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Short Paper

Project Amihan: Online Air Monitoring System for Selected Areas along McArthur Highway, Valenzuela City

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Abstract

Purpose – Air pollution, through the years, is a major problem in the Philippines. Different illnesses came about as its consequence. To mitigate air pollution particularly in Valenzuela, the Department of Environment and Natural Resources with the help of Valenzuela City Government's City Environment and Natural Resources Office installed an air monitoring system. Inspired by such technological innovation, the researchers aimed to design and develop "Project Amihan: Online Air Monitoring System for Selected Areas along McArthur Highway, Valenzuela City." The study is significant to Valenzuela residents along McArthur Highway, to the community, educational institutions, the government, and future researchers.

Method – For data gathering, survey and interview was used. The researchers' method was Agile Prototyping Model and they used Arduino Uno microcontroller, wi fi module, gas sensors, and jumper wires for the hardware; HTML, PHP, JavaScript, jQuery, Ajax to develop the website and embed the system, as well as a webhost to disseminate information. The system was tested in four (4) selected areas along McArthur Highway of Valenzuela namely: Balintawak Beer Brewery (BBB), Fatima, Karuhatan, and Malinta. Twenty (20) Valenzuela residents and five (5) IT Experts served as respondents who evaluated the system. Five-point Likert Scale using the ISO 9126 as the standard reference was used to evaluate it.

Results – The system was evaluated 4.17 or Very Acceptable by the end-users, 4.49 or Very Acceptable by the IT Experts and garnered an overall mean of 4.33 which is equivalent to Very Acceptable. The information derived from the air monitoring system was disseminated through a website and email notification to raise awareness by providing insights of what bad air may cause the residents.

Conclusion – In conclusion, the system most notably detected Carbon Dioxide (CO_2) gas in the air. It can monitor the Carbon Dioxide gas in the air as its innovation. Pollutants in the four selected locations varied at different time schedules. Such areas are not always polluted, but it happens mostly during rush hours.

Recommendations - Users must sign up in the system to receive a notification if ever the air quality reaches the dangerous level; the city government – as the beneficiary of the

said system – shouldprovide a stable internet connection for the system to have real-time monitoring of the air quality along McArthur Highway.

Research Implications – Future developers must integrate more sensors to improve the accuracy of the current system and they may opt to integrate a renewable power source such as solar panel for the system so it can run even without the city's electric power supply.

Keywords – air monitoring system, Arduino microcontroller, online, embedded system, web server

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INTRODUCTION

According to Mendoza (2017), air pollution might be one of the most dangerous aspects of general well-being that individuals think little of and disregard. The overall population should consider air pollution important, particularly when it can be a factor in the deterioration of anyone's health, which is far more regrettable than what was once known.

According to a report from Penolio (2011) and Mendoza (2017), the transport sector contributes to about 80% of air pollutants in the City of Valenzuela. It is because of the growing population of the city that results to higher volume of commuters. Pollutants can travel deeply into a man's respiratory tract and can cause short-term health impacts and compound medicinal conditions to people with asthma or coronary illness (Geronimo, 2017).

This project aims to disseminate information about the air quality in Valenzuela City that can raise awareness about the neglected dangers of air pollution and in turn may reduce the likelihood of acquiring certain fatal diseases.

BACKGROUND OF THE STUDY

One of the major problems society is facing today is pollution. Air pollution particularly brings harm not only to the environment but mostly to one's health. Air pollution is a mixture of gas and solid particles that automobiles and industrial factories mostly emit. These particles, if inhaled, can result in serious diseases such as allergies, asthma and even cancer. Calderon-Garciduenas et al. (2002) mentioned that exposure to certain air pollutant mixtures produces inflammation in the upper and lower respiratory tract.

In the Philippines, the government has mandated a law known as the Philippine Clean Air Act of 1999 (Republic of the Philippines, 1999). This law recognizes the importance of

preventing the spread of air pollution in the country. It enforces different government agencies to make a resolution on how to maintain the country's air quality. To support the government's objective, the proponents decided to make a capstone project that will help to monitor the air pollution of some selected areas in Valenzuela City.

The proponents aim to develop an embedded system that will monitor the quality of air in selected areas along McAthur Highway namely: Balintawak Beer Brewery (or BBB), Fatima, Karuhatan, and Malinta. If the system detects that the air pollution is above the normal range, it will automatically send a notification to the users of the system. Through this system, users can be aware whether the air that they are inhaling is good or bad for their health.

