



**SPATIAL ANALYSIS OF CARBON MONOXIDE FACTORS ON THE
PREVALENCE OF LOW-BIRTH-WEIGHT INFANTS IN THE CITY OF
PALEMBANG**

Anisah Zalabila*, Dwi Septiawati, Yustini Ardillah, Rahmatillah Razak

Environmental Health Program, Faculty of Public Health, Universitas Sriwijaya, Indralaya, Ogan Ilir, Sumatera Selatan 30662, Indonesia

*anisahzalabilaa@gmail.com

ABSTRACT

Carbon monoxide (CO) exposure has been linked to various health problems, including the risk of low birth weight (LBW) in newborns. Geographic Information Systems (GIS) in the health sector can be a way to collect information to manage health and environmental problems in regional-based environmental management. This study aims to analyze spatially the relationship between ambient CO concentrations and the prevalence of LBW in Palembang. This study used a quantitative approach with an ecological study design. CO concentration data were obtained from the Environmental Agency of Palembang City, while LBW prevalence data were obtained from the Health Office of Palembang City. Spatial and time-series analyses were conducted to examine the serial relationship between pollutant concentration time series data and LBW occurrence time series data during the period of 2019 – 2023. In the 2019-2022 period, the CO concentrations in the city of Palembang showed fluctuating results in each district. The lowest CO concentration was recorded in 2020 at 1984 $\mu\text{g}/\text{Nm}^3/\text{hour}$ and the highest was in 2022 at 13568 $\mu\text{g}/\text{Nm}^3/\text{hour}$. The highest number of LBW cases was 58 babies in 2023, and consistently zero case during the period of 2020-2023 in one district. There is a relationship between CO concentrations in 2021-2022 and LBW occurrences in 2022-2023 in Ilir Timur I district. However, when viewed over a longer period, there is no relationship between the average CO concentration from 2019-2022 and the average LBW prevalence from 2020-2023 in the city of Palembang.

Keywords: CO concentrations; LBW; spatial

How to cite (in APA style)

Zalabila, A., Septiawati, D., Ardillah, Y., & Razak, R. (2024). Spatial Analysis of Carbon Monoxide Factors on the Prevalence of Low-Birth-Weight Infants in the City of Palembang. *Indonesian Journal of Global Health Research*, 6(S5), 725-734. <https://doi.org/10.37287/ijghr.v6iS5.4884>.

INTRODUCTION

Low Birth Weight (LBW) has become a public health issue faced by many countries around the world. Babies born weighing less than 2500 grams regardless of gestational age are one of the criteria for LBW. Survey results from 147 countries showed that globally, 1 in 7 live births suffered from LBW, with nearly half of these cases occurred in South Asia (UNICEF-WHO, 2019). Furthermore, the World Health Organization (WHO) prioritizes LBW as a key outcome indicator in the Global Nutrition Monitoring Framework. Based on the Indonesian Health Profile for the year of 2023 (Kemenkes, 2024), there was an increase in the prevalence of LBW from 2.5% in 2022 to 3.9% in 2023. The province of South Sumatera recorded an incidence of LBW cases amounting to 3387 in 2023, with the city of Palembang accounting for 295 cases of LBW infants. In 2022, the three leading causes of neonatal mortality were asphyxia, LBW, and infections (Dinkes, 2022).

LBW can hinder physical growth and development in children. It can result in lower academic cognitive scores, prevalence of mental disorders, and serious emotional and behavioral problems (Leijon *et al.*, 2016). Pregnant women are among the vulnerable groups because the decrease in their immunity makes any form of action could potentially affect the fetus in the

womb. Risk factors for LBW from the mother include age, prenatal care, nutritional status, anemia, smoking habits, parity, and underlying diseases. Intrauterine Growth Retardation (IUGR) can inhibit the overall growth of the fetus due to the lack of blood and nutrient supply to the fetus through the placenta.

A study of WHO (2022) states that CO gas is produced from the incomplete combustion of carbon fuels, such as wood, gasoline, charcoal, natural gas, and kerosene. Polluted air contributes to 37% of premature deaths due to respiratory and cardiovascular complications. Environmental factors, especially air pollutants such as ozone (O₃), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), hydrocarbons, and particulate matter (PM), have the potential to increase the risk of LBW babies (Sarizadeh *et al.*, 2020). This condition is further exacerbated by the high mobility of vehicles in the metropolitan city of Palembang. In the year of 2019-2022, the average types of vehicles in Palembang included 139017 passenger cars, 796 buses, 21545 trucks, and 380575 motorcycles (BPS, 2024). CO becomes a latent threat because it is undetectable by human senses. Acute CO toxicity during pregnancy causes fetal hypoxia through the formation of carboxyhemoglobin, which inhibits the dissociation of oxygen from hemoglobin and reduces transplacental oxygen transfer (Tuoni *et al.*, 2023).

