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Carbon Monoxide Gas Pollution Control Model Using Reducing Plants

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Abstract

Objectively, this study addresses several objectives, such as 1) identifying the existing vegetation conditions and the amount of CO concentration in the study location, 2) to investigate the ability to reduce plants to absorb CO, and 3) to projecting the absorption capacity of vegetation by CO through air prediction models. The research location was conducted at Veteran Selatan, Makassar City, Indonesia. The survey was conducted in Makassar City, Indonesia, as well as data available in the field. The research period from January to April 2020. From the analysis of the results and discussion, the conclusions drawn from this study are: 1) The CO concentration based on the calculation results is 1.186.52 µg / m3. While the CO concentration measured in the field is 2,290.39 µg / m3, so the difference between the calculation and measurement results is 1,103, (48.2%). The number of trees as vegetation, namely 189 trees, had an enormous average volume of cover, namely 2,673.01 m3. 2). The existing plants or vegetation on exsiting location can absorb CO of 1,889.8 tons/year. 3). A balance between CO pollutants and vegetation uptake can be achieved by applying a scenario of planting vegetation for trees, shrubs, and shrubs. Modeling and simulation results show that the total CO emissions will reach 3,184.6 tons/year in the next ten years. However, by applying the planting scenario, the total CO emission in the next ten years will only reach 2,761.9 tons/year, with an average percentage reduction of 8.93%.

Keywords: Air Pollution, Pollution Reduction Plant, Absorbing CO, Planting trees, Makassar City

1 Introduction

The rapid progress in the transportation sector, especially in urban areas, including the City of Makassar, is evident from the increasing number of vehicles available. This continues to grow from year to year. As the capital city of South Sulawesi Province, Makassar City is the fourth largest city in Indonesia and the largest in the Eastern Region (Murdifin et al., 2018, Suriyanti et al., 2020). The number of motorized vehicles in South Sulawesi increased every year, namely 579,732 units in 2012, 2,352,750 units in 2013, and the number reached 2,615,538 units in 2014, an increase of 6.8% from the previous year. The number of vehicles in Makassar City, both public and private, came around 856 thousand units in 2010 with a growth rate of 12% per year. On several roads in Makassar City, mostly the Veteran Selatan road, traffic problems such as congestion, queues, and delays are everyday things. This generally occurs at certain hours (peak hours), when people want to move for the same purpose and at the same time (Surya et al., 2020; Mallongi et al., 2019). One of the problems mentioned above is caused by an increase in the volume of vehicles every year, which is not followed by an increase in road length or an increase in old roads' capacity. The increase in the number of motorized vehicles impacts reducing air quality due to emissions from pollutants from fuel combustion. Analysis of BLHD data for South Sulawesi Province in 2013 and 2014 shows that 96.96% uses gasoline, and 3.04% uses diesel fuel in terms of the type of energy used.

The dominance of the use of BBM compared to other energy sources has a profound effect on air quality, especially in cities or provincial capitals and in district capitals in South Sulawesi. High traffic volumes cause high pollutant concentrations and vice versa. Common types of pollutants produced from motorized vehicle exhaust are Nitrogen oxide (NOx), Carbon monoxide (CO), Sulfur dioxide (SO2), particles in the form of real particles (TSP), particles with a diameter of 10 microns and 2.5 microns, and below (PM10). And PM2,5), Hydrocarbons (HC), heavy metals, and Ozone (O3). Of these several types of pollutants, carbon monoxide (CO) is one of the most pollutants produced by motorized vehicles (Mayer, 1999; Levy, 2015). The total CO pollutants concentration in the air, 80.22% - 92%, comes from motorized vehicles [7].

Carbon monoxide is a compound that results from incomplete combustion due to a lack of oxygen during combustion due to sub-optimal engine performance. CO pollutants released by motorized vehicles harm human health. Carbon monoxide is a

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highly toxic gaseous pollutant (Thomas & Hendricks, 1961, Kampa & Castanas, 2008). This compound binds to hemoglobin (Hb), which functions to deliver fresh oxygen throughout the body, causing the function of Hb to carry oxygen throughout the body to be disturbed. The reduced supply of oxygen throughout the body will cause shortness of breath and cause death if you do not get fresh air. (Zeng et al., 2019, Leghari & Zaidi, 2013). Air pollution in Makassar City will worsen if it is not balanced with optimal air pollution control. CO emission control in the city of Makassar is carried out by applying a dynamic model scenario, including 1) design of limiting the number of vehicles through the application of mass transportation (Busway) [10], 2) Scenarios for reducing emission concentrations through the application of environmentally friendly fuels, namely the application of Gas Fuel (BBG) for large capacity vehicles (buses and trucks) [12], 3) vehicle inspection and maintenance scenarios, and 4) combined procedures, namely the application between systems 1, 2 and 3 simultaneously. The reduction percentages of CO pollutants for plans 1 to 4 are 16.88%, 25.48%, 99.89%, and 134.81%.

