The Development of Low-Cost Cloud-Based CO_2 Monitoring System for Green City Application

Mohamad Hanif Md Saad
Mohd Zaki Sarnon
Aini Hussain
Mohd Rezdwan Rosli

Center of Integrated System and Advanced Technology Engineering (INTEGRA),
Faculty of Engineering and Built Environment,
Universiti Kebangsaan Malaysia,
43600 Bangi, Selangor, Malaysia
** hanifsaad@ukm.edu.my*

ABSTRACT

Nowadays, our society, especially those big city dwellers, are very concerned about the air quality they breathe in since the quality of air has a great impact on their health and will affect how they live. As such, availability of an affordable carbon dioxide (CO_2) Monitoring System that can provide a standalone real-time CO_2 monitoring is very much needed. Such a system could serve as a useful tool for the local council to identify the level of concentration of harmful gases in selected locations. This study presents the results of a qualitative study undertaken for a period of six days. It also discussed the design, development and implementation of the CO_2 monitoring system. The findings suggest that the level of CO_2 concentration varies throughout the day and affects the environment in a green city. Quantitative data were made available via this low-cost web cloud-based monitoring response to sensing taken in 1-minute intervals, continuously. Thus, it can be concluded that the developed low-cost cloud-based air quality (CO_2) monitoring system with a real-time graphical display was successfully implemented and provided information on how the environments are affected from people's daily activities.

ISSN 1823- 5514, eISSN 2550-164X

Received for review: 2018-10-11
Accepted for publication: 2018-07-31
Published: 2018-11-30

Keywords: *Cloud-Based System, Data Acquisition, Environmental Monitoring, Sensors, Air Quality.*

Introduction

The world's cities are becoming increasingly congested and polluted. The green environment provides an ecosystem service that could help improve lives, especially the health of people. Trees in green spaces might reduce air pollution by absorbing certain airborne pollutants from the atmosphere. Green cover and trees can also moderate temperatures by providing shade and cooling areas, thus, helping in reducing the risks of heat-related issues [1].

Globally, cities account for about 70% of Carbon Dioxide (CO_2) emission, which comprises a significant share of global greenhouse gas emissions, the bulk of which is generated in buildings and construction, urban transport, and the energy sector [2]. According to the Intergovernmental Panel on Climate Change (IPCC), it is clear that buildings, energy and transport are the largest CO_2 emitters. Studies from 50 cities in Japan show that less fragmented and compact cities emit less CO_2 from the passenger transportation sector compared to sprawling cities [3].

In this study, a low-cost CO_2 Monitoring system successfully provided data for determining the relationship between CO_2 and a green city. The cost of one online CO_2 monitoring system station is about RM 900.00, which is comparatively much lower as the market cost for a station is more than RM 3,000.00, inclusive of the online monitoring system. The next topic of study will discuss the need for monitoring CO_2 and the source of its emission.

Monitoring CO_2 for green city application

Peoples often take the air that they breathe for granted, especially in a big city where the level of air pollution is high [4]. The interconnecting green infrastructure improves air quality in congested cities by facilitating the circulation of fresh air from rural to urban areas [5]. There is a relationship between green components that emphasizes their role in promoting the future sustainability of cities. This paper offers a comprehensive study of a green city as a viable and sustainable alternative for the present urban environment. The personality of a green city was revealed through qualitative and quantitative analysis methods based on modern monitoring tools such as cloud-based remote sensing [6].

Source of CO_2 Emission

Breathing a high concentration of Carbon Monoxide (CO) typical of a polluted environment leads to reduced oxygen (O_2) in the blood, which contributes towards unhealthy effects, such as heart disease and impaired reaction timing. The top four CO_2 emitting countries/regions, which together account for almost two thirds (61%) of the global CO_2 emissions, are China (30%), United States (15%), the European Union (EU-28) (10%) and India (6.5%) [7]. CO_2 levels in urban environments are typically qualified based on emission inventories from estimates of fossil fuel consumption, evaluations of the amount of carbon sequestered in urban vegetation and short-term studies of ambient CO_2 concentrations [8].

According to the Malaysian National Communication (NC2) report, the inventory for carbon emissions for the year 2000 in 10 sectors found that the energy supply industry generated the highest percentage of carbon with 35%, followed by the transportation sector with 21%. This shows that the high energy consumption of electricity could increase carbon emissions [9]. A study on the projection of CO_2 emissions in Malaysia based on four energy demand trends showed that by 2020 there could be about 285.73 million tonnes of CO_2 emissions. The largest emitting sector would be electricity generation with CO_2, Sulfur Dioxide (SO_2) and NOX as by-products [10].