The Indonesian health profile by the Ministry of Health (2024) states that maternal and child health is one of the targets of the 2020-2024 National Medium-Term Development Plan (RPJMN). LBW can have serious impacts on infant health, including stunting. The national target for 2024 is to reduce the prevalence of stunting to 14%. It is hoped that LBW will no longer be a risk factor for stunting in children in Indonesia. A good quality of prenatal care, especially in the first and third trimesters, is crucial for early identification of various risk factors that can lead to pregnancy complications, such as premature birth and LBW, and hence, appropriate preventive measures can be taken promptly to protect the health of both the mother and the fetus.

Geographic Information System (GIS) in the health sector is useful in enhancing health surveillance. Spatial analysis can become a way to collect information to manage health and environmental issues in an effort to implement area-based environmental management. The incidence data of LBW can be processed into meaningful maps, in this case, capable of presenting the distribution of LBW incidents based on air quality factors, i.e., CO concentration in the city of Palembang. Therefore, this research was aimed to conduct a spatial analysis of the risk factor of CO concentration in ambient air on the prevalence of low-birth-weight infants in the city of Palembang from 2019 to 2023.

METHOD

This study uses ecological study design, a combination of spatial analysis (GIS) and time-series analysis to examine the relationship between the independent variable, i.e., CO concentration, and the dependent variable, i.e., LBW infants. The data used includes birth data of infants from 2020 to 2023 from the Health Office of Palembang City and CO concentration data from 2019 to 2022 from the Environmental Agency of Palembang City through sampling at seven locations representing seven districts. Air sampling was conducted using the active manual method, where an air pump draws air through a collection medium, and then the air sample is analyzed at the Environmental and Land Agency Laboratory of South Sumatra Province using a CO analyzer based on SNI 7119.10-2011, calculation the concentration of CO gas is read directly from the recorder in ppm and can be converted to µg/Nm³/hour. Spatial analysis with overlay techniques in QGIS software will process the data into a distribution map of LBW incidence based on ambient CO concentration.

RESULT

CO Concentration in Ambient Air in the City of Palembang in the Period of 2019-2022

Table 1.

CO concentrations in the period of 2019-2022

| District | CO concentration ($\mu\text{g}/\text{Nm}^3/\text{hour}$) | | | | |
|-------------------|--|-------|-------|-------|---------|
| | 2019 | 2020 | 2021 | 2022 | Average |
| Bukit kecil | 5460 | 1984 | 5649 | 8312 | 5396 |
| Iilir Timur I | 7801 | 6010 | 12816 | 10528 | 9288 |
| Iilir Timur III | 4296 | 3600 | 5563 | 13568 | 6756 |
| Jakabaring | 4178 | 10112 | 8112 | 6704 | 7276 |
| Kertapati | 5408 | 6069 | 10535 | 7342 | 7338 |
| Alang-alang Lebar | 6906 | 6842 | 12994 | 8594 | 8834 |
| Plaju | 2899 | 4804 | 8431 | 6542 | 5668 |