One of the factors controlling air pollution is the availability of vegetation in roads and the surrounding environment. The number of motorized vehicles that continue to increase with an increasing number of emissions will also reduce air quality if it is not balanced with an increase in the number of pollutants absorbing existing vegetation [13]. The amount of CO reduction by various types of trees, shrubs, and shrubs using experimental methods through laboratory observation techniques [14]; [15]. One type of tree, namely the Trembesi-tree (Samanea saman), is a type of CO reducing plant with a high absorption capacity, namely 28,448.39 kg/tree/year (Arora et al., 2011, Lal, 2004). Mahogany plants' existence on roads is also quite useful in absorbing CO pollutants in the air due to motor vehicle exhaust emissions. These conditions motivate the author to provide a solution to control air pollution, especially CO pollutants, namely by using plants that reduce or absorb CO pollutants, which will be analyzed through dynamic systems approach using modeling and simulation and vegetation planting scenarios. The type and amount of existing vegetation availability on Veteran Selatan Street need to be done so that CO absorption can give optimal results. By modeling and simulating CO air pollution control with reducing plants, the authors hope to balance CO emissions by absorbent plants in the future.

Objectively, this study addresses several objectives, such as 1). Identifying the existing vegetation conditions and the amount of CO concentration in the study location, 2) Investigating the ability to reduce plants to absorb CO 3). Projecting the absorption capacity of vegetation by CO through air prediction models.

2 Literature Review

Air is a mixture of several gases whose proportions are not fixed, depending on the state of air temperature, air pressure, and environmental conditions. Air is the atmosphere that surrounds the earth whose function is crucial for life in this world. Clean air is a gas that is invisible, odorless, colorless, or tasteless. However, clean air is difficult to obtain, especially in big cities that are densely industrialized and have heavy traffic [17]. Air that contains pollutants is called polluted air. Polluted air will damage the environment and human life. Environmental damage means a lack of natural support for life, which in turn will reduce the quality of human life as a whole [18]. Based on Indonesian Government Regulation Number 41/1999, concerning Air Pollution Control, what is meant by air pollution is the entry or entry of substances, energy, and other components into the ambient air by human activities, so that ambient air quality cannot fulfill its function (Edinger et al., 1998, García et al., 2007).

Air pollution enters or introduces living things, substances, energy, and or other components into the air and or changes in the air system by human activities or natural processes so that air quality decreases to a certain level causing the air to become less or no longer functioning according to its designation [21], [22]. Air pollution is the presence of contaminants in an open space with such a concentration and duration that it causes a disturbance, harm, or has the potential to harm the health/life of humans, animals, plants, objects, and affect comfort [23]. Air pollution due to essential transportation activities is the result of motorized vehicles on land. Motor vehicles are a source of air pollution by producing CO, NOx, hydrocarbons, SO2, and tetraethyl lead, which are tin metal, which is added to low-quality gasoline octane value to prevent engine eruptions. Important parameters due to this activity are CO, particulate matter, NOx, HC, Pb, and Sox [24]. The atmosphere surrounding the earth is a mixture of gases and suspended solids where, as it gets higher, its density will gradually decrease and disappear in a vacuum that is hundreds of kilometers from the earth's surface. The presence of pollutants in the air generally comes from human activities, scientifically rare [25].

