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Correlation Analysis Between Vehicle Number and Meteorological Factors on Carbon Dioxide Concentration at Bojonegoro University

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Abstract

The Bojonegoro University Campus area has a high level of vehicle traffic every hour, which makes it one of the locations where air pollution spreads. Bojonegoro University always has vehicle activities such as motorbikes and employee and student cars. This allows for increased exposure to CO2 ambient air pollutants around campus. The number of vehicles and meteorological conditions such as air humidity, temperature, and wind speed can influence air quality. The quality of the outside air is influenced by the large number of motorized vehicle activities and meteorology, which causes the spread of air pollution at Bojonegoro University. Air quality that exceeds quality standards impacts health, such as respiratory problems. The research method used is a quantitative descriptive approach. Based on the measurement results, the CO2 concentration is included in the polluted air category, namely in the range 403 - 514 ppm, while the quality standard set by WHO is 350-700 ppm. The influence between CO2 concentration and the number of motorized vehicles has a positive correlation value with a coefficient of 0.825. The impact of CO2 concentration on meteorological conditions includes temperature, air humidity, and wind speed. The correlation coefficient values for temperature, humidity, and wind speed are 0.825, -0.820, and -0.882. Therefore, the number of vehicles and meteorological conditions strongly correlate with CO2 concentrations in the ambient air.

Keywords*: Correlation; CO_2; meteorology; number of vehicles*

INTRODUCTION

Transportation is a basic or essential need for urban communities, but it impacts the production of CO_2 gas and air emissions (Permatasari et al., 2021). An increase in CO_2 gas emissions will accompany the rise in motorized vehicles. Situations like this cause air pollution to get worse. The effects of air pollution are now being felt; many diseases are caused by air problems, for example, the

increase in acute respiratory infections and the increase in people aging prematurely (Tampa et al., 2019). Apart from the effects on health, there are also adverse effects on the environment. Excess concentrations of CO_2 in the atmosphere can also cause an increase in air temperature on earth. High concentrations of greenhouse gases will reflect heat to the planet, increasing the earth's temperature and causing global warming (Winatama et al., 2023).

Bojonegoro University has a high vehicle traffic density every hour, essential in spreading air pollution. Initial observation results show this location has a high vehicle traffic density, especially in the morning. Every day, Bojonegoro University is a location with dense motor vehicle activity for students, lecturers, and employees, including motorbikes and cars. This condition increases the concentration of the ambient air pollutant CO_2 around the campus. Vehicle traffic and meteorological conditions such as air temperature, humidity, and wind speed are some factors that can influence air quality. As the number of vehicles increases, air pollution increases. This occurs because vehicles cause an increase in CO_2 air pollutants in the ambient air (Vandyck et al., 2020). In this way, it is essential to know the CO_2 concentration and the correlation between the number of motorized vehicles and meteorological conditions at Bojonegoro University to monitor air quality. This is because a university must provide an environment free of air pollution so that activities at that location run well and do not impact health.