The general objective of the study is to design and develop the system entitled "Project Amihan: Online Air Monitoring System for Selected Areas along McArthur Highway, Valenzuela City" that will monitor the air quality index of certain areas in Valenzuela. Specifically, it aims to: (1) monitor the air quality in selected areas along McArthur Highway – BBB, Fatima, Karuhatan, and Malinta; (2) create a prototype using an Arduino Uno microcontroller and develop a website by using HTML, PHP, JavaScript, jQuery, Ajax and a webhost that will disseminate information derived from the system; (3) detect the pollutants in the air by integrating gas sensors such as MQ7 and MQ135; (4) view the air quality by logging onto the system's website (bit.ly/ProjectAmihan); and (5) notify the user by sending an email notification if the air quality in one of the selected areas is below the normal level to inform the user how air pollution can bring harm to human health.

SIGNIFICANCE OF THE STUDY

This system will help the users to detect whether the air that they are inhaling is good or bad for their health. This may also help them prevent acquiring diseases, such as asthma and allergies by giving them information about the air quality. It can raise the community's awareness about the importance of monitoring the air quality that they breathe. Schools and universities can help their students to gain knowledge about air pollution by exposing them to this research. By doing this, their students can get insights about how air pollution affects them and how to prevent it.

This study can further contribute to the realization of the government's mission to prevent the spread of air pollution in the country. It may help future researchers to gain a better understanding on how to address the air pollution problem in the country. This research can serve as a basis on how they will conduct their project or experiment in the future.

RELATED LITERATURE

In this era, people live in constant danger not only because of widespread poverty and terrorism; but also specifically because of the worsening problem in pollution. According to Vallero (2014), planet earth is composed of abundant resources that transform into compounds to support its environment. As temperature, oxygen content and essential mixtures of mass and energy changes brought about by pollution, the quantity of these compounds fall in smaller range. If such compounds do not exist in the environment, living things could not even last for a day.

Pollution is the culprit of unnatural events in the environment. Merriam Webster Dictionary (2018) defined it as the act of contaminating the atmosphere with man-made waste. Pollutants that bring harm to the environment are such. Society ironically relies too much on nature yet people are gradually destroying it. Mahatma Gandhi once said that "*Earth has enough to satisfy every man's need, but not every man's greed*" as human population increases, people demand too much thus exceeding the environment's capacity to supply such demands.

Alcott (2016) stated that humans negatively affect the environment in many ways. Industrial waste from factories, illegal logging in preserved forests, and overconsumption of fossil fuels are the typical examples of how humanity destroys the ecosystem. These activities cause different types of pollutions, such as water pollution, air pollution and soil pollution that bring disasters like flash floods and landslides.

Different types of pollution exist. They are categorized based on the element of the environment that they affect according to Read and Digest (2018). Similarly, Asthana (2013) emphasized that the ruin of the environment can be classified based on either the pollutant's type or the nature of the surroundings it affects. He further grouped pollution into three (3) main classifications: water pollution, soil pollution, and air pollution.

The last of the three main types of pollution is air pollution. Rapid industrial development and urbanization in unindustrialized countries led to a surge in air pollution (Huang et al., 2014). The World Health Organization (2018) defined air pollution as the contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. The main agents that pollute the air are gases such as, carbon monoxide, methane and chlorofluorocarbons. Automobiles, industrial factories and house appliances, such as the refrigerator and air conditioner commonly emit these gases. Consequently, suburbanization results in rising traffic density that in turn becomes a major cause of air quality decline (Kanabkaew, Nookongbut, & Soodjai, 2013).

Moreover, researchers have linked air pollution to a wide array of health effects for a significant period. Among them are respiratory problems, such as asthma and lung

problems. Air pollution could also cause cancer to humans. The World Health Organization (2018) and National Institute of Health (2018) concluded that the contaminants in the atmosphere are carcinogenic substances to humans. Premature death due to a wide range of causes included long-term health effects of ozone and fine particulate matter with a diameter smaller than 2.5 micrometers as emphasized by Lelieveld et al. (2015). Gowrie et al. (2016) hypothesized that, there are cases of valid physician-diagnosed cases of paediatric asthma – which led to emergency room visits in Trinidad.

