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Research Article

Model Prediction of Potential Disease Effects from PM2.5 Emission Among School Children in Coming 30 years in South Tangerang

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ABSTRACT

Background: The largest global environmental health risk factor is the ambient of air pollution, that largely attributed to transportation emissions. One of the main causes of $PM_{2.5}$ emissions is thought to be on-road transportation. $PM_{2.5}$ has an impact on health, especially on children that relate to the respiratory system such as asthma, lung cancer, and decreased intelligence. **Objective:** The research objective was to predict the risk potential disease due to $PM_{2.5}$ in children from vehicle emissions in South Tangerang City. **Method:** This research is an observational analytic study with a cross-sectional study design using a dynamic model approach using STELLA software. The environmental and human samples aare used to calculate the exposure level to $PM_{2.5}$ taken from 32 points in 7 sub-districts of South Tangerang City (North Serpong, Serpong, Pondok Aren, Ciputat, East Ciputat, Pamulang, and Setu). then, meteorological data was also collected. Results: The number of vehicles in the city of South Tangerang is quite high, especially between 11:00 and 15:00 with the majority of vehicles passing by are cars and motorbikes. $PM_{2.5}$ pollution levels will fluctuate until 2053. The effects of temperature, weather, and humidity might cause an increase in $PM_{2.5}$ pollutants at specific times. According to the modeling calculation results, even though there are occasions when $PM_{2.5}$ pollution levels fall, acute respiratory infection (ARI) incidence in children will continue to rise over time. Although $PM_{2.5}$ emissions fluctuate, exposure to $PM_{2.5}$ in low concentrations poses a risk to human health.

Key words: Children, Transportation, Particulate matter, Acute respiratory infection.

INTRODUCTION

Transport emissions are important because many people are exposed to exhaust gases and other particles from moving vehicles.[1-3] 45% of air pollution is caused by transportation. One of the emissions resulting from transportation is $PM_{2.5}$.[4-7] $PM_{2.5}$ can pass through the nose and throat and penetrate deep into the lungs and circulatory system. In addition, because of their small size and lightweight, $PM_{2.5}$ tends to last longer in the air than heavier particles.[8]

Humans' ability to absorb $PM_{2.5}$ depends on a number of factors, including their age and metabolism, the way they are exposed (*via* ingestion, inhalation, or skin), and the environment in which they are exposed (temperature, humidity, solar radiation, wind speed, and rainfall). $PM_{2.5}$ exposure primarily occurs through inhalation.[9]

$PM_{2.5}$, or particles with a diameter of less than 2.5 m, is a pollutant frequently studied due to its variety of detrimental health effects. $PM_{2.5}$ has an impact on health, especially on children. More than 90% of the global population in 2019 lived in areas where concentrations exceeded the 2005 WHO air quality guideline of 10 μg/m3. The latest recommendation from WHO for $PM_{2.5}$ in 24 hours is 15 μg/m^3.[10,11]

$PM_{2.5}$ is not easily removed by ciliary action in the trachea, bronchi, and bronchioles or by inertial impaction in the nasopharynx, so it enters the lower airways and causes inflammation leading to respiratory epithelial disease. In addition, $PM_{2.5}$ also causes cardiovascular disease, asthma, acute respiratory infection (ARI)[12,13] and lung cancer and increases susceptibility to infectious diseases.[14] Moreover, $PM_{2.5}$ can result in fatalities.[15]

Studies have shown that children are more likely to experience cognitive deterioration in locations with high levels of air pollution.[16-20] $PM_{2.5}$ affects children's brain development even in low concentrations.[21-23] Moreover, $PM_{2.5}$ exposure can affect intelligence, children have difficulty concentrating and impaired motor function.[23-26] According to data from the Metropolitan Mexico City Brainstem Auditory Evoked Potentials (BAEPs) and the Montreal Cognitive Assessment (MoCA), approximately 66% of children have slowed brain development and are at risk of developing Alzheimer's disease.[27]

A location with a high residential density, industrial areas, areas of rapid trade growth, and an increase in the number of air-polluting means of transportation is South Tangerang City. The city in Indonesia with the highest annual average level of pollution is South Tangerang City. According to studies, South Tangerang, Indonesia, has high levels of $PM_{2.5}$ pollution. Based on IQ Water data from South Tangerang City, $PM_{2.5}$ concentrations of 74.9 μg/m^3 are above WHO guidelines which are considered unhealthy for humans.[28] Dynamic models using STELLA are needed to predict the impact of $PM_{2.5}$ on acute respiratory infections and help decision-making. The research objective was to predict the

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risk of disease due to $PM_{2.5}$ in children from vehicle emissions in South Tangerang City.

