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Research

DIESEL ENGINE EXHAUST EMISSIONS SURVEY OF UNDERGROUND MINE IN INDONESIA

ARIF SUSANTO *, PURWANTO PURWANTO, HENNA R SUNOKO AND ONNY SETIANI

School of Postgraduate Studies, University of Diponegoro, Semarang, Indonesia

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ABSTRACT

Ambient air pollutant concentration measurement in underground mining is the first step in identifying environmental-health hazards and risk to the miners; that may result from exploitation of underground mining. Poor air quality in underground mining are generally caused by lack of air ventilation and the sources of contaminants. The objectives of this study were to characterize exposure to diesel engine exhaust emissions (DEE) from deep ore zone (DOZ) underground mining facilities, and to obtain spatial air quality for estimating miner's exposure to from DEE pollutant including CO from gaseous product of combustion (POC) and DPM. Design of this research is an observational research with a cross sectional design. Data of air pollution were measured by using OSHA analytical method number ID-209 and NIOSH method number ID-6014 and 5040. Details of mining activities and vehicles characteristics among workers control system were recorded in relation to mining activities. Kriging method used to obtain quantitative information on workplace exposure to CO and DPM. The results that show that the concentration of CO will be in the highest range in value of 6.38 ppm to 7.92 ppm, while the concentration exceeding the permissible exposure limit (PEL) for DPM will range in value 643.26 μg/m^3 to 618.23 μg/m^3. From these results, concluded that the concentration mapping can be used to evaluate exposure-response relationships.

INTRODUCTION

Studies of air pollution in Indonesia are limited and models from other countries are used to policy making related to regulatory decisions. Air pollution has become an important that requires attention due its impact on health and environmental. Epidemiological studies have shown that air pollution causes adverse human health effects (Lestiana, *et. al*. 2013) Pollution from motor vehicles constitutes one of the most ubiquitous environmental health problems and motor vehicle emissions are a major source of airborne pollutants (Parent, *et al*., 2013; Noue, *et al*., 2011).

Diesel engines have of industrial applications including in mining (off-road) The highest levels of elemental carbon were reported for enclosed underground work sites in mining (Rushton, 2012). Diesel-powered heavy equipment (HE) operating in underground environments (mines and tunnels) were determined by multiplying the vehicle power by a ventilation rate; that was either mandated by regulation(s) or determined empirically from known quantities (Parent, 2007).

DOZ (deep ore zone) copper mine is located in the province of Papua, Indonesia. A block cave layout is being developed to mine this deposit. The ore production started in November 2000 at rate of 2000 tonnes/day (tpd) and this rate is increase to 25,000 tpd by year 2003 (Calizaya, *et al.,* 2001). Existing underground mine infrastructure change were required for both production and ventilation purposes. Ventilation system design to cover fresh air to all personnel working in the undercut, panel and/or truck haulage drifts (Fig. 1).

DOZ mine airflow area provides sufficient for airways were required. Air control in the working areas can be challenging in block cave mines, because of the multiple parallel drifts on the extraction level and each extraction drift has an exhaust ventilation raise located near the center of the panel. The ore will be trammed by diesel loaders from the draw points to ore passes. Then dumped to a truck haulage level

***Corresponding author's email:** arifssnt@yahoo.com

by fifty-ton trucks and the ore will be transport to primary underground crushing and conveyed to surface for processing. Airflow requirements were based on minimum velocity concern in main travel ways and dilution of diesel contamination (Stinnette and Souza, 2013)

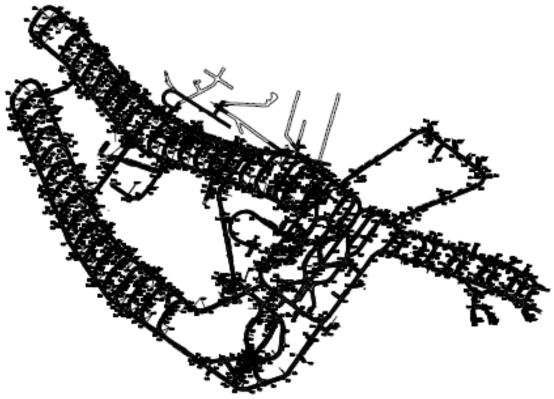

Fig. 1 Topographic of Truck Haulage in DOZ underground mine.