MATERIALS AND METHODS

The research was carried out in October-November 2024 at the entrance and exit gates of Bojonegoro University. Sampling by SNI 19-7119.6-2005: determining sampling locations for air quality monitoring tests.
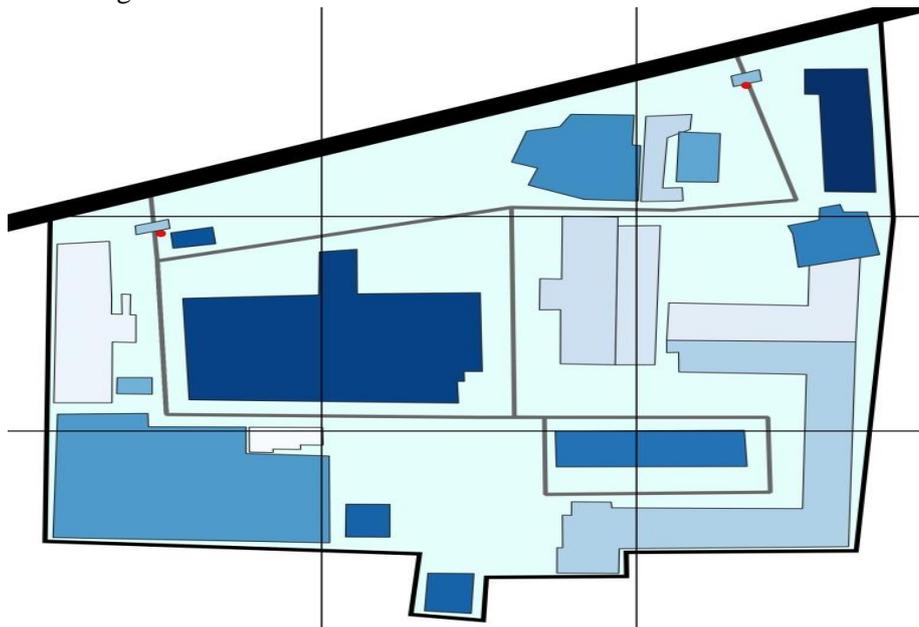

Figure 1. Sampling Point at Bojonegoro University.

Sampling time is 60 minutes in the morning, afternoon, and evening on weekdays and weekends. This time is adjusted to peak motor vehicle activity hours. The sampling tool uses a Lutron and anemometer. Lutron is used to sample CO_2 concentrations, and an anemometer is used to determine meteorological conditions. Meteorological data includes temperature, wind speed, and humidity. Manual hand counting is used to count the number of motorized vehicles. CO_2 concentration sampling results were analyzed at the Environmental Science Laboratory, Bojonegoro University. The method used is univariate data analysis, which looks at the value of the research variable, namely the

carbon dioxide (CO_2) parameter. Next, the sampling results will be compared with air quality standards according to WHO standards. Namely, the CO_2 concentration for clean air is 310-330 ppm, while for polluted air, it is 350-700 ppm. The use of WHO standards is because no specific standards regulate CO_2 concentrations in ambient air in regulations or standards in Indonesia. The results of statistical tests using SPSS software show the influence of the number of vehicles and meteorological conditions on the CO_2 concentration in the ambient air at Bojonegoro University. Interpreting the correlation coefficient results for each variable can determine the level of correlation.

Table 1. Interpretation of Correlation Coefficient

Coefficient Interval	Correlation level
0.00 – 0.199	Very low
0.20 – 0.399	Low
0.40 – 0.599	Medium
0.60 – 0.799	Strong
0.80 – 1.00	Very strong

RESULTS AND DISCUSSION
Number of Vehicles, Meteorological Conditions, and CO_2 Concentration

Bojonegoro University is a location with heavy motor vehicle activity. Motorized vehicle activities have the potential to produce air pollutants, one of which is CO_2 gas. Carbon dioxide (CO_2) is the primary pollutant in motor vehicle exhaust gas. An increase in CO_2 gas emissions will accompany the increase in motorized vehicles. This situation causes worsening air quality in that location. The number of vehicles entering and exiting Bojonegoro University, meteorological conditions (temperature, humidity, and wind speed), and CO_2 concentrations at Bojonegoro University can be seen in Table 2.

