International Journal of Research in Environmental Science (IJRES)
Volume 10, Issue 2, 2024, PP 39-46
ISSN No. (Online) 2454-9444
DOI: http://dx.doi.org/10.20431/2454-9444.1002004
www.arcjournals.org

Air Quality Assessment in Danao City, Cebu, Philippines

Delfa G. Castilla[1*], Yushine Mae C. Cabahug[2], Mark Alaien C. Calderon[3], Charrefel S. Lima[4], Karen S. Monteron[5]

[1]*Professor, College of Engineering, Cebu Technological University - Danao Campus*

[2345]*Student, College of Engineering, Cebu Technological University - Danao Campus*

Corresponding Authors:** ***Delfa G. Castilla, *Professor, College of Engineering, Cebu Technological University - Danao Campus*

Abstract: *This study aimed to evaluate air pollutant across various urban zones using a portable air quality detector over ten days. The monitored areas included residential, commercial, industrial, and high-traffic zones. The pollutants assessed were Volatile Organic Compounds (VOCs), Particulate Matter (PM2.5 and PM10), Carbon Monoxide (CO), and Carbon Dioxide (CO2). Results indicated that VOC levels were consistently within the good range in Danao City, suggesting minimal risk from these pollutants. PM10 concentrations were also good, reflecting effective dust control measures and the absence of significant construction activities. CO levels were consistently low, indicating effective management of vehicular and industrial emissions. However, PM2.5 levels were moderate, posing potential health risks, particularly for sensitive groups such as children, older people, and individuals with preexisting respiratory conditions. This finding underscores the need for improved control measures targeting fine particulate emissions from traffic and industrial activities. A significant finding was the variation in CO2 levels. Taytay and Maslog locations exhibited unhealthy CO2 concentrations, likely due to dense traffic and industrial activities, necessitating targeted interventions like improved ventilation and traffic management.*

Conversely, CO2 levels in Sabang, Looc, Poblacion, Guinsay, and Dunggoan were moderate but required attention to prevent escalation to unhealthy levels. These findings highlight the necessity for targeted air quality strategies in Danao City. While the city enjoys good air quality concerning VOCs, PM10, and CO, addressing moderate PM2.5 levels and elevated CO2 concentrations is crucial. Implementing strategies will help safeguard public health and ensure sustainable air quality improvements across the city.

Keywords: *volatile organic compounds, particulate matter, carbon monoxide, carbon dioxide*

1. INTRODUCTION

Air quality is a critical environmental and public health concern worldwide. Poor air quality can lead to a range of health problems, including respiratory and cardiovascular diseases, and can significantly impact the quality of life. Urban areas, in particular, are often hotspots for air pollution due to factors such as industrial activity, traffic emissions, and construction.

Common air pollutants that draw intense concern include particulate matter (PM2.5) (PM10), carbon monoxide (CO), Total Volatile Organic Compounds (TVOC), and Carbon Dioxide (CO2) (Muir et al., 2020) are harmful to the environment. Particulate matter (PM) comprises a variety of components produced through numerous natural and human-related processes (Guerra et al., 2019). High levels of PM exposure elevate the risk of lung cancer, respiratory illnesses, arteriosclerosis, and alterations in heart rate variability (Alves et al., 2018). Additionally, aerosol particles affect the environment by reducing visibility and causing the discoloration of buildings (de Kok et al., 2021; Sun et al., 2004; Virtanen et al., 2021).

Carbon monoxide (CO) is a flammable and toxic gas produced from the incomplete combustion of carbon-containing materials. Upon inhalation, CO is absorbed into the plasma, crosses the red blood cell membrane, and binds with hemoglobin (Hb) in the cytoplasm to form oxygen, rendering it unable to bind with oxygen (Fang et al., 2018).

Volatile Organic Compounds (VOCs) are organic chemicals with boiling points approximately between 50-250°C (Shaw, 2020). Outdoor VOC concentrations vary with season, temperature, and proximity to

emission sources like industries, traffic, and gas stations (Jia et al., 2019; Kwon et al., 2019). Indoor VOC levels are influenced by outdoor concentrations due to air exchange and by various indoor sources (Batterman et al., 2018; Charles et al., 2018). At room temperature, VOCs can enter the atmosphere and potentially cause headaches, dizziness, nausea, and irritation of the mucous membranes (Nathanson, 2020).