Diesel engine exhaust (DEE) is a complex mixture of combustion products of diesel fuel, and the exact composition of the mixture depends on the nature of engine, operating conditions, lubricating oil, additives, emission control system, and fuel composition (Pronk, *et al*., 2009) and substances characterized by polycyclic aromatic hydrocarbons (PAH) surrounding an elemental carbon core (Rushton, 2012) The principal gaseous components are carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxides (NOx) while the particulate fraction mainly comprises fine carbon particles formed by incomplete combustion. The carbon particles are mixed with organic vapours and gaseous derived from oil, unburned fuel and products of combustion and, as the mixture issues from the engine, it cools and the higher boiling organic materials condense onto the carbon particles k (Calizaya, *et al*., 2001).

DEE including diesel particulate matter (DPM) was classified as a known human carcinogen by the international agency for research on cancer (IARC) and (as a Group 1 classification) by the occupational safety and health administration (OSHA) and the mining safety and health administration (MSHA). To evaluate employee exposure, OSHA recommend monitoring for DEE constituents. The OSHA/MSHA hazard alert that was released in January 2013 regarding the carcinogenity of DPM suggested the miners monitor the DPM of at risk employees. OSHA recommends sampling for the gas phase component (CO, NO and NO_2) of DPM to determine if at risk miners are exposed to DPM. A literature review suggested that the extrapolation of DPM from CO or NO_2 levels may not accurately assess exposure to DPM. Miners are covered by the MSHA, and currently enforces DEE standards at underground metal mines. A miner's personal exposure to DPM must not exceed 160 micrograms per cubic meter (μg/m^3) of total carbon (TC) when measured as an 8-hour-time-weighted average (Occupational Safety and Health Administration, 2016).

To obtain spatial interpolation analysis is using air dispersion model by numerically processing emission and meteorological data (Zou, *et al*., 2009). Kriging method is a common method used and represents spatially continuous phenomena. A method has formed the basis for environmental pollution mapping in recent years (Isaaks, *et al*., 2013). This report describes DOZ mine air quality exposure model for predicting CO and DPM concentrations to which the miners' is exposed.

METHOD

Surveys method

Montoring reports indicated mining industry has higher levels and wider range of DEE exposure levels than other industries (Pronk, *et al*., 2009). Survey (Fig. 2) were carried out in DOZ mine. Sample were collected simultaneously from October 2014 to September 2015. Measurement were taken to represent ambient conditions and a comprehensive chemical analysis was performed. The sampling and analytical methods for gaseous product of combustion (POC) concentrations for CO was measured performed with OSHA analytical method no. ID-209 (Occupational Safety and Health Administration, 2016) and for NO, and NO_2 were measured performed with national institute for occupational safety and health (NIOSH) method no. ID-6014. Total carbon (TC) was defined as the sum of elemental carbon (EC) and organic carbon (OC). Both EC and OC were measured performed by NIOSH Method No. 5040 (Centers for Disease Control and Prevention, 2016). Observation of microstructure to elemental analysis using scanning electron microscope (SEM) with JEOL JSM-6510Low-vacuum mode 5.0 nm (20 kV), magnification x5,000 to x20,000.