Source: The Environmental Agency of Palembang City

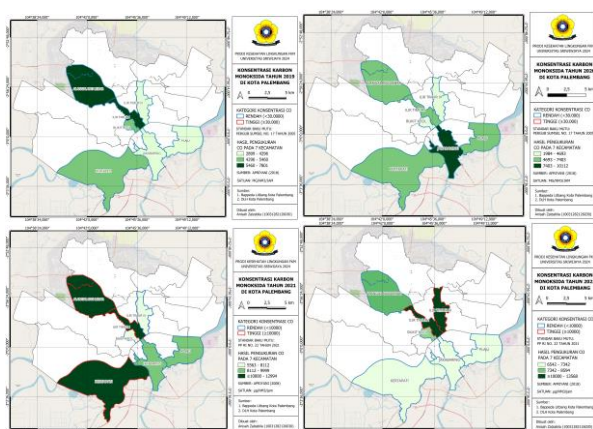


Figure 1. The pattern of CO concentration 2019 – 2022

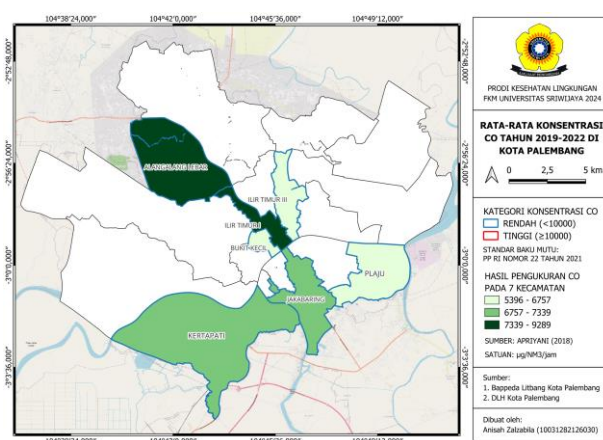


Figure 2. Average CO concentration pattern 2019 – 2022

The mapping of CO concentration from 2019 to 2022 can be seen in Figure 1. The categorization of CO concentration levels in each district is mapped with the help of outlines, where the blue line indicates low CO concentration, and the red line indicates high CO concentration. In 2019, the highest CO concentration was 7801 $\mu\text{g}/\text{Nm}^3/\text{hour}$ in Iilir Timur I District and the lowest was 2899 $\mu\text{g}/\text{Nm}^3/\text{hour}$ in Plaju District. In 2020, the highest CO concentration was 10112 $\mu\text{g}/\text{Nm}^3/\text{hour}$ in Jakabaring District and the lowest was 1984 $\mu\text{g}/\text{Nm}^3/\text{hour}$ in Bukit Kecil District. The categorization of high-low CO concentration is based on the Regulation of the Governor of South Sumatera Province of the Republic of Indonesia No. 17 year 2005, which is 30000 $\mu\text{g}/\text{Nm}^3/\text{hour}$. The map shows that CO concentration in 2019-2020 is still classified as low.

In 2021, the highest CO concentration was 12994 $\mu\text{g}/\text{Nm}^3/\text{hour}$ in Alang-Alang Lebar District, and the lowest was 5563 $\mu\text{g}/\text{Nm}^3/\text{hour}$ in Iilir Timur III District. In 2022, the highest CO concentration was 13568 $\mu\text{g}/\text{Nm}^3/\text{hour}$ in Iilir Timur III District, and the lowest was 6542 $\mu\text{g}/\text{Nm}^3/\text{hour}$ in Plaju District. The CO concentration quality standard is set in the Government Regulation of the Republic of Indonesia No. 22 Year 2021, which is 10000 $\mu\text{g}/\text{Nm}^3/\text{hour}$. Based on the mapping results, the CO concentration in Alang-Alang Lebar District in 2021 and Iilir Timur III District in 2022 has exceeded the quality standard.

Figure 2 above provides a visual representation of the average CO concentration from 2019 to 2022 in the city of Palembang. Areas with light green color indicate that the districts of Bukit

Kecil, Plaju, and Ilir Timur III have CO concentrations in the range of 5396 – 6757 $\mu\text{g}/\text{Nm}^3/\text{hour}$, medium green color includes the districts of Kertapati and Jakabaring with CO concentrations in the range of 6757 – 7339 $\mu\text{g}/\text{Nm}^3/\text{hour}$, and dark green color includes the districts of Alang-Alang Lebar and Ilir Timur I with CO concentrations in the range of 7339 – 9289 $\mu\text{g}/\text{Nm}^3/\text{hour}$. The variation in color within the districts does not reflect standard concentration categories but serves as a tool to compare the relative concentration levels between districts. Based on the Government Regulation of the Republic of Indonesia No. 22 Year 2021, the average CO concentration from 2019 to 2022 in the city of Palembang is still classified as low.

The Prevalence of LBW in the City of Palembang in the Period of 2020-2023

Table 2.
LBW in the periode of 2020 – 2023

| District | Prevalence of LBW | | | | |
|-------------------|-------------------|------|------|------|---------|
| | 2020 | 2021 | 2022 | 2023 | Average |
| Bukit kecil | 4 | 4 | 1 | 2 | 3 |
| Ilir Timur I | 4 | 4 | 27 | 58 | 23 |
| Ilir Timur III | 5 | 5 | 24 | 30 | 16 |
| Jakabaring | 3 | 3 | 8 | 4 | 5 |
| Kertapati | 0 | 0 | 0 | 0 | 0 |
| Alang-alang Lebar | 0 | 0 | 2 | 24 | 7 |
| Plaju | 23 | 23 | 24 | 33 | 26 |

