

# Spatial analysis of nitrogen dioxide concentration in ambient air and its relationship to low birth weight incidence in Palembang City

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## ABSTRACT

One of the factors influencing the incidence of low birth weight (LBW) is exposure to air pollutants such as nitrogen dioxide (NO<sub>2</sub>). Therefore, this study aims to analyze the relationship between NO<sub>2</sub> air pollution exposure and the incidence of LBW in Palembang City. This research uses an ecological study design with secondary data obtained from the Palembang City Health Office, the Palembang City Environmental Office, and the Regional Development Planning and Research Agency (Bappeda Litbang) of Palembang. Data analysis was conducted using Geographic Information Systems (GIS). The study focused on seven subdistricts as sampling locations based on air monitoring points established by the Environmental Office. The results of the study show that the highest number of LBW cases was found in Ilir Timur I Subdistrict, with 58 cases in 2022. Meanwhile, the highest NO<sub>2</sub> concentration was recorded in Plaju Subdistrict, reaching 266  $\mu\text{g}/\text{m}^3/\text{hour}$  in 2020. Overlay analysis indicated no significant relationship between NO<sub>2</sub> concentration and LBW incidence in most areas, except in Plaju Subdistrict during 2020-2021, where both NO<sub>2</sub> concentrations and the number of LBW cases were relatively higher compared to other subdistricts.

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## INTRODUCTION

Low birth weight (LBW) is a key indicator of infant health and is often associated with various health risks, both in the short and long term (Handayani et al., 2019). Globally, UNICEF and the World Health Organization (WHO) reported that in 2020, 15% or approximately 19.8 million babies were born with low birth weight, making LBW an urgent health issue to address (UNICEF, 2023; WHO, 2024). In Indonesia, the prevalence of low birth weight (LBW) was 6.0% according to the 2022 Indonesian Nutrition Status Survey (SSGI), with several regions reporting higher rates (Kementerian Kesehatan Republik Indonesia, 2022). In Palembang City, the Health Office recorded 687 cases of low birth weight (LBW) in 2022, making this issue a key focus in efforts to improve maternal and infant health quality (Dinas Kesehatan Kota Palembang, 2022).

One of the factors that can influence the incidence of low birth weight (LBW) is exposure to air pollutants, including nitrogen dioxide (NO<sub>2</sub>) (Akmal et al., 2024). Air pollution is a growing global issue driven by industrial growth, urbanization, and increased motor vehicle use. The WHO states that nearly the entire world population (99%) is exposed to air pollution containing various pollutants, such as PM<sub>2.5</sub>, carbon monoxide (CO), ozone (O<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>), and sulfur dioxide (SO<sub>2</sub>) (WHO, 2022). Nitrogen dioxide (NO<sub>2</sub>), one of the main pollutants from vehicle emissions and industrial activities, has serious health impacts, particularly for pregnant women (van den Hooven et al., 2012). Exposure to nitrogen dioxide (NO<sub>2</sub>) during pregnancy can disrupt placental function, inhibit fetal growth, and increase the risk of low birth weight (Slama et al., 2008). In Indonesia, transportation activities are one of the main contributors to NO<sub>2</sub> emissions (Kristi & Boedisantoso, 2015). In 2008, emissions from the transportation sector reached 3.9 thousand tons, with major cities like Jakarta, Surabaya, and Medan accounting for more than 50% of the NO<sub>2</sub> concentration in the air, originating from motor vehicles (Kementerian Lingkungan Hidup Republik Indonesia, 2022). Exposure to nitrogen dioxide (NO<sub>2</sub>) during pregnancy is known to affect placental function, disrupt the supply of nutrients to the fetus, and increase the risk of growth disturbances, including low birth weight (LBW) (Slama et al., 2008; van den Hooven et al., 2012).