Moreover, based on the report by Ellis (2017), UNICEF Executive Secretary mentioned that around 6,000 children under age 5 die because of air pollution especially in poor nations. He also said that pollutants do not only harm the developing lungs of children but also damage their developing brains. He further emphasized that no society can disregard air pollution; and he therefore encourages world leaders to take steps in order to stop the spread of world pollution (Ellis, 2017). Even Colombia is concerned about their urban air quality (Ramírez, Mura, & Franco, 2017).

Air pollution concerns all the countries across the globe, thus each nation has its own ways to combat its effects. In the Philippines, in keeping the nation's atmosphere safe to breathe, the government has mandated Republic Act 87495 or commonly known as the "Clean Air Act of 1999". It provides the policy's framework for the country's air-quality management act. In order to do so, the act requires different government agencies to draft and enforce regulations to monitor and to prevent the spread of air pollution.

RA 8749 assigns the Department of Environment and Natural Resources (DENR) as the governing body on the overall implementation on the provisions of the law. It also delegated several agencies such as Department of Transportation and Communication (DOTC), Department of Science and Technology (DOST), Philippines Atmospheric and Geophysical and Astronomical Services Administration (PAG-ASA), Department of Education (DepEd) and the Local Government Units to support the mission of the law.

Smoke-belching vehicles are one of the factors that pollute the atmosphere. To address this, the Department of Environment and Natural Resources, in partnership with the Land Transportation Office, formulated an ordinance that prohibits smoke-belching vehicles to travel on roads. They also created an ordinance that implements travel ban for phased-out and long overdue cars. These ordinances will not only lessen heavy traffics on roads but will also lessen the contaminants in the air.

Similarly, smokes emitted from cigarettes also contain harmful elements that contaminate the air, thus the government also formulated some policies to control its negative effects. Inspired by the success of the ordinance in Davao, the present administration launched a nationwide smoking ban that forbids the act of smoking in public areas (Aurelio, 2017). This includes establishments like schools, hospital, restaurants, and hotels. The government will designate smoking areas with adequate

ventilation separated from other rooms. He further said that those who cannot comply might end up as offenders, thus he encourages the public to heed the executive order or face the consequences.

As for Nitrogen Dioxide content in the air, road transport is mainly the cause of NO2. Likewise, Henschel et al. (2015) noted that recent studies suggest that traffic (roadside) (TR) NO2 concentrations have not declined as expected, and in some cases increased, probably due to the use of oxidation catalysts and particle filters in diesel vehicles. Consequently, Esquivel-Hernández et al. (2015) noted that HYSPLIT back air mass trajectories analysis, and weather data available for the Central Valley suggest that such differences arise as result of a decline in the mixing layer of depth (~425 m) and the wind speed (~1.5 m/s) favoring the buildup of polluted air masses in the urban area.

Today, pollution levels in many areas of the United States exceed national air quality standards with at least one of the six common pollutants. Although levels of particle pollution and ground-level ozone pollution are substantially lower than in the past, levels are unhealthy in numerous areas of the country. Both pollutants are the result of emissions from diverse sources, and travel long distances and across state lines. An extensive body of scientific evidence shows that long and short-term exposures to fine particle pollution, also known as fine particulate matter, can cause premature death and harmful effects on the cardiovascular system, including increased hospital admissions and emergency department visits for heart attacks and strokes. Scientific evidence also links it to harmful respiratory effects, including asthma attacks.

Based on Lanzafame et al. (2014), their study revealed, as expected, how pollutant concentrations peak especially during commute times (early morning and afternoon). Moreover, the long-lasting health effects associated with sustained exposures to high concentrations of air pollutants are an important issue for millions of big city residents and millions more residing in smaller urban and rural areas (Calderón-Garcidueñaset al., 2015).

DESIGN AND METHODOLOGY

Project Scope

The respondents of the study include twenty (20) Valenzuela City residents and five (5) IT experts that will evaluate the system. The proponents will develop an air monitoring system that will be installed in the selected areas (BBB, Fatima, Karuhatan, Malinta). Alpha testing will be held on the first week of January 2018 and the location of the test will be held in selected areas along McArthur Highway of Valenzuela namely, Balintawak Beer Brewery (or BBB), Fatima, Karuhatan, and Malinta. Twenty-five (25) respondents underwent a sampling procedure with the aid of survey questionnaires. The respondents include 20 end-users and 5 IT experts (Table 1).

