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Original Research

AIR POLLUTION AND LUNG CAPACITY OF PEOPLE LIVING AROUND THE CEMENT INDUSTRY, INDONESIA

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ABSTRACT

Backgrounds: A cement industry is one of anthropogenic sources of air pollution. In polluting the air, the industry creates some dust particles, nitrogen oxide (NO_2), sulfur oxide (SO_2), and carbon monoxide (CO).

Research Purpose: The research aimed at finding out the ambient air quality around a cement industry and relating it with the lung capacity of people living around the area.

Methodology: This was a cross sectional studies by measuring the ambient air quality in the morning, noon, and evening in four different settlements within 3 km from the cement industry. The measurement is then correlated with the FEV1 and FVC of lung capacity of people living around the area.

Result: Of all four locations, three have ambient air quality ($PM_{2.5}$ = 109.47 µg/Nm^3, TSP = 454.7 µg/Nm$^{3)}$ that surpass the quality standard ($PM_{2.5}$ = 65 µg/Nm^3, TSP = 230 µg/Nm^3). Of 241 respondents, the average level of FVC and FEV1 is respectively 1.9352 liter (SD: 0.45578) and 1.7486 liter (SD: 0.43874). Furthermore, the level of $PM_{2.5}$ in the morning and at noon is respectively p=0.009 and p=0.003; the level of TSP in the morning and at noon is respectively p=0.003 and p=0.01; the level of NO_2 in the morning is p=0.006; the level of SO_2 in the morning, at noon and in the evening is respectively p=0.000, p=0.022, and p=0.000; and the level of CO in the morning, at noon and in the evening is respectively p=0.003, p=0.015, and p=0.024. Those levels are associated with the level of respondents' FEV1. Moreover, the level of TSP in the morning is p=0.024; the level of SO_2 in the morning and in the evening is p=0.007. These levels relate to the level of respondents' FVC.

Conclusion: The ambient air quality around a cement industry is affected by dispersion of industrial emission and of other sources which can cause some impairment to lung capacity.

Key words: FVC, FEV1, CO, NO_2, SO_2, TSP, $PM_{2.5}$, cement industry.

INTRODUCTION

Cement industries are considered one of the biggest contributors of air pollution.[1-3] The average parameter concentration of PM_{10}, $PM_{2.5}$, TSP, SO_2, NO_2 and CO within 250 to 3000 meter from a cement industry surpass the quality standard.[4,5]

PT Semen Tonasa is one of the largest cement companies in Indonesia. Its factory is in Biringere Village, District of Bungoro, Regency of Pangkep, Province of South Sulawesi. This factory has a cement production capacity of as many as 5.98 million tons of cement per year.[6] According to satellite imagery; the closest settlement is approximately one kilometer to the factory. There is a relation between the concentration of $PM_{2.5}$ and PM_{10} and the lung capacity of people living around the cement industry of PT Semen Tonasa.[7]

Lung capacity is the basic indicator in pulmonary systems. Breathing has a role in exchanging gases in respiratory tract and blood vessels.[8] When exhaling polluted air, some pollutants will get into the lungs which can damage the respiratory tract. Being exposed to air pollution can trigger asthma aggravate previous respiratory diseases, or even develop chronic disease including lung cancer, Chronic Obstructive Pulmonary Disease (COPD), and emphysema. Air pollutants harm the development of the lungs and cause certain pulmonary diseases.[9,10] Air pollution also affects some vulnerable groups of people, such as pregnant women, children, old people and people who have serious pulmonary diseases, or even people with low income.[11,12] Some epidemiologic studies have been conducted on finding a relation between congenital pulmonary disease and the air quality of the environment.[13,14]

Based on these backgrounds, the researchers aimed to find out the relation between the ambient air quality ($PM_{2,5}$, TSP, SO_2, NO_2 and CO) and the lung capacity (FEV1 and FVC) of people living around the cement industry.

