Carbon Monoxide (CO) Level Measurement Using Internet of Things (IoT) Based Drone with NodeMCU ESP32

Sefrina Putri Trisnanti
Department of Physics, Faculty of Mathematics and Science,
State University of Surabaya,
Surabaya 60231, Indonesia.
Telp : (031) 8280009,
sefrinaputri.19035@mhs.unesa.ac.id

Meta Yantidewi
Department of Physics, Faculty of Mathematics and Science,
State University of Surabaya,
Surabaya 60231, Indonesia.
Telp : (031) 8280009,
metayantidewi@unesa.ac.id

Utama Alan Deta
Department of Physics, Faculty of Mathematics and Science,
State University of Surabaya,
Surabaya 60231, Indonesia.
Telp : (031) 8280009,
utamadeta@unesa.ac.id

Abstract – **Carbon monoxide (CO) is a dangerous gas with no odor, color, or taste and can easily mix with other air around it. This study aims to design and determine the results of measuring CO levels using a drone integrated with an MQ-7 gas sensor and an IoT-based ESP32 nodeMCU by manipulating the time and height of measuring CO levels. The method used is data acquisition in the form of a data retrieval process from the MQ-7 sensor programmed with the ESP32 nodeMCU via the ThingSpeak web. The results of measurements of CO levels in Ketintang, Surabaya air quality in the medium category at 07.00-11.00 WIB and good at 15.00 WIB. Measurement at 07.00 WIB CO levels are higher than at 11.00 WIB and 15.00 WIB. This can occur because the use of motorized vehicles and the process of burning waste in households is denser. Most of these activities are carried out close to the ground so that the higher the altitude in measuring CO levels, the lower the CO levels detected. Other factors that affect CO levels are temperature, wind speed, and weather when taking measurements. Based on the results of the study, it can be concluded that hours and altitude affect the CO levels produced.**

Keywords: **Carbon monoxide (CO), MQ-7 sensors, nodeMCU ESP32, drones, IoT.**

I. Introduction

Air quality is important for human survival [1] in sustaining life [2]. Air quality in Indonesia ranks fourth in the world as the most polluted country. Air pollution is caused by various human activities that mostly come from power plants, vehicle fumes, and industrial chimney exhausts that produce harmful gases such as carbon dioxide (CO2), sulfur oxides (SOx), nitrogen oxides (NOx), and carbon monoxide (CO) [3]. Carbon monoxide (CO) is a dangerous gas when inhaled beyond safe limits [4] because it is odorless, tasteless, and colorless which can be mixed with other gases [5]. Increased carbon monoxide (CO) gas concentrations can have an impact on human health such as decreased central nervous system function, changes in heart and lung function, drowsiness, coma, shortness of breath, and can cause death [6].

In general, measurements of carbon monoxide (CO) levels have been carried out by several studies. Prakoso & Rakhmawati, 2018 conducted research related to the monitoring system of carbon monoxide (CO) levels in industrial chimneys with Bluetooth communication via smartphones using the MQ-7 sensor, Arduino UNO microcontroller, and Bluetooth HC-06 module [7]. However, there are several weaknesses, namely the poor connecting and pairing process and the short measurement range. Further research was conducted by Asmazori, 2021 related to the design of NOx and CO detection devices based on telegram and voice notifications using MQ-135 and MQ-7 sensors, ISD 1820 modules, ESP32, and data displayed via telegram [8] In this study there are weaknesses, namely telegrams can only display data when carbon monoxide (CO) levels are more than 50 ppm so it is less effective for measuring carbon monoxide (CO) levels.

The rapid development of technology has made many new innovations appear, one of which is drones and the use of the Internet of Things (IoT). Drones are unmanned aerial vehicles (UAVs) that can be controlled remotely via a wave beam [9]. Drones can reach several locations that are difficult to conduct research and data collection processes, one of which is the measurement of carbon monoxide (CO) gas which is easily dispersed and cannot be observed directly [10]. Furthermore, IoT is a collection of objects equipped with sensors and connected via an internet network that can later be used in data collection [11] so that the range of data transmission is wider and faster because it uses high-frequency waves [12]. This IoT will send data through the ThingSpeak web, a service that contains applications and Application Programming Interface (API), an interface that connects one platform to another without any minimum limit in measurement. So this study is very important to do considering that carbon monoxide

(CO) gas is one of the dangerous gases which if produced in excessive amounts can endanger human health.