Table 2. Number of Vehicles, Meteorological Conditions, and CO_2 Concentration at Bojonegoro University

Day and Date	Time	Meteorology			Number of Vehicles				CO₂ Concentration (ppm)
		Temperature (°C)	Humidity (%RH)	Wind Speed (m/s)	Motorcycle		Car		
					Entry Gate	Exit Gate	Entry Gate	Exit Gate	
Monday, October 28, 2024	Morning	37.43	45.4	2.6	594	31	26	10	437
	Afternoon	45.77	27.88	0.5	229	412	13	18	467
	Evening	34.33	51.6	3.6	102	280	15	19	432
Tuesday, October 29, 2024	Morning	33.73	48.8	3.0	360	35	16	7	435
	Afternoon	39.83	33.45	0.5	245	440	9	14	489
	Evening	36.32	46.13	2.9	82	409	7	27	436
Wednesday, October 30, 2024	Morning	37.78	44.83	2.4	594	31	26	10	446
	Afternoon	39.03	38.23	1.6	229	412	13	18	454
	Evening	33.93	52.82	3.93	102	280	15	19	428
Thursday, October 31, 2024	Morning	32.87	56.47	3.8	330	21	12	6	425
	Afternoon	40.15	37.5	0.5	316	392	11	29	514
	Evening	29.85	71.78	4.9	45	154	8	16	412
Friday, November 1, 2024	Morning	32.07	59.07	4.2	313	22	13	7	420
	Afternoon	31.2	76	4.5	141	67	23	6	412
	Evening	31	67.73	4.5	35	180	18	60	415
Saturday, November 2, 2024	Morning	27	80.17	5.4	147	16	9	2	411
	Afternoon	32.07	63.13	4.3	99	172	21	56	418
	Evening	25.53	90.02	8.15	28	66	7	6	403

Based on Table 2, meteorological conditions during sampling in the morning, afternoon, and evening of the first to sixth sampling days differed. Differences or variations in meteorological conditions are influenced by time solar radiation. The difference in the number of motorized vehicles at Bojonegoro University is also depicted in Table 1. The difference in the number of motorized vehicles is influenced by the effective days of teaching and learning activities, lecture hours, student extra-curricular activities, and other supporting activities. Based on tests, it is known that on effective teaching and learning days (Monday to Thursday), the number of motorized vehicles at Bojonegoro University is more significant than on Friday and Saturday. The number of motorized vehicles from Monday to Saturday included 1,649 units, 1,651 units, 1,748 units, 1,340 units, 885 units, and 647 units. The number of vehicles influences the presence of CO_2 pollutants in the ambient air.

CO_2 concentration measurement uses the direct reading method (real-time sampling). Real-time describes precisely what is happening at the time of sampling. The CO_2 concentration on the Bojonegoro University campus generally exceeds the quality standards set by WHO; clean air has a CO_2 concentration in the air of 310-330 ppm. The CO_2 concentration at Bojonegoro University is between 403 and 514 ppm. This figure has exceeded WHO quality standards, which illustrates that air quality, especially CO_2, no longer meets the requirements on weekdays and weekends. The highest CO_2 concentration occurred on Thursday at noon, reaching 514 ppm. The high concentration of CO_2 is influenced by motor vehicle activity on weekdays and holidays. Motorized vehicles are a basic need for society, but they impact the presence of CO_2 gas emissions in the ambient air (Permatasari et al., 2021). Increased motorized vehicles will generally be accompanied by increased CO_2 exhaust emissions in the ambient air (Sudarti et al., 2022). This causes the CO_2 concentration on the Bojonegoro University Campus to increase along with the number of motorized vehicles operating there. High concentrations of CO_2 in the air can cause health problems, such as increasing the incidence of ISPA (Pinontoan & Sumampouw, 2019). In addition, excess CO_2 in the air can increase the air temperature on the face of the earth. This is because CO_2 is a greenhouse gas, which, in high concentrations, can reflect its heat to the earth, increasing the earth's temperature and causing global warming (Vandyck et al., 2020).

