Phytoremidation by *Sansevieria* sp. through absorption of Carbon Monoxide (CO)

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ABSTRACT

This study aims to determine the quality of Sansevieria plants in absorbing carbon monoxide (CO) and to determine the relationship of stomatal conditions to the quality of carbon monoxide (CO) absorption. The research was conducted in the form of a 2-factor factorial experiment using a Randomized Group Design as the environmental design. The experiment consisted of 2 factors, the first factor was the variety of Sansevieria plants consisting of three varieties, namely Sansevieria trifasciata, Sansevieria cylindrica and Sansevieria green hahnii, while the second factor was the concentration of carbon monoxide (CO) consisting of two levels, namely: the concentration of carbon monoxide released at 300 ppm and the concentration of carbon monoxide released at 800 ppm. The results showed that there was no interaction between varieties of Sansevieria plants with carbon monoxide concentrations on the quality of carbon monoxide (CO) gas absorption. The results showed no interaction between the varieties of Sansevieria plants and carbon monoxide concentrations in terms of the quality of carbon monoxide (CO) gas absorption. Sansevieria plant varieties that are given a carbon monoxide concentration of 300 ppm give the best effect on the total percentage of carbon monoxide gas absorption, which is 89.50%.

***Keywords**: Phytoremediation, carbon monoxide (CO), Sansevieria, Stomata*

INTRODUCTION

The existence of industry, population and transportation density has caused serious pollution in big cities. (Iswoyo et al., 2019; ; Al-Hakim, 2019) One of the negative impacts of industry is the decline in air quality due to the increase in pollutants and greenhouse gases in the air. (Soviyanti, 2019). In addition, the increase in the number of motorized vehicles also contributes to reduced air quality, especially in urban areas. (Ramdhani & Fatimah, 2013). Data from the Korlantas Polri shows that the total vehicle ownership in Indonesia reaches more than 140 million units. (Sari, 2022; Sadya, 2022). This number increased by 4.30% from the previous year.

Approximately 71% of this number, or 123,377,429 vehicles, are motorcycles or scooters which parts are not supporting clean combustion for air health efforts. (J. P. I. Sari, 2022). Furthermore, all of these motorcycles use gasoline as their main fuel, which has adverse health effects due to the pollutants produced. (Makhyani et al., 2009).

Makassar is one of the cities that supports the development of business and industry in various sectors. Makassar is densely populated with enormous number of vehicles (Iswoyo et al., 2013; Y. P. Sari, 2020). The presence of industry, population and transportation has caused serious pollution in the city. (Makhyani et al., 2009). According to the Ministry of Environment and Forestry of Makassar City (2021), The Air Pollution Standard Index (ISPU) value in Makassar City in 2021, especially in January for the CO parameter on all road sections was 59. This value is in the moderate category (ISPU value > 50).

Carbon monoxide (CO) is a silent killer because of its physical properties that are tasteless, colorless, and odorless, but in high concentrations can cause death in humans who are exposed quickly. (Cooper & Alley, 2010). All types of incomplete combustion from natural processes contain CO carbon fuels. The human activities that produce the most CO are engine combustion, gas, oil, wood or coal-fired appliances, and solid waste disposal. The use of cigarettes or firewood for cooking are examples of CO accumulation in enclosed spaces. (Wu & Wang, 2005).

Carbon monoxide (CO) gas is non-irritating, flammable and highly toxic, and insoluble in water. This gas is the result of incomplete combustion of motor vehicles, heating devices and equipment that use fire materials. CO compounds have the potential to be toxic and harmful to humans, because they can form strong bonds with blood pigments, namely hemoglobin. Exposure to air with CO gas can result in poisoning of the central nervous system and heart. This poisoning occurs if exposure to CO gas exceeds the limit of what the body can tolerate, which is more than 250 ppm. (Rezki et al., 2013).

Carbon monoxide that comes out of the exhaust will be in the ambient air, if inhaled by humans, the molecule will enter the respiratory tract and then enter the lungs and then will attach to blood hemoglobin to form Carboxy Hemoglobin (COHb). The higher the concentration of CO inhaled by humans, the more fatal the risk. (Maryanto & Purwanto, 2009).

Plants can remove pollutants from soil, water and air, in various ways through a process known as

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phytoremediation. It is a bioremediation process that uses various types of plants to remove, transfer, and or break down contaminants. (Cunningham et al., 1995). Plants can damage or break down organic pollutants, as well as absorb and stabilize metal pollutants. In this case, organic pollutants can be removed by plants through one mechanism or a combination of phytodegradation, rhizo-degradation, and phytovolatilization processes. (Ghori et al., 2016; Kumar et al., 1995).