II. Basic of Theory

Carbon monoxide (CO) is a poisonous, colorless, odorless, and tasteless gas. The odorless nature of carbon monoxide (CO) is usually mixed with other gases that smell so that carbon monoxide (CO) can be inhaled unconsciously along with the inhalation of other gases that smell [5].

Table 1. Properties of carbon monoxide (CO) gas

Properties	Description
Molecular formula	CO
Form	Colorless and odorless gas
Molecular Weight	28,0101 g/mol
Freezing Point	-205° C
Boiling Point	-192° C
Density	0,789 g/cm^3; liquid 1,250 g/L at 0° C; 1 atm; 1,145 g/L at 25° C; 1 atm
Solubility in Water	0,0026 g/100 mL (20° C)

Scientifically, relatively little CO gas is formed as a result of volcanic activity and biological processes. Whereas in artificial processes (anthropogenic) the formation of CO gas through the combustion process of fossil fuels often occurs in combustion engines either motorized or industrial vehicles [13] The largest producer of carbon monoxide (CO) according to the survey states that at least 90% in urban air is produced from motor vehicle emissions and then comes from cigarette smoke [14]. Even in big cities, the largest contributor to gas emissions is transportation, around 60%, industry 25%, households 10%, and waste as much as 5% [15].

The Air Pollution Index (API) is an air quality report to the public that aims to explain how clean or polluted the air quality is and how it affects public health after breathing the air for several hours or days.

Tabel 2. Air Pollution Standard Index (ISPU) Decree of the Environmental Impact Control Agency (Bapedal) Number KEP-107/KABAPEDAL/11/1997

ISPU (ppm)	Air Pollution Level
0 - 50	Good
51 - 100	Moderate
101 - 199	Unhealthy
200 - 299	Very Unhealthy
300 - 500	Hazardous

The measured pollutant parameters are Carbon Monoxide (CO), Sulfur Dioxide (SO2), Nitrogen Dioxide (NO2), Ozone (O3), and particulates (PM10) as well as meteorological conditions, which include wind speed and direction, temperature, global radiation and air humidity. After obtaining the final results, it can then be analyzed to determine the level of pollution that has been determined by ISPU [16].

Drones referred to as Unmanned Aircraft Systems (UAS), Unmanned Aerial Vehicles (UAV) or Remotely Piloted Aircraft (RPA), are pilotless aircraft on board that are remotely controlled by a pilot on the ground or aboard another aircraft [17]. Drones have the ability to reach difficult areas, move quickly through sensors and send information without the need to expose human activity. Drones can minimize inspection costs and avoid the risk of danger in certain situations, the type of drone used must be in accordance with the needs, because each drone has characteristics that match certain operating requirements.

III. Method and Design

The stages in designing of this research are carried out in stages such as literature studies, namely by observing several research-related studies such as journals, books, and the web. Then analyze needs such as the need for tools and materials in measuring carbon monoxide (CO) levels which consists of designing hardware and software systems. Hardware includes MQ-7 sensors, drones, NodeMCU ESP32, cables, and power supplies. The software includes programming on the Arduino IDE and ThingSpeak web. After that, the calibration of the tool is carried out for data collection and the last stage is to analyze the results obtained to conclude. The design of measuring carbon monoxide (CO) levels using a drone is shown in Figure 1.

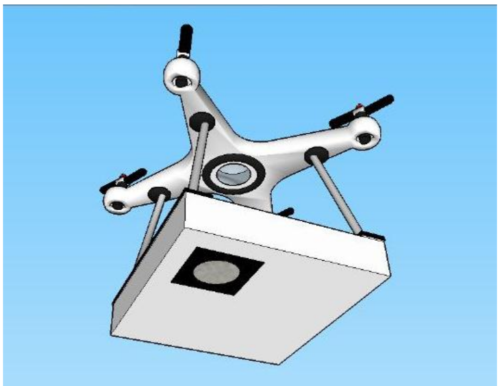

Figure 1. Design of carbon monoxide (CO) measurement using drones

Figure 1, shows a 3D picture of measuring carbon monoxide (CO) levels with a drone. The drone will be assembled with a box containing tools including the MQ-7 sensor, NodeMCU ESP32, cable, Charge De Lithium Module, and power supply. In Figure 2 the bottom view, the box is given a gap so that the MQ-7 sensor can detect carbon monoxide (CO) around it.

The hardware design for measuring carbon monoxide (CO) levels is shown in Figure 2.