Source: The Health Office of Palembang City

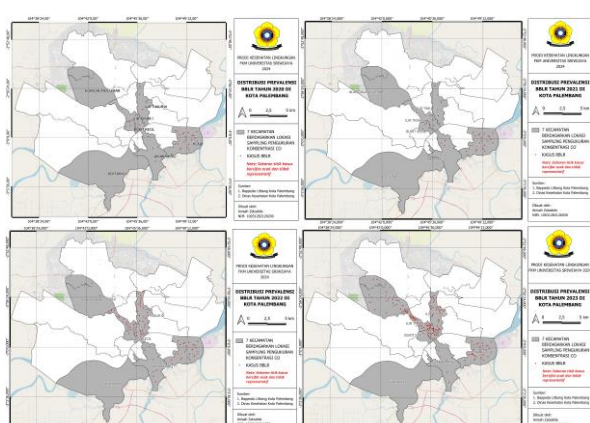


Figure 3. The pattern of LBW 2020 – 2023

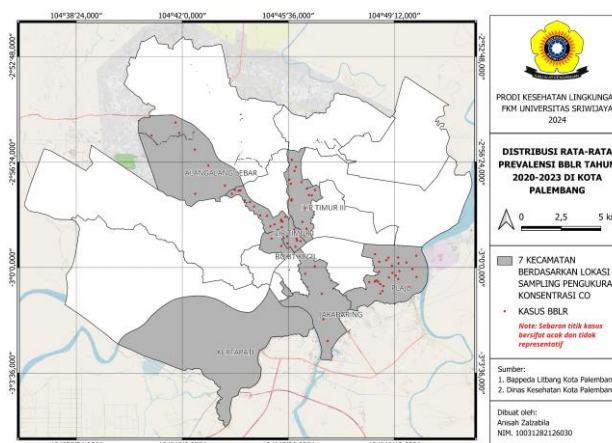


Figure 4. Average LBW pattern 2020 – 2023

Figure 3 presents the distribution pattern of LBW prevalence from 2020 to 2023. The district areas shaded in gray are determined as the main research areas and also serve as the locations for CO concentration data collection. In 2020 and 2021, the highest number of LBW cases was 23 babies in the Plaju District, while the lowest was zero case in Kertapati and Alang-Alang Lebar Districts. In 2022, the highest number of LBW cases was 27 babies in the Ilir Timur I District, while the lowest was zero case in Kertapati District. In 2023, the highest number of LBW cases was 58 babies in the Ilir Timur I District, while the lowest was zero case in Kertapati District. The mapping of the average prevalence of LBW from 2020 to 2023 in the city of Palembang can be seen in Figure 4. Plaju District has the highest average number of LBW with 26 cases, while Kertapati District has the lowest average number of LBW cases with zero case. The visualization of LBW prevalence uses a geospatial method with manual placement of coordinate points. Each red dot represents one case of LBW,

without any categorization of high-low cases.

The Relationship Between CO Concentration and the Incidence of Low Birth Weight in Palembang 2019 – 2023

In general, districts with the highest CO concentration tend to have higher cases of LBW as well. For example, Ilir Timur I District, which has the highest average CO concentration, also recorded the highest number of LBW cases in 2022 and 2023. Plaju District recorded the highest LBW cases in 2020 and 2021, although its CO concentration was not always the highest. Kertapati District consistently records the lowest number of LBW cases. Figure 6 below shows that CO concentration varies significantly between districts in the city of Palembang. The district with an average CO concentration in the range of 7339–9289 $\mu\text{g}/\text{Nm}^3/\text{hour}$, i.e., Ilir Timur I district, has 23 cases of LBW, followed by Alang-Alang Lebar district with seven cases. Jakabaring and Kertapati districts, with five cases and zero case of LBW respectively, have an average CO concentration in the range of 6757–7339 $\mu\text{g}/\text{Nm}^3/\text{hour}$. On the other hand, Plaju and Ilir Timur III districts, with lower CO concentration in the range of 5396–6757 $\mu\text{g}/\text{Nm}^3/\text{hour}$, have a high number of LBW cases, i.e., 26 and 16 cases, respectively.