The three main components are the emission source, atmosphere, and receptors. The process that goes on in air depends on the type of contaminant being released. Conversely, if the air contaminants have sufficiently met the requirements (quantity, duration, and potential), these contaminants can only be called pollutants or pollutants. The air in nature has never been found clean without pollutants. Pollutants, which comprise 90% of the total air pollutants, can be divided into five groups as follows: Carbon monoxide (CO), Nitrogen oxides (NO), Hydrocarbons (HC), Sulfur dioxide (SO2), and particles. The primary source of air pollution comes from transportation / motorized vehicles. Other sources of pollution come from combustion, industrial processes, waste disposal, and others. Air pollution in Indonesia, especially in big cities, is caused by motor vehicle exhaust gases (60-70%); industry (10-15%), and the rest comes from households, burning garbage, forest/field fires, and others (DEWITA et al., 2015, Jakarta, 2013, Pradiptyas et al., 2011)

Gases in the air can form secondary pollutants by photochemical reactions; for example, peroxide radicals with oxygen will form ozone and nitrogen oxides change to nitrogen monoxide with oxygen, and so on. Exposure of gas to humans is generally through breathing and how to overcome it, especially by reducing the release of pollutants directly into the air, for example, by using "gas scrubbers," auxiliary devices in the exhaust, and so on. Particles with a size between 0.01-5gm are the primary source of air pollutants because they are not visible and remain in the atmosphere for quite a long time and are likely to change into secondary pollutants by chemical processes (Ebers, 2008, Humpel et al., 2002, Lal, 2004). The negative impact of these pollutants is usually a disturbance to building materials, plants and animals, and humans. Motor vehicle emissions are exhaust gases resulting from the combustion reaction (in this case, fossil fuels) with oxygen (O2). However, because the air's oxygen also contains nitrogen, the combustion reaction here also involves nitrogen (N2). The ratio of nitrogen and oxygen in the air is about

78% to 21%; the rest is other elements.

One form of the urban forest is a green strip. Road shade trees in green lanes are built and developed to obtain the benefits of a good quality urban environment. Planting with tall and shady plants can be useful for absorbing pollutants assumed by motorized vehicles. [29], [30]. An urban forest is a plant or woody vegetation in a metropolitan area that provides the most significant environmental benefits for protection, aesthetic, recreational, and other particular uses. Vegetation or plant communities available in nature are the most promising solution to overcome air pollution. Therefore, carrying out reforestation actions must be carried out immediately so that air pollution does not worsen. All green plants will convert CO2 gas into O2 through photosynthesis. But in addition to green leaves, choosing the type of reforestation plant should also consider its function as a shade that can improve the microclimate and function as a barrier against the spread of air pollution from vehicles [16], [23]. Plants need CO2 for growth. Increasing the concentration of CO2 in the atmosphere, among others, will stimulate the photosynthetic process, increase plant growth and productivity without being followed by an increase in water demand (transpiration). Photosynthesis generally occurs in all green plants that have chloroplasts or in all plants that have dyes [14]. Plant chloroplasts capture light energy that has traveled 150 million kilometers from the sun and converts it into chemical energy stored in sugars and other organic molecules. This conversion process is called photosynthesis.

3 Research Method

The research location was conducted in the Veteran Selatan Area of Makassar City, Indonesia. Before determining the research location, a survey was completed first. The survey was conducted to determine existing conditions and data available in the field. The research time was carried out from January to April 2020.

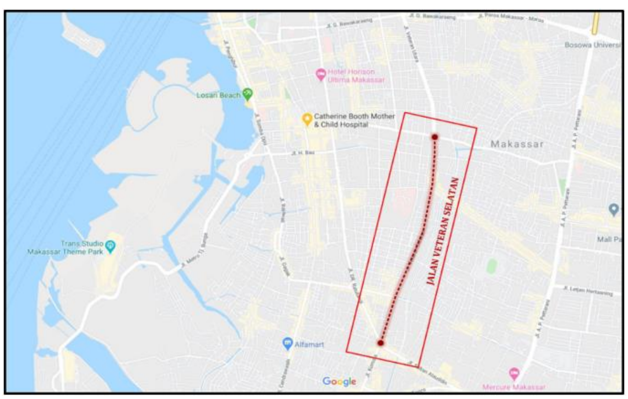

Figure 1: Map of Research Location

The tools used were stationery, calculator, laptop with Microsoft Word, Microsoft Excel, and Stella 6.0.1 software. This study's material is secondary data obtained from the Regional Environmental Agency (BLHD) of South Sulawesi Province, related agencies, and the results of previous studies required in this study. The data used in this study are primary data and secondary data to describe the condition of the existing vegetation and its absorption of CO emissions caused by motorized vehicles. Primary data collection was carried out through interviews and direct observations in the field of CO concentrations, namely by measuring the quality of ambient air and conducting traffic surveys of the existing locations. The types and sources of secondary data in this study can be seen in table 1