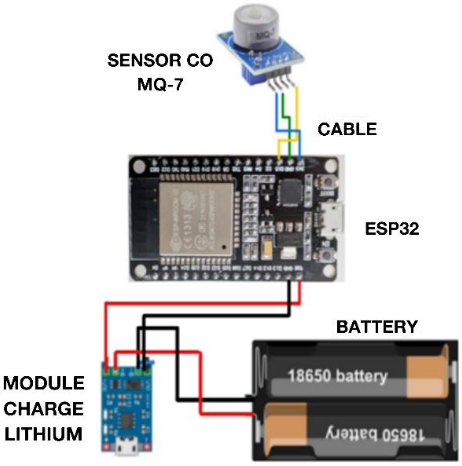

Figure 2. Schematic of the hardware circuit for measuring carbon monoxide (CO) levels

In Figure 2, the hardware circuit, namely the power supply, comes from the battery into the lithium charge module, which protects the battery from over-discharge and as over-load protection. The lithium charge module goes to the Vin pin of the ESP32 and the ground (GND). After that, the MQ-7 Vcc sensor goes to 3.3 Volts ESP32, for GND MQ-7 goes to GND ESP32, and the yellow analog output (AO) cable goes to D15 ESP32 as Analog to Digital Converter (ADC). The results will be processed by the microcontroller to be displayed on a smartphone or laptop via ThingSpeak web.

The software design for measuring carbon monoxide (CO) levels is shown in Figure 3.

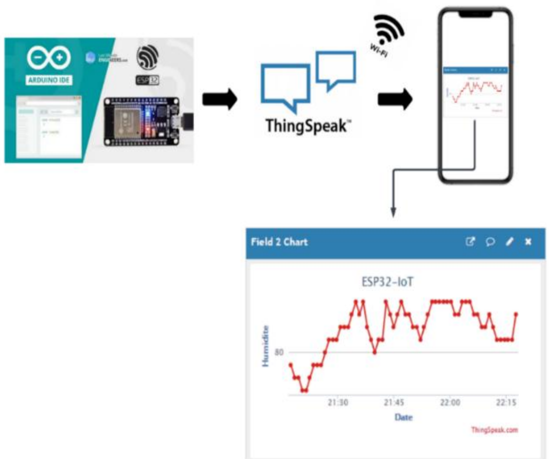

Figure 3. Software programming scheme for measuring carbon monoxide (CO) levels

In Figure 3, the programmer uses the Arduino IDE to sketch the code. Then with the ThingSpeak web which is open source, the data will be displayed in the form of graphs and tabular data. This ThingSpeak web can be accessed using either a smartphone or laptop.

The outline of the carbon monoxide (CO) measurement system is shown in Figure 4.

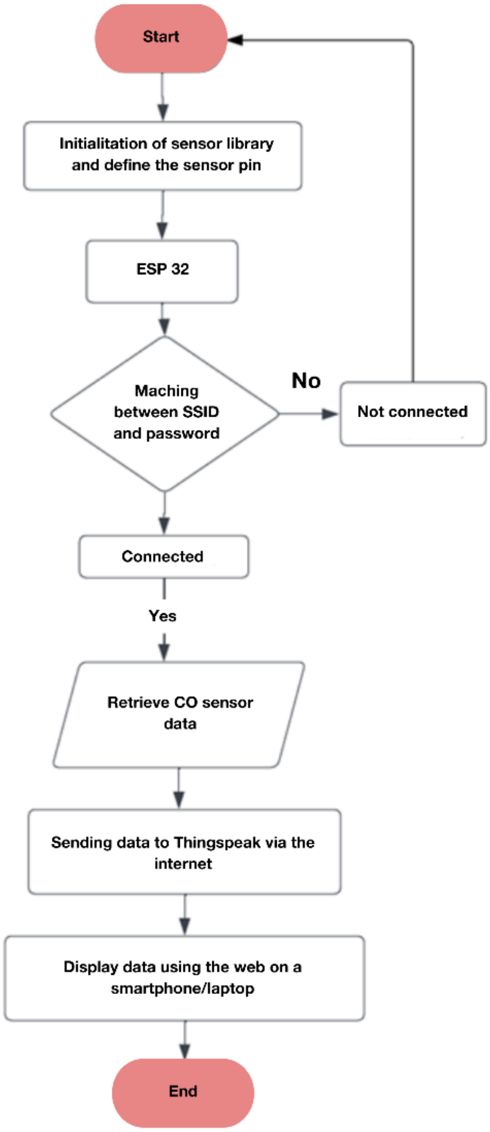

Figure 4. Flowchart of carbon monoxide (CO) measurement system

Figure 4, shows a flow in the carbon monoxide (CO) measurement system with IoT, so that it can be read through a smartphone or laptop. Results can be connected to a smartphone or laptop via the ThingSpeak web. If the results match "Yes" then the value will be displayed on a smartphone or laptop, but if not "No" the results cannot be displayed and will return to the initial measurement.