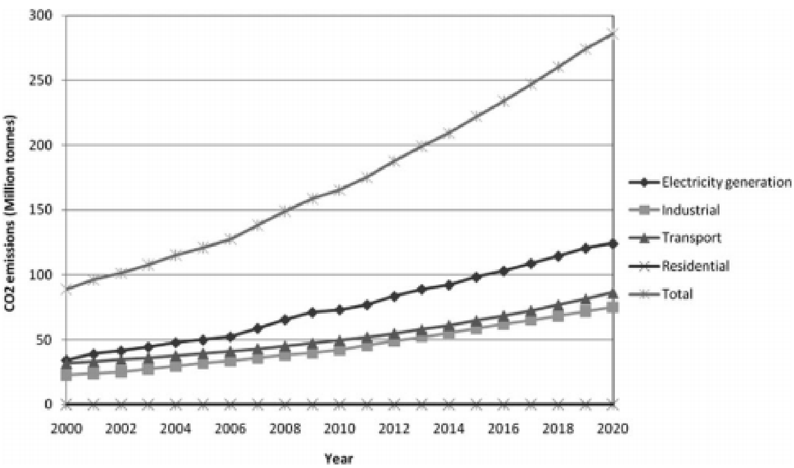

Figure 1: Projected CO2 emissions for four sectors in Malaysia.
(Source: Projection of CO2 Emissions in Malaysia, 2010)

Materials and Methods

Instrumentation

The development of the monitoring system is shown in Figure 2. Several sensors, such as the air particle, CO_2, CO and Ozone (O_3) sensors were attached to the Remote Terminal Unit (RTU) to collect readings of all environmental gases in order to study air quality. This low-cost CO_2 monitoring system uses the power line as the power source. Then, raw data were sent to the server in 1-minute intervals using the GSM inside the RTU. At the monitoring portal, data from the web server are displayed and interpolated as a real value in parts per million (ppm) for CO_2. This type of gas will be observed for six days during the dry season beginning in June 2017 (June 12-16).

The measurement of CO_2 uses the sensor type MG811 Carbon Dioxide Gas Sensor Module with the TTL level signal output. The working voltage is 6VDC while the output voltage from the solar is 12VDC. The conversion was done by using the Step-Down voltage converter. This type of sensor is highly sensitive during long-term use and is reliably stable. Analog output wiring was connected to the RTU's analog port. Since there are many ports in the RTU, other sensors for CO, O_3 and Air Particles could also be installed in the system but for this study, only the CO_2 gas sensor was considered.

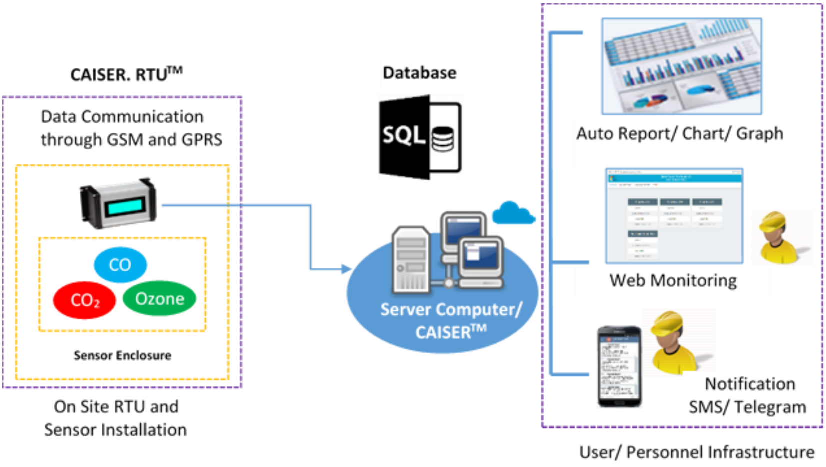

Figure 2: Overall Structure of CO_2 Monitoring System using CAISER.

Figure 3 shows the implementation of low-cost cloud-based CO2 monitoring using CAISER in Melaka Bandaraya Bersejarah. Raw data is sent to the web server and appears in graphic form in the monitoring portal. Users can extract data by downloading the historical report from the monitoring portal. At the backend of the web portal monitoring system (cloud-based system), all raw data are saved using the SQL database and presented to the front end of the web portal. Another part of web portal monitoring is the heat map, which shows the location of stations with a real-time reading of sensors.