The implementation flow of the survey divided as below

Underground permissible exposure limit in mining: The composition of toxic gaseous and DPM concentration was taken from data analysis. Its peaks data without could provide information about spatial changes in the composition of the organic and gas component. Permissible Exposure

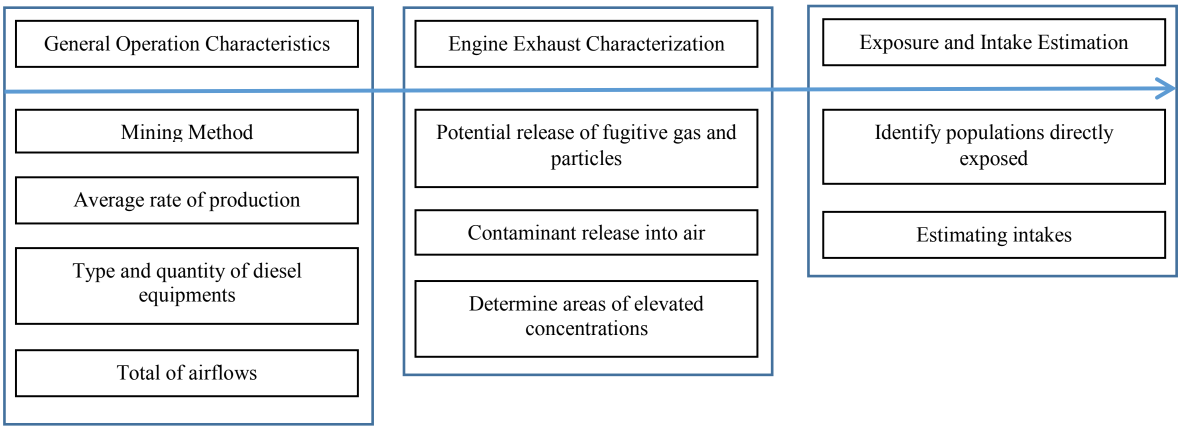

Fig. 2 Flow of the survey.

Limit (PEL) for CO, NO and NO_2 gas standard refer to Regulation of the Ministry of Manpower and Transmigration of Republic of Indonesia (Ministery of ManpowerandTransmigrationof Republic of Indonesia, 2011). MSHA currently enforces DPM standards at underground mines. A miner's personal exposure to DPM must not exceed 160 µg/m^3 of TC when measured as an 8-hour-time-weighted average (TWA). Most studies on conditions of exposure have concentrated on rather uncommon occupations involving high expsosure to diesel exhaust (Gamble, *et al*., 1987; Whittaker, *et al*., 1999; Groves, *et al*., 2007). and there have been few studies on exposure in common occupations with lower levels of exhaust. Litle is known about exposure in common occupations such as drivers or mechanics (Lewne, 2007). Due to complexity of the content of exhaust fumes, indicator substances are used to quantify the exposure. CO and NO_2 has commonly been used as an indicator for diesel exhaust and CO was a major toxic component.

Determination of Miner's Exposure to DPM

Exposure assessment (Fig. 3) is the process of measuring or estimating the magnitude, frequency and duration of human exposure to a compound in the environment. Human exposure evaluation involved describing the nature and size of the population exposed to a air contaminants and magnitude and duration of their exposure. The dose, its duration and timing, the nature and size of the critical measures of exposure for risk characterization. It is possible to measure human exposure directly, by measuring levels of contaminants in the environment or by using personal monitors. Human exposures must be estimate by using measured concentrations in environmental in conjuction with models of human activity patterns (Birch, *et al*., 1996; Birch, *et al*., 2004).

RESULT AND DISCUSSION

General Operation Characteristics

The DOZ mining main method used block caving, while the ore deposit is approximately 200 m wide and 900m long with maximum draw height of 350 m. In production, panel drift is equipped with a central ore pass. It to deliver the ore to the truck haulage level. Truck haulage level is a combination of chutes. It delivers the ore from the muck raises to a 1372 × 1956 mm gyratory crusher and discharged into an 1800-ton capacity ore bin, and bottom of this is equipped with an apron feeder, which discharges the ore in a 3500 tpd conveyor system. DOZ ore will be trammed by diesel loaders from the draw points to ore passes and dumped to a truck haulage level. 50 tons trucks on the haulage level will transport the ore to a primary underground crusher, and conveyed to surface for processing (Calizaya, *et al*., 2001)

The average ore production rate (Fig. 4) in November 2000 at a rate of 2,000 tpd. Then increase to 25,000 tpd by year 2003. In October 2014 at a rate of 68,000 tpd, and decrease since January 2015 at a rate of 56,000 tpd.