A study by (Inoue et al., 2020) also showed that exposure to nitrogen dioxide (NO<sub>2</sub>) during the first two months of pregnancy, particularly if combined with malnutrition, can increase the risk of preterm birth and low birth weight (LBW). Meanwhile, research by (Nyadanu et al., 2022) found that prenatal exposure to air pollutants (such as PM<sub>2.5</sub>, NO<sub>2</sub>, CO, O<sub>3</sub>, SO<sub>2</sub>, and PM<sub>10</sub>) may be associated with birth outcomes, with more consistent evidence for some pollutants. However, some other associations showed lower consistency or unclear directions. The existing evidence suggests a potential causal effect of air pollutants on birth outcomes, but more high-quality research is needed to strengthen these findings, especially in low- and middle-income countries. This study also highlights the need for the precautionary principle regarding exposure to air pollutants during pregnancy. Meanwhile, research by (Nurhasana, 2021) indicated a significant relationship between exposure to haze, education level, and history of low birth weight with the occurrence of LBW. Haze exposure increases the risk of LBW and is a dominant factor in LBW occurrences in the area. This is supported by a study by (Ningrum & Nurahmawati, 2017) which found a relationship between air pollution and LBW incidents. During pregnancy, frequent exposure to sources of air pollution such as factory smoke, vehicle exhaust, and cigarette smoke affects fetal growth in the womb, leading to LBW.

Based on previous studies, although there is evidence indicating a relationship between exposure to air pollutants, particularly nitrogen dioxide (NO<sub>2</sub>), and the occurrence of low birth weight (LBW), most research has focused more on the relationship between exposure to other air pollutants, such as PM<sub>2.5</sub>, CO, and SO<sub>2</sub>, and birth outcomes, without specifically addressing spatial analysis. Additionally, previous studies have emphasized the cumulative effects of air pollutants overall, while there is limited research examining the specific relationship between ambient NO<sub>2</sub> concentrations and LBW occurrences. On the other hand, although prior research shows a relationship between haze exposure and air pollutants with LBW incidents, spatial factors in this analysis remain unclear. Furthermore, these studies did not account for more detailed data periodization, such as specific time frames like 2019-2023, which could provide clearer insights into exposure trends or patterns and their impacts.

This study offers a new approach by conducting a spatial analysis of ambient NO<sub>2</sub> concentrations and their relationship with LBW incidents in Palembang City during the period of 2019-2023. By utilizing spatial data, this study aims to provide deeper insights into the geographic distribution of NO<sub>2</sub> concentrations and their impact on maternal and infant health, particularly LBW occurrences. The strength of this research lies in its integration of spatial analysis with a more specific time period, which has not been widely applied in previous studies. Moreover, this study also takes

into account local factors, such as pollution sources around urban areas, which may significantly contribute to findings regarding NO<sub>2</sub> exposure during pregnancy.

This research contributes by integrating local data from Palembang City and using a Geographical Information System (GIS) approach to analyze the spatial relationship between NO<sub>2</sub> concentrations and LBW. The study offers a new perspective on the impact of air pollution on low birth weight infants in developing cities where previous research has been limited, and it identifies areas with the highest risk for public health interventions. This study uses a spatial analysis approach, leveraging GIS to understand the distribution of NO<sub>2</sub> concentrations and the spread of LBW cases. Consequently, the research can provide evidence-based recommendations for public policy in air pollution mitigation and the protection of maternal health in urban areas. Therefore, this study aims to analyze the relationship between ambient NO<sub>2</sub> concentrations and LBW occurrences in Palembang City during the 2019-2023 period. The results of this research are expected to provide relevant information for stakeholders to formulate effective mitigation strategies and interventions to improve maternal and infant health quality in Palembang City.

## RESEARCH METHOD

This study examines the relationship between nitrogen dioxide (NO<sub>2</sub>) concentration as the independent variable and the distribution of low birth weight (LBW) cases as the dependent variable in Palembang City. The sample locations include seven sub-districts: Bukit Kecil, Ilir Timur I, Ilir Timur III, Jakabaring, Kertapati, Alang-Alang Lebar, and Plaju.