IV. Results and Discussion

The research entitled "Measurement of Carbon Monoxide (CO) Levels Using Internet of Things (IoT) Based Drones with NodeMCU ESP32" aims to design and determine the results of measuring carbon monoxide (CO) levels using a drone integrated with an MQ-7 gas sensor and NodeMCU ESP32. Control variables in measuring CO levels are the research location, namely in the area in Ketintang, Surabaya, manipulation variables include the measurement hours of CO levels, namely at 07.00 WIB, 11.00 WIB, and

15.00 WIB, as well as drone heights of 0 m, 2 m, and 5 m with the response variable, namely CO levels with units of Part Per Million (ppm) concentration. The results of the design of the CO level measuring device can be seen in Figure 5 as follows.

Figure 5. CO level measuring device using drone

Figure 5, shows that after the device is assembled as in Figure 1, it is then assembled on the drone leg and ready for data collection. The data will be sent via the internet on the ThingSpeak web as in Figure 3. From the measurement of CO levels, the results are obtained as in Table 3.

Table 3. Data of CO level measurement results in Ketintang, Surabaya

Time (WIB)	CO Level (ppm) at height			Air Quality
	0 m	2 m	5 m	
07.00	88,56	73,17	67,75	Medium
	89,35	72,10	68,28	
	86,48	70,87	68,58	
11.00	67,16	56,87	43,79	Medium (0-2 m) & Good (5 m)
	66,18	56,30	45,06	
	65,93	55,23	43,99	
15.00	48,16	41,94	33,53	Good
	48,14	41,64	32,36	
	50,48	40,27	30,90	

This research has produced a prototype of a measuring device for carbon monoxide (CO) levels in the air. This tool can measure CO levels in ppm units and then the results are displayed via the ThingSpeak web which has previously been programmed in the Arduino IDE. This tool uses nodeMCU ESP32 as a microcontroller because, in addition to its affordable price, the features on nodeMCU ESP32 are superior to other microcontrollers such as 32 GPIO pins, 12 ADCs, and 2 DACs, 16 MB memory capacity, 512 KB SRAM, Bluetooth, and WiFi available that can be used to apply IoT [18].

The use of the MQ-7 sensor is because this sensor can work with changes in resistance from the power supply so it is effective for knowing the amount of ppm content in measuring CO levels. MQ-7 sensors do not require large electrical power so they are very practical with high durability for measuring CO levels as an early detector of air pollution hazards [19].

Based on the data in Table 3 related to the results of measuring CO levels in urban locations, a graph can be made as in Figure 6.

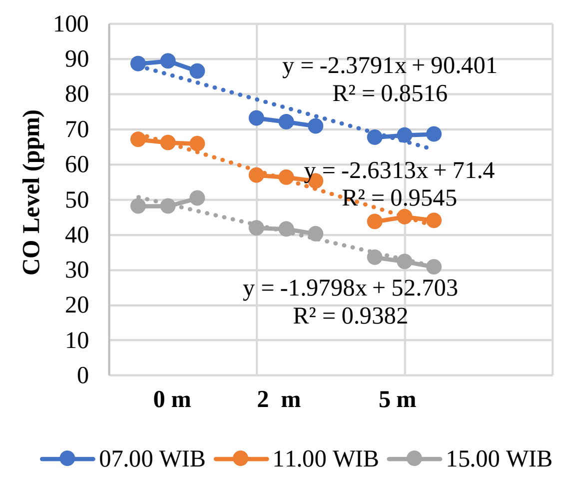

Figure 6. Graph of CO level measurement in Ketintang, Surabaya

From Figure 6, it can be seen that the highest CO levels are at 07.00 WIB at a height of 0 m then at a height of 2 m and 5 m. CO levels at 11:00 am and 3:00 pm decreased along with the height of the drone. At 07.00 WIB, the air quality is classified as moderate in the range of 67-88 ppm. At 11:00 am, the air quality is classified as moderate at 0 m and 2 m altitude, then the air quality becomes good at 5 m altitude in the range of 43-67 ppm. At 15.00 WIB the air quality changed to good with a range of CO levels of 30-50 ppm.