Table 1. Respondents of the Study

Respondents	Frequency	Percentage
IT Experts	5	20%
End-users	20	80%
Total	25	100%

Conceptual Framework

The below Figure 1 shows the construction of the system "Project Amihan: Online Air Monitoring System for selected areas along McArthur Highway, Valenzuela City" using Hierarchical Input, Process and Output framework.

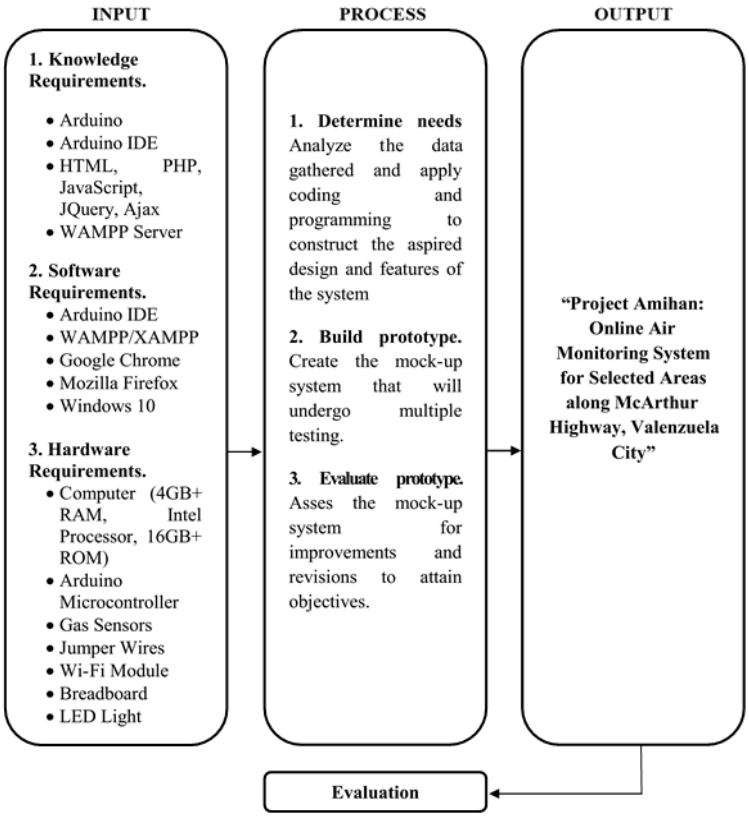

Figure 1. Conceptual Framework

Agile Prototyping Model

The researchers used the agile prototyping model to develop the system. It is a combination of iterative and incremental process models. This model enables the researchers to focus on process adaptability thereby helping them to achieve rapid delivery of the working software product by creating builds through process iterations.

Every iteration involves cross-functional teams working simultaneously on various areas like planning, requirements analysis, design, coding, unit testing, and acceptance testing.

Project Development

The sequential phases in Agile Prototyping model (Ambler, 2014) are:

- **Determine needs**: The researchers sent communication letters and secured scheduled appointments with the major respondents of the study. They also interviewed experts about the safety of the hardware design. Researchers chose experts with requisite qualifications, observed the way they used the system, and quantified their evaluations. Surveys were conducted to determine the average quantity of devices to be used;
- **Build prototype:** On the hardware part, researchers carefully selected necessary equipment. Arduino Uno, Wi-Fi Module (ESP8266), gas sensors (MQ7 and MQ135), jumper wires, breadboard, LEDs, power source and other necessary hardware were tested especially on the compatibility criterion so that the hardware part will run smoothly. On the software part, the researchers used Arduino as Integrated Development Environment (IDE) in programming the hardware and HTML5 for building the system's website; and
- **Evaluate prototype:** The researchers evaluated the prototype by testing it in four selected locations and compared the results from an international air quality monitoring system (Figure 2).