In the Table 1 shown a total number active panels, and number and size of main fans performance in operation during survey.

Total airflow demand (Table 2) for DOZ underground mine is 1.498 m^3/s. Airflow to each primary level, undercut, extraction and haulage was based on providing 0.079 m^3/s/kW over diesel equipment and a minimum air velocity of 0.76 m/s in areas where personnel and non-diesel operate.

Intake (Table 3) and exhaust (Table 4) airways were required to provide sufficient airflow. It caused by the multiple parallel drifts on the extraction (production) level to control block-caving mines. Concerning to main trainways, airflow required for dilution of DEE contamination and minimum velocity. Moreover, to provide fresh airflows to the mine, three main fans (fan #1, #2, and #3) will be operating for intake within an exhaust system (5m to 6 m diameter raises in parallel from the level of DOZ ventilation to surface).

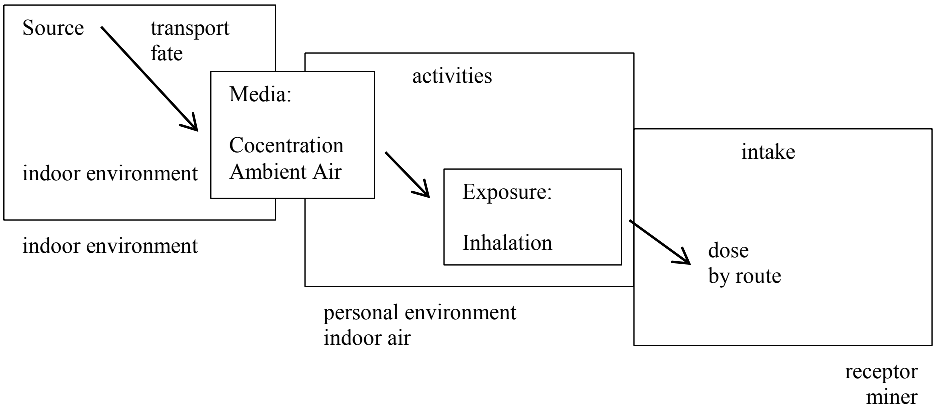

Fig. 3 Exposure assessment and estimating intakes concept.

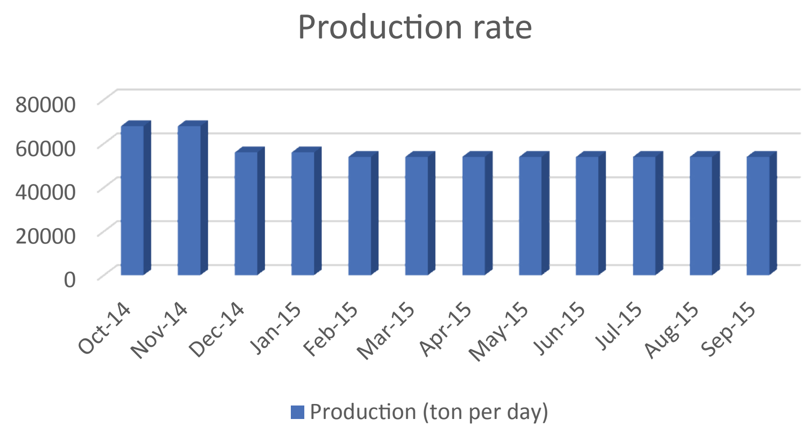

Fig. 4 DOZ ore production rate in Oct 2014 to Sept 2015.