Some types of plants are specifically known as phytoremediators for certain types of pollutants. One of the plants known as an air purifier is Sansevieria (Sansevieria sp). This plant is known as a room pollution neutralizer (Dewatisari & Lyndiani, 2015; Andayani et al., 2018) generally for pollution caused by cigarette smoke. (Purwanto, 2006). In addition to the absorption of carbon monoxide from cigarette smoke, research on the absorption of pollutants from vehicles by Sansevieria has been conducted on the metal pollutant lead. (Miftakhudin et al., 2012). As for its effectiveness in absorbing carbon monoxide from motorized vehicles has not been done much.

The composition contained in the Sansevieria in general includes (255) ruscogenin, 4-0 methyl glucuronic acid, beta sitosterol, d-xylose, fiber, hemicellulose, n butyl 4 OL propyl phthalate, neo ruscogenin, Sansevieria genin, and pregnane glycosid. The active ingredient pregnane glycosid functions to reduce various types of pollutants into organic acids, sugars and amino acids that are no longer harmful to humans through the metabolic breakdown process. (Tahir & Sitanggang, 2008).

MATERIALS AND METHODS

Tools and Materials

The main tools in this study are for the calculation of the amount of carbon monoxide in the room, namely Gas Detector SPD 200 / CO, plastic tablecloths, les wood with a size of 20 cm as many as 36 sticks, a size of 30 cm as many as 36 sticks, and a size of 70 cm as many as 72 sticks, preparatory glass, laptop, calculator, hammer, pliers, zip plastic bag, cellphone, stationery, Microsoft Excel, stapler shoot, CCM (Content Chlorophyll Meter), and microscope.

The materials used in this study are 3 varieties of Sansevieria plants, namely: *Sansevieria trifasciata*, *Sansevieria cylindrica*, and *Sansevieria green hahnii* (Figure 1) which have the same age and size ranging from 6-12 months of age as many as 18 plants (can be seen from the number of leaves and uniform plant height). Other materials were 1 inch nails, plastic 60 cm x 100 cm *trash bag*, clear cuttings, stapler bullets, and clear plaster.

Research Methods

This study was organized based on a 2-factor factorial design (RF2F) in a Randomized Group Design (RAK), as an environmental design. This study consisted of two factors:

The first factor is the type of Sansevieria plant (V) which consists of 3 varieties, namely:

V1 = *Sansevieria trifasciata*

V2 = *Sansevieria cylindrica*

V3 = *Sansevieria green hahnii*

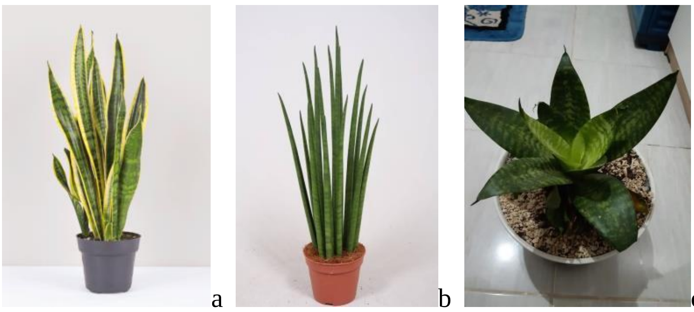
The second factor is carbon monoxide concentration which consists of 2 levels, namely :

C1 = Carbon monoxide concentration of 300 ppm

C2 = Carbon monoxide concentration of 800 ppm

There were 6 treatment combinations that were repeated 3 times making a total of 18 experimental units. The data obtained were analyzed for variance and if the results had a significant effect, it was continued with the LSD test at the 5% or 0.05 confidence level.

The hood was hand-made using 20 cm and 60 cm of les wood, resulting in a block model that does not have a base (Figure 2). Measurements of carbon monoxide from motor fumes were taken three times. The first measurement was taken when the CO was trapped in the plastic container. This first measurement showed how much CO is put into the hood; the second measurement was taken 2 hours after the carbon monoxide is released into the hood. This second measurement showed the amount of CO that has been reduced due to absorption by plants and the third measurement was taken after the carbon monoxide has been allowed to stand in the hood overnight to see the remaining CO. The third measurement showed a value that is assumed to be the initial concentration. Measurements were taken 28 times, 7 times a week.



a b c

Figure 1. a. *Sansevieria trifasciata;* b. *Sansevieria cylindrica; c. Sansevieria green hahnii*.