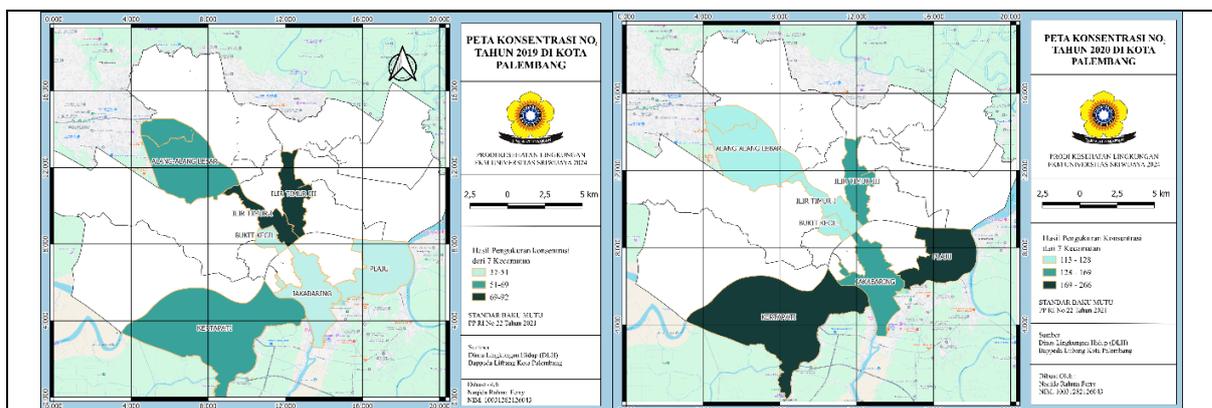
The study utilizes secondary data obtained from the Palembang City Environmental Agency for the nitrogen dioxide (NO<sub>2</sub>) concentration data for the period of 2019-2022, and from the Palembang City Health Agency Profile for the LBW case distribution data for the period of 2020-2023. Spatial data on the administrative map of Palembang City was downloaded through the Geoportals.

Data analysis is performed using a spatial analysis approach with QGIS, which includes mapping the distribution of LBW cases and NO<sub>2</sub> concentrations, overlaying the data to identify the relationship between the two, and descriptive analysis to illustrate distribution patterns. The analysis results are used to determine the correlation between NO<sub>2</sub> exposure and LBW occurrences in Palembang City.

## RESULTS AND DISCUSSIONS

### Map of NO<sub>2</sub> Concentration in Palembang City from 2019-2022

Based on the mapping results using the QGIS application, the map of nitrogen dioxide (NO<sub>2</sub>) concentration in Palembang City for the period of 2019-2022 is shown below:



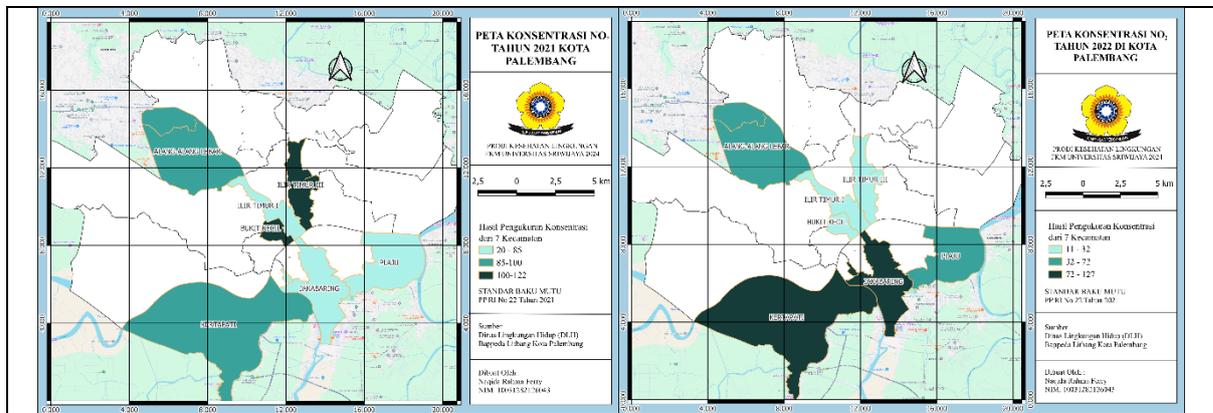


Figure 1. Map of NO<sub>2</sub> Concentration in Palembang City from 2019-2022

The map of NO<sub>2</sub> concentration in Palembang City for the period 2019-2022 provides an overview of the variation in air pollution levels across different districts. According to the map presented, the districts of Kertapati and Plaju recorded the highest NO<sub>2</sub> concentrations, with an average of 115 μ/NM<sup>3</sup>/hour. In contrast, Jakabaring had the lowest concentration, with an average value of only 65 μ/NM<sup>3</sup>/hour. The high NO<sub>2</sub> concentrations in Kertapati and Plaju may be attributed to factors such as high vehicle volume, industrial activity, and higher population density in these areas, which can contribute to increased air pollution.

