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Coal Dust Characteristics and Its Association with Air Quality in Palembang Coal Unloading Station

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Abstract

The problem of coal dust due to the accumulation and loading of coal to barges for shipping has not been studied optimally. This study aimed to investigate the characteristics of coal dust and the air quality of the three coal industries. Coal dust characteristics were tested through proximate analysis, XRD, XRF, and SEM. Meanwhile, air quality is viewed from exposure to gases that cause emissions (CO, NO_2, and SO_2), PM_{10} and TSP, humidity, and temperature. Coal dust consists of SiO_2, Al_2O_3, and Fe_2O_3 as the main components with high ash. Exposure to SO_2 and TSP can potentially exceed the annual threshold value.

Keywords: Coal dust, air pollution, coal transportation, health impact,

Abstrak (Indonesian)

Permasalahan debu batubara akibat akumulasi dan pemuatan batubara ke tongkang kapal belum diteliti secara optimal. Penelitian ini bertujuan untuk mengetahui karakteristik debu batubara dan kualitas udara dari ketiga industri batubara tersebut. Karakteristik debu batubara diuji melalui analisis proksimat, XRD, XRF, dan SEM. Sedangkan kualitas udara dilihat dari paparan gas-gas penyebab emisi (CO, NO_2, dan SO_2), PM_{10} dan TSP, kelembaban, dan suhu. Debu batubara terdiri dari SiO_2, Al_2O_3, dan Fe_2O_3 sebagai komponen utama dengan kadar abu yang tinggi. Paparan SO_2 dan TSP berpotensi melebihi nilai ambang batas tahunan.

Kata Kunci: Debu batubara, polusi udara, transportasi batubara, dampak kesehatan,

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INTRODUCTION

Coal is one of the essential sources of energy in the world. Indonesia is one of the largest coal producers in the world. Many countries, including Indonesia, depend on coal and other fossil fuels to generate electricity. The demand for coal production is increasing due to industrialization and population growth. Coal mining activities generally consist of mining, storage, and transportation [1]. The stages of mining activities and the coal processing process have an impact on environmental health. One of the issues raised in this activity is the formation of coal dust. The high frequency of coal operational activities in the Stockpile, from loading and unloading, distribution, and crushing to barge transportation on the Musi River route, Palembang, has impacted air quality changes. In addition, the coal loading process can harm air quality, namely the emergence of coal dust, where the impact's magnitude depends on the wind's direction and wind speed.

The dust produced includes small enough particles. When inhaled, it can be stored in the air passages in the lungs. In addition to harming health, the dust has different sizes and shapes, depending on where the emission source comes from. Naturally, particulate dust can be produced from dry soil dust carried by the wind. At the coal stockpile location, as a result of the operation of the crusher, belt conveyor, and the traffic of coal trucks transporting coal and loading and unloading coal, they contribute to the formation of coal dust [2]. The effect of dust particulates in the air depends on their size. The size of particulates that endanger health generally ranges from 0.1 µm to 10 µm [3], [4]. The size of the dust particulates is about 5 µm, which can directly enter the lungs and settle in the alveoli. Meanwhile, particulate sizes larger than 5 m can irritate the upper respiratory tract and cause irritation [5].

The characteristics of coal dust need to be studied to determine the possible impact on health. Moreover, the coal loading station is opposite the settlement. In our previous work [6], exposure to coal dust in the form of particulate matter and its impact on the incidence of respiratory distress in the community have been studied. In the present work, air quality measurement around coal loading and settlements needs to be carried out to monitor the level of pollution caused. Therefore, this study aims to examine the characteristics of coal dust and air quality in the coal unloading station and residential areas directly adjacent to it and can assess the impact on public health, especially respiratory health.

MATERIALS AND METHODS

Materials

Coal dust samples were collected from the coal unloading station in Palembang, South Sumatra (Figure 1). Three coal companies are occupying the station, hereinafter referred to as PT. A, PT. B, and PT. C. Detailed sampling was carried out at the three stockpiles of each coal company, where falling dust was collected from the air intakes near the coal filling line to barges, stockpiles, and residential areas. When collecting, using a clean brush, gently sweep away the fallen dust and seal it into the bag for later use.