METHOD

This research is an observational analytic study with a cross-sectional study design using a dynamic model approach using STELLA. This model is used to predict the impact of disease on school children from $PM_{2.5}$ emissions. The environmental samples used are exposure to $PM_{2.5}$ taken from 32 points in 7 sub-districts of South Tangerang City (North Serpong, Serpong, Pondok Aren, Ciputat, East Ciputat, Pamulang, and Setu) and meteorological data such as air temperature, humidity and wind speed and wind direction. while the human sample used was 64 schoolchildren from 7 districts. The map below shows the sampling region for the research.

South Tangerang is situated at coordinates 106'38'-106'47' East Longitude and 06'13'30'-06'22'30' South Latitude in the eastern region of Banten Province. $PM_{2.5}$ sample points are taken based on proximity to the main road and the children's school is located close to the sampling point. For modeling using data on child ARI cases taken for 5 years from 2018 to 2022, as shown in the figure 1.

RESULTS

Meteorological data

Air pollution is distributed due to a number of factors. One of the factors is wind speed and direction, which can disperse pollution both horizontally and vertically. DKI Jakarta borders South Tangerang, which has a relatively flat landscape with an average slope of 0-3% and an elevation range of 0-25 dpl. Temperature, humidity, wind speed, and direction are taken from the Meteorology, Climatology, and Indonesia Geophysics Agency's web database (BMKG). http://dataonline.bmkg.go.id/.

The relative humidity ranged from 61% to 96% with an average of 73%, while the wind speeds ranged from 0.11 m/s to 4 m/s with an average of 2 m/s. The temperature ranged from 20°C to 42°C with an average of 28°C. Figure 2 displays an overview of wind speed.

Using a viewing of 106° for 3 years, wind conditions were analyzed using WRPLOT 8.0.2's Wind Rose Plot (2020-2022). Although the wind pattern is quite stable, the maximum frequency direction in 2021 is southwest as opposed to 2020 and 2022, when it is northeast. The concentration of pollutants is impacted by the wind's direction in relation to the highway. From 2020 through 2023, the average wind speed remains stable, with moderate gusts of 50.3% in 2020, 43% in 2021, and 41.6% in 2022.

$PM_{2.5}$ concentration in South Tangerang

South Tangerang City is a city with a high population level with heavy traffic. In addition, there is an industrial area in South Tangerang City. High vehicle emissions from transportation will have a negative impact on humans, especially school children as a vulnerable group. $PM_{2.5}$ health impact on children such as acute respiratory infections, pneumonia and bronchitis.[29] The $PM_{2.5}$ prediction model for the incidence of ARI in children for 30 years can be seen in Figure 2A and 2B below.

Figure 2B describes the prediction results for 30 years show that in 2023-2053, $PM_{2.5}$ pollutant levels fluctuate until 2053. $PM_{2.5}$ pollutants can increase at certain times due to the influence of temperature, weather and humidity. But the graph of ARI incidence in children from year to year based on the simulation results will continue to increase even though there are times when $PM_{2.5}$ pollutant levels decrease. Although $PM_{2.5}$ emissions fluctuate, exposure to $PM_{2.5}$ in low concentrations poses a risk to human health.