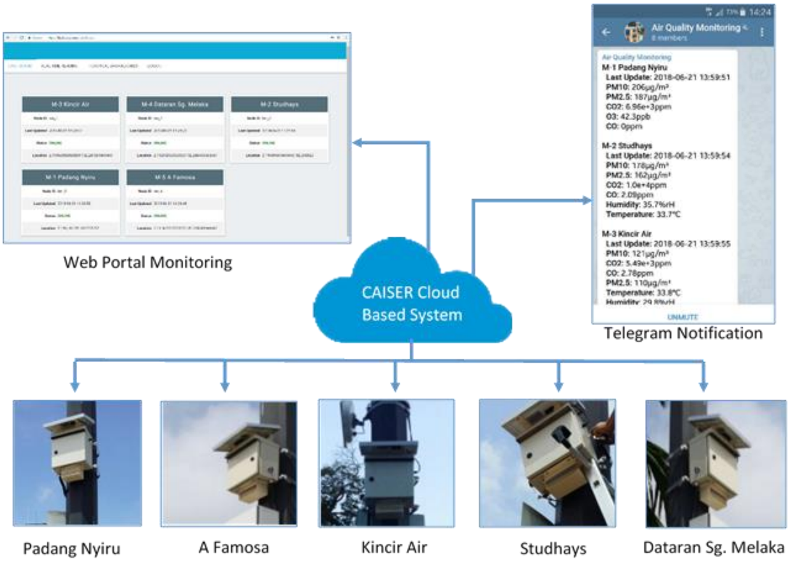

Figure 3: Implementation of Low-Cost Cloud-Based CO_2 Monitoring Using CAISER in Melaka Bandaraya Bersejarah.

Measurement site and analysis study

Bandaraya Melaka has a high population density. The total population of Bandaraya Melaka in 2016 was 0.9 million and the immensity was 1,652 km^2 with a population density of 1,675 people per km^2. Bandaraya Melaka is a tourism city surrounded by many historical buildings. In this study, the measurement was taken in one of the high-density roads in Bandaraya Melaka, which was Padang Nyiru (Coordinate 2.196, 102.251). Bandaraya Melaka is located 6 meters above sea level (elevation) and experiences temperatures of 24°C – 35°C.

Figure 4: Location of Padang Nyiru, Melaka using Google Maps

Implementation

The Remote Terminal Unit (RTU), as shown in Figure 5, was installed in the station to collect reading from sensors. The function of RTU is to collect data from sensors (CO, CO_2, O_3 and Air Particle) and send it to the web server. Raw data is feed into the web server and the conversion is executed. As for the station panel, the system used a voltage source of 12VDC, which becomes a common voltage input for most sensors. A solar panel system was also needed as a backup in case of an accidental disruption in power supply. The panel enclosure with RTU and sensors inside were placed at a height of approximately 15 feet from the ground by attaching it to the pole.

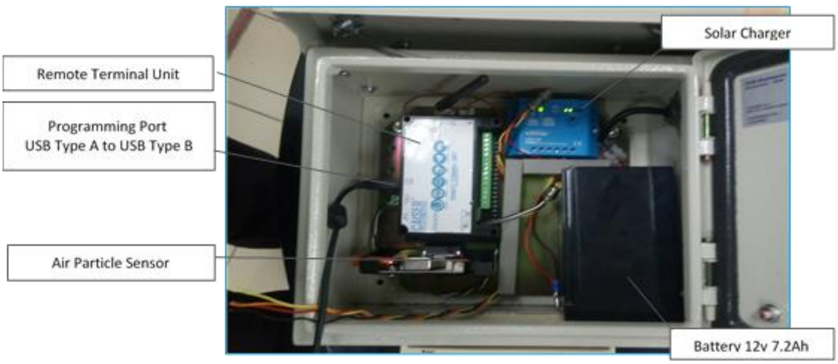

Figure 5: Remote Terminal Unit (RTU) Enclosure Setup

The air particle sensor used the UART Communication Protocol and was located inside the enclosure, as shown in Figure 6, while there was an inlet hose outside the enclosure to make sure air could enter into the sensor. Other sensors, such as the CO and CO_2 sensors that provided analog output and the O_3 sensor that provided TTL output, were located in the Sensor Box.