Methods

Dust samples collected in **Figure** 1 were tested according to proximate analysis according to ASTM standards. An X-ray diffractometer using (PANalytical), interval 2θ 10 – 100, Cu anode, K-α 1.54060 Ao (40kV, 30 mA) was used for qualitative analysis of the mineral composition of coal dust. Coal dust morphology was observed through SEM analysis using SEM Tescan VEGA3. The chemical composition in the form of oxidizing compounds of coal dust was analysed by X-ray Fluorescence Spectroscopy (PANalytical Epsilon 3 XLE XRF).

Figure 1. Coal dust sampling at coal unloading station

Ambient Air Sampler uses the HVAS TISCH Environmental TSP TE-5170 VFC Plus product. This product complies with the SNI 7119.3:2005 standard regarding the total suspended particulate matter test standard in ambient air by the Indonesian National Standards Agency, which is installed at the measurement point for 24 hours. Collecting dust concentration (PM_{10}), relative humidity, and air temperature at the location around the wharf were measured using the Particle Counter Portable CEM-DT-96 equipped with a thermometer and hygrometer (**Table** 1). The results of air sampling are analysed in the laboratory.

RESULTS AND DISCUSSION

Coal dust characteristics

The proximate analysis results (**Table** 2) show that the dust in each mine consists mostly of organic matter, along with different amounts of minerals. The ash content of all three places is in the range of 4.7–11.73%. The ash content of dust from different companies shows a difference that is not low. It can be seen that the composition of the dust is very complex. Higher ash content and lower fixed carbon content generally cause wettability of PT.C. The chemical composition is more straightforward if the ash content is higher due in part to the higher density of dust [7]. However, the mineral composition is more complex when the ash content is lower because minerals and coal can easily form aggregates in the dust with low ash content, which is not conducive to sorting during its flight [8]. Coal dust from the sampling point shows volatile matter and fixed carbon content of more than 40% by weight. Volatile matter and fixed carbon are the main combustible components in coal [9], so it is prone to self-heating resulting in air pollution. Sulphur content in the sample is included in the low category, which is below 0.6. [22]

Table 1. Air quality test parameters at coal unloading stations and residential areas

Parameter	Operational definition	Measurement	Measuring instrument	Scale
Temperature	Ambient air temperature	Thermometer	Particle Counter Portable CEM-DT-9, HVAS (High Volume Air Sampler)	Interval
Relative humidity	Ambient relative humidity	Hygrometer	Particle Counter Portable CEM-DT-9, HVAS (High Volume Air Sampler)	Interval
Wind speed	Movement of wind from high pressure to lower pressure	Anemometer	Anemometer CEM-DT-82	Interval
PM_{10}	Particulates measuring less than 10 μm in diameter		Particle Counter Portable CEM-DT-9, HVAS (High Volume Air Sampler)	Interval
TSP	Air particles measuring < 50-100 μm		HVAS (High Volume Air Sampler)	Interval

Table 2. Coal dust proximate analysis results

Parameter	This research		
	PT. A	PT. B	PT.C
Moisture (%)	2.32	0.81	1.32
Volatile Matter (%)	48.53	48.60	44.79
Ash (%)	4.70	8.97	11.73
Fixed Carbon (%)	48.50	41.94	42.21
Sulphur (%)	0.49	0.40	0.46

XRF analysis of coal dust from the three companies is shown in **Table** 3. Coal dust samples mostly contain SiO_2, Al_2O_3, Fe_2O_3, and CaO. Certain minerals produced during the mining process are estimated to significantly impact human health [10]. For example, silicosis is believed to be caused by prolonged inhalation of dust with a high quartz content [11], [12]. Coal dust with the main chemical components SiO_2 (52.902 wt%) and Al_2O_3 (26.069 wt%) in the study can be used in the construction industry if collected properly and reduces environmental pollution and health impacts.