Districts with lower concentrations, such as Jakabaring, likely have more limited pollution sources or are located in areas with less vehicle traffic and industrial activity, leading to better air quality. However, despite the lower NO<sub>2</sub> concentration in Jakabaring, it is important to note that other factors, such as overall environmental quality and air management policies, can influence these results. The average nitrogen dioxide (NO<sub>2</sub>) concentration in Palembang City for the period 2019-2022 can be seen as follows:

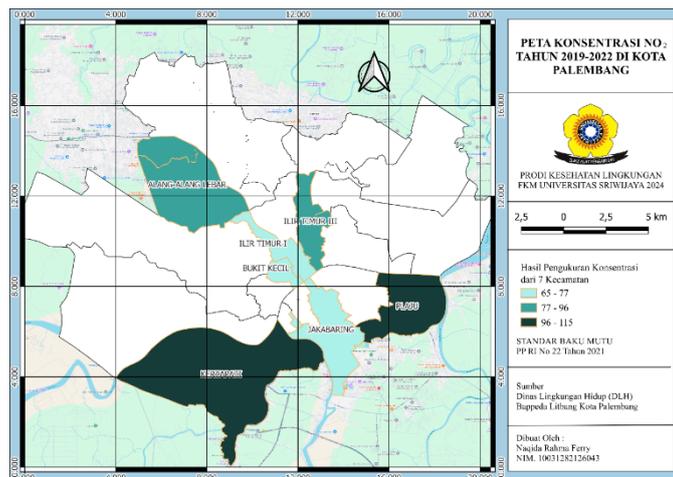


Figure 2. Average NO<sub>2</sub> Concentration Map in Palembang City for the Years 2019-2022

Based on the map in Figure 2, which shows the average nitrogen dioxide (NO<sub>2</sub>) concentration in seven districts of Palembang City during the period of 2019-2023, there is a significant variation in air pollution levels across the districts. The Kertapati and Plaju districts have the highest NO<sub>2</sub> concentrations, with an average value of 115 μ/NM<sup>3</sup>/hour, reflecting high levels of air pollution in

these areas. This condition may be influenced by factors such as heavy vehicular traffic, industrial activities, and land-use patterns in these districts, which are often associated with increased NO<sub>2</sub> emissions. In contrast, the Jakabaring district has the lowest average NO<sub>2</sub> concentration, at 65 μ/NM<sup>3</sup>/hour. This suggests that Jakabaring may be less exposed to high levels of air pollution, possibly due to a greater presence of green spaces, residential areas, or locations less directly impacted by major pollution sources such as transportation or industry.

These differences in concentration also reflect the varying potential health impacts on the population in each district. Districts with higher NO<sub>2</sub> concentrations, such as Kertapati and Plaju, may be more vulnerable to health issues related to air pollution, such as respiratory disorders, cardiovascular diseases, and impacts on fetal development, which could lead to cases of low birth weight (LBW). On the other hand, districts with lower concentrations, like Jakabaring, may face a lower risk of health problems due to air pollution. Overall, these findings emphasize the importance of prioritizing air pollution control efforts in districts with high NO<sub>2</sub> concentrations in order to reduce the potential negative health impacts on the population, particularly on newborns.

**Map of Low Birth Weight (LBW) Case Distribution in Palembang City for the Year 2019-2022**

Based on the mapping results using the QGIS application, the distribution of low birth weight (LBW) cases in Palembang City for the period 2020–2022 is as follows:

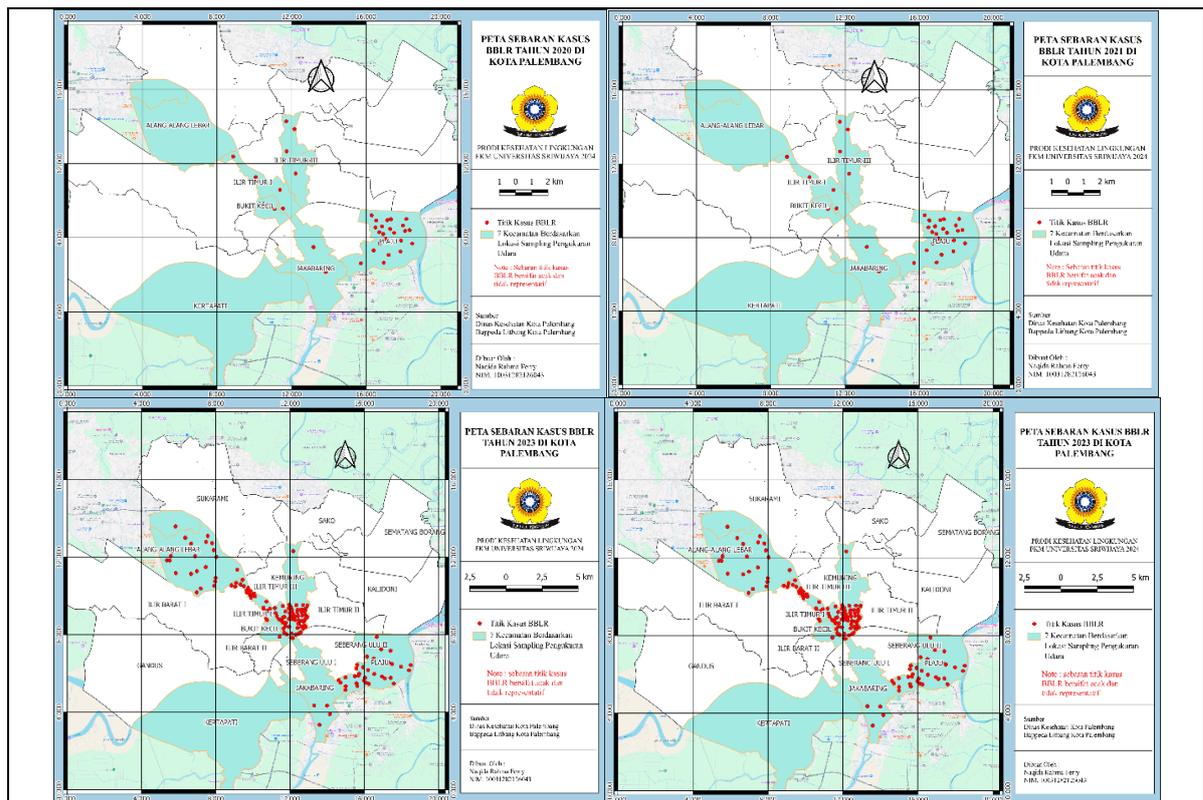
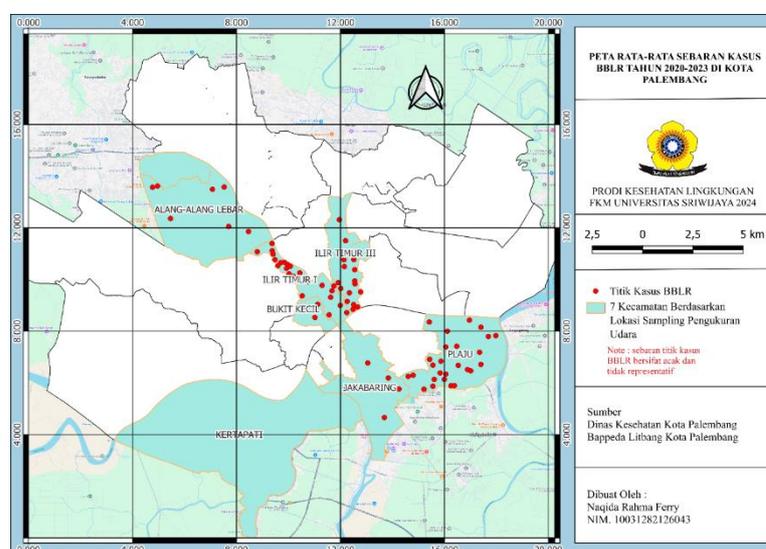