METHODS

Location of the Research

This research was undertaken in some settlements within 1 to 3 km from the cement industry of PT Semen Tonasa, Regency of Pangkep, Indonesia. The climax level of emission dispersion occurs within 1 km and the dispersion level decreases significantly after that until 3 km from the industry. Within this range, some health problems are found, such as Upper Respiratory Tract Infection or URI, bronchitis, asthma, emphysema, and some irritation to eyes and skin.[5]

Location 1: Macinna Village, Sub-district of Bontoa, District of Minasatene (S:4°48'2.86"; E:119°37'13.05),

Location 2: Sela Village, Sub-district of Mangilu, District of Bungoro (S:4°46'51.92"; E:119°37'59.46),

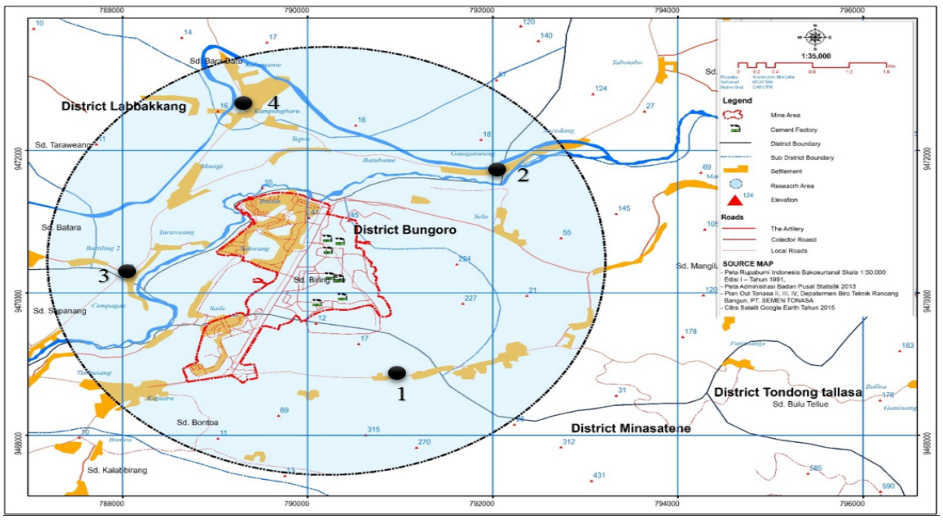
Location 3: Boronguntia Village, Sub-district of Biringere, District of Bungoro (S:4°47'32.85"; E:119°36'13.12),

Location 4: Gattagattareng Village, Sub-district of Taraweang, District of Labakkang (S:4°46'12.93"; E:119°36'54.45).

Population and Sample

The population of the research area is 609 people and 241 samples were collected by using *Slovin's formula*. Samples were taken from four different places, using *simple random sampling*; there are 44 respondents from Location 1 (Macinna Village, Sub-district of Bontoa, District of Minasatene); 51 respondents from Location 2 (Sela Village, Sub-district of Mangilu, District of Bungoro); 75 respondents from Location 3 (Boronguntia Village, Sub-district of Biringere, District of Bungoro); and 71 respondents from Location 4 (Gattagattareng Village, Sub-district of Taraweang, District of Labakkang).

Picture 1. Map of the Study Area



RESULTS

Lung Capacity

The respondents' lung capacity was obtained from the level of FVC and FEVI. Those levels are measured using a spriometer.

Table 1. Distribution of the Level of FEV1 and FVC of Respondents Living around the Cement Industry

Lung Capacity	n	Mean	Std. Deviation	Minimum	Maksimum
FVC	241	1.9352	0.45578	0.41	3.26
FEV1	241	1.7486	0.43874	0.21	2.68

Ambient Air Quality

The ambient air quality in four locations was measured for an hour in the morning, at noon, and in the evening by using Indonesian quality standard according to PP RI No. 41 Year of 1999 about Air Pollution Control.

Table 2 The Ambient Air Quality around Cement Industry

NO	Location	Coordinate Point	Pollutant	Unit	Standard	Result		
						Morning (09.00 AM)	Day (01.00 PM)	Night (08.00 PM)
1	2	3	4	5	6	7	8	9
1	1	S: 4°48'2.86"	$PM_{2,5}$	µg/Nm^3	65	78.78	109.47	81.3
		E: 119°37'13.05"	TSP	µg/Nm^3	230	243.75	454.7	249.43
			NO_2	µg/Nm^3	400	0.0513	0.0754	0.0399
			SO_2	µg/Nm^3	900	0.0471	0.0589	0.0408
			CO	µg/Nm^3	30000	1389.44	1578.93	1587.72
2	2	S: 4°46'51.92"	$PM_{2,5}$	µg/Nm^3	65	69.97	82.41	57.84
		E: 119°37'59.46"	TSP	µg/Nm^3	230	241.55	289.73	210.83
			NO_2	µg/Nm^3	400	0.0387	0.0417	0.0324
			SO_2	µg/Nm^3	900	0.0516	0.0379	0.0662