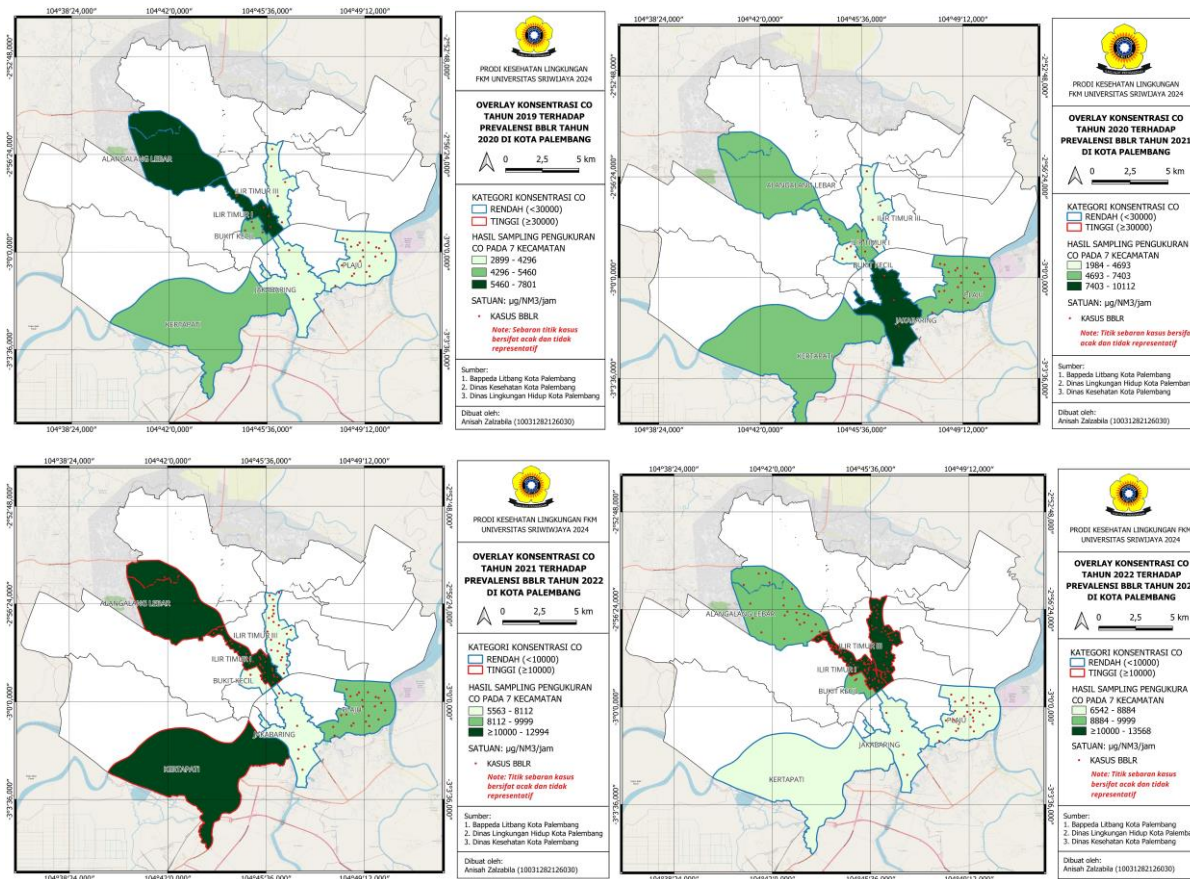


Figure 5. Overlay map of CO concentration and LBW prevalence

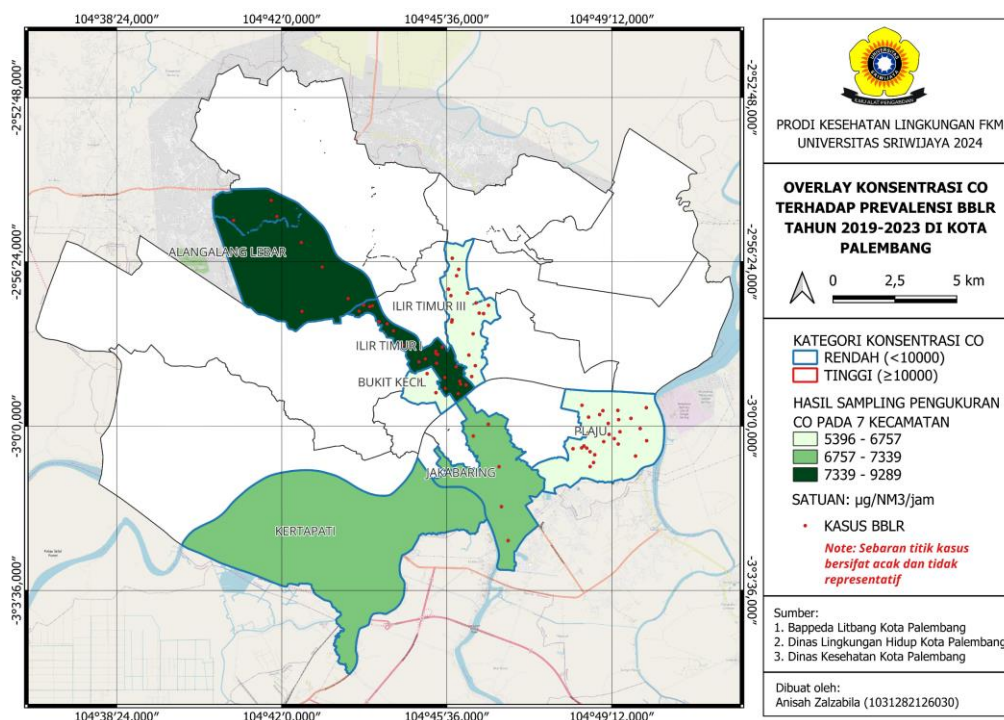


Figure 6. Overlay map of average CO concentration and average LBW prevalence

DISCUSSION

CO Concentration in Ambient Air in The City of Palembang

Spatial mapping shows a complex dynamics of CO concentration, whereby in the same period, each district experiences an increase in CO concentration while other districts experience a decrease. The study conducted by Apriyani and R Suharyadi (2018) divided CO concentration into three categories based on the range of CO concentration values. However, the researchers did not establish standard value limits to determine high, medium, or low categories. Another study that was conducted by Rahmawati (2008) indicate a fairly strong correlation value of 0.663 (r square 0.4402), which suggests that CO gas concentration can be influenced by traffic factors by 44.02% and 55.08% by other factors such as wind, congestion, road networks, and the presence of buildings. The congestion factor is related to mobility activities and vehicle movement. Traffic congestion forces vehicle engines to work harder, consuming 80% more fuel at low RPMs Treiber *et al.* (2008). This condition causes combustion efficiency to decrease and produces more CO gas. Therefore, the more traffic congestion points there are, the higher the level of air pollution due to CO gas emissions (Mansour & Aljamil, 2022). The city of Palembang, which is situated in the altitude of 8 MASML, can influence air pollutants. According to the Copernicus Atmosphere Monitoring Service, European Union's Earth Observation Programme, lower altitude areas tend to have higher pollutant concentrations because warm air containing pollutants tends to rise and accumulate in the lower layers of the atmosphere (Copernicus, 2022).