CO_2 Concentration on Air Quality Standards

Improving the quality of human life and advancing science and technology have increased people's interest in pursuing education. In this way, the mobilization of activities in the educational environment is increasing, one of which is Bojonegoro University. Increased mobilization is, of course, correlated with an increase in the volume of motorized vehicles. In this way, it indirectly impacts the concentration of ambient air pollutants. Indonesia's ambient air quality standards do not explicitly regulate CO_2 concentrations in ambient air. The CO_2 concentration standard approach used as a reference in this research is the clean air standard according to WHO, 310 - 330 ppm, and for polluted air, 350 - 700 ppm. The results of CO_2 concentration measurements at Bojonegoro University from Monday to Saturday can be seen in Figure 2.
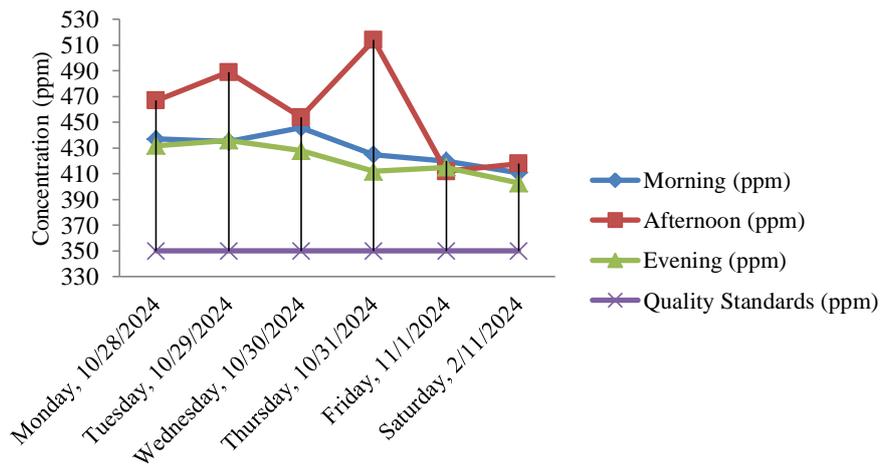
Figure 2. CO_2 concentration at Bojonegoro University.

Figure 2 shows that the CO_2 concentration processed has exceeded the quality standards set by WHO. This concentration indicates that the air quality status on the Bojonegoro University Campus is already in the polluted air range, namely between 350 – 700 ppm. High CO_2 concentrations can cause environmental and public health problems. The presence of excess CO_2 in the atmosphere can cause an increase in the earth's temperature and cause global warming (Vandyck et al., 2020). This happens because greenhouse gases, including CO_2, in the atmosphere will reflect heat to the earth, causing the earth's temperature to increase. Increasing CO_2 concentrations in the environment can disrupt metabolic processes and plant growth. Increasing CO_2 concentrations in the air can increase the rate of photosynthesis by 30-100%, depending on temperature and humidity conditions (Jamloki et al., 2021). In this way, it causes the accumulation of carbohydrates and reduces the rate of plant respiration, reducing the energy plants need to survive.

The presence of CO_2 in the air at high concentrations can affect the quality of public health. Based on the United States National Institute for Occupational Health and Safety (NIOSH) explanation, carbon dioxide (CO_2) is an air pollution gas that is not toxic and does not directly impact human health. However, over time, people exposed to CO_2 can reduce heart performance. At a CO_2 concentration of 3%, CO_2 is a mild narcotic and causes an increase in blood pressure and pulse rate, reducing hearing ability. A concentration of 5% CO_2 in the ambient air can affect the ability of respiratory center stimulation, causing dizziness, confusion, difficulty breathing, headaches, and shortness of breath. Meanwhile, a CO_2 concentration of 8% in ambient air can cause headaches, sweating, blurred vision, tremors, and loss of consciousness after exposure to CO_2 for 5-10 minutes (Anggraini et al., 2024).

Correlation of CO_2 Concentration, Meteorological Conditions, and Number of Vehicles

The CO_2 concentration at Bojonegoro University fluctuates quite a lot every day. Fluctuations in CO_2 concentration are influenced by meteorological factors, pollutant sources (number of motorized vehicles), and weather. Table 3 shows a strong relationship between the number of vehicles, meteorological conditions, temperature, humidity, wind speed, and the CO_2 concentration in the ambient air.