			CO	µg/Nm^3	30000	987.93	874.75	843.71
3	3	S: 4°47'32.85"	$PM_{2,5}$	µg/Nm^3	65	77.85	73.78	91.95
		E: 119°36'13.12"	TSP	µg/Nm^3	230	241.09	244.79	351.38
			NO_2	µg/Nm^3	400	0.0309	0.0917	0.0532
			SO_2	µg/Nm^3	900	0.0251	0.0344	0.0403
			CO	µg/Nm^3	30000	476.87	544.28	682.35
4	4	S: 4°46'12.93"	$PM_{2,5}$	µg/Nm^3	65	37.31	39.77	41.07
		E: 119°36'54.45"	TSP	µg/Nm^3	230	122.36	171.36	155.92
			NO_2	µg/Nm^3	400	0.0263	0.0278	0.0319
			SO_2	µg/Nm^3	900	0.0163	0.0275	0.0259
			CO	µg/Nm^3	30000	345.83	437.95	378.79

Data Analysis

Analysis was done with correlation check to find out the degree or the closeness of relation between independent and dependent variables of 241 respondents in the study area. The result of this check can be seen in Table 3 as follows.

Table 3. Result of Correlation Test of Research Variables

Variabel		**Lung Capacity**	
		FEV1	**FVC**
PM2.5 Morning	r	-0.168	-0.117
	p	0.009	0.069
PM2.5 Day	r	-0.193	-0.115
	p	0.003	0.074
PM2.5 Night	r	-0.077	-0.039
	p	0.234	0.547
TSP Morning	r	-0.193	-0.145
	p	0.003	0.024
TSP Day	r	-0.165	-0.078
	p	0.01	0.226
TSP Night	r	-0.048	-0.034
	p	0.461	0.601
NO2 Morning	r	-0.178	-0.093
	p	0.006	0.149
NO2 Day	r	-0.053	-0.019
	p	0.414	0.774
NO2 Night	r	0.007	0.013
	p	0.918	0.841
SO2 Morning	r	-0.233	-0.174
	p	0.000	0.007
SO2 Day	r	-0.148	-0.060
	p	0.022	0.357
SO2 Night	r	-0.224	-0.206
	p	0.000	0.001
CO Morning	r	-0.192	-0.112
	p	0.003	0.082
CO Day	r	-0.156	-0.070

	p	0.015	0.282
CO Night	r	-0.158	-0.071
	p	0.014	0.271

DISCUSSIONS

Air quality is affected by air pollution. The main source of air pollution in a city is from vehicles (60%) and industries (20-30%). Cement industries are one of the biggest contributors to air pollution. Emissions from a cement industry exist out of particulate materials, sulfur dioxide, and nitrogen oxide which can cover the vegetation and the soil and can affect all biotical life, in the future all ecosystems around the industry will be harmed. Chinese cement industries contribute around 10 to 18 of CO_2 emission. The gas is obtained from chemical reaction occurring when cement is produced, especially in the process of calcination of limestones, and when fossil fuel is used.[15]

Forced Vital Capacity or FVC measures how much air a person can exhale during a forced breath, while *Forced Expired Volume in one second* or FEV1 is the volume expired during the first second of a forced expiratory. The average level of FVC of 241 respondents is 1.9352 liter (SD: 0.45578) while the level of FEV1 is 1.7486 (SD: 0.43874).

The ambient air quality exceeds the quality standard in Location 1, 2, and 3, in which two out of five parameters are above the standard; they are $PM_{2.5}$ and total dust. The level of $PM_{2.5}$ in these locations is around 70.07 µg/Nm^3 to 89.85 µg/Nm^3 (the quality standard of $PM_{2,5}$ is 65 µg/Nm^3), while total dust is around 247.37 µg/Nm^3 to 315.96 µg/Nm^3 (the quality standard of total dust is 230 µg/Nm^3).