Table 1. Main fans performance

DOZ	HP	KW	Pressure	Air Quantity (m^3/s)											
				Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Fan #1	2200	1600	1,309	345	322	387	387	342	346	346	303	419	411	411	385
Fan #2	2200	1600	1,308	365	339	385	385	357	356	356	340	401	412	412	326
Fan #3	2200	1600	1,400	339	335	396	396	376	399	399	390	423	425	425	304
Fan #11	1000	746	2,78	305	275	229	185	185	203	203	229	229	229	200	171
Fan #12	1000	746	2,31	194	196	0	217	217	217	217	258	258	258	205	205
Fan #13	1000	746	2,37	200	187	191	186	186	211	211	182	182	182	180	180
Fan #14	1000	746	2,42	230	217	202	204	204	204	204	248	248	248	263	263
Fan #15	1000	746	2,29	183	185	189	154	154	198	198	193	193	193	187	187

Table 2. Exhaust fans performance balance

Exhaust	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All access B/Hole-3 to 3186 Exhaust Drift	34	34	32	32	31	32	33	29	33	33	28	36
#1 Gallery Drift to V/raise 3186/L	384	384	292	346	371	343	439	400	400	400	382	390
#2 Gallery Drift to V/raise 3186/L	310	308	224	260	290	285	305	295	295	305	278	281
#2 Gallery Drift XC-1 to V/raise 3186/L	310	308	224	260	290	285	305	295	295	305	278	281
NED #1 Chamber	345	322	387	294	342	346	275	303	419	411	214	210
NED #2 Chamber	365	339	385	375	357	356	273	340	401	412	241	233
NED #3 Chamber	339	335	396	407	376	399	369	390	423	524	229	237
SVD Undercut V/R to 3186/L Exhaust Drift	60	60	60	60	60	60	60	60	60	60	154	151
Area-2 DOM Service and Access to 3186/L	3	4	7	5	7	7	6	6	6	7	50	40
Sucking DMLZ by NED #1 and NED #3	362	245	258	258	308	351	324	340	373	368	18	18
Total Exhaust	1788	1849	1749	1781	1816	1762	1741	1778	1959	1990	1872	1877

Table 3. Intake fans performance balance

Intake	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
DOZ Intake-1	437	442	363	311	288	307	348	387	389	464	408	161
DOZ Intake-2	340	278	215	176	257	204	25	33	32	397	240	294
DOZ Intake-3	77	86	283	388	398	424	410	417	431	146	215	188
DOZ Intake-4	847	850	727	768	790	785	874	890	1087	958	605	288
Upper rump intake	98	85	77	83	84	84	87	79	74	74	84	575
MLA Services Audit	66	68	68	48	45	45	47	56	62	62	62	119
Conveyor M-1	87	89	87	88	85	85	87	87	89	89	88	98
GRS-34 Conveyor	77	75	74	63	63	63	73	60	35	35	54	39
GRS-68 MLA	29	28	27	24	27	21	24	22	25	25	25	23
GRS-69 MLA	24	28	24	24	21	21	24	22	25	25	25	23
MLA access Conveyor Drift	28	25	22	26	26	34	26	25	43	43	26	29
DOM Top Service Drift	40	40	40	40	40	40	40	40	40	40	40	40
Intake to DMLZ	362	245	258	258	308	351	324	340	373	368	0	0
Total Intake	1788	1849	1749	1781	1816	1762	1741	1778	1959	1990	1872	1877

Table 4. Details on the type and quantity of diesel equipment in use and total airflow quantity