The results of the XRD analysis showed that the most abundant phase in coal dust was kaolinite, which was identified in all samples. Quartz is the main constituent of the mineral in most coals. The XRD spectra of each coal dust are shown in **Figure** 2.

Table 3. Chemical composition of coal dust

Compound	PT. A	PT. B	PT. C
MgO	0.743	8.839	3.477
Al_2O_3	26.069	16.983	18.156
SiO_2	52.902	30.857	30.713
P_2O_5	2.415	3.492	12.472
SO_3	9.809	25.245	11.843
K_2O	0.938	0.586	0.481
CaO	1.887	5.141	10.424
TiO_2	0.819	0.892	1.187
Fe_2O_3	3.894	6.435	9.092
Ag_2O	0.34	0.948	1.36

Diffractogram pattern of coal dust of PT. A shows the most dominant quartz and kaolinite minerals found in coal dust. This follows what has been found by previous researchers [13]. Peaks 12.3351°(12,34), 24.9274°(25), and 38.427°(38,43) belong to kaolinite, while peaks at 20.8627°(20,9), 26.6075°(26,61), and 50.1320°(50,13) correspond to quartz. Similar peaks were found in research [14]. At a peak of about 45.6534°(45,65), the mineral pyrite was found. Most of the oxides are SiO_2 and Al_2O_3; the remainder is hematite and alumina at 34.9250°(35). Furthermore, alumina-β forms a peak at an angle of 38.4278°(38,43). In coal dust PT. B, quartz is found at peaks of 12.3644(12,36) and 26.6181°(26,62). While

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at the peak around 24.8666°(24,86) and 38.4379°(38,44) correspond to kaolinite. Not much different from that found in PT.C, quartz and kaolinite are dominant in coal dust which is marked by peaks at 12.4430° and 26.7062°(26,71) for quartz and 25.0091°(25,01) for kaolinite.