In Figure 6, it is known that the y equation at 07.00 WIB at 0 m, 2 m, and 3 m shows a gradient result (m) of -2.3791 with a constant (c) of 90.401 and a correlation coefficient value (R2) of 0.8516. The y equation at 11:00 am at 0 m, 2 m, and 3 m shows a gradient (m) of -2.6313 with a constant (c) of 71.40 and a correlation coefficient (R2) of 0.9545. The y equation at 15.00 WIB at 0 m, 2 m, and 3 m shows the gradient result (m) of -1.9798 with a constant (c) of 52.703 and a correlation coefficient value (R2) of 0.9382. This means that the MQ-7 sensor has almost the same value and is well-calibrated so that it can be used in measuring CO levels.

From the results in Table 3 and Figure 6, it can be seen that CO levels are influenced by the hour and height of measurement. This can occur because in the morning, such as at 07.00 WIB, human activities are denser than at 11.00 WIB and 15.00 WIB. There is research that has been conducted by NAFAS Indonesia in 2021 shows that Air Quality Indexes (AQI) in the morning tend to be higher with the dominance of PM2.5 air pollution [20]. Activities carried out include going to school, work, and other activities that make the volume of vehicles increase. In the afternoon, such as at 11:00 am, the volume of vehicles has begun to normalize, and in the afternoon, such as at 3:00 pm, the volume of vehicles is also normal but is influenced by higher air temperatures and sometimes rain. When the air temperature gets higher, CO levels decrease because the air will be more tenuous so the concentration of CO levels becomes lower [21].

Then at higher altitudes, wind speeds are higher and CO levels can decrease because the number of particles spreads so that CO levels become smaller than measurements at ground level [22]. In addition, CO gas is produced by human activities that are mostly carried out close to the ground such as vehicle exhaust and garbage burning which are then mixed with the surrounding air [23]. However, although CO levels are generally lower at higher altitudes, several other factors can affect CO levels such as regional or global air pollution that can be carried by air, weather, and geographical and topographical factors. Therefore, research in measuring CO levels is needed to anticipate the occurrence of air pollution that results in the disruption of human survival.

V. CONCLUSION

From the research that has been done, it can be concluded that the time and height of measurement affect the CO levels produced. In the morning measurements, CO levels are higher than in the afternoon and evening. This can occur because at 07.00 WIB human activities such as the use of motorized vehicles and the process of burning waste in households are more done than at 11.00 WIB and 15.00 WIB. The higher the altitude in measuring CO levels makes CO levels lower because human activities in producing CO gas such as the use of vehicles and burning garbage are carried out close to the ground. CO levels can also be influenced by other factors such as temperature, wind speed, and weather when taking measurements.

REFERENCE

[1] A. N. Hidayah, D. Triyanto, and Y. Brianorman, "Perancangan Alat Ukur Gas Karbon Monoksida (CO) Berbasis Pesawat Tanpa Awak," *Coding Jurnal Komputer dan Aplikasi*, vol. 2, no. 1, 2014.

[2] R. Madugala, and E. G. Aklilu, "Impacts of Environmental Air Pollution on Human Health," *International Journal of Science and Research* (IJSR), vol. 6, no. 3, pp. 1104–1107, 2017.

[3] R. Armus *et al.*, *Pengelolaan Sampah Padat*. Yayasan Kita Menulis, 2022.

[4] K. Amiroh, O. A. Permata, and F. Z. Rahmanti, "Analisis Kualitas Udara untuk Monitoring Kesehatan Lingkungan Rumah Sakit," *Jurnal Nasional Informatika dan Teknologi Jaringan*, vol. 4, no. 1, pp. 29–36, 2019.

[5] D. I. Saputra, "PERANCANGAN SISTEM PEMANTAU KEBISINGAN, GETARAN, SUHU, DAN KELEMBABAN RUANG COATING BERBASIS IOT," *Journal of Energy and Electrical Engineering (JEEE)*, vol. 3, no. 1, 2021.

[6] D. IRAWAN, "RANCANG BANGUN APLIKASI PEMANTAUKADAR ASAP BERBASIS WIRELESS SENSOR NETWORK DI LINGKUNGAN INDOOR," *Prodi Teknik Informatika Universitas PGRI Yogyakarta*, 2017.