1.1 Air Quality Guidelines (AQG) by EPA, WHO, and OSHA

Table1. *Air Quality Guidelines (AQG) by EPA, WHO, and OSHA*

Parameter (Unit)	EPA / WHO	OSHA
CO_2 (ppm)	1,000	Various 0 - 700 GOOD 701 - 1,000 MODERATE 1,001 - 2,500 UNHEALTHY 2,501 - 5,000 VERY UNHEALTHY > 5,001 HAZARDOUS
$PM_{2.5}$ (µg/m3)	35 (mean)	Various 0 - 700 GOOD 701 - 1,000 MODERATE 1,001 - 2,500 UNHEALTHY 2,501 - 5,000 VERY UNHEALTHY > 5,001 HAZARDOUS
PM_{10} (µg/m3)	150 (mean)	Various 0 - 700 GOOD 701 - 1,000 MODERATE 1,001 - 2,500 UNHEALTHY 2,501 - 5,000 VERY UNHEALTHY > 5,001 HAZARDOUS
TVOC (µg/m3)	300 (TLV-TWA)	Various 0 - 700 GOOD 701 - 1,000 MODERATE 1,001 - 2,500 UNHEALTHY 2,501 - 5,000 VERY UNHEALTHY > 5,001 HAZARDOUS
CO (ppm)	50	N/A

The EPA provides various standards for air quality, including CO2, PM2.5, and PM10 concentrations (EPA, 2018). According to the WHO, the mean acceptable levels for PM2.5 and PM10 are 35 µg/m³ and 150 µg/m³, respectively (WHO, 2019). OSHA offers guidelines for permissible exposure limits to various substances, including TVOCs and CO (OSHA, 2021).

Danao City, located in the province of Cebu, Philippines, has experienced rapid urbanization and

industrialization over the past few decades. Minebea Mitsumi is the number one manufacturing industry in Danao, with a population of approximately 25,000 employees, followed by Republic Cement, which is into cement manufacturing with about 10,000 employees. This development brings with it the potential for increased air pollution, which can affect both the environment and the health of the city's residents.

This study aimed to assess the air quality levels in various areas of Danao City, specifically measuring and analyzing air pollutants such as particulate matter (PM2.5 and PM10), carbon monoxide (CO), carbon dioxide (CO2), and VOC. The purpose of the study is to evaluate and communicate air quality levels in Danao City to provide timely warnings and safeguard public health.

2. Materials And Method

2.1 Research Design

This study employed an Observational and Monitoring approach to assess air quality levels at various locations in Danao City. Instrumental Data Collection is utilized to measure air quality parameters using specialized devices. Purposive Sampling is employed to select specific areas for data collection,

focusing on areas that are located along the National Road. Data analysis involved the application of Descriptive Statistics to summarize and compare air quality data across different areas of Danao City.

2.2 Study Site

The study site is located in Danao City, which is situated 27 kilometers north of Cebu City, Philippines. One of the primary sampling locations is along the national road at Barangay Maslog, Sabang, Looc, Poblacion, Taytay, Guinsay, and Dunggoan. During the study, air pollution levels were measured: at street level at seven distinct locations within the city. The first location was in front of the Maslog Church. The second location was in front of Cebu Technological University- Danao Campus. The third location was in front of Looc Barangay Hall. The fourth location was in front of Danao Church. The fifth location was in front of the Taytay Church. The sixth location was in front of Colegio de San Antonio de Padua- Danao Campus. The seventh location was in front of Republic Cement & Building Materials, Inc. in Danao City.

2.3 Research Instrument

Various air pollutants, including PM2.5, PM10, CO2, CO, and VOCs, were measured using an air quality measuring device at street level in Danao City. The VT-6IN1 Multi-Gas Monitor was used to measure gaseous pollutants outdoors, with a detection range of PM2.5: 0-999 ug/m3, PM10: 0-999 ug/m, CO: 0-999 ppm, TVOC: 0-1999 ug/m3, CO2: 400-5000 ppm. Multiple readings of each pollutant were recorded in parts per million (ppm) over one hour in various areas in Danao City.