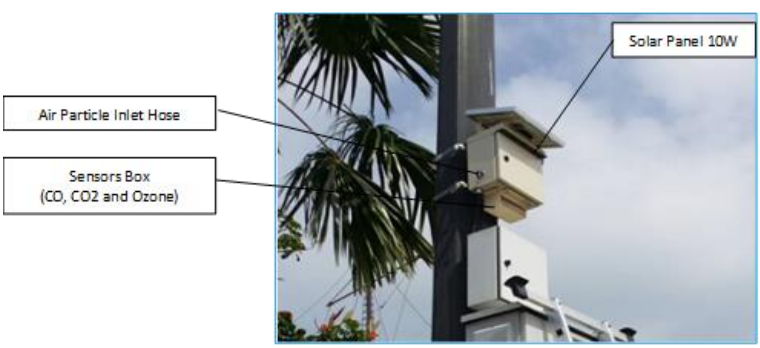

Figure 6: Set of RTU with gas sensors set up on a pole

Results and Discussions

Figure 7 shows a Station Dashboard on web monitoring. All data gathered for measuring the level of CO_2 concentration in this study showed that the highest concentration occurred at 8.00 a.m. Examination of the graph showed that the increasing concentration of CO_2 at that time was caused by the existence of vehicles on the road. The average concentration was approximately 362 ppm to 365 ppm.

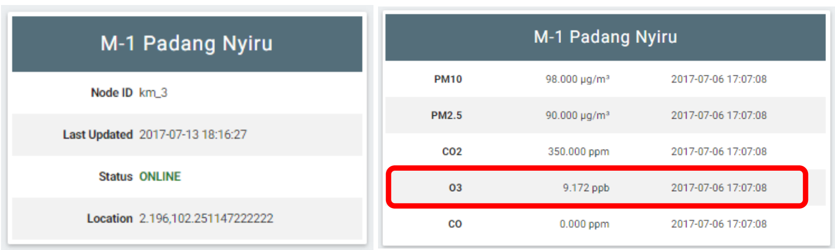

Figure 7: (a) Station Dashboard on Web monitoring (5 locations of installation) and (b) Stationary sensor value (for Air Particle PM10 & PM 2.5, CO_2, CO and O_3)

Another observation based on the graph was that the CO2 concentration from 0000-0400 hours was higher compared to the duration from 1600-2000 hours (Figure 8a), 1200-2000 hours (Figure 8b), 0800-2400 hours (Figure 8c) and 2000 hours (Figure 8f). This is because, during that time, CO2 was emitted from plants during the respiration process. Plants perform only respiration and no photosynthesis takes place during that time (due to the absence of sunlight), thus the concentration of CO2 released was higher during that time.

Low temperatures also contribute to high CO concentrations. Engines and vehicles, which are emission-controlling equipment, operate less efficiently when cold because during this time the air-to-fuel ratio is lower, combustion is incomplete and catalysts take longer to become fully operational. This results in products of incomplete combustion, including CO, that is formed in higher concentrations. This leads to the formation of CO, which is actually poisonous when temperatures are low. Locations with a high concentration of Carbon Monoxide should be monitored remotely in real-time for further mitigation efforts.

Figure 9 shows the mean CO2 Concentration of (ppm) for the study period. The study found that the highest concentration of CO2 occurred at 8.00 a.m. and decreased to the lowest level at 18.00 p.m.