Based on the analysis by year, a decrease in CO concentration was recorded in 2020 at most sampling points. This indicates a significant influence from the COVID-19 pandemic and the Large-Scale Social Restriction policy implemented during that period based on the Regulation of the Mayor of Palembang Number 14 Year 2020. Meanwhile, data from 2021-2022 shows inconsistent increases and decreases in CO concentration in several districts. This phenomenon occurred despite the ongoing Community Activities Restrictions Enforcement policy, indicating the community's efforts to adapt to the new situation. The result of analysis that was performed based on the sampling location shows that the intersection of the South

Sumatera Regional Police Office in the Ilir Timur I district had a relatively higher CO concentration level compared to other districts. This is not unrelated to the geographical conditions of the area, especially the presence of the main intersection connecting Jalan Demang Lebar Daun and Jalan Jenderal Sudirman, as well as the flyover on Jalan Lintas Sumatera. Conversely, the average CO concentration measurements in the Bukit Kecil District are relatively lower compared to other areas. The presence of vegetation such as trees along several sections of Jalan Merdeka and the green area of Kambang Iwak Park (< 2 kilometers) near the sampling points is suspected to contribute to these conditions. A study by Uka *et al.* (2019) shows that trees along the roadside act as natural filters. Through the stomata on their leaves, they absorb and store various types of air pollutants present in the surrounding environment. The physical, chemical, and functional changes in these plants are responses to the exposure to those pollutants.

The Prevalence of LBW in The City of Palembang

Based on WHO standards, babies born weighing less than 2500 grams are categorized as LBW babies. Analysis of LBW prevalence data in 2020-2021 in the city of Palembang shows a relatively stable or homogeneous pattern. However, it should be noted that this period coincided with the COVID-19 pandemic. The main focus of the local government, particularly the Health Office of Palembang City, was diverted to handling the COVID-19 pandemic. Analysis of data from 2022-2023 revealed a striking disparity in the number of LBW cases across various working areas of community health centers. Some areas recorded a very high number of cases, while other areas reported no new cases at all.

The prevalence of LBW infants is influenced by various determinants, including maternal, fetal, and environmental factors. Although antenatal visits are not a direct factor causing LBW in fetuses, regular and good quality check-ups can help prevent the occurrence of LBW. The success of increasing antenatal visits is greatly influenced by the initiatives and active efforts of community health centers in each region. For example, the Kertapati Public Health Center in Palembang City has successfully implemented an innovative program called Ki Merogan (Monitoring Pregnant Women at Risk of Malnutrition and Anemia) that focuses on preventing malnutrition and anemia in pregnant women. This program has had a significant impact, i.e., achieving optimal health for mothers and fetuses. The tangible evidence of the success of this program is the absence of LBW cases in the period of 2020 to 2023.

The prevalence of LBW infants in several sub-districts of the city of Palembang, which is relatively higher, can be caused by a number of conditions in pregnant women. According to Kepley *et al.* (2023), pregnancy brings significant physiological changes to a woman's body, including increased respiratory rate, blood volume, and metabolic changes. These changes can increase the absorption of chemicals through the lungs and digestive tract, as well as affect the way the body processes and excretes these chemicals. As a result, pregnant women become more vulnerable to the toxic effects of chemicals. A study by Herwanto *et al.* (2024) shows the risk of giving birth to LBW babies, including extreme maternal age, anemia, high blood pressure during pregnancy (preeclampsia), low amniotic fluid volume (oligohydramnios), premature rupture of membranes (PPROM), and a history of miscarriage in previous pregnancies. In addition, malnutrition in pregnant women can cause various complications in newborns, including LBW and stunted growth (Gala *et al.*, 2016).

The Relationship Between CO Concentration and the Incidence of Low Birth Weight

The environment is one of the risk factors for health problems. The concentration of air pollutants serves as a clear indicator that the air quality is beginning to degrade. There are

three studies Jia *et al.* (2020); (Khamirchi *et al.*, 2020; Šrám *et al.*, 2005) that show that exposure to outdoor air pollution during pregnancy has been linked to fetal development issues, premature birth, and pregnancy complications, including pregnancy-induced hypertension disorders. District areas in the city of Palembang with relatively higher CO concentration levels show a not-so-strong correlation with the increase of LBW cases in infants. An experimental study by Venditti *et al.* (2011) indicates that there are other factors that play a more significant role, such as exposure levels.