Figure 3. Distribution of LBW Cases from 2020 to 2022

The map in Figure 3 shows the distribution of low birth weight (LBW) cases in Palembang City during the period 2020 to 2022. This map presents the distribution of LBW cases across seven districts, which are also locations for air quality monitoring conducted by the Palembang City Environmental Agency. From the map, it is evident that the Ilir Timur I district has the highest

number of cases, with 58 cases recorded in 2022. This indicates that Ilir Timur I has a higher prevalence of LBW compared to the other districts. In contrast, Kertapati district is recorded as having the lowest number of cases, with no LBW cases reported between 2020 and 2022. This phenomenon could be attributed to various factors, such as differences in healthcare services, socio-economic patterns, or the varying air quality across the districts. The variation in the number of cases may also reflect a relationship between environmental conditions, such as air quality monitored by the Environmental Agency, and the prevalence of LBW in each district. This case distribution provides valuable insight into areas that require more public health intervention, particularly in reducing the LBW rate, and highlights the importance of better air quality management to support maternal and infant health in Palembang City. Meanwhile, the average distribution of LBW cases in Palembang for the 2019-2022 period is as follows:



**Figure 4.** Average Distribution of LBW Cases from 2020-2023

In Figure 4, the average distribution of LBW cases during the period 2020-2023 shows that Ilir Timur I remains the district with the highest number of cases, with an average of 27 cases per year. This further emphasizes the need for more focused strategies in this district to reduce LBW prevalence, through measures such as improving air quality, providing education for pregnant women, and enhancing healthcare facilities to help prevent LBW. Overall, these findings indicate significant variation in the distribution of LBW cases in Palembang City, with some districts experiencing higher prevalence than others. This mapping provides a clear picture of areas that require more attention in efforts to reduce LBW rates, which can be influenced by environmental and other social factors. Further research is needed to explore the relationship between air quality, socio-economic factors, and LBW occurrences.

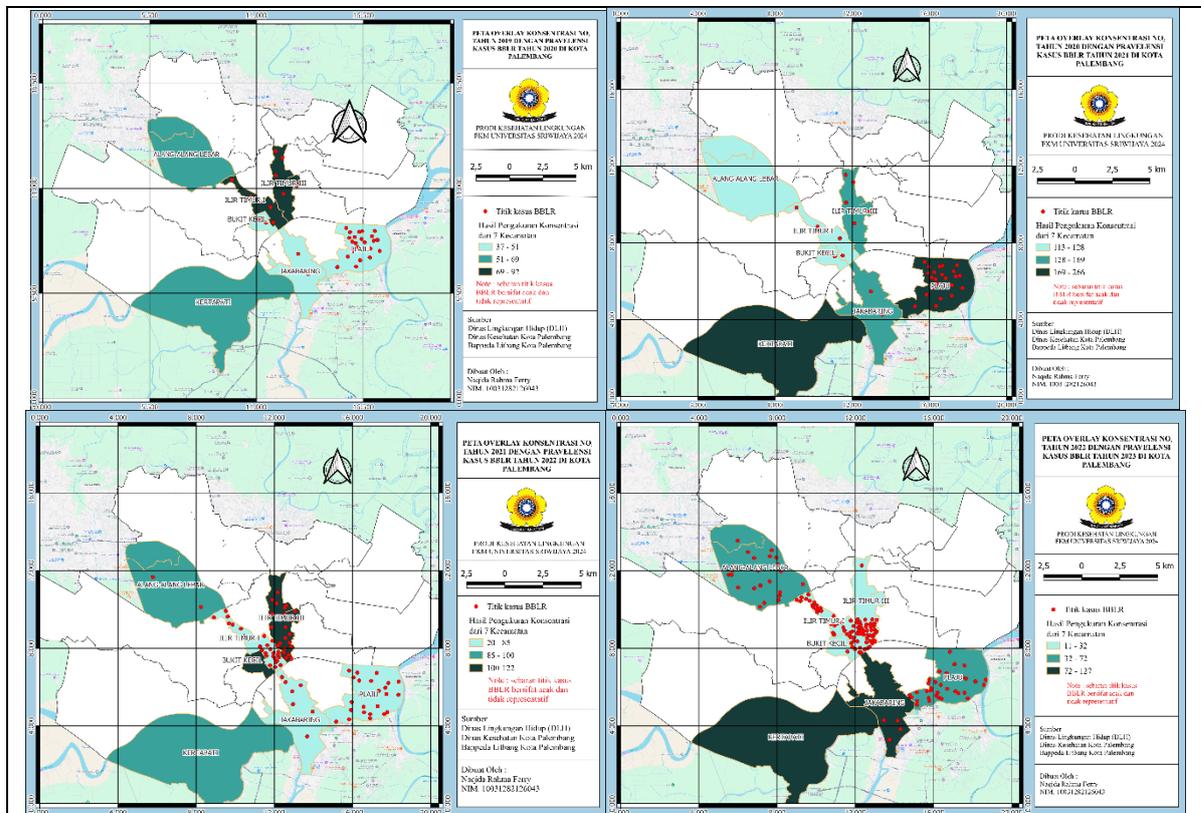
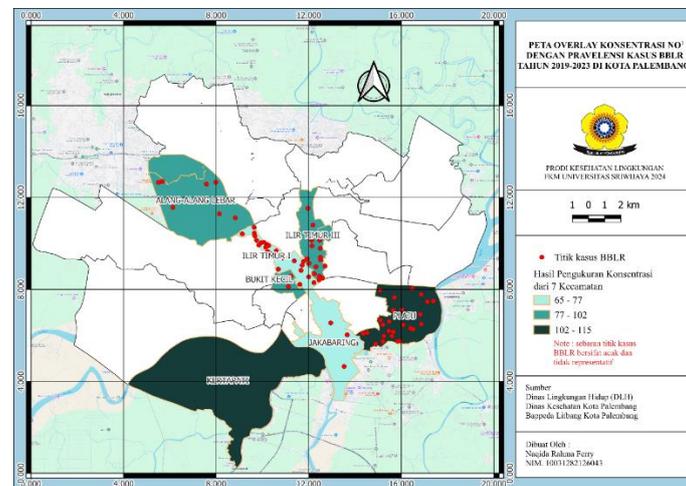