Table 1: Types and Sources of Secondary Data

No.	Types	Data Sources
1	CO concentration	BLHD
2	Vehicle Volume	BLHD
3	Number and Types of Existing Vegetation	Journal of Research Results
4	CO Uptake Capability by Vegetation	Journal of Research Results

The CO concentration data at the Veteran Selatan location was obtained based on ambient air quality monitoring activities carried out by the AAS laboratory by sending 2 (two) laboratory technicians. Its implementation uses several tools: dampeners and so on, with 22-029 / IK / SMM-AAS (CO meter). The electricity source for monitoring was provided using a generator set by the South Sulawesi Provincial BLHD Team. The ambient air quality test uses automatic equipment that works for 24 hours, and the CO concentration sample test is carried out in the laboratory. Existing vegetation data at the Veteran Selatan Location was obtained through the results of previous studies. The sampling method used was field observation of where the research was going to be carried out, tree sampling using the cruise method, and quantitative data collection by recording all types of trees that grew in the research location. The types of trees that grow are inventoried and identified, then tabulated by ethnicity (family) and species (species). The technique of collecting vegetation data through data collection is done using an application from a smartphone, namely the Smart Tool Angle, which is used to measure angles. This application is used to calculate the height of a tree by measuring angles. The pitch will then be processed with the trigonometric formula. Using the application above, the angle formed is obtained and then entered in the trigonometric formula to calculate the height of a tree. Here is Figure 2 to apply the trigonometric formula

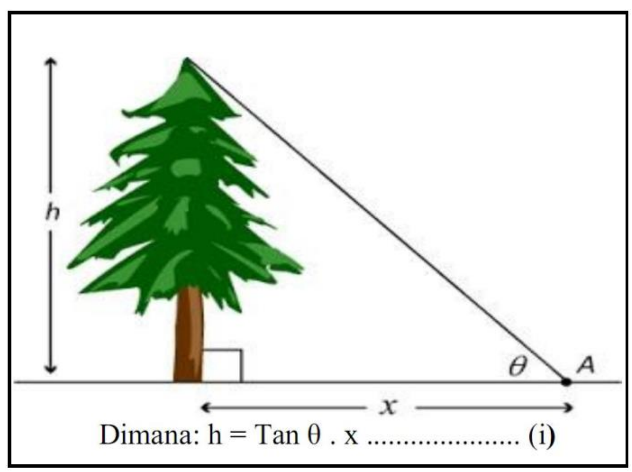

Figure 2: Trigonometry

Smart Tool Angle, which functions to find angles and is calculated to get a tree height described above. In addition to finding tree height, the tool is also combined with a meter to find the tree cover volume. In calculating the volume of tree cover, several formulas are used, as seen from the growing leaf canopy shape. Based on the tree canopy condition, not all forms of the ceiling are leaves, so the volume result is multiplied by the percentage of leaf cover.

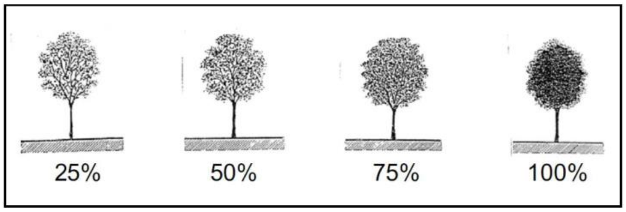

Figure 3: Conditions of Reducing Plants

The data that has been collected is then analyzed by designing a dynamic model to see the behavior of the CO pollution control system with reducing plants on the Location of Veteran Selatan section, Makassar. The model is based on the study results' factual conditions combined with theoretical concepts from various literature. Furthermore, the modeling and simulation of CO pollution control strategies are carried out by applying scenarios of planting tree species, shrubs, and shrubs using the Stella 6.0.1 program. Model design is done with a systems approach. The systems approach provides problem-solving with methods and tools that can identify, analyze, simulate, and design systems with interrelated components formulated in a cross-disciplinary and complementary manner. In principle, the system methodology goes through six stages of analysis, namely: (1) needs analysis, (2) problem formulation, (3) system identification, (4) system modeling, (5) verification and validation, and (6) implementation.