[7] M. A. A. Prakoso and L. Rakhmawati, "Sistem monitoring kadar karbon monoksida (CO) pada cerobong asap industri dengan komunikasi bluetooth melalui smartphone Android," *Jurnal Teknik Elektro*, vol. 7, no. 01, pp. 23–30, 2018.

[8] M. Asmazori, "Rancang Bangun Alat Pendeteksi NOx dan CO Berbasis Mikrokontroler ESP32 dengan Notifikasi Via Telegram dan Suara," *JITCE (Journal of Information Technology and Computer Engineering)*, vol. 5, no. 02, pp. 57–62, Sep. 2021, doi: 10.25077/jitce.5.02.57-62.2021.

[9] F. Nex, C. Armenakis, M. Cramer, D. A. Cucci, M. Gerke, E. Honkavaara, A. Kukko, C. Persello, and J. Skaloud, "UAV in the advent of the twenties: Where we stand and what is next," *International Society for Photogrammetry and Remote Sensing (ISPRS)*, vol. 184, pp. 215–242, 2022.

[10] S. Steiniger and A. J. S. Hunter, "The 2012 free and open source GIS software map–A guide to facilitate research, development, and adoption," *Comput Environ Urban Syst*, vol. 39, pp. 136–150, 2013.

[11] G. H. Cahyono, "Internet of things (sejarah, teknologi dan penerapannya)," *Swara Patra: Majalah Ilmiah PPSDM Migas*, vol. 6, no. 3, 2016.

[12] M. Chwalisz, "thingspeak Documentation," *SL ThingSpeak*, 2016.

[13] T. R. Fahrisa, "Studi Kualitas Udara (Karbon Monoksida, Sulfur Dioksida dan PM10) dengan Stasiun Pemantau Di Kota Surabaya.," Intitute Teknologi Sepuluh November, Surabaya, 2017.

[14] J. L. Fetterman, M. J. Sammy, and S. W. Ballinger, "Mitochondrial Toxicity of Tobacco Smoke and Air Pollution," *Comput Environ Urban Syst*, vol. 391, pp. 18–33, 2017.

[15] D. Kusumawardani and A. M. Navastara, "Analisis Besaran Emisi Gas CO2 Kendaraan Bermotor Pada Kawasan Industri SIER Surabaya," *Jurnal Teknik ITS*, vol. 6, no. 2, Mar. 2018, doi: 10.12962/j23373539.v6i2.24392.

[16] A. A. Kiswandono, "Kajian Indeks Standar Polusi Udara (ISPU) Nitrogen Dioksida (NO2) Di Tiga Lokasi Kota Bandar Lampung," *Analit: Analytical and Environmental Chemistry*, vol. 2, no. 1, pp. 42–51, 2017.

[17] S. G. Gupta, M. Ghonge, and P. M. Jawandhiya, "Review of Unmanned Aircraft System (UAS)," *SSRN Electronic Journal*, 2013, doi: 10.2139/ssrn.3451039.

[18] M. F. Wicaksono, "Hidayat, Mudah Belajar Mikrokontroler Arduino Disertai 23 Proyek, termasuk Proyek Ethernet dan Wireless Client Server." Bandung: Informatika, 2017.

[19] K. U. P. A. G. FASILKOM and M. F. AKBAR, "PEMANFAATAN SENSOR MQ-135 SEBAGAI MONITORING," 2021.

[20] Setyaji, "webinar NAFAS Air Quality Report 2021: Bagaimana Kualitas Udara tahun 2021?," Jakarta, Mar. 2022.

[21] Yuliando, "Strategi Pengendalian Pencemaran Gas Karbon Monoksida (CO) olehAktivitas Transportasi di Kota Padang Sumatera Barat," *J. Presipitasi*, vol. 19, no. 2, pp. 262–270, 2017.

[22] M. Ashar, S. Sumarlin, and M. Assiddieq, "Analisis Parameter Karbon Monoksida (CO) dari Aktivitas Transportasi di Sekitar Industri Pertambangan Nikel: Studi Kasus: Jalan Poros Puuruy-Morosi, Desa Puuruy, Kecamatan Morosi, Kabupaten Konawe,"

Jurnal TELUK: Teknik Lingkungan UM Kendari, vol. 2, no. 2, pp. 10–15, 2022.

[23] I. Manisalidis, E. Stavropoulou, A. Stavropoulos, and E. Bezirtzoglou, "Environmental and Health Impacts of Air Pollution: A Review," *Front Public Health*, 2020.