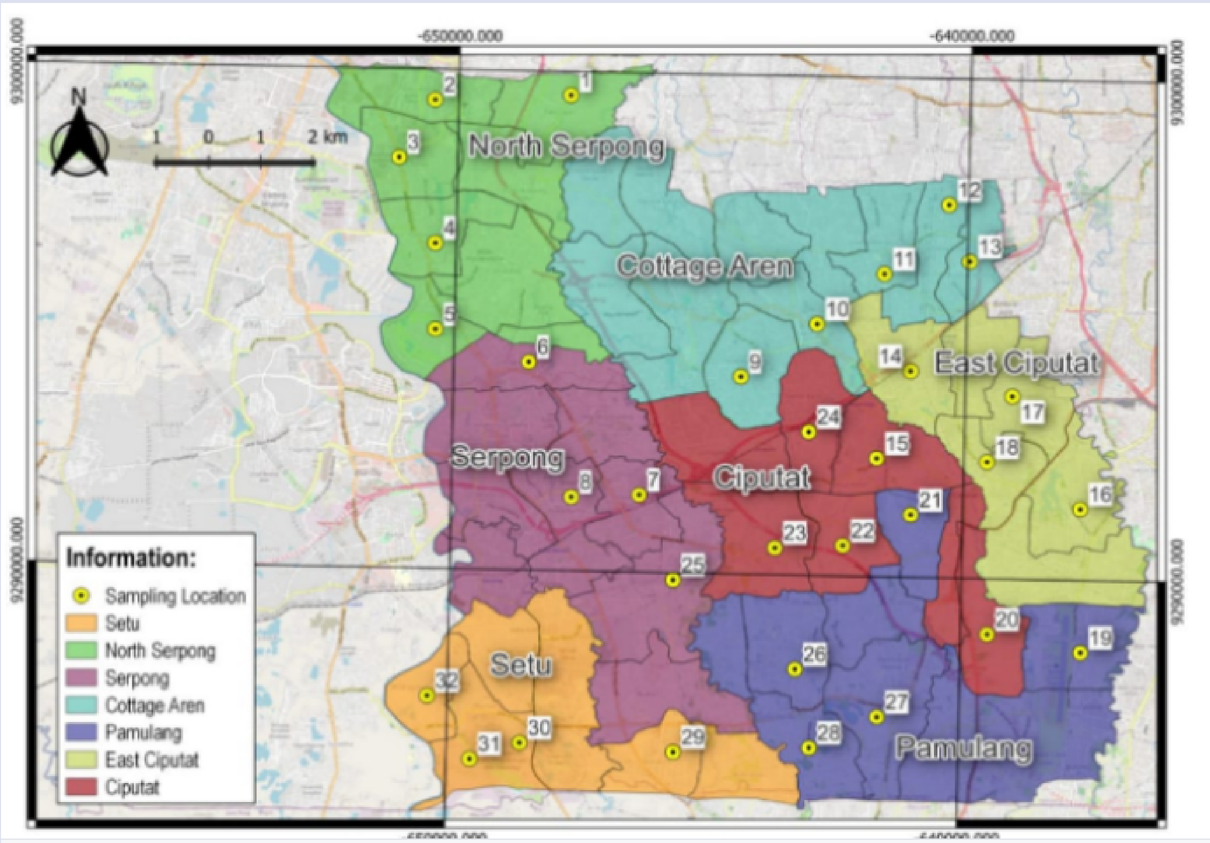

Figure 1: Geographic location of 32 $PM_{2.5}$ exposure sampling points in South Tangerang city