Table 3. Correlation of CO_2 Concentration, Meteorological Conditions, and Number of Vehicles

Meteorological Conditions	CO_2 Concentration
Temperature	0.825
Humidity	-0.820
Wind velocity	-0.882
Number of Vehicles	0.825

The closer the value is to 1, the stronger the correlation, and the smaller or closer to the value of 0, the weaker the correlation (Sugiyono, 2022). Correlation coefficient values with a negative sign (-) indicate the relationship is negative; if the X value increases, the Y value will decrease or vice versa. The correlation coefficient is positive (+), indicating that the relationship is positive, meaning that when the X value increases, the Y value also increases (Riduan, 2010). The correlation between CO_2 concentration (ppm) and temperature (°C) has a coefficient of 0.825. This correlation coefficient figure shows the correlation between CO_2 concentration (ppm) and temperature is strong and positive. The correlation between CO_2 concentration and temperature can be seen in Figure 3.
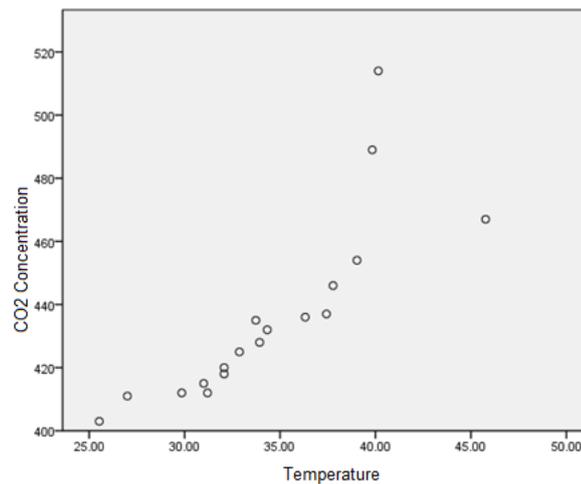

Figure 3. Correlation of CO_2 Concentration with Temperature.

Based on Figure 3, it can be seen that when the temperature increases, there will also be an increase in the concentration of CO_2 in the air. The highest air temperature occurred on Thursday afternoon, reaching 40.15°C, with the highest CO_2 concentration, 516 ppm. In contrast, the lowest air temperature occurred on Saturday afternoon at 25.53°C, with the lowest CO_2 concentration at 403 ppm. This is based on research by Laoh, dkk., (2024), which states a straightforward and directly proportional relationship between CO_2 concentration and ambient air temperature. The intensity of radiation influences the high air temperature. The higher the intensity of solar radiation a surface receives, the higher the air temperature it produces. The correlation between CO_2 concentration (ppm) and air humidity (% RH) has a coefficient of -0.820. This value shows strong and negative correlations between CO_2 concentration and air humidity. The correlation between CO_2 concentration and air humidity can be seen in Figure 4.
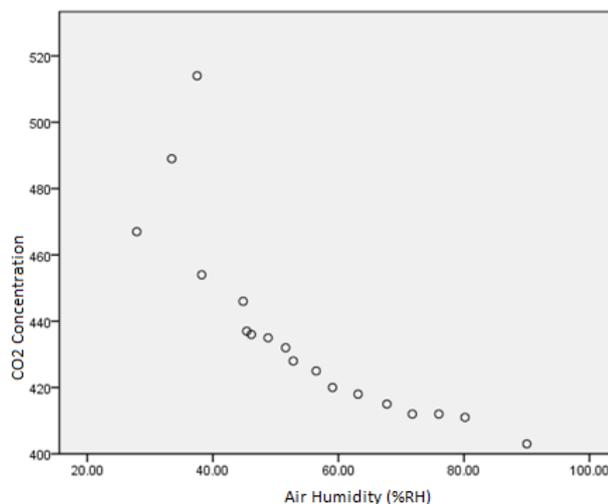
Figure 4. Correlation of CO_2 Concentration with Air Humidity.

