle exhaust gases on roads (30 %) and kerosene burning or trickery tools (28 %). NOx action mechanisms can cause respiratory tract infection and lung function impairment.

The higher the concentration of NO_2 in the residence has bigger risk, which is acutely will cause bronchial fetal reactions and if chronically increase the lungs so that it will easily infected with bacteria and virus. The potential effects on health lead to shortness of breath and exacerbation, respiratory infections and decreasing lung function, especially moreover for children (*Bruce et al., 2002*).

2.5.3. Carbon Monoxide as Product of Combustion (POC)

CO Gas is an odorless, colorless, and unstimulated gas *(Chale, 1993; Benowitz, 1997).* Someone cannot observe the presence or absence, but this gas is toxic, so he should be careful when there is a combustion that might excrete CO (*Bleecker, 1994*). Car exhaust and other outlet engines can be a major source of CO. Fuel combustion, besides, form CO_2, generally also formed as a little carbon monoxide. The more perfect the combustion process, the less carbon monoxide is formed. Gas poisoning CO (code illness T.58 ICD-10 in 1992) will cause tissue hypoxia body that can harm the tissues in the human body *(Kindwall, 1994; Chale, 1993; Jonas & Volans, 1999; Kales, 1993).*

The impact of CO poisoning was first reported by Bernard (*Chale, 1993*). CO is produced from unperfected combustion process of organic material either in the groove of industry process *(occupational)* or process in the environment *(Kindwall, 1994).* Industry accounts for about 20% of the total CO gas present (*Chale, 1993*), whereas from the environment can come from cigarette smoke (about 4 % of total CO gas in the air), exhaust fumes and fire (*Bleecker, 1994*). CO is practically manufactured by artificial processes, and 80 % is thought to come from motor vehicle fume.

The concentration of CO in the air shows a positive correlation with the traffic density, and the negative correlation with wind speed. Increased CO generally occurs due to incomplete combustion processes, especially from vehicles or motor engines. This two gas form stable compounds with blood hemoglobin and become carboxi-hemoglobin and give the effect of interference on the human respiratory tract.

The impact on worker health due to CO swelling causes hive in heart and lung tissue. In the cardiovascular system, CO binds myoglobin, cytochrome P-450, and myocardial a3 mitochondrial cytochrome myocardium enzyme that causing mitochondrial oxidation of *adenosine triphosphate* (ATP) decreases. For workers easily suffer coronary disease due to faster hypoxia, more frequent angina attacks, an increasing in ST wave depression even with low CO exposure. Complications of the nervous system cause cerebral hypoxia (*Chale, 1993; Benowitz, 1994*). Pulmonary complications may include pulmonary edema and bleeding. Edema may result from impaired left ventricular function of the heart or directly as a result of parenchymal hypoxia (*Di Maio, 1993*) and respiratory failure (*Kales*, *1993*). Lighter symptoms include dyspnea, tachypnea, and shortness of breath (*Lu, 1995*).

2.5.4. DEE Acute and Chornic Exposure

Acute exposure is limited for the characteristics of potential health effects related to short-term exposure. However, based on available human and animal proofs, it is concluded that short-term or acute (for example, episodic) DEE exposure can cause acute irritation (e.g. eyes, throat, bronchus), neurophysiological symptoms (for example, queasiness), and respiratory symptoms (cough, sputum).

There is also a proof for immunity of exacerbation-effect of allergy response toward allergen known and looks like asthma symptoms. The lack of information on exposure-response that is adequate in the study on acute health effect will prevents the development of recommendation on exposure level to be considered safe for this effect.

Considering the danger of carcinogenicity, EPA usually conducts assessment on dosage-response on human or animal data to develop risk estimation on cancer unit that can be used with exposure information to characterize the impact of potential cancer disease on exposed population. Based on the risk assessment done by EPA, lifetime work exposure of 20 mg/m^3 of diesel particle will make lungs cancer risk more than one out of a thousand, which is often used as the upper limit of permissible work risks. *American Conference of Governmental Industry Hygienists* (ACGIH) has proposed exposure limit at workplace recommended from 20 mg/m^3 DPM (*elemental carbon*).

Exposure limit states and applies the chemical exposure limit at workplace. Currently, there is no *Permissible Exposure Limit* (PEL) both for the diesel exhaust itself and for the small particles that may be the most important part from DEE. There are PELs for several other DEE main components, such as carbon monoxide and PAH. MSHA limits the number of DPM (total carbon) in underground non-coal mine of 400 mg/m^3. In 2006, this limit decreases into 160 mg/m^3.

Inhaling DEE can affect health while smoke exposure can cause eye irritation or respiratory channel. This effect is generally short-term in nature and must disappear when it is far from exposure source. Getting exposed by DEE too long, especially for every blue or black smoke, can cause cough and hard to breathe. There are several proofs that continuous exposure to DEE around 20 years can cause lungs cancer risks.