Type	**Unit**	**Operational factor (%)**	**Unit power (HP)**	**Air flow/unit (m^3/s)**	**Total air flow**
Axera	1	50	149	4.40	4.40
Axera 7	3	50	149	4.40	13.20
Commando 120	10	50	111	3.27	32.70
Commando 300	1	50	111	3.27	3.27
Cubex Drill	7	30	111	1.96	13.72
Medium Reach Drill	2	30	111	1.96	3.92
Robolter	1	30	111	1.96	1.96
EJC145	4	30	123	2.18	8.72
Elphinstone R1300	1	30	123	2,18	2.18
Elphinstone R1600	23	80	270	12.74	293.02
Elphinstone R1700	19	80	310	14.63	277.97
Elphinstone AD 30	1	80	400	18.88	18.88
Elphinestone AD 55	17	80	650	30.68	521.56
930 Series Loader	2	80	115	5.43	10.86
938 WH Loader	4	80	126	5.95	23.80
960 Series Loader	2	80	206	9.72	19.44
Boom Truck	5	30	81	1.43	7.15
Water Truck	2	30	81	1.43	2.86
Fire/Rescue Truck	1	20	81	0.96	0.96
Getman Flatbed	3	30	130	2.30	6.90
Getman Mixer Truck	11	30	154	2.73	30.03
Scissor Unit	12	50	81	2.39	28.68
Western Star Concrete Truck	2	30	380	6.73	13.46
Western Star Isotainer Truck	1	30	380	6.73	6.73
Backhoe	6	30	82	1.45	8.70
Crane	2	30	130	2.30	4.60
Grader	3	40	93	2.19	6.57
Forklift DP40	1	30	82	1.45	1.45
Shotcrete Sprayer	3	30	154	2.73	8.19
Water Canon	1	30	80	1.42	1.42
Telehandler	6	30	78	1.38	8.28
Iveco Bus	9	30	380	6.73	60.57
Isuzu Manhaul	3	30	380	6.73	20.19
Bobcat 2200	1	30	43	0.76	0.76
Bobcat 5600	1	30	43	0.76	0.76

Kubota Tractor	6	30	43	0.76	4.56
Personnel Vehicles	8	30	43	0.76	6.08
Personnel (people)	650	100	-	0.03	19.50
Total Required	1498.00				

For ventilation system designed to assure all personnel working in truck hauage drifts in fresh air. Determination of airflow quantity that influence by mining equipment and wide variations in characteristics of emissions even amongst vehicle of similar size and power. The number of parameter affecting the total airflow required for amount of diesel equipment (Table 4).

Engine exhaust characteristics

The gaseous POC (from DEE) include CO, NO and NO_2. Even diesel engines also produce water vapor; not considered as gaseous contaminant. Water vapor influence to the ambient of underground mining environment. Some of the gaseous present in DEE that established Regulation of the Ministry of Manpower and Transmigration of Republic of Indonesia (Ministery of ManpowerandTransmigrationof Republic of Indonesia, 2011) permissible exposure limit (PEL)s include CO and NO_2 (Table 5). Quantification of CO and NO_2 concentrations is to evaluate miners' exposure to these harmful gaseous.

Tabel 5. TWA-PEL Regulation of the Minsitry of Manpower and Transmigration of Republic of Indonesia

Substances	PEL
Carbon Monoxide (CO)	50 ppm
Nitric Oxide (NO)	25 ppm
Nitrogen Dioxide (NO_2)	5 ppm

CO average levels varied between 0 ppm to 3 ppm for drift and intake area, 0 ppm to 2 ppm for exhaust area, 0 ppm to 7 ppm for panel areas and 1 ppm to 8 ppm for haulage area. NO_2 and CO have often been used historically as surrogate for DEE (Isaaks, *et al.*, 2003). For this study, CO was selected to estimate relative difference in DEE concentrations over time. CO spatial data analysis (Fig. 5) carried out by using ArcGIS (GIS Mapping) software and (Kriging) were used to interpolate CO concentrations.

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NO and NO_2 levels were low 0 ppm in this survey. It is could be the use of a lower-sulphur diesel. In a Canadian railways company different occupations, no correlations were found between respirable combustible dust and NO_2 or between EC and NO_2. NO_2 is secondary constituent of the exhaust gaseous and that the transformation from NO to NO_2 depends on the levels of ozone and other photochemical oxidants. In underground mine, the transformation to NO_2 is slower due to low levels of ozone.

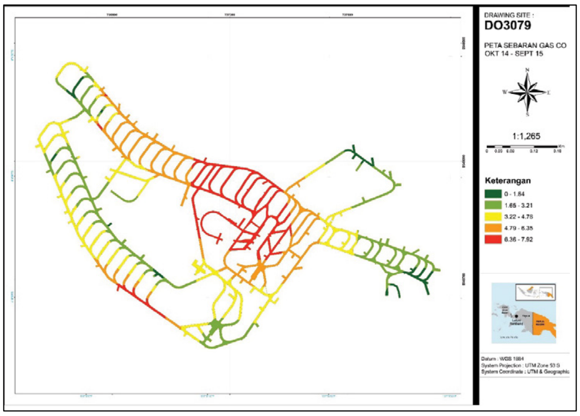

Fig. 5 Distribution of DOZ Truck Haulage CO Concentrations.