2.4 Data Gathering

Data collection employed air quality detectors (VT-6IN1 Multi-Gas Monitor) in a systematic approach. Seven monitoring sites were purposively selected along the National Road in Danao City, focusing on areas with varying land use, population density, and proximity to pollution sources. Detectors measured key pollutants (PM2.5, PM10, CO, TVOC, and CO2), calibrated per manufacturer specifications, and positioned at 1.5-2 meters above ground.

Data collection spanned ten days (March 10-19, 2024), with hourly recordings from 12:00-1:00 PM to capture diurnal and daily variations. Detectors, equipped with data loggers, automatically recorded pollutant concentrations, ensuring data integrity. By rotating detectors among sites and integrating meteorological data, the study provided a detailed assessment of air quality across Danao City, supporting public health and environmental management strategies.

2.5. Data Treatment

The collected air quality data, including measurements of PM2.5, PM10, CO, TVOC, and CO2, underwent rigorous treatment using one-way Analysis of Variance (ANOVA).

Initially, data was encoded from air quality detectors at the end of each monitoring period. Raw data underwent preliminary inspection to identify anomalies, ensuring data integrity. Processed data were compiled into comprehensive reports with graphical representations to communicate findings and insights into pollution sources and environmental factors. Treated data formed a robust foundation for informed recommendations to improve air quality in Danao City.

To ensure accurate analysis of Volatile Organic Compounds (VOC) and Carbon Monoxide (CO) levels, data from Day 1, which coincided with a Sunday experiencing unusually high traffic, was identified as an outlier and excluded from the dataset. This exclusion was justified as the elevated pollutant levels on that specific day did not represent typical conditions. By removing Day 1 data, the subsequent analysis of the remaining days provided a more accurate reflection of the usual air quality. This process was thoroughly documented to maintain transparency and credibility, ensuring that the findings accurately represent typical air quality trends without distortion from a typical event.

3. Results And Discussions

3.1. Average Levels of TVOC Air Pollutant

Figure 1 shows the average levels of TVOC air pollutants in various areas of Danao City. Maslog had the highest average level of TVOC, 0.0405 mg/m3, and Sabang with 0.0133 mg/m3. Looc with 0.0131 mg/m3. Poblacion with 0.0133 mg/m3. Dunggoan with 0.0129 mg/m3. Guinsay had the lowest level, 0.0128 mg/m3.

Air quality guidelines (AQG) are concentrations over a given period that are considered acceptable for each pollutant's effects on health and the environment. They can also be used as a benchmark to see if air pollution is getting better or worse (Charles et al., 2018). The air quality standards are suggested by different international scientific agencies (such as the U.S. Environmental Protection Agency, EPA, WHO, and OSH) and Arab countries (such as Egypt and Saudi Arabia).