Figure 2. Plant Hood

RESULTS AND DISCUSSION

Total Carbon Monoxide (CO) Absorption

The results of observations of total carbon monoxide absorption showed that the treatment of carbon monoxide concentration had a very significant effect on the concentration of carbon monoxide absorbed as shown in Table 1.

Figure 3 shows that there are differences in the average total carbon monoxide absorption in each variety and carbon monoxide concentration. The highest average total carbon monoxide absorption was performed by *Sansevieria green hahnii* variety which was exposed to 300 ppm of carbon monoxide concentration which was 89.50%. The lowest average percentage of carbon monoxide absorption was found in the *Sansevieria cylindrica* variety with 800 ppm of carbon monoxide concentration which was 57.46%.

Stomatal Opening Area (μm^2)

The results of the observation of stomatal opening area and the variance analysis showed that the treatment of carbon monoxide concentration had a very significant effect on stomatal opening area (Table 2).

The LSD 0.05 test shows that the *Sansevieria trifasciata* showed the highest average stomatal opening area of 765.64 μm2 and was significantly different from other varieties.

Stomatal Density (μm^2)

The results of observations of stomatal density and variance analysis showed that the treatment of carbon monoxide concentration had a very significant effect on stomatal density as shown in Table 3. The LSD 0.05 test showed that the *Sansevieria green hahnii* showed the highest average stomatal density of 20.38 mm2 and was significantly different from the other varieties.

Number of Stomata

The results of observations of the number of stomata and variance analysis showed that the treatment of carbon monoxide concentration had a significant effect on the number of stomata as shown in Table 3. The LSD 0.05 test in table 8 shows that the *Sansevieria green hahnii* had the highest average number of stomata at 4.00 and was significantly different from the other two varieties.

Table 1. Average Percentage (%) of Total Carbon Monoxide Absorption in Carbon Monoxide (CO) Concentration treatments.

Variety (v)	Carbon Concentration	
	300 ppm (c1)	800 ppm (c2)
Sansevieria trifasciata (v1)	89.12	58.33
Sansevieria cylindrica (v2)	88.62	57.46
Sansevieria green hahnii (v3)	89.50	59.24
Average	89.08a	58.34b
LSD	3.38	

Note: Numbers followed by the same letter in column (a,b) are not significantly different in the LSD further test at the 0.05 confidence level.

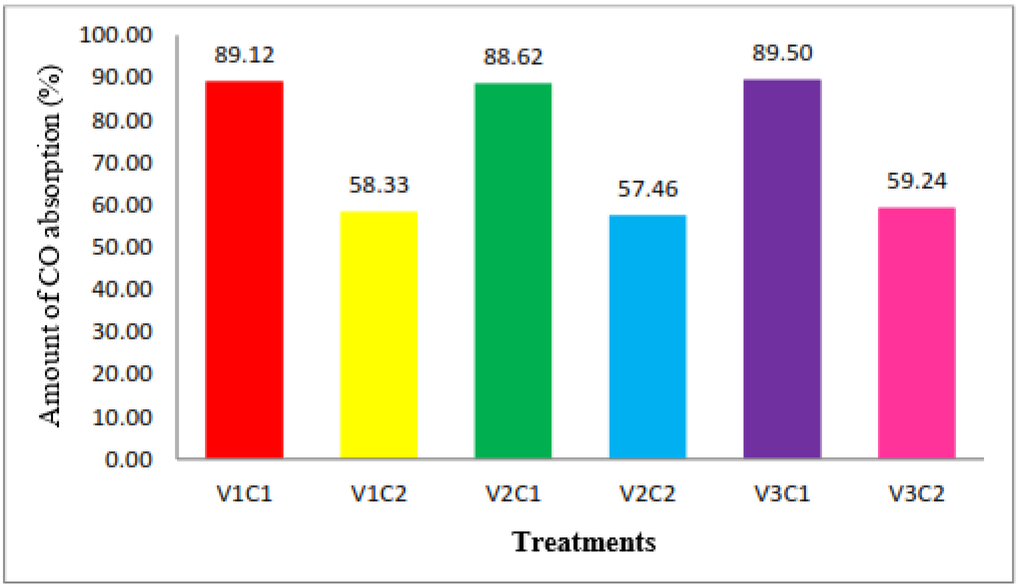


Figure 3. Graph of the average percentage of total carbon monoxide absorption in several varieties of *Sansevieria* sp.

Table 2. Average stomatal opening area at two carbon monoxide (CO) concentration

Variety (v)	Carbon Concentration		Average	LSD
	300 ppm (c1)	800 ppm (c2)		
Sansevieria trifasciata (v1)	739.99	791.28	765.64[a]	
Sansevieria cylindrica (v2)	295.16	353.77	324.47[b]	542.52
Sansevieria green hahnii (v3)	266.90	203.05	234.98[b]	

Note: Numbers followed by the same letter in column (a,b) are not significantly different in the LSD further test at the 0.05 confidence level.