Figure 5. Overlay Map of NO<sub>2</sub> Concentration and LBW Cases from 2019-2023

### Overlay Distribution of Average NO<sub>2</sub> Concentration and LBW Cases from 2019-2023

Based on the mapping results using the QGIS application, the overlay of the NO<sub>2</sub> concentration and the distribution of LBW cases in Palembang City from 2019 to 2023 is as follows:

In Figure 5, which shows the overlay between NO<sub>2</sub> concentration and the distribution of LBW cases in Palembang City from 2019 to 2023, an interesting relationship between air pollution levels and the prevalence of LBW is observed. The Plaju sub-district recorded the highest NO<sub>2</sub> concentration in 2020-2021, with a value of 266  $\mu\text{g}/\text{m}^3/\text{hour}$ , and during this period, a relatively high number of LBW cases were also reported, with 23 cases in 2021. This suggests that areas with high NO<sub>2</sub> concentrations, such as Plaju, tend to experience an increase in LBW cases. The high levels of air pollution may affect the health of pregnant women and fetuses, potentially increasing the risk of LBW. However, interestingly, Ilir Timur I, which had the highest number of LBW cases in 2022-2023 with 58 cases, recorded relatively low NO<sub>2</sub> concentrations, only 17  $\mu\text{g}/\text{m}^3/\text{hour}$ . This indicates that despite the low air pollution in Ilir Timur I, other factors such as social, economic, or access to healthcare facilities may play a more significant role in increasing the number of LBW cases. In other words, while air quality is an important factor, other factors also play a significant role in LBW occurrences. The average Overlay of NO<sub>2</sub> Concentration and LBW Cases from 2019-2023 is as follows:



**Figure 6.** Overlay Map of Average NO<sub>2</sub> Concentration and LBW Cases from 2019-2023

In Figure 6, which shows the average NO<sub>2</sub> concentration and the distribution of LBW cases in Palembang City from 2019 to 2023, Ilir Timur I continues to record the highest average number of LBW cases, with 27 cases per year. However, despite having the highest number of cases, this district has a relatively low NO<sub>2</sub> concentration of 76  $\mu\text{g}/\text{m}^3/\text{hour}$ . On the other hand, Plaju and Kertapati have higher NO<sub>2</sub> concentrations, with an average of 115  $\mu\text{g}/\text{m}^3/\text{hour}$ , but the number of LBW cases in these districts is lower compared to Ilir Timur I. Plaju, with an average of 25 LBW cases, shows that although air pollution is higher, its impact on the LBW rate appears less significant than in Ilir Timur I. From these findings, it can be concluded that while there is a tendency for higher NO<sub>2</sub> concentrations to correlate with an increase in LBW cases, this relationship is not absolute. Other factors, such as maternal health, access to healthcare services, and social and economic factors, also play important roles in determining the prevalence of LBW in each district. Therefore, further research that integrates various other risk factors is crucial to provide a more comprehensive understanding of the causes of LBW in Palembang City.

Based on data from 2020 to 2023, the distribution of BBLR cases in Palembang city has increased, although some sub-districts experienced temporary declines, followed by a surge in the following year. This trend is associated with fluctuations in NO<sub>2</sub> concentrations, which sometimes rise and fall in several sub-districts. Overall, no direct correlation was found between the distribution of BBLR cases and NO<sub>2</sub> concentrations across Palembang city, except in Plaju sub-district during 2020-2021, which recorded the highest NO<sub>2</sub> concentrations and the highest number of BBLR cases among the seven sub-districts studied.

The main causes of BBLR occurrence are related to several factors, including maternal hemoglobin levels, maternal age, parity (the number of previous births), and maternal weight gain during pregnancy. These factors have been found to significantly influence the risk of BBLR in infants (Marlenywati et al., 2015). Other studies have also shown that exposure to air pollution, particularly NO<sub>2</sub>, is closely associated with the occurrence of BBLR, especially during the first and second months of pregnancy (Oktora & Susanna, 2014). Furthermore, maternal conditions such as the presence of diseases (e.g., anemia or malaria), pregnancy age, maternal habits, and environmental factors, including exposure to air pollution, play a significant role in increasing the risk of BBLR. Air pollution, including NO<sub>2</sub>, can directly affect fetal development by disrupting the placenta, which plays a critical role in the pregnancy process (Rahmadani et al., 2022). High exposure to NO<sub>2</sub>, especially during the first trimester, can also increase the risk of premature birth, which in turn raises the likelihood of BBLR (Sarizadeh et al., 2020).

Several studies have shown that air pollution from vehicle emissions, factories, and cigarette smoke can reduce birth weight and cause other health issues in infants (Akmal et al., 2024). Additionally, exposure to NO<sub>2</sub> during early pregnancy has been proven to be one of the main causes of BBLR (Niu et al., 2022). The decline in air quality caused by factors such as traffic congestion, the use of low-quality fuel, and environmental conditions that do not support good air circulation has worsened air quality in Palembang and contributed to the increase in BBLR cases. Overall, although there are fluctuations in NO<sub>2</sub> concentration and the number of BBLR cases, this study emphasizes the importance of controlling air pollution and raising awareness of risk factors that can affect the health of pregnant women and newborns.

## CONCLUSION

Based on the map generated using QGIS, districts with the highest NO<sub>2</sub> concentrations, such as Kertapati and Plaju, have recorded higher levels of air pollution, which may contribute to an increased risk of health problems, including BBLR. On the other hand, districts with lower NO<sub>2</sub> concentrations, such as Jakabaring, show better air quality, but social, economic, and healthcare access factors still play a significant role in the prevalence of BBLR.

The overlay map of NO<sub>2</sub> concentration and BBLR distribution indicates a tendency for higher NO<sub>2</sub> levels to be associated with an increase in BBLR cases, as seen in Plaju District. However, the findings also suggest that other factors, such as maternal health conditions, pregnancy age, and access to healthcare services, also contribute to the prevalence of BBLR. In this case, although air quality is an important factor, its influence on BBLR is not always absolute, and the role of environmental, social, and economic factors must be further considered.

Overall, despite fluctuations in NO<sub>2</sub> concentrations and the distribution of BBLR cases in Palembang, it is crucial to prioritize air pollution control and raise awareness of the risk factors related to maternal health. Further research that incorporates other risk factors is needed to provide a more comprehensive understanding of the causes of BBLR and prevention efforts.

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