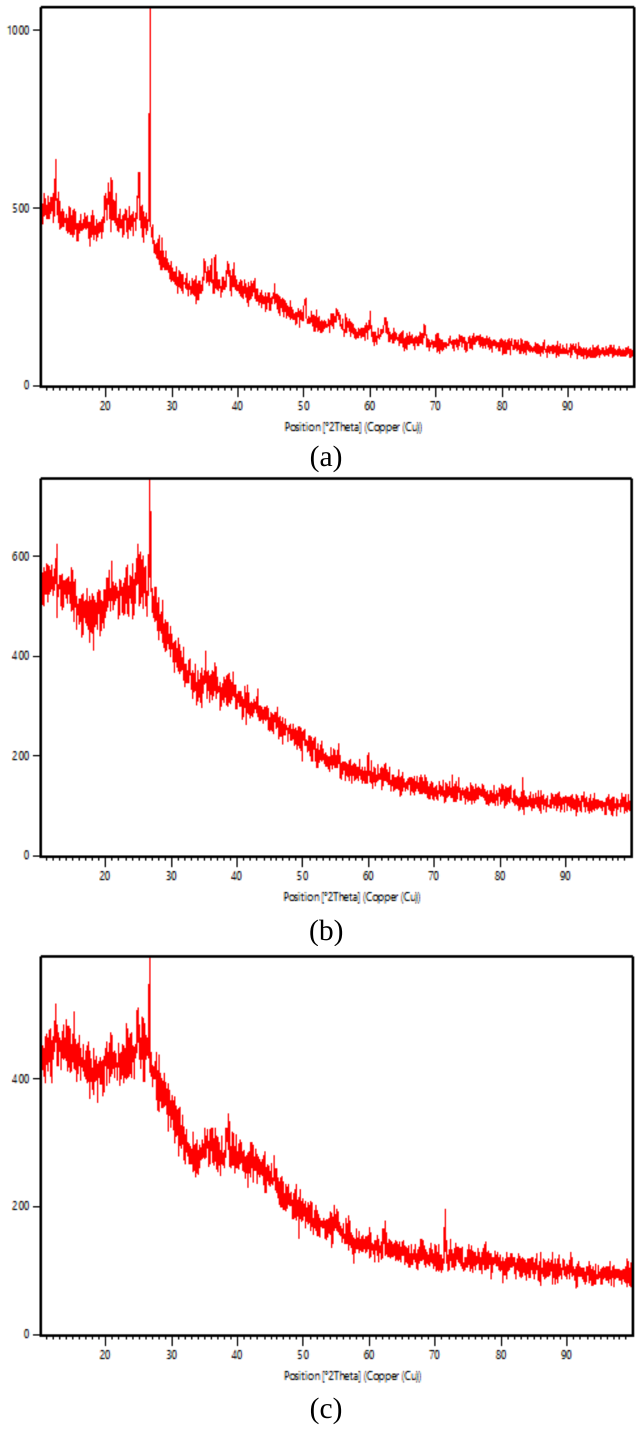

Figure 2. XRD pattern of coal dust from (a) PT. A, (b) PT. B, and (c) PT. C

Coal dust morphology in **Figure** 3 shows that almost all samples contain coal and clay minerals dominated by accordion-shaped kaolinite [23]. Among other minerals, quartz has a relatively intact hexagonal columnar shape, and pyrite has a crystal size and appears as an aggregate.

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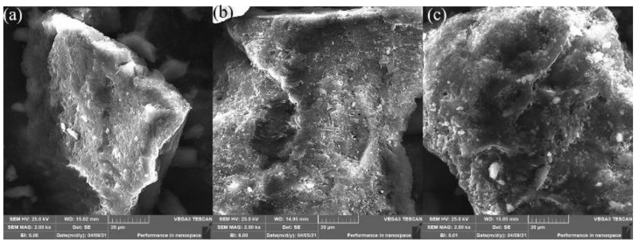

Figure 3. Coal dust morphology of (a) PT. A, (b) PT. B, and (c) PT. C

Air quality as a result of exposed coal dust

Air quality at Stockpile Kertapati Station, Palembang, is presented in **Table** 4–6. Measurements were carried out at the location of PT. A, PT. B, and PT. C in three areas around the stockpile from now on referred to as S1, S2, and S3, as well as residential areas across from the coal unloading station (S4), which are affected by coal loading and transportation activities at station. CO, NO_2, and SO_2 are categorized as climate change triggers because of the radiation force they cause in the atmosphere by forming other chemical species. NO_2 and SO_2 are precursors for nitrate and sulphate aerosols, respectively. CO is a precursor for tropospheric ozone, which induces a net warming effect [15]. These compounds also have short atmospheric lifetimes, realistically, days to months. SO_2 is in the atmosphere for two days, while for NO_2, the time is longer at 1 to 10 days, and CO has a maximum residence time of thirty to ninety days [16]. Although at the three sampling points, it was found that CO exposure was still below the threshold (<10000 µg/Nm^3) because of its strong bond with the hemoglobin molecule, carboxyhemoglobin was formed. Carboxyhemoglobin impairs the oxygen-carrying capacity of the blood, putting pressure on tissues with high oxygen demand, such as the heart and brain. Cytochromes are also bound by carbon monoxide so that the ability of cells to utilize oxygen is reduced.

The higher NO_2 concentration at the three coal unloading station locations is associated with the high movement of coal hauling and other mining activities. However, it is undeniable that human activities also have an impact. The NO_2 threshold in the air is 100 µg/Nm^3, and the measurement results are still below that limit. But the air around the stockpile 1 (S1) PT. B has reached 98 µg/Nm^3, while in the residential area directly opposite, the NO_2 concentration has passed the threshold of 122.7 µg/Nm^3. Short exposure to NO_2 can even increase respiratory problems, especially in children and asthmatics. Long-term exposure reduces resistance to respiratory infections [17], [18].