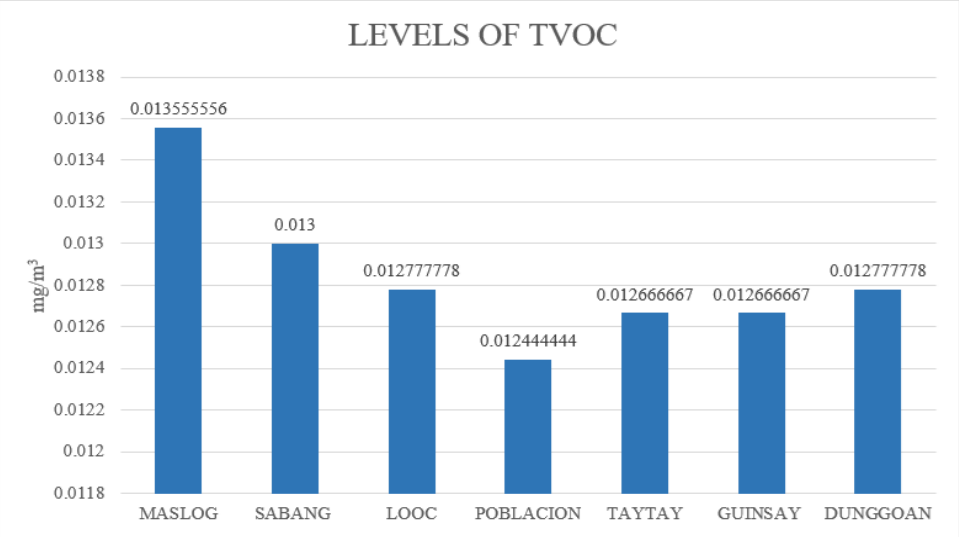

Figure1. *Average Levels of TVOC Air Pollutant*

Figure 1 shows the average levels of TVOC air pollutants in various areas of Danao City. Maslog had the highest average level of TVOC, 0.0405 mg/m3, and Sabang with 0.0133 mg/m3. Looc with 0.0131 mg/m3. Poblacion with 0.0133 mg/m3. Dunggoan with 0.0129 mg/m3. Guinsay had the lowest level, 0.0128 mg/m3.

Air quality guidelines (AQG) are concentrations over a given period that are considered acceptable for each pollutant's effects on health and the environment. They can also be used as a benchmark to see if air pollution is getting better or worse (Charles et al., 2018). The air quality standards are suggested by different international scientific agencies (such as the U.S. Environmental Protection Agency, EPA, WHO, and OSH) and Arab countries (such as Egypt and Saudi Arabia).

According to EPA, WHO, and OSHA, within 0-50 mg/m3 is considered good. Across all monitored sites, VOC levels were consistently found to be within the "good" range. This indicates that the concentration of VOCs was low and not likely to pose a significant health risk to the residents of Danao City. The primary sources of VOCs, such as industrial emissions and vehicular exhaust, appeared to be well-managed, resulting in minimal impact on air quality.

3.2. Average Levels of PM2.5 Air Pollutant

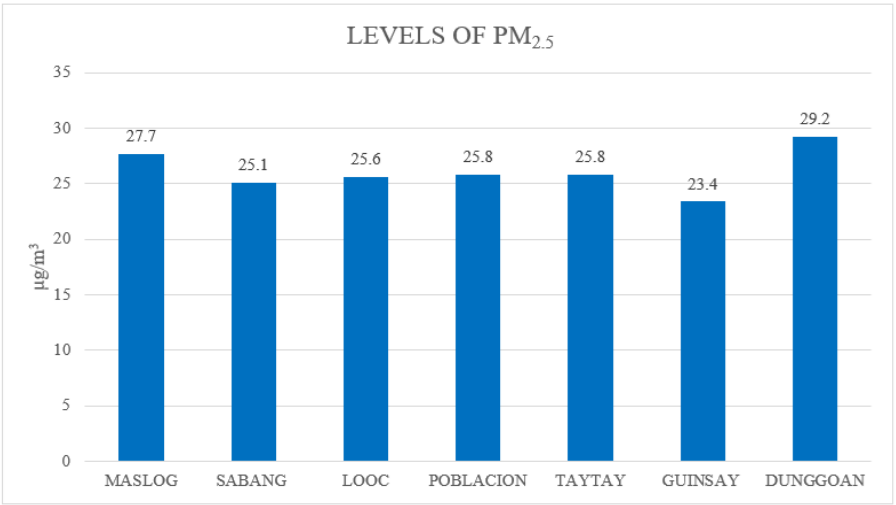

Figure2. *Average Levels of $PM_{2.5}$ Air Pollutant*

Figure 2 shows the average levels of PM2.5 air pollutants in various areas of Danao City. Maslog area had an average level of 27.7 µg/m3 compared to Sabang with only 25.1 µg/m3. In Looc with 25.6 µg/m3 while in Poblacion with 25.8 µg/m3. Going to Taytay with an average level of 25.8 µg/m3, Guinsay decreases to 23.4 µg/m3 while it increases to 29.2 µg/m3 in the Dunggoan area. The highest average level among the areas in Danao City is observed in Dunggoan, with 29.2 mg/m3, indicating a potential for significant air quality concerns.

According to EPA, WHO, and OSHA, within 0-12 µg/m3 is considered good, while 12.1-35.4 µg/m3 is considered moderate. PM2.5 levels were classified as "moderate" throughout the monitoring period. This suggests that while the concentration of fine particulate matter was not critically high, it was still sufficient to pose a potential health concern, particularly for sensitive groups such as children, the elderly, and individuals with preexisting respiratory conditions. The moderate levels of PM2.5 could be attributed to a combination of vehicular emissions, industrial activities, and possibly residential burning practices.