Table 2. Average Stomatal Density as affected by Concentration Carbon monoxide (CO)

Variety (v)	Carbon Concentration		Average	LSD
	300 ppm (c1)	800 ppm (c2)		
Sansevieria trifasciata (v1)	13.59	13.59	13.59[b] 13.59	
Sansevieria cylindrica (v2)	15.29	13.59	14.44[b] 13.59	5.31
Sansevieria green hahnii (v3)	18.68	22.08	20.38[a]	

Note: Numbers followed by the same letter in column (a,b) are not significantly different in the LSD further test at the 0.05 confidenc level.

Table 3. Average number of stomata affected by concentration of Carbon dioxide (CO).

Variety (v)	Carbon Concentration		Average	LSD
	300 ppm (c1)	800 ppm (c2)		
Sansevieria trifasciata (v1)	2.67	2.67	2.67 [b]	
Sansevieria cylindrica (v2)	3.00	2.67	2.83[b]	5.31
Sansevieria green hahnii (v3)	3.67	4.33	4.00 [a]	

Note: Numbers followed by the same letter in column (a,b) are not significantly different in the LSD further test at the 0.05 confidence level

Table 4. Average Chlorophyll a as affected by Carbon monoxide (CO) Concentration

Variety (v)	Carbon Concentration		Average	LSD
	300 ppm (c1)	800 ppm (c2)		
Sansevieria trifasciata (v1)	428.95	433.38	431.17 [ab]	
Sansevieria cylindrica (v2)	479.11	497.79	488.45[a]	62.0
Sansevieria green hahnii (v3)	420.32	427.41	423.86 [b]	

Note: Numbers followed by the same letter in column (a,b) are not significantly different in the LSD further test at the 0.05 confidence level.

Table 5. Average Chlorophyll b as affected by treatment of Carbon monoxide (CO) Concentration

Variety (v)	Carbon Concentration		Average	LSD
	300 ppm (c1)	800 ppm (c2)		
Sansevieria trifasciata (v1)	237.44	239.64	238.54 [ab]	
Sansevieria cylindrica (v2)	303.49	318.48	310.98[a]	73.76
Sansevieria green hahnii (v3)	221.76	229.18	225.47 [b]	

Note: Numbers followed by the same letter in column (a,b) are not significantly different in the LSD further test at the 0.05 confidence level.

Table 6. Average Total Chlorophyll at two Carbon Monoxide (CO) Concentrations

Variety (v)	Carbon Concentration		Average	LSD
	300 ppm (c1)	800 ppm (c2)		
Sansevieria trifasciata (v1)	630.05	636.67	633.36 [b]	
Sansevieria cylindrica (v2)	712.11	741.01	726.56[a]	100.0
Sansevieria green hahnii (v3)	615.08	626.34	620.71 [b]	

Note: Numbers followed by the same letter in column (a,b) are not significantly different in the LSD further test at the 0.05 confidence level.

Chlorophyll a (µmol.m^{-2})

Chlorophyll a observation results and variance analysis showed that carbon monoxide concentration treatment had a significant effect on Chlorophyll a. The LSD 0.05 test in table 8 showed that *Sansevieria cylindrica* varieties had the highest average Chlorophyll a of 488.45 µmol.m^{-2} and is significantly different from the other varieties.

Chlorophyll b (µmol.m^{-2})

Chlorophyll b observation results and variance analysis showed that carbon monoxide concentration treatment had a significant effect on Chlorophyll b (Table 5).

The LSD 0.05 test shows that the *Sansevieria cylindrica* variety shows the highest average Chlorophyll b of 310.98 µmol.m^{-2} and is significantly different from other varieties.

Total Chlorophyll (µmol.m^{-2})

Total Chlorophyll observation results and variance analysis showed that carbon monoxide concentration treatment had a significant effect on chlorophyll index.The LSD 0.05 test showed that the *Sansevieria cylindrica* variety showed the highest average total chlorophyll of 726.56 µmol.m^{-2} and was significantly different from the other varieties.

Discussion

The results showed that there was no interaction between the varieties of Sansevieria plants and the concentration of carbon monoxide (CO). Each plant variety tested shows relatively the same carbon monoxide absorption. The ability of the Sansevieria plant was due to the special function of its stomata which are often referred to as vacuum cleaner stomata. (Larasati et al., 2016). Toxic gases that enter the metabolic system in the plant body are sent to the roots and detoxified by microbes using the active substance called Pregnane Glycoside.