Furthermore, the level of $PM_{2.5}$ in houses around the cement industry of PT Semen Tonasa in the morning and in the evening is respectively 117.20 µg/Nm^3 and 109.03 µg/Nm^3, in which the quality standard of this particle, according to Indonesian Health Ministry Regulation No. 1077 Year of 2011, is 35 µg/Nm^3).[16]

In Macinna Village of Location 1 and Sela Village of Location 2, the level of $PM_{2.5}$ and total dust peak at noon. The level is 82,41 µg/Nm^3 to 109,47 µg/Nm^3 for the former particle and 289,73 µg/Nm^3 to 454,70 µg/Nm^3 for the latter mentioned. Differently, in Biring Ere Village of Location 3, those particles peak in the evening with the level of $PM_{2.5}$ and total dust is respectively 91.95 µg/Nm^3 and 351.38 µg/Nm^3.

Based on the observation, the difference in which the level of particles is higher in Location 1 and 2 at noon occur due to the intensity of mining activity in both locations also being greater. This activity contributes to dust and particles sizing 2.5 micron. Moreover, both locations are close to the limestone mining area where blasting the hills is carried out at 12 to 3 PM. A research by Mirsha in 2004 states that limestone contributes to air pollution causing tuberculosis to people living around a mining area. In analysis of particles in dust from limestone mining, it contains 46% CaO, 4% MgO, 5% SiO, 1.4% Al_2O_3, and 0.9% Fe_2O_3.[17] In addition, in a book titled *Cement Factories, Air Pollution and Consequences* by Syed Sana Mehraj and Dr.G.A Bhat, a cement industry is said to be one of 17 industries that pollute the most according to *Central Pollution Control Board*. The industry contributes to emission of SO_2, NO_2, and CO. Also, cement dust contains toxic heavy metals, such as chromium, nickel, cobalt, lead, mercury. Those metals are pollutants that can harm biotic environment, including vegetation, human and animal's health, and ecosystem.[18]

Table 3 shows a negative score meaning a negative relation. This relation describes that if the level of a variable goes up, the other variable will go down, for example, an emission increase will decrease lung capacity. Not all level of particles are significant ($p<0.05$). The significant particles to the level of FEV1 are $PM_{2.5}$ and TSP in the morning and at noon, NO_2 during the morning, SO_2 and CO during the morning, the noon, and the evening. Meanwhile, particles that are significant to the level of FVC are TSP in the morning and SO_2 in the morning and in the evening. However, the relation is quite weak in which $r<0.25$.

A person exposed to these particles will face some problems, depending on how much and long that person gets exposed. Some problems the particles can cause are lung function impairment, increase of bronchial hyper-responsiveness, pathology change of emphysema and fibrosis, hemorheological change, and comorbidity, also cardiovascular, serebrovascular, peripheral disease, and even cancer.[13]

A short term exposure to the ambient PM relates to the increase of Telomere Length or TL, a biomarker for cardiovascular disease. A driver has higher TL, with average TL0.87; 95% CI: 0.74; 1.03, compared to an office worker, with average TL 0.79; 95% CI: 0.67; 0.93; p = 0.001. Generally, TL is connected to the increase of PM_{10} and $PM_{2.5}$.[19]

Epidemiology has studied the relation of pulmonary disease potency caused by particulate matter of air pollution leading to lung cancer. In the study, the disease and cancer are caused by the exposure of particulate matter in low levels. Particles can be exhaled into respiratory systems, go into alveoli of the lung, and create Reactive Oxygen Species or ROS and free radicals. ROS in respiratory systems will increase inflammation of the lungs and start the carcinogenesis process.[20]

The respiratory system is affected by gasses or particles in the air that go in and out of the body. The polluted air containing particles will sediment in respiratory tract. They will stay if the person keeps inhaling polluted air. The effect of inhaling polluted air is not suddenly felt by the person. It will be a long term effect. The gasses will undergo some processes before turning into particles; those processes are reactions or neutralizations, nucleases, steam condensations or hygroscopic growths. The latter is the most important mechanism in respiratory tracts in a normal condition since atmosphere and anthropogenic aerosol will generally show some affinity in water steam. It is possible that a saturated condition in human respiratory tract can lead to unstable hygroscopic growth of aerosol even in a balanced ambient condition.[21]

CONCLUSION

The ambient air quality around a cement industry is affected by dispersion of industrial emission and of other sources which can cause some impairment to lung capacity.

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