CO gas is colorless, odorless, and tasteless. The inability of human senses to detect the presence of CO makes it a serious threat to human health. Studies conducted by Balogun *et al.* (2020); (Quinn *et al.*, 2021; Rizaldi *et al.*, 2022) show that environmental risk factors of CO exposure are associated with the incidence of LBW infants. Although the incidence of CO poisoning during pregnancy is relatively low, its impact on morbidity and mortality is very significant. The maternal and fetal mortality rates due to acute CO poisoning during pregnancy show significant variability, ranges from 19-24% and 36-67%, respectively. This variability is influenced by several factors, including the severity of the poisoning and the gestational age (Friedman *et al.*, 2015). The high affinity of CO for hemoglobin causes a reduction in the blood's oxygen-carrying capacity. An increase in carboxyhemoglobin (COHb) levels in pregnant women will inhibit the release of oxygen from hemoglobin and reduce the transport of oxygen across the placenta. The increase in metabolism at the end of the first trimester of pregnancy triggers excessive production of reactive oxygen species (ROS) in the placenta. The accumulation of ROS induces oxidative stress, which can damage the structure and function of the placenta, thereby hindering the transfer of oxygen and nutrients to the fetus.

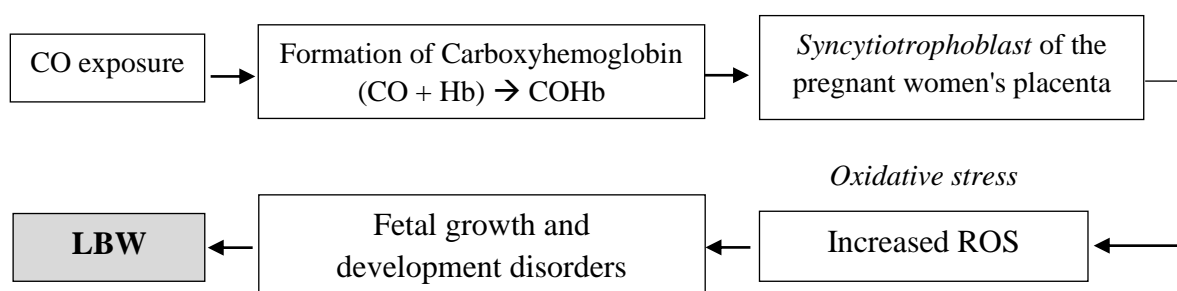


Figure 7. The process of CO exposure on the incidence of LBW
Sources: Tuoni *et al.* (2023), Grzeszczak *et al.* (2023), Jauniaux *et al.* (2006)

In urban areas, exposure to air pollution is unavoidable. Air, as an environmental medium that constantly interacts with human, can pose a serious threat to the health of vulnerable groups, such as pregnant women. The biological mechanisms underlying CO exposure in pregnant women support the interpretation of this study's results, although they are estimative in nature. Nevertheless, further research is needed to confirm these findings and to identify the underlying biological mechanisms more specifically. Pregnant women residing in areas with high CO concentrations face significant risks of various health complications. As a mitigation effort, it is recommended to undergo regular prenatal check-ups, consume a balanced diet rich in nutrients, limit outdoor activities during peak traffic hours, and use masks as an additional protective measure.

CONCLUSION

Spatial and time-series analysis shows the relationship between CO concentration in 2021-2022 and the incidence of LBW in 2022-2023 in Ilir Timur I District. However, when viewed

over a longer period, no relationship is found between the average CO concentration from 2019-2022 and the average prevalence of LBW from 2020-2023 in the city of Palembang.

REFERENCES

- Apriyani, S., & R Suharyadi, R. S. (2018). Pemanfaatan Penginderaan Jauh dan Sistem Informasi Geografi untuk Pemodelan Spasial Potensi Karbon Monoksida (CO) Ambien (Studi Kasus: Kecamatan Ngampilan dan Gondomanan. *Jurnal Bumi Indonesia*, 7(1).
- Balogun, H. A., Rantala, A. K., Antikainen, H., Siddika, N., Amegah, A. K., Ryti, N. R. I., Kukkonen, J., Sofiev, M., Jaakkola, M. S., & Jaakkola, J. J. K. (2020). Effects of Air Pollution on The Risk of Low Birth Weight in a Cold Climate. *Applied Sciences*, 10, 1-18, Article 18.
- BPS. (2024). *Jumlah Kendaraan Bermotor Menurut Jenis Kendaraan 2019-2022*.
- Copernicus. (2022). *Cool, dry conditions favour high pollution levels: your CAMS guide to winter's air quality issues*. European Union's Earth Observations Programme.
- Dinkes. (2022). *Profil Dinas Kesehatan Kota Palembang*.
- Friedman, P., Guo, X. M., Stiller, R. J., & Laifer, S. A. (2015, Nov). Carbon Monoxide Exposure During Pregnancy. *Obstet Gynecol Surv*, 70(11), 705-712. <https://doi.org/10.1097/ogx.0000000000000238>
- Gala, U. M., Godhia, M. L., & Nandanwar, Y. S. (2016). Effect of maternal nutritional status on birth outcome. *Int J Adv Nutr Health Sci*, 4(2), 226-233.
- Grzeszczak, K., Łanocha-Arendarczyk, N., Malinowski, W., Ziętek, P., & Kosik-Bogacka, D. (2023, Dec 9). Oxidative Stress in Pregnancy. *Biomolecules*, 13(12). <https://doi.org/10.3390/biom13121768>
- Herwanto, E. S., Hudiyanto, P. S., & Muhammad, I. (2024). Factors of Maternal Influence on Low Birth Weight. *Asian Journal of Health Research*, 3(1), 5-10.
- Jauniaux, E., Poston, L., & Burton, G. J. (2006). Placental-related diseases of pregnancy: involvement of oxidative stress and implications in human evolution. *Human reproduction update*, 12(6), 747-755.
- Jia, L., Liu, Q., Hou, H., Guo, G., Zhang, T., Fan, S., & Wang, L. (2020). Association of Ambient air Pollution with risk of preeclampsia during pregnancy: a retrospective cohort study. *BMC Public Health*, 20(1), 1663.
- Kemenkes. (2024). *Profil Kesehatan Indonesia Tahun 2023*.
- Kepley, J. M., Bates, K., & Mohiuddin., S. S. (2023). *Physiology, Maternal Changes*. StatPearls Publishing.
- Khamirchi, R., Moslem, A., Agah, J., Pozo, Ó. J., Miri, M., & Dadvand, P. (2020). Maternal exposure to air pollution during pregnancy and cortisol level in cord blood. *Science of The Total Environment*, 713, 136622.
- Leijon, I., Ingemansson, F., Nelson, N., Wadsby, M., & Samuelsson, S. (2016, Jan). Reading deficits in very low birthweight children are associated with vocabulary and attention issues at the age of seven. *Acta Paediatr*, 105(1), 60-68. <https://doi.org/10.1111/apa.13094>