4 Result and Discussion

The Veteran Selatan location is a protocol location in downtown Makassar. Based on its function and role, the Location of Veteran Selatan, Makassar is a location for arteries, based on its class, including class III-A with national location status. The Veterans Southern Site is approximately 2.4 km long, is a two-way location divided into six lanes separated by a median of opposite moving traffic. There are many offices and shopping centers in the study location that trigger heavy traffic activities, especially during peak hours. Analysis of CO Absorption by Existing Vegetation Based on the results of calculations and data processing on the total CO emission from motorized vehicles at the Veteran Selatan location, 37.48 gr / s, and analysis of existing vegetation, the absorption of CO by existing vegetation can be known. For types of plants that can absorb and reduce CO, we refer to the Technical Guideline for Planting Air Pollutant Absorbing Tree Species published by the Ministry of Environment and Forestry (2015). The following is a list of plants that absorb and reduce CO pollutants, presented in tables 2 and 3.

Table 2: Types of Plants that Have the Ability to Absorb CO

No	Name of Plant	Ability to Absorb CO (ppm / day)
1	Croton (Codiaeum Interuptum)	125 ppm / day
2	Red Bean Plant (Phaseolus Vulgaris)	12-20 ppm / day
3	Dutch Betel (Epipremnum Aerum)	113 ppm / day
4	Angsana (Pterocarpus Indicus)	109 ppm / day

Table 3: Types of Plants that can Reduce CO

No	Local name of plant	Latin name	CO Absorption (Kg / Tree / Year)
1	Trembesi	Samanea saman	28448.39
2	Cassia	Cassia sp.	5295.47
3	Kenanga	Canangium adoratum	756.59
4	Pingku	Dysoxylum excelsum	720.49
5	Beringin	Ficu benyamina	535.9
6	Krey Payung	Fellicium decipiens	404.83
7	Matoa	Pornetia pinnata	329.76
8	Mahoni	Mahagoni swettiana	295.73
9	Saga	Adenanthera pavoniana	221.18
10	Bungkur	Lagerstoema speciosa	160.14
11	Jati	Tectona grandis	135.27
12	Nangka	Arthocarpus heterophyllus	126.51
13	Johar	Cassia grandis	116.25
14	Sirsak	Annona muricata	75.29
15	Puspa	Schima wallichii	63.31
16	Akasia	Acacia auriculiformis	48.68
17	Flamboyan	Delonix regia	42.2
18	Sawo Kecik	Manilkara kauki	36.19

To determine the amount of CO uptake by existing vegetation at the Veteran Selatan location, the existing plant types are adjusted to the kinds of plants that have known their ability to reduce CO. As for other kinds of plants; further research is needed to determine their ability to absorb CO. The absorption of CO by the existing vegetation at the Veteran Selatan location is presented in table 4 below.

Table 4: CO Absorption by Existing Vegetation at the Southern Veteran Site

No	Local name plant	CO Absorption (Kg / Tree / Year)	Amount Tree	Total Absorption (Kg / Tree / Year)
1	Trembesi	28448.39	66	1,877,593.74
2	Mahoni	295.73	15	4,435.95
3	Akasia	48.68	3	146.04
4	Krey Payung	404.83	19	7,691.77
5	Angsana	0.039785	78	3,1
	Total CO Uptake			1.889.870,6

The CO absorption capacity at the Veteran Selatan location by the existing vegetation is assumed to have the same cover volume for each tree based on the previous calculation of the average forest cover volume.

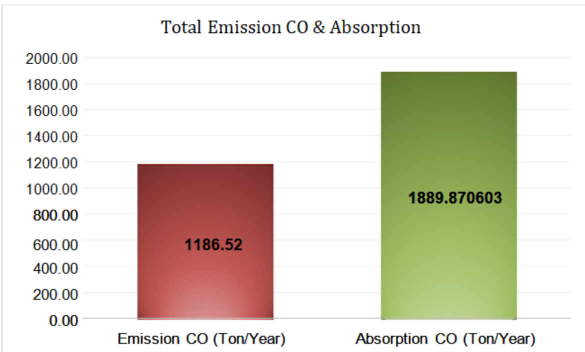

Figure 4: Total CO Emissions and Removals at the Southern Veteran Site

If seen in the comparison diagram above, the existing vegetation's CO uptake is currently higher than the total CO emissions produced by motorized vehicles each year. However, this condition may change in the next few years if the CO concentration due to motorized vehicles continues to increase with the number of trees or vegetation that does not increase. For this reason, it is necessary to carry out a planting scenario that can optimize CO uptake by greenery in the existing location.