Based on Figure 4, it can be seen that the correlation between CO_2 concentration and air humidity is powerful but negative. This means that when air humidity increases, the CO_2 concentration will decrease (Laoh et al., 2024). The lowest air humidity was on Monday afternoon, namely 27.88% RH, with the CO_2 concentration in the air relatively high, reaching 467 ppm. Minimum air humidity occurs on Saturday afternoon, namely 90.02% RH, with the lowest CO_2 concentration in the air, 403 ppm. High air temperatures cause low air humidity, meaning the amount of water vapor in the air is low. Therefore, when the air humidity is relatively low, the air is dry, so sources of pollutants are easily lifted and float in the free air. That way, humans are more easily exposed to pollutants, which increases the CO_2 concentration value in the air. The correlation between CO_2 concentration (ppm) and wind speed (m/s) has a coefficient of -0.882. This value shows strong and negative correlations between CO_2 concentration and wind speed. The correlation between CO_2 concentration and wind speed can be seen in Figure 5.
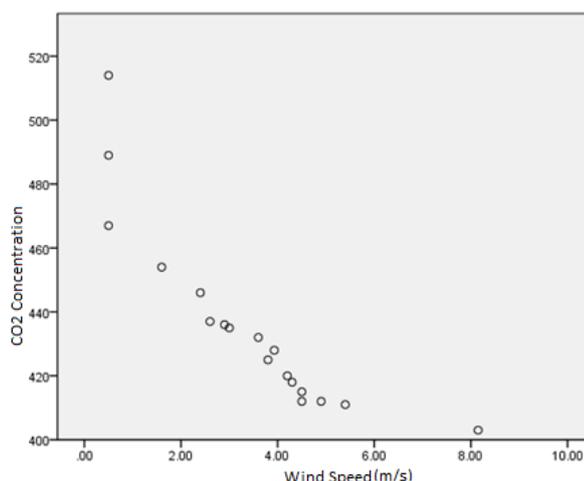

Figure 5. Correlation of CO_2 Concentration with Wind Speed.

Based on Figure 5, it can be seen that the correlation between CO_2 concentration and wind speed is powerful but negative. This means that when the wind speed increases, the CO_2 concentration in the air will decrease, and vice versa. If the wind speed decreases, the CO_2 concentration in the air will increase. Increasing wind speed causes a decrease in CO_2 concentration by 83% (Laoh et al.,

2024). For example, on Tuesday afternoon, Thursday afternoon, and Monday afternoon, with a low wind speed of 0.5 m/s, the CO_2 concentration in the ambient air is the highest compared to other days, namely in the 460-514 ppm range. Vice versa, on Saturday afternoon, with a wind speed of 8.15 m/s, the CO_2 concentration in the ambient air was the lowest, namely 403 ppm. Wind speed is a factor that influences the concentration value of air pollutants in an area. The faster the wind speed in an area, the greater the mixing process of pollutants from emission sources will cause less dilution of pollutants in that area.