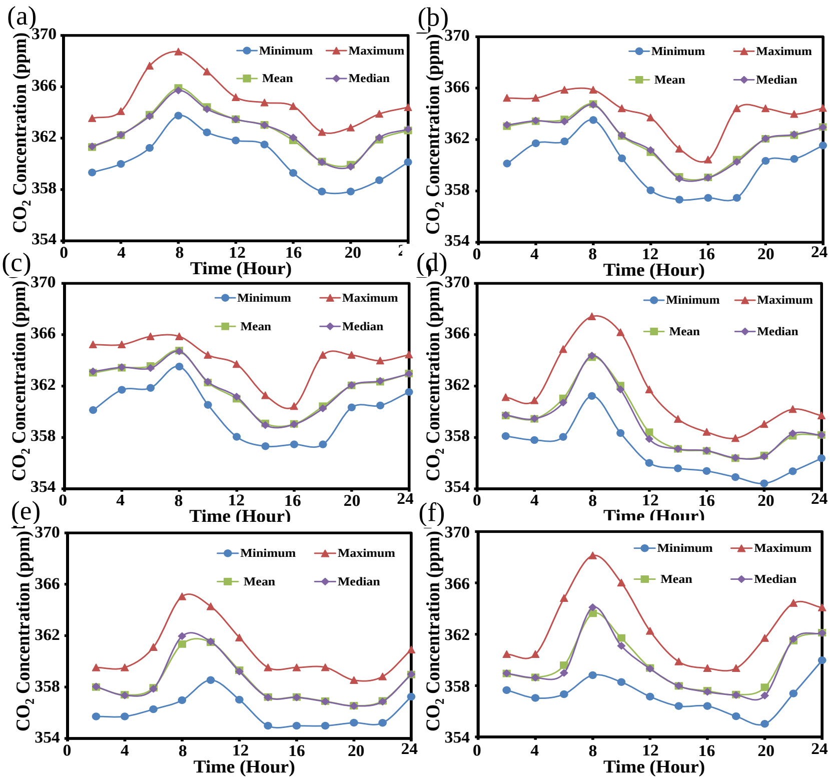

Figure 8: Measurement of CO_2 concentration for 24 hours at six different days (a)12, (b)13, (c)14, (d)15, (e)16 and (f)17 in June 2017 at Padang Nyiru, Bandaraya Melaka

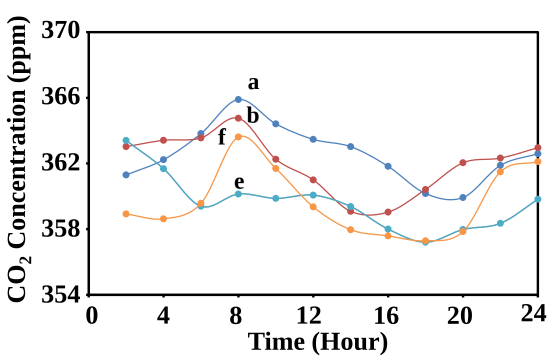

Figure 9: Mean concentration of CO_2 (ppm) versus duration time (hours)

Conclusion

This paper had provided the basic concept of a low-cost CO_2 monitoring system using the cloud. Measurements of CO_2 gas concentration made at one location in Bandaraya Melaka was observed and the trends and variations during the period of study were discussed. The results indicated that CO_2 concentration for 6 days was affected by local sources according to the duration of time. The concentration was generally higher in the morning (8.00 a.m.) and decreased during the evening and night. This could be the result of a large volume of vehicles used (transportation etc.) during that time. The reason for measuring CO_2 concentration was to ensure that the development of the green city approach was a success.

Acknowledgements

We express our greatest appreciation to the CAISER@INTEGRA Team, UKM, who contributed towards the installation and maintenance of the system at the stations. We also would like to thank Khairummu Zammil Nordin and Muhammad Faiz Mohd Shukri for the technical assistance in the implementation of the system.

References

[1] J.R.Wolch, J. Byrne and J. P. Newell, “Urban green space, public health, and environmental justice: The challenge of making cities ‘just green enough’”. Landscape and Urban Planning, 1-2 (2014).

[2] The World Bank, “Cities’ Contribution to Climate Change: An Urgent Agenda”, Part III (2010).

[3] M. Yasuyo, D. Shibhakar and Y. Yoshiki, “Relationship between Urban Form and Co2 Emissions: Evidence from Fifty Japanese Cities”, 1 (2012).

[4] “The Ongoing Challenge of Managing Carbon Monoxide Pollution in Fairbanks”, Alaska, 19-21 (2002).

[5] C. Ren, E.Y. Ng and L. Katzschner, “Urban climatic map studies: A review”. Int. J. Climatol, 2213–2233 (2010).

[6] G. Manea, “Green Cities – Urban Planning Models of the Future”, 463 (2014).

[7] J.G.J. Olivier, “Maenhout, Trends in Global CO_2 Emissions”, 5 (2016).

[8] E. Velasco, S. Pressley, E. Allwine, H. Westberg and B. Lamb, “Measurements of CO_2 Fluxes From The Mexico City Urban Landscape”, Atmospheric Environment, (2005).

[9] Putrajaya Report 2012, "Putrajaya Corporation's Green City Committee", 46.
[10] N. Sharliza, Z. Zainura, H. Haslenda, U. Zaini and T. Juhaizah, "Projection of CO_2 Emissions in Malaysia", 3 (2010).
[11] S. X. Fang, L.X. Zhou, P.P Tans, P.Ciais, M. Steinbacher, L. Xu and T.Luan, "In Situ Measurement of Atmospheric CO_2 at the Four WMO/GAW Stations in China", (2013).