4.1 Simulation Model of CO Concentration and Vegetation Uptake Based on the calculation of CO concentration at the Veteran location

In line with the Gaussian model, the CO concentration was 1186.52 µg / m3. As previously discussed, the CO concentration is directly proportional to the increase in vehicle volume each year. The percentage growth rate of CO concentration originating from motorized vehicles is assumed to be the same as the percentage increase in the importance of vehicles passing through the Veteran Selatan location, which is 10.46%.

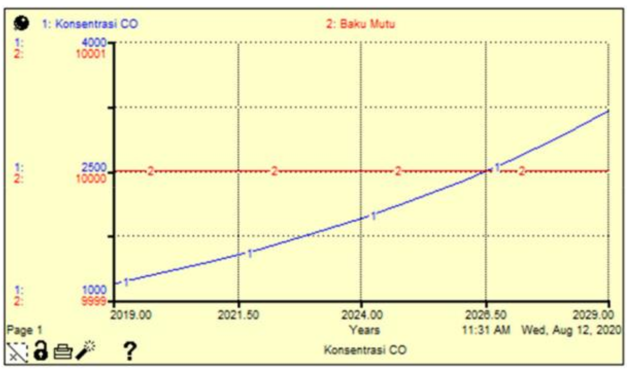

Figure 5: Total CO Emissions and Removals at the Southern Veteran Site

Figure 5 shows the predicted increase in CO concentration in the next ten years. The simulation results show that the CO concentration at the Veteran Selatan location will exceed CO's quality standard value based on Pergub No. 69 of 2010, namely 10,000 µg / m^3. To create a scenario for planting CO-reducing plants at the Veteran Selatan location, it is necessary to first know the provisions of the RTH (Green Open Space) planning procedure in the area. The provision of green open space must be adjusted to the allotment determined in the spatial plan stipulated by the local government. Based on the results of the identification of green open space for Makassar City in 2015 by BLHD of Makassar City, the total area of green free space for Makassar City is 1,277.60 hectares 7.311%. This percentage shows that Makassar City has not reached 30% green open space as mandated in the Spatial Planning Law. The location of Veteran Selatan is between Makassar and Mamajang sub-districts, with an area of green free space of 76.18 hectares or 0.436% of the total green free space for Makassar City. The number of vegetation that can absorb CO at the Veteran Selatan location is 181 trees out of 189 trees. The scenario in the model is increasing the planting of tree species, shrubs, and shrubs that can reduce CO in the Veteran Selatan area so that it reaches 95.7% of the total trees, with detailed scenarios as follows:

1. The tree planting was 50%, that is, 80 trees.
2. Shrubs were planted at 31.3%, that is, as many as 50 shrubs.
3. Bush planting was 18.8%, which was 30 bushes.

For selecting types of CO-reducing plants, it can be done by choosing the types of plants that have a large enough ability to reduce CO. One of the characteristics of plants that can absorb polluting gases is to have a lot of stomata. For tree species, tamarind trees can be used because they have many stomata, ranging from 61-73. Planting at the Veteran Selatan location can also be done by producing the types of plants with the highest stomata density in that location, namely mahogany (743 / mm2), filicium (933 / mm2), and Japanese ornamental bamboo (885 / mm2). For shrubs, Iriansis (Impatiens sp), which has an average CO reduction of 0.638 ppm, can be used. Philodendron (Philodendron sp) can be used for shrub types, which has an average CO reduction of 0.664 ppm. The selection of other kinds of plants can also be made by considering various things, such as having resistance to certain gases and having a fast growth rate.