Some latest research publications have added worries on health that give disadvantageous effect from DEE exposure. Study on train workers hired between 1959 and 1996 shows that death rate of lungs cancer increases in the works related to the tasks in diesel locomotive train. It shows that diesel smoke gives contribution on the death rate of lungs cancer in the groups of this study. However, lungs cancer mortality does not increase with the increase of years of service in this job (*Garchisk et al., 2004; Laden et al., 2000*).

The second study investigates temporary exposure for DEE and its effects on cardiovascular function. Previous study finds a relationship between related traffic pollution and cardiovascular effect, such as acute infarct myocardia. Mills et al (2005) gives 30 healthy men DEE exposure liquified into exposure room. The researchers find that inhaling DEE in a level found in urban environment is disturbed by two important aspects of vascular function in human: tonus arrangement of blood vessel and fibrinolysis endogen. This finding gives mechanism potential that connects air pollution with heart disease including heart attack (*Mills et al., 2005*).

A number of studies on emission from heavy-duty diesel engine have been done. In one set of research, toxic pollutant emission is measured from this usage – transit diesel bus year model well-equipped as oxidative exhaust or Catalyzed Particulate Filter (DPF) (*Ayala et al., 2002; Kado et al., 2005*). The emission level of related toxic compound measured is far lower for an engine to be equipped with DPF compared to the emission level from diesel engine equipped with oxidative muffler. Genetic toxicity from emission is similar on two configurations above, both low sulfur diesel-powered and depends on the test cycle used.

Exposure on underground metal and non-metal miners is personal exposure of a miner for DPM not exceeding 160µg/m^3 from TC when measured as weighed-time 8 hours in average. Technique and administration of feasibility control is needed to reduce miner exposure for or lower than the PEL. Respiratory protection must be used to equip the feasible technique and control administration if the control does not reduce miner exposure on PEL, engineering or infeasible control administration or failed technique and control administration to create significant decrease in DPM exposure.

2.5.5. Functions of Lungs and COPD

The main function of lungs is respiratory process, i.e. taking oxygen from outside air into airway and continues into the blood. Oxygen is used for metabolism process and carbon dioxide formed in the process, released from blood to outside air.

All lungs volume can be measured directly with spirometer, except the residual volume. In order to know the function of lungs, the parameter used is VC, FVC, and FEV. While generally disruption/abnormality of lungs function is (*Ministry of Manpower and Transmigration, 2005*):

- Restrictive lungs function disruption
- Obstructive lungs function disruption
- Mixed (Obstructive-Restrictive) lungs function disruption

Useful examination for lungs function is to measure air maximum volume that is able to be exploited by someone in a certain time range called *Forced Expiratory Volume* (FEV). Air volume in the first second of expiration (FEV1) extremely needs to be evaluated. In certain obstructive lungs disease, for example asthma and emphysema, expiration is facing a disruption and the amount of air exhaled forcedly by individuals, mainly quickly will decrease (*Ministry of Manpower and Transportation, 2005)*.

A simple method that can be used to measure volume and lungs capacity is spirometry with a calculation of examination result using Baldwin nomogram, which useful to find out:

1. Vital Capacity (VC)
2. Forced Vital Capacity (FVC)
3. Forced Expiratory Volume in 1 Second (FEV1)
4. Maximum Expiratory Flow Rate (MEFR)

Chronic Obstructive Pulmonary Disease (COPD) is used for a group of disease with mixed characteristics of bronchus obstruction and emphysema. Bronchus obstruction can be caused by chronic bronchitis, bronchial asthma or bronchiectasis. COPD etiology is strongly related to environment pollution inhalation. The most typical pathophysiology overview is the increase of airway holding. This can be measured with two lungs function tests known as FEV1 and FVC. After full inspiration, FEV1 is the air volume that can be forcedly exhaled in 1 second; FVC is the total volume that can be forcedly exhaled. The ration of FEV1/FVC in healthy population is about 0.70 or more.

Spirogram equipped with time keeper can measure volume exhaled from the lungs in several time intervals. If air flow is plotted upon exhalation volume, the curve of maximum expiration flow volume (MEFV) can be defined. This curve can be used to measure air flow in certain time during exhalation, for example Vmax 75 % is the flow achieved after exhaling 75 % of FVC. Vmax 75 % is considered as a more sensitive indicator for respiratory disfunction compared to FEV1, which measures the flow at the beginning of expiration and depends more on the efforts. However, because Vmax 75 % shows bigger variability than FEV1 and needs bigger patient cooperation, FEV1 is a more important clinical test to assess how heavy the obstructive abnormality of the airway is (*Burrow, 1981*).