3.3. Average Levels of PM_{10} Air Pollutant

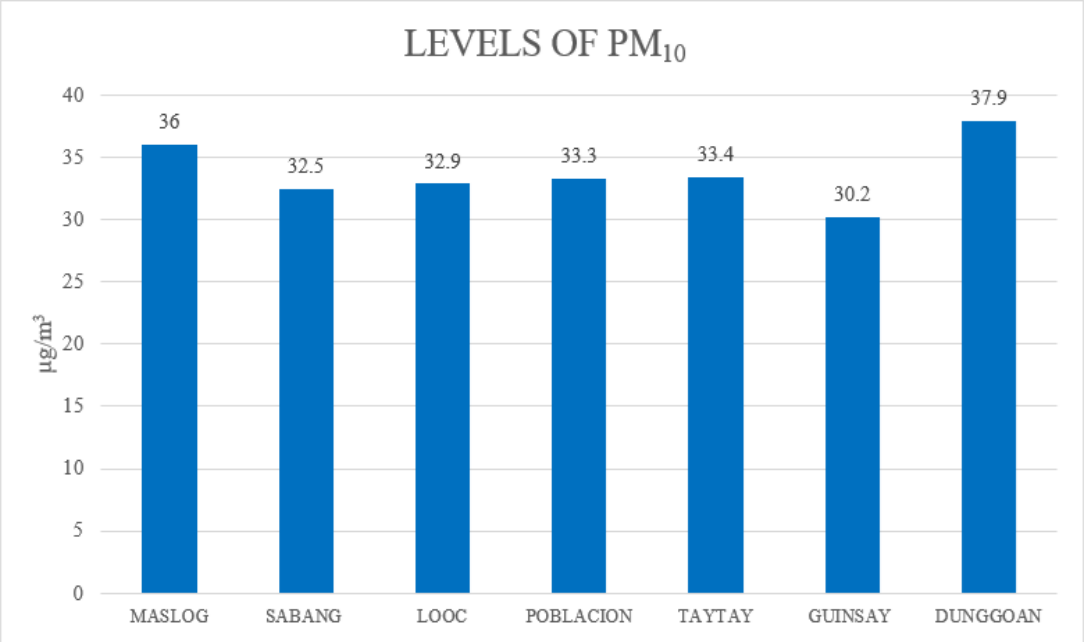

Figure3. *Average Levels of PM10 Air Pollutant*

Figure 3 shows the Average Level of PM10 air pollutants in various areas of Danao City, indicating Maslog with 36 µg/m3. Sabang with 32.5 µg/m3, Looc with 32.9 µg/m3 while Poblacion with 33.3 µg/m3. Taytay with 33.4 while it decreased to 30.2 µg/m3 in the Guinsay area. Lastly, Dunggoan increases to 37.9 µg/m3. The highest and lowest average level of PM10 is observed in Dunggoan and Guinsay, with a level of 37.9 and 30.2 µg/m3

According to EPA, WHO, and OSHA, concentrations within 0-54 µg/m3 are considered good. The concentrations of PM10 were found to be in the "good" range at all monitored locations. This indicates that the levels of coarser particulate matter were low and unlikely to cause adverse health effects. Effective dust control measures and the absence of significant construction activities during the monitoring period likely contributed to the favorable PM10 levels.

3.4. Average Levels of CO Air Pollutant

Figure 4 shows the average levels of CO air pollutants in various areas of Danao City. Maslog had the highest level of CO, with 2.8 ppm; Sabang had 1.5 ppm, Looc had 1.2 ppm, and Guinsay had 1.2 ppm. Dunggoan with 1.5 ppm. Taytay had the lowest level of CO, with 0.9 ppm.

According to the EPA, WHO, and OSHA, a concentration within 0-50 ppm is considered good. Carbon monoxide levels across all sites were consistently in the "good" range, indicating that CO concentrations were low and did not pose a health risk. This positive result reflects effective traffic management and the limited use of fossil fuels for heating or cooking in the area.