Fig. 5 shows the CO concentrations in truck haulage, an average CO concentrations was 3.0 ppm. Spatially continuous of CO concentrations mapping for points where there are no measurement data have to estimated, and can be done by a spatial interpolation. Measurement value both minimum and maximum CO and NO_2 concentrations presented in Table 6.

Table 6. Descriptive statistics of DOZ Truck Haulage for POC components

Agent	n	Average	Min-Max	PEL
CO-drift	14	1.2857	0-3.0	50
CO-exhaust	4	1.0	0-2.0	50
CO-haulage	14	3.0	1.0-8.0	50
CO-intake	3	1.0667	0-3.0	50
CO-panel	67	2.5672	0-7.0	50
NO_2-drift	14	0	0	5
NO_2-exhaust	4	0	0	5
NO_2-haulage	14	0	0	5
NO_2-intake	3	0	0	5
NO_2-panel	67	0	0	5
NO-drift	14	0	0	25
NO-exhaust	4	0	0	25
NO-haulage	14	0	0	25
NO-intake	3	0	0	25
NO-panel	67	0	0	25

DPM generation varies considerably among types, sizes, series manufacturers of diesel engine. DPM behave as an aerosol (Stinnette and Souza, 2013). Being sub-micron in size (Fig. 6) have aerodynamic diameters falling within a range 0.1 µm to 0.25 µm, its control is similar to other gaseous contaminant and classified by the international agency for research on cancer (IARC) as a Group 2A carcinogenic to human's (International Agency for Research on Cancer, 1989). Scanning electron microscopes are used in observations of microstructure to elemental analysis with JEOL JSM-6510Low-vacuum mode 5.0 nm (20 kV) and magnification x5,000 to x20,000.

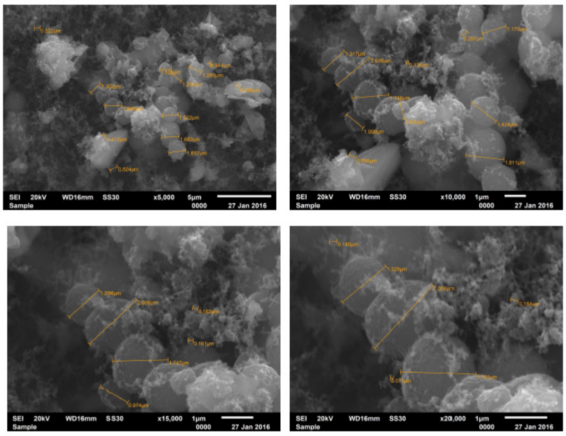

Fig. 6 Size and morphology (SEM images) of DPM in truck haulage area with different magnification x5,000 (DPM size 0.344~1.682 µm); x10,000 (DPM size 0.297~2.005 µm); x15,000 (size 0.161~2.009 µm); and x20,000 (size 0.071~2.009 µm).

Fig. 7 shows the DPM concentrations in truck haulage. Spatially continuous of DPM concentrations mapping for points where there are no measurement data have to estimated, and can be done by a spatial interpolation. Measurement value both minimum and maximum DPM concentrations presented in Table 7. Minimum airflow value of 0.03 $m^3/s/$worker Decree of the (Minister of Mines and Energy. 1995) and 0.067 $m^3/s/kW$ for DEE dilution as per Indonesian mining regulation (Minister of Mines and Energy. 1995). 0.080 $m^3/s/kW$ is a design value and is higher than the typical MSHA equipment quantities provided for gaseous compliance (McPherson, 1993). For truck haulage routes is 6.1 m/s as the maximum velocity. Ventilation for diesel shops based on the dilution of exhaust gaseous for two large loaders, which requires approximately 40.0 m^3/s. Ventilation of non-diesel shops has been established at 23.5 m^3/s based on experience at the mine. Airflow through the lube shop areas has been determined to be 28.2 m^3/s based on expected equipment usage. Operating factors represent the percentage of time that the equipment will be running and have to applied to determine approximate airflow requirements.