Coal piled on the stockpile is prone to self-heating and releases SO_2 into the air. From the measurement results, the concentration of SO_2 in the air around the stockpile and settlements at PT. A and PT C. have great potential to exceed the established annual threshold (60 µg/Nm^3). SO_2 is highly irritating to the eyes, nose, and throat and exacerbates asthma and chronic bronchitis symptoms. Prolonged exposure to SO_2 can significantly lead to lung and heart cancer and, in severe cases, death [19].

The analysis results confirmed that the PM10 exposure level was high in PT. B, 54.2 – 82.1 µg/Nm^3 at coal loading stations and 90.6 µg/Nm^3 in residential areas (S4). This confirms that coal dust does fly to the settlements directly opposite PT. B. This high concentration of PM_{10} is present even though the population is relatively small around the coal loading area. Still, more elevated amounts will accumulate in the years even though the residential area is not in the urban centre. Vulnerable populations in residential areas such as children, pregnant women, the elderly, and those with respiratory problems may be most at risk from pollutants related to coal dust loading activities onto ship barges. TSP concentration at PT. A is still below the threshold value set by the Indonesian government. As for PT. B and PT. C TSP concentration does not exceed the national standard limit for 24 hours but will potentially exceed the annual national limit standard (90 µg/Nm^3).

The concentration of pollutant gases in the air is best proportional to temperature. At low temperatures, gases in the atmosphere are in high concentrations and vice versa. The air temperature at the coal unloading station and residential areas directly adjacent to it ranges from 30.2 to 34.5°C. Relative humidity has to do with particulate matter and NO_2 emissions. In this study, the relative humidity ranged from 49.7 to 76.7%. High relative humidity promotes the hygroscopic growth of particles [20]. The higher relative humidity is associated with higher NO_2 concentrations [21].

Table 4. The air quality around PT. A

Parameter	Unit	S1	S2	S3	S4
CO	µg/Nm^3	<1145	<1145	<1145	1145
SO_2	µg/Nm^3	152	68.9	69	103
NO_2	µg/Nm^3	85.5	43.1	43.1	49
Relative Humidity	%	68.0	55.5	61.3	62.9
TSP	µg/Nm^3	37.1	23.7	27.1	24.8
PM_{10}	µg/Nm^3	18	12.4	13.6	12.4
Temperature	°C	31.6	34.2	34.5	32.6

Table 5. The air quality around PT. B

Parameter	Unit	S1	S2	S3	S4
CO	µg/Nm^3	<3675	<1085	<1640	5775
SO_2	µg/Nm^3	39.3	22.4	25.7	31.4
NO_2	µg/Nm^3	98.0	28.3	30.1	122.7
Relative Humidity	%	63.0	51.5	57.3	57.9
TSP	µg/Nm^3	113.2	93.3	85.1	147.8
PM_{10}	µg/Nm^3	82.1	61.3	54.2	90.6
Temperature	°C	31.6	33.4	32.9	31.7

Table 6. The air quality around PT. C

Parameter	Unit	S1	S2	S3	S4
CO	µg/Nm^3	<1250	<1230	<1230	1230
SO_2	µg/Nm^3	71.2	102.3	87.4	75.4
NO_2	µg/Nm^3	52.4	91.5	67.5	51.3
Relative Humidity	%	76.7	58.6	49.7	62.4
TSP	µg/Nm^3	109	111	64	101
PM_{10}	µg/Nm^3	20.8	50	58	32
Temperature	°C	30.2	32	31	31.5

CONCLUSION

The characteristics of coal dust at the coal unloading station in Palembang have been investigated together with air quality. The analysis results revealed that SiO_2, Al_2O_3, and Fe_2O_3 were the main constituents of coal dust from the three places. Air quality in the three-coal operational and residential areas has concentrations of SO_2 and TSP exposure that can exceed the annual threshold value. Exposure of NO_2 concentrations in residential areas has also exceeded the threshold value. The characteristics of coal dust impact the health quality of workers and the community in settlements. The analysis results can be used as a reference in handling coal dust or further utilization.

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