- Mansour, A. I., & Aljamil, H. A. (2022). Investigating the effect of traffic flow on pollution, noise for urban road network. IOP Conference Series: Earth and Environmental Science,
- Quinn, A. K., Adjei, I. A., Ae-Ngibise, K. A., Agyei, O., Boamah-Kaali, E. A., Burkart, K., Carrión, D., Chillrud, S. N., Gould, C. F., Gyaase, S., Jack, D. W., Kaali, S., Kinney, P. L., Lee, A. G., Mujtaba, M. N., Oppong, F. B., Owusu-Agyei, S., Yawson, A., Wylie, B. J., & Asante, K. P. (2021, Oct). Prenatal Household Air Pollutant Exposure is Associated with Reduced Size and Gestational Age at Birth Among a Cohort of Ghanaian Infants. *Environ Int*, 155, 106659. <https://doi.org/10.1016/j.envint.2021.106659>
- Rahmawati, N. (2008). *Pola Spasial Konsentrasi Gas Karbon Monoksida (CO) di Kota Jakarta Universitas Indonesia*. Depok.
- Rizaldi, M. A., Azizah, R., Latif, M. T., Sulistyorini, L., & Salindra, B. P. (2022, 2022-10-16). Literature Review: Dampak Paparan Gas Karbon Monoksida Terhadap Kesehatan Masyarakat yang Rentan dan Berisiko Tinggi [Karbon Monoksida; Paparan; Kesehatan]. 2022, 21(3), 13. <https://doi.org/10.14710/jkli.21.3.253-265>
- Sarizadeh, R., Dastoorpoor, M., Goudarzi, G., & Simbar, M. (2020). The Association Between Air Pollution and Low Birth Weight and Preterm Labor in Ahvaz, Iran. *Int J Womens Health*, 12, 313-325. <https://doi.org/10.2147/ijwh.S227049>
- Šrám, R. J., Binková, B., Dejmek, J., & Bobak, M. (2005). Ambient air pollution and pregnancy outcomes: a review of the literature. *Environmental health perspectives*, 113(4), 375-382.
- Treiber, M., Kesting, A., & Thiemann, C. (2008). How much does traffic congestion increase fuel consumption and emissions? Applying a fuel consumption model to the NGSIM trajectory data. 87th Annual Meeting of the Transportation Research Board, Washington, DC,
- Tuoni, C., Nuzzi, G., Scaramuzzo, R. T., Fiori, S., & Filippi, L. (2023, 2023-November-03). Neonatal hypoxic-ischemic encephalopathy after acute carbon monoxide intoxication during pregnancy. A case report and brief review of the literature [Case Report]. *Frontiers in Pediatrics*, 11. <https://doi.org/10.3389/fped.2023.1264855>
- Uka, U. N., Belford, E. J. D., & Hogarh, J. N. (2019, 2019/06/07). Roadside air pollution in a tropical city: physiological and biochemical response from trees. *Bulletin of the National Research Centre*, 43(1), 90. <https://doi.org/10.1186/s42269-019-0117-7>
- UNICEF-WHO. (2019). *Low Birthweight Estimates Levels and trends 2000–2015*.
- Venditti, C. C., Casselman, R., & Smith, G. N. (2011, 2011/12/14). Effects of chronic carbon monoxide exposure on fetal growth and development in mice. *BMC Pregnancy and Childbirth*, 11(1), 101. <https://doi.org/10.1186/1471-2393-11-101>
- WHO. (2022). *Ambient (outdoor) Air Pollution*. World Health Organization. Retrieved 5 Mei from [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)