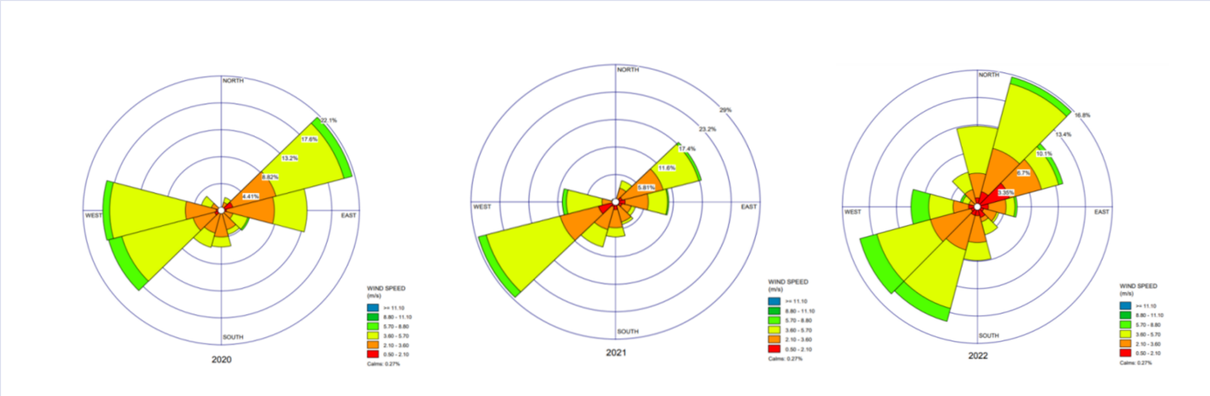

Figure 2A: Annual wind conditions in South Tangerang city in during 3 years from 2020 to 2022

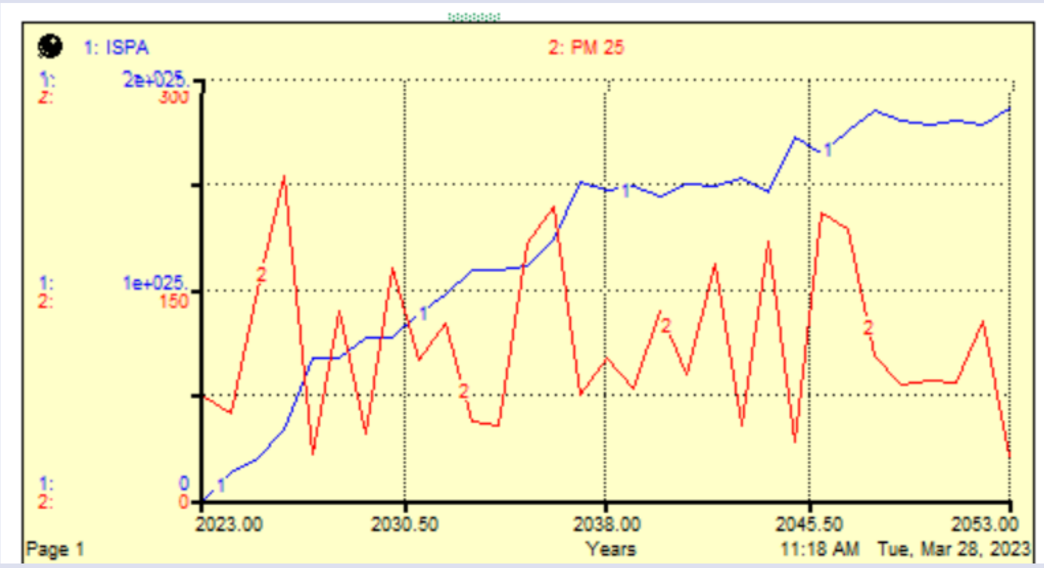

Figure 2B: Prediction of $PM_{2.5}$ concentration on ARI incidence in children during the period of 30 years from 2023 until 2053