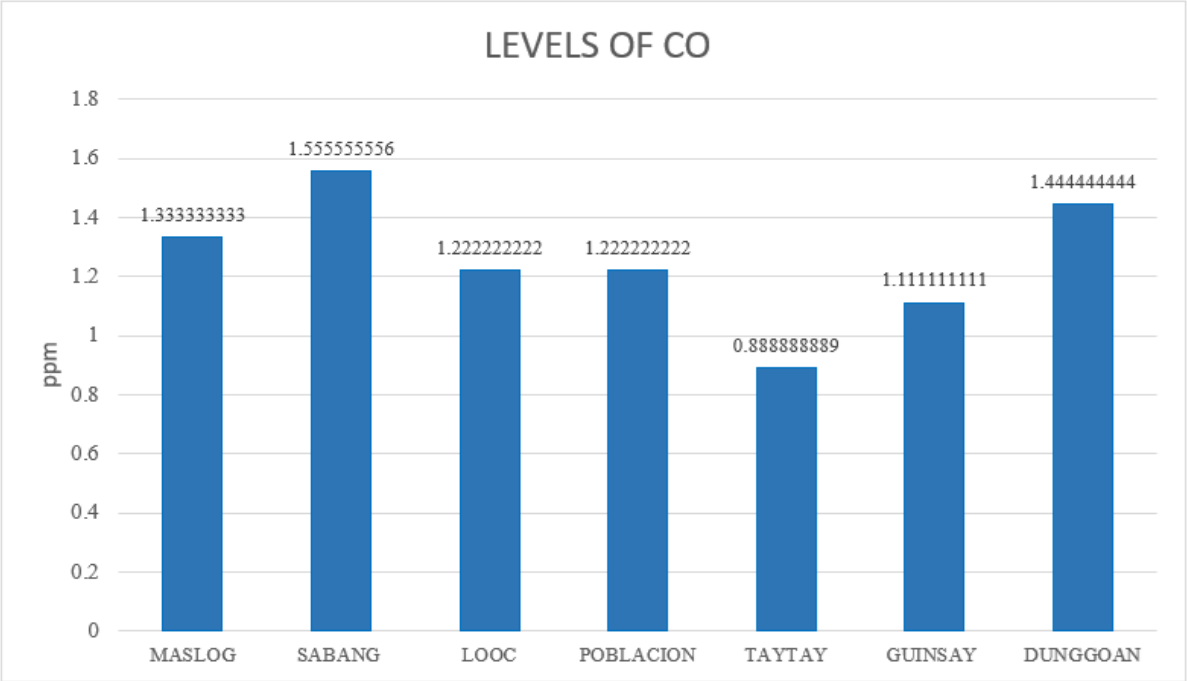

Figure4. *Average Levels of CO Air Pollutant*

3.5. Average Levels of CO2 Air Pollutant

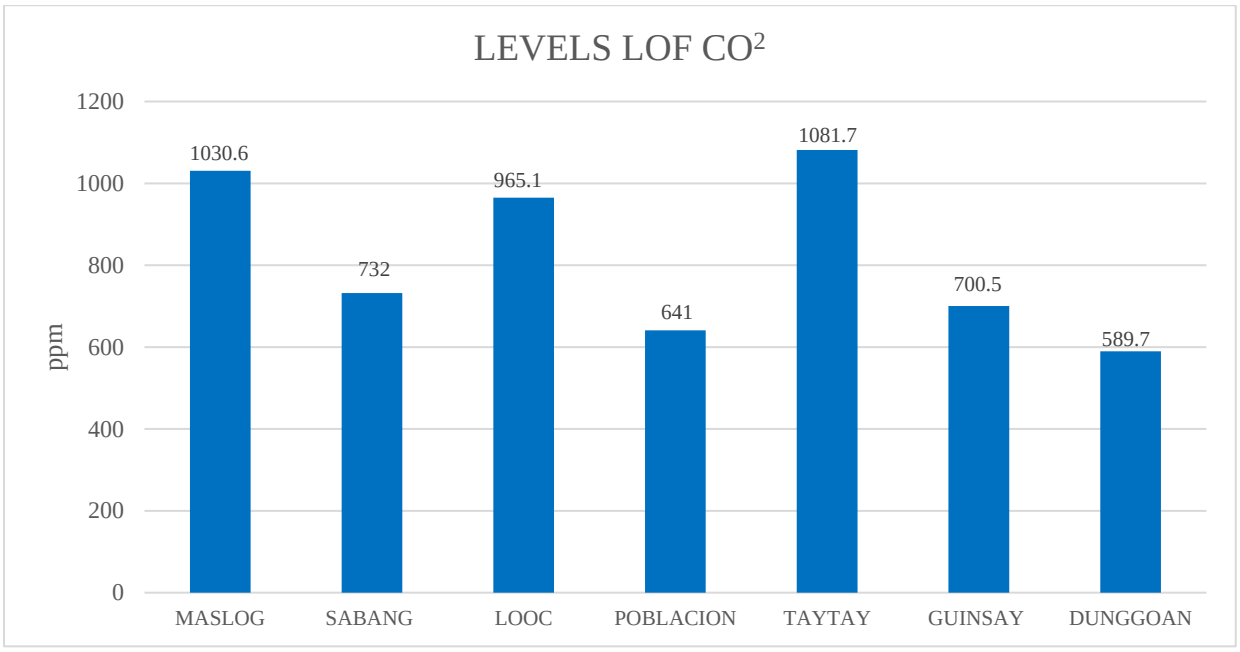

Figure5. *Average Levels of CO_2 Air Pollutant*

Figure 5 shows the average level of CO2 air pollutants in various areas of Danao City. Taytay had the highest level of CO2, with 1081.7 ppm, followed by Maslog, with 1030.6 ppm; Sabang, with 732 ppm; Looc, with 965.1 ppm; Poblacion, with 641 ppm; Guinsay, with 700.5 ppm; and Dunggoan, with 589.7 ppm.

According to EPA, WHO, and OSHA, within 0-700 ppm is considered good, 701-1,000 ppm is considered moderate, and 1,001-2,500 is considered unhealthy. The analysis of CO2 levels revealed significant spatial variation. In the Taytay and Maslog locations, CO2 concentrations were found to be "unhealthy," suggesting high levels of CO2 that could impact air quality and pose health risks, especially in enclosed or poorly ventilated areas. The high CO2 levels in these areas could be due to dense traffic, industrial emissions, or limited green spaces.

In contrast, CO2 levels in Sabang, Looc, Poblacion, Guinsay, and Dunggoan were categorized as "moderate." While not as severe as in Taytay and Maslog, the moderate levels of CO2 in these areas still indicate elevated concentrations that warrant attention. These findings suggest the need for improved ventilation, traffic management, and the implementation of green infrastructure to enhance air quality.

3.6. One Way – ANOVA

Table2. *One Way – ANOVA*

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12249122	4	3062280	4.940823	0.002896	2.641465
Within Groups	21692706	35	619791.6			
Total	33941827	39				

The One-Way ANOVA analysis was conducted to determine whether there are significant differences in pollutant levels across various locations in Danao City. The hypotheses for this analysis were: the null hypothesis (H0) stating that there is no significant difference between locations, and the alternative hypothesis (H1) asserting that there is a significant difference between locations.

The ANOVA analysis shows that the variation in pollutant levels between different locations in Danao City is statistically significant. The data supports the alternative hypothesis (H1) that there is a significant difference between locations. This finding suggests that environmental factors or sources of pollution vary significantly across the different areas, and targeted interventions might be necessary to address the higher pollution levels in certain locations.