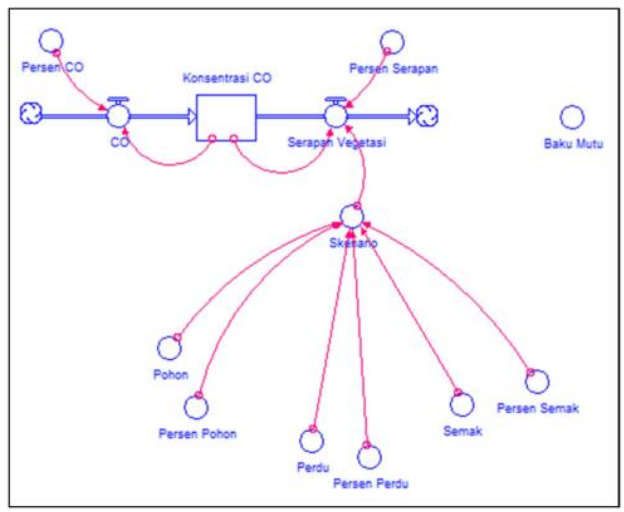

Figure 6: Prediction Model of CO Concentration and Absorption Scenarios

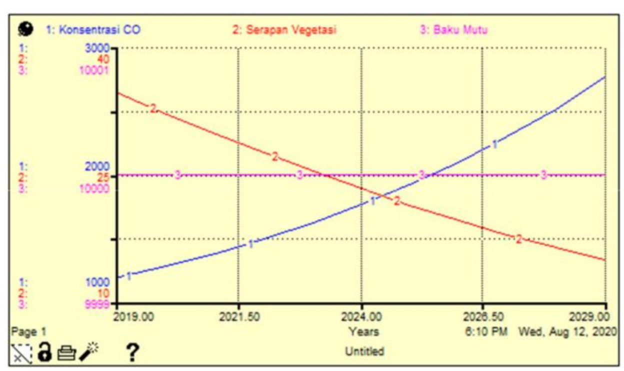

Figure 7: Graph of CO Concentration Simulation after Scenario Determination

The blue line on the graph in Figure 7 shows the value of CO concentration produced by the increase in vehicle volume each year. The red line shows CO's absorption by the vegetation after the vegetation planting scenario is carried out, while the pink line is the quality standard set by the BLHD. Comparison of CO emissions before and after the application of the scenario can be seen in the following table 5.

Table 5: Prediction of CO Emissions Before and After Scenarios

	Before Scenario After Scenario		Before Scenario After Scenario	
Year	CO Emissions (Tonnes / Year)	Vegetation Uptake	CO Emissions (Tonnes / Year)	Vegetation Uptake
2019	1186.52	0.56	1186.52	34.56
2020	1309.35	0.51	1275.36	32.15
2021	1445.02	0.46	1375.85	29.8
2022	1594.83	0.42	1489.13	27.54
2023	1760.28	0.38	1616.47	25.37
2024	1942.97	0.34	1759.21	23.31
2025	2144.69	0.31	1918.86	21.37
2026	2367.43	0.28	2097.06	19.55
2027	2613.38	0.26	2295.6	17.88
2028	2884.89	0.23	2516.48	16.29
2029	**3184.69**		**2761.9**	

5 Conclusion

From the analysis of the results and discussion, the conclusions that can be drawn from this study are: 1) the concentration of CO at the Veteran Selatan location based on the calculation results is 1.186.52 µg / m3. In contrast, the CO concentration measured in the field was 2,290.39 µg / m3, so that the difference between the calculation and measurement results was 1,103, with a percentage of 48.2%. The number of trees as existing vegetation at the Veteran Selatan location is 189 trees, where the Angsana has the most massive average volume of cover, namely 2,673.01 m^3. 2) Existing plants or vegetation at the Veteran Selatan location can absorb CO of 1,889.8 tons/year. 3) The balance between CO pollutants and their vegetation uptake can be achieved by applying the planting tree species, shrubs, and shrubs in the Veteran Selatan section. Modeling and simulation results show that the total CO emissions will reach 3,184.6 tons/year in the next ten years. However, by applying the planting scenario, the total CO emission in the next ten years will only get 2,761.9 tons/year with an average percentage reduction of 8.93%. Some suggestions that can be given from this research are: (a) it is necessary to carry out further research on plant types whose ability to reduce CO pollutants is not yet known; (b) measurement of CO concentrations should be carried out based on time intervals, for example, morning, afternoon, evening, and night because the CO concentration in the air can change; (c) making efforts to plant vegetation for all parties so that air quality remains good, not only functions to reduce CO pollutants but also other functions. Making efforts to reduce the volume of vehicles makes public transportation comfortable so that people leave private cars.

Aknowledgment

Journal editorial doard thanks following reviewers to review this article.

Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

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