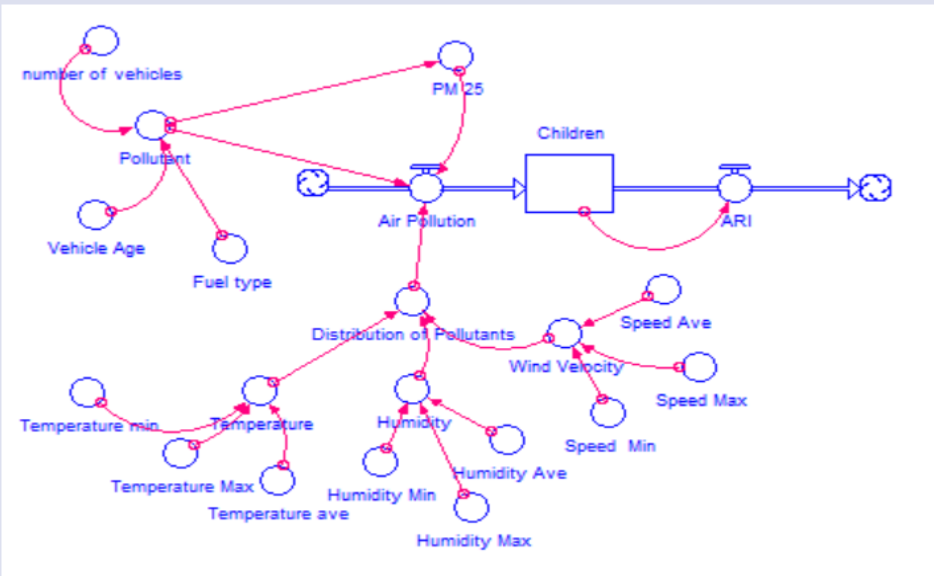

Figure 3: Model for the incidence of child ARI in South Tangerang city

The greater the number of vehicles, the older the age of the vehicles, and the use of this type of fuel can increase air pollutants, especially $PM_{2.5}$, which can trigger ARI incidents in residents in the city of Tangerang, as seen in figure 3.

This model explains that the number of vehicles, vehicle age, temperature, humidity, and weather can affect the level of the $PM_{2.5}$ pollutant in the air, which in turn can impact human health.

DISCUSSION

High traffic density has an impact on decreasing air quality due to pollutants in the atmosphere. One type of pollutant that is very dangerous to human health is dust particles with a diameter of 2.5 μm ($PM_{2.5}$). One source of $PM_{2.5}$ pollutants is emissions from motorized vehicles. Vehicles can emit exhaust gas containing $PM_{2.5}$ particles, especially vehicles with diesel engines. When these particles enter the human respiratory tract, they can cause irritation and inflammation in the tissues of the lungs and respiratory tract, thereby increasing the risk of developing acute respiratory infections (ARI). Moreover, $PM_{2.5}$ particles have the ability to transport and cling to viruses that cause respiratory illnesses. Under specific circumstances, these particles may facilitate the quicker and easier spread of viruses throughout the human body. Hence, an increase in $PM_{2.5}$ pollutants brought on by vehicle emissions may possibly be a factor in the rise in ARI cases.[30]

The number of vehicles in the city of South Tangerang is quite high, especially between 11:00 and 15:00 with the majority of vehicles passing by are cars and motorbikes. $PM_{2.5}$ concentrations can change at any time so that a person may be exposed to more than the permitted threshold value. Low $PM_{2.5}$ concentrations can be caused by wind speeds that carry airborne particles away from pollutant sources, so that they can produce low concentration values in areas adjacent to the source. According to a research done in Beijing, China, there is a 3.2% chance of getting ARI for every 10 g/m3 increase in $PM_{2.5}$ particle concentration.[31]

Children are particularly vulnerable to the negative health impacts of air pollution because of their young immune systems, underdeveloped lung and metabolic systems, and the co-infection of respiratory infections.[32] Children between the ages of 6 and 14 begin to engage in more outside activities, but their understanding of how to protect themselves from air pollution is still limited.[33] Furthermore, due to their high rates of mouth breathing and ventilation as well as the fact that they spend more time playing outside than adults do, children are proportionally more exposed to ambient air pollution than adults.[34] Exposure to $PM_{2.5}$ has negative effects on lung function and raises the incidence of respiratory illnesses.[35]

The group of children aged 6 -17 years in Jinan, China is more susceptible to exposure $PM_{2.5}$. Each increase per 10 μg/m^3 $PM_{2.5}$ will add to the total acute respiratory tract infection hospitalization.[36] Boys and girls were equally vulnerable to air contaminants in numerous gender-specific analyses, and sex was not a relevant modifier because no discernible difference was found between them.[37,38] By effectively regulating environmental pollutants, childhood respiratory illnesses may be avoided and provide personal protective equipment and knowledge about the impact of exposure to $PM_{2.5}$

CONCLUSION

$PM_{2.5}$ exposure in South Tangerang City fluctuates and is closely related to the incidence of acute respiratory infections in school children. Even though $PM_{2.5}$ concentrations are low, it will have an impact on respiratory diseases. School children are vulnerable because of their young immune system, underdeveloped pulmonary and metabolic systems and their limited knowledge. the need for regulations regarding emissions and personal protective equipment for children.

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