3.7. Air Quality in various areas in Danao City

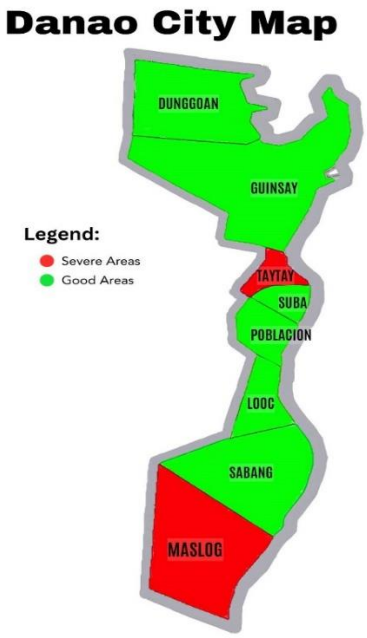

Figure6. *Air Quality in various areas in Danao City*

The air quality analysis in Danao City reveals that the areas of Maslog and Taytay are experiencing severe pollution conditions, indicated by their red coloring on the map. This suggests that the levels of pollutants such as TVOC, PM2.5, PM10, CO, and CO2 in these areas are significantly higher compared to other regions in the city. In contrast, the remaining areas, including Dunggoan, Guinsay, Suba, Poblacion, Looc, and Sabang, are marked in green, indicating that they have good air quality. This means that the pollutant levels in these areas are within acceptable limits and do not pose a significant

health risk to the residents. The significant difference in air quality across these regions is corroborated by the One-Way ANOVA analysis, which showed notable variations

in the levels of several pollutants, highlighting the need for targeted environmental interventions in Maslog and Taytay.

4. CONCLUSION

In conclusion, while Danao City generally enjoys good air quality in terms of Volatile Organic Compounds (VOCs), Particulate Matter (PM2.5 and PM10), Carbon Monoxide (CO), and Carbon Dioxide (CO2) levels need to be addressed. Focused efforts to reduce PM2.5 and CO2 emissions and improve overall air quality are essential to protecting public health and enhancing the quality of life for all residents. This study provides a valuable baseline for ongoing air quality monitoring and the development of targeted strategies to ensure sustainable air quality management in Danao City.

REFERENCES

1. Alves, C.A., Pio, C.A. and Duarte, A.C. (2018) Particle size distributed organic compound in a forest atmosphere. Environmental Science Technology 25: 2113-40
2. Batterman, S., Jia, C. and Hatzivailis, G. (2018) Migration of volatile organic compounds from attached garages to residences: a major exposure source. Environmental Research 104: 224-240.
3. Charles, K., Magee, R.J., Won, D. and Lusztyk, E. (2018) Outdoor Air Quality Guidelines and Standards. National Research Council Canada, RR-204.
4. Kok, T.M.C., Driece, H.A.L., Hogervorst, J.G.F. and Briede´, J.J.B. (2021) Toxicological assessment of ambient and traffic-related particulate matter: A review of recent studies. Mutation Research 613: 103-122.
5. Guerra, A.I., Lerda, D. and Martines, C. (2019) Benzene emissions from motor vehicle traffic in the urban area of Milan: hypothesis of health impact assessment. Atmos Environ 29: 3559- 69.
6. Fang, G-C., Wu, Y-S., Chen, J-C., Rau, J-Y., Huang, S-H. and Lin, C-K. (2018) Concentrations of ambient air particulates (TSP, PM2.5 and PM2.5–10) and ionic species at offshore areas near Taiwan Strait. Journal of Hazardous Materials B132: 269-276.
7. Jia, C., Batterman, S. and Godwin, C. (2019) VOCs in industrial, urban and suburban neighborhoods - Part 2: Factors affecting indoor and outdoor concentrations. Atmospheric Environment 42: 2101-2116.
8. Muir, D., Longhurst, J.W.S., and Tubb, A. (2020) Characterization and quantification of the sources of PM10 during air pollution episodes in the UK. Science of the Total Environment 358: 188-205.
9. Nathanson, T. (2020) Indoor Air Quality in Office Buildings: A Technical Guide. Minister of National Health and Welfare, Canada.
10. Occupational Safety and Health Administration. (2021). Permissible Exposure Limits – Annotated Tables.
11. Shaw, C.Y., Won, D., Reardon, J. (2020) Managing Volatile Organic Compounds and Indoor Air Quality in Office Buildings – An Engineering Approach National Research Council Canada, RR-205.
12. U.S. Environmental Protection Agency. (2018). National Ambient Air Quality Standards (NAAQS).
13. World Health Organization. (2019). Air Quality Guidelines: Global Update 2018.

Citation: *Delfa G. Castilla, et.al.," Air Quality Assessment in Danao City, Cebu, Philippines", International Journal of Research in Environmental Science (IJRES), vol. 10, no. 2, pp. 39-46, 2024. Available: DOI: http://dx.doi.org / 10.20431/2454-9444.1002004*