The relationship between CO_2 concentration (ppm) and the number of vehicles (units) with a correlation coefficient value of 0.825. This value shows the correlation between CO_2 concentration and the number of cars is powerful and positive. The correlation between CO_2 concentration and the number of vehicles (units) can be seen in Figure 6. Based on Figure 6, it can be seen that the correlation between CO_2 concentration and the number of vehicles is powerful but positive. This means that when the number of cars increases, the CO_2 concentration in the air will also increase. For example, on Thursday during the day, the highest number of vehicles was 928 units, with the largest CO_2 concentration, 514 ppm. The number of cars on Saturday afternoon was 107 units, with the lowest CO_2 concentration, 403 ppm. Transportation is essential in daily life and is vital to producing air pollutant emissions (Rahmawati & Pratama, 2023). Motor vehicle activity is the most significant contributor to producing the primary pollutant, CO_2, followed by NO_2, CO, PM10, and PM2.5 pollutants (Sumadi, 2023).
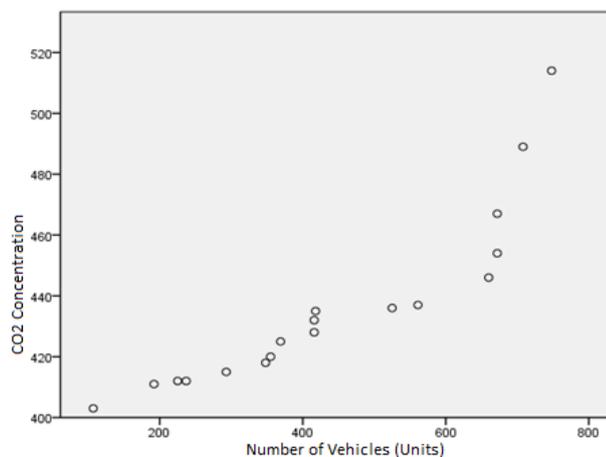

Figure 6. Correlation of CO_2 Concentration with Number of Vehicles.

The increase in the number of motorized vehicles increases the amount of pollutant emissions in the ambient air (Hamzah et al., 2022), including CO_2. The increase in the number of vehicles is exponential, while the environmental carrying capacity tends to be constant. The most significant exhaust gases produced from motor vehicle activities into the atmosphere by mass are carbon dioxide gas (CO_2) and water vapor (H_2O), formed from the complete combustion of fuel, which can be achieved with an excess air supply (Siregar et al., 2023). In this way, the concentration of pollutants in the air, especially CO_2, increases with the increasing use of motorized vehicles. Based on research conducted by Sudarti et al., (2022), it is stated that motorbike-type motor vehicles have the potential to produce CO_2 emissions of 44%, car-type motor vehicles have the potential to be a source of CO_2 emissions of 42%, truck-type motor vehicles produce CO_2 emissions of 12%, and bus-type motorized vehicles produce 2% CO_2 emissions in the ambient air. Differences in CO_2 emissions produced are caused by the type of fuel used, type of motor vehicle, year of motor vehicle production, number of motor vehicles, and fuel consumption rate (Siregar et al., 2023).

According to WHO standards, the CO_2 concentration at Bojonegoro University is within the polluted air range. That way, efforts are needed to reduce and control the increase in CO_2 concentrations. Avoiding and reducing the use of motorized vehicles is one effort that can be implemented to reduce and control increasing CO_2 concentrations (Sudarti et al., 2022). Reducing motorized vehicles and switching to public transportation or more environmentally friendly vehicles can help reduce CO_2 concentrations in the ambient air. Reducing CO_2 concentrations can be done by planting trees with broad and dense canopies. Compared to non-woody vegetation, trees can absorb CO_2 in the long term (Cahyanti & Poemaningsih, 2020). CO_2 storage can be more effective if trees are managed wisely and do not convert to other landscape components such as grass or herbal plants. Several types of trees with a high percentage of CO_2 absorption include trembles, mango, tabebuia, teak, and others. This type of tree can be a shade tree and absorb CO_2 in the air.

CONCLUSION

The influence between CO_2 concentration and the number of motorized vehicles has a positive correlation value with a coefficient of 0.825. This means that the greater the number of motorized vehicles, the higher the CO_2 concentration in the ambient air. The influence of CO_2 concentration on meteorological conditions includes temperature, air humidity, and wind speed. The correlation coefficient values for temperature, humidity, and wind speed are 0.825, -0.820, and -0.882. This means that the higher the air temperature, the higher the CO_2 concentration in the ambient air; the higher the air humidity and wind speed, the lower the CO_2 concentration in the air. According to WHO standards, the CO_2 concentration at Bojonegoro University is within the polluted air range. That way, efforts are needed to reduce and control the increase in CO_2 concentrations.

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