Fig. 7 Distribution of DOZ Truck Haulage DPM Concentrations.

Table 7. Descriptive statistics of DOZ Truck Haulage for DPM

Area	n	Average	Min-Max	PEL
Access Center Crusher #1-2	2	42	0-84	160
Truck Haulage Shop	5	247.2	140-527	160
Maintenance Shop	2	164.5	154-175	160
Office Area	6	154.5	66-428	160
PM Shop	2	161	53-269	160
Welding Shop	3	172	90-272	160
West Empty Haulage	2	223.5	179-568	160
South Full Haulage	2	1151	1055-1247	160
Access #1HN to 1JS	2	171	0-342	160
Access South Empty	2	591	0-1182	160
Access West Full Haulage #10	2	263.5	0-527	160
Access West Full Haulage #1-6	2	214	0-428	160
Center Crusher #1	2	204	175-233	160
Center Crusher #2	2	185.5	160-211	160
LP#1 E-1F South	2	595.5	0-1191	160
LP#1 G South	2	591.5	0-1183	160
LP#1 H South	2	971.5	725-1218	160
LP#1 J South	2	198.5	194-203	160
LP#1 IE	2	798	759-837	160

Exposure and intake estimation

Many potentially hazardous gaseous mixtures exist in DOZ. The TLVs for references from national institute for occupational safety and health (NIOSH), the U.S. occupational safety and health administration (OSHA), the U.S. mine safety and health administration (MSHA) and the Indonesian Ministry of Mines and Energy.

NIOSH recommended exposure limits as time-weighted average (TWA) concentrations for up to a 10-hour workday during a 40-hour workweek (The National Institute for Occupational Safety and Health, 2016). The OSHA permissible exposure limits are from the OSHA general industry air contaminants standard (29 CFR 1910). The OSHA

TWA concentrations must not be exceeded during any 8-hour workday of a 40-hour workweek (Occupational Safety and Health Administration, 2016). Additional ventilation requirements have also been provided based on Indonesian Mining Regulation and relate to a TWA based on working 8 hours/day and 40 hours/week (Ministery of ManpowerandTransmigrationof Republic of Indonesia).

DEE associated with diesel engines consists of various gases and diesel particulates. Diesel particulates usually less than one micron (µm or $\times 10^{-6}$ m), which causes them to be more easily inhaled and retained in the body. Presently the United States mining industry is in the process of phasing in stringent regulations relating to diesel particulates in underground mines. Exposure limits for DPM adopted by MSHA for metal or non-metal underground mines (non-coal). The present PEL for DPM as per MSHA (30 CFR 57.5060(b)) is 160 µgTC/m^3 (Safety and Health Standards-Underground Metal and Nonmetal Mines. 2016) (measurement of limit by the NIOSH 5040 method), with the defined as total carbon (TC) content (Centers for Disease Control and Prevention. 2016).

CONCLUSION

This survey shows distribution of CO and DPM concentrations predicted with an appropriate method by using Kriging Spatial Interpolation. This survey has the advantage to form DEE pollution mapping in DOZ mine and due to a lack of monitoring measurement in some locations. Kriging method can be used to obtain quantitative information on workplace exposure to CO and DPM. The results that show that the concentration of CO will be in the highest range in value of 6.38 ppm to 7.92 ppm, while the concentration exceeding the permissible exposure limit (PEL) for DPM will range in value 643.26 $\mu g/m^3$ to 618.23 $\mu g/m^3$. The results of this survey may be useful to assess the impact of diesel engine emission on health, especially for DOZ underground miners' from estimation of exposure and intake in adequate occupational safety and health manner.

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