Observations of physiological parameters in the form of stomatal opening area, stomatal density, number of stomata, Chlorophyll a, Chlorophyll b, and Total Chlorophyll showed the Sansevieria variety gave a significant effect. As a CAM plant (crassulacean acid metabolism), this plant takes CO_2 at night, and uses it for photosynthesis during the day. (Gardner et al., 1991). During the day, the closed stomata of the Sansevieria occurs decarboxylation of C4 compounds and the addition of CO_2 back through carboxylase activities (rubisco). at night, the stomata of the Sansevieria open, this plant breaks down starch in the leaf mesophyll through the process of glycolysis (respiration) to form PEP. (Song, 2012). CO_2 that enters the leaf after reacting with water and converted into malic. The malic acid formed is transformed into the vacuole to be stored during the day. During the day, Sansevieria plants are not so optimal in absorbing carbon due to closed stomata conditions, but at night the absorption actually increases because the stomata of this plant are wide open. This resulted in the measurement of CO before the application of the plant to obtain a lower CO value than during the third measurement, which was after being allowed to stand overnight.

In the observation of stomatal opening area, *Sansevieria trifasciata* had the best stomatal opening area compared to *Sansevieria cylindrica* and *Sansevieria green hahnii*. Based on the results of stomatal observations, it was also found that the stomata of *Sansevieria trifasciata were* larger and wider while the other two varieties had stomata that tended to be smaller. The mechanism of opening and closing stomata can be affected by several factors, namely the turgor mechanism, osmotic pressure, accumulation of potassium ions, abscisic acid accumulation, CO gas concentration and environmental influences such as temperature, humidity, and light.

For the parameter of stomatal density, Nasaruddin and Musa (2012) stated that the stomatal density of CAM plants is generally influenced by genetic. *Sansevieria green hahnii* has the best stomatal density compared to *Sansevieria trifasciata* and *Sansevieria cylindrica.*

Observation of the number of stomata showed *Sansevieria green hahnii* had the highest number of stomata. The difference in the number of stomata of each variety is strongly influenced by adaptation to the environment related to environmental factors such as temperature, gas, light, and humidity. In this study, it was closely related to environmental factors such as gas and light. *Sansevieria green hahnii* has a denser stomatal density so it has more stomata than the other two varieties. In addition, the leaf condition of Sansevieria *green hahnii* Sansevieria *green* *hahnii* is wider lotus-shaped than *Sansevieria trifasciata* and *Sansevieria cylindrica* which are more like an upward spear.

Observations of Chlorophyll a, Chlorophyll b, chlorophyll index and Total Chlorophyll parameters showed that *Sansevieria cylindrica* had better chlorophyll than *Sansevieria trifasciata* and *Sansevieria green hahnii*. This was due to differences in morphology and internal factors, namely genetics in each variety of Sansevieria plants. Kurniawan et al. (2010) It is said that differences in species indicate the ability of chlorophyll biosynthesis is not the same between each species. Chlorophyll biosynthesis is carried by certain genes in the chromosome. These genes carry enzymes that will play a role in the biosynthetic pathway of tetrapyrrole (porphyrin core) as the structural center of chlorophyll.

Based on the results of this study, it can be seen that the higher the concentration of CO given, the lower the CO content that can be absorbed by Sansevieria sp. This is because the high concentration of CO given actually makes the stomata limited in absorbing CO. The limited stomata in absorbing CO is closely related to the condition of the stomata that have begun to experience damage. This is in accordance with Siregar (2005) who stated that high exposure to pollutants will cause damage to plant stomata. Damage to the stomata will cause the ability of plants to absorb gas to be minimal or low. In addition, there can be fluctuations in CO absorption every day which are closely related to environmental factors. Such as temperature and humidity. The higher the temperature in an area, the greater the movement of CO gas, on the other hand, if the temperature is low, the slower the movement of the gas, as stated by Ruskell & Mosca (2004) that gas will experience a slowdown at relatively low temperatures. However, high temperatures will encourage gas movement to accelerate.

CONCLUSIONS

The results of this study indicate that there was no interaction between varieties of aloe vera plants with natural carbon monoxide concentrations in terms of the quality of carbon monoxide (CO) gas absorption. Sansevieria plant varieties did not show a significant effect on the quality of carbon monoxide (CO) gas absorption. The variety of Sansevieria which was exposed by a concentration of 300 ppm carbon monoxide gave the best effect on the total percentage of carbon monoxide gas absorption which is 89.50%.

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