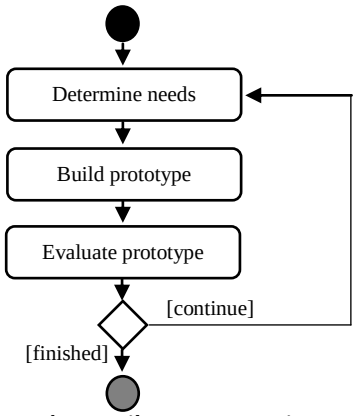

Figure 2. The Agile Prototyping Model

The Arduino Uno microcontroller, gas sensors, Wi-Fi module, and LEDs were connected to the breadboard with the help of jumper wires. Then the researchers used HTML and other web development tools to embed the system. The system will automatically function as long as it is connected to a working power source. A web host made the air monitoring system available through the internet. The system must have internet connectivity so that it can continuously send data to the website. Upon loading the system's website, Valenzuela City residents can view the monitored air quality data by

the system. If the air quality reaches beyond 300 Air Quality Index (AQI), it will send email notification to registered users regarding the polluted area and it will suggest what to do in such a situation.

System Architecture

As regards the system architecture, Figure 3 shows how the project's devices are connected to one another. Figure 3 shows that the Arduino Uno, Wi-Fi module, and the gas sensors are connected to the breadboard through jumper wires.

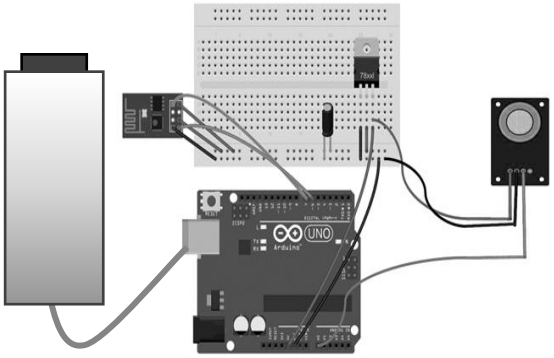

Figure 3. System Architecture

Figure 4 below shows the map of the four selected areas that will undergo project testing. The abovementioned figure shows the selected areas along McArthur Highway in Valenzuela City where the researchers tested the project.

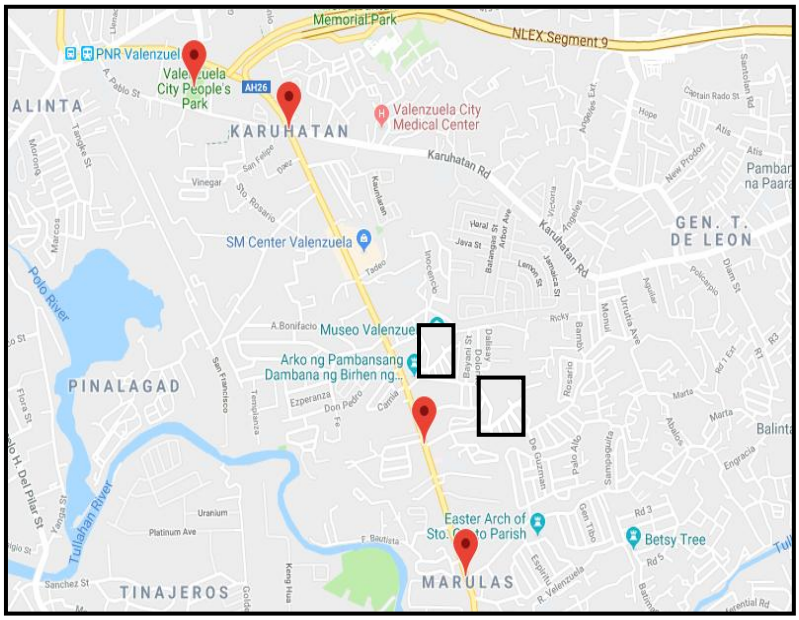

Figure 4. Selected locations of project testing

Table 2. International Air Quality Index

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

The above table (Table 2) shows the classifications of air quality according to the United States Environmental Protection Agency (2017). It describes the values of the International Air Quality Index, levels of health concern with the corresponding color codes (AirNow, 2016).

Evaluation Procedure and Calculation of Data

The researchers used the Five-Point Likert Scale to evaluate the operational feasibility of the proposed system (Table 3). Functionality, Reliability, Usability, Efficiency, Maintainability and Portability are the different criteria for evaluating the proposed system. The researchers used the rating 1 to 5: 1-Unacceptable, 2-Moderately Acceptable, 3-Acceptable, 4-Very Acceptable, 5-Highly Acceptable. The standard of reference was ISO 9126.

The weighted mean (Equation 1) of the set of data represented by x_1, x_2, x_3,...,x_n can be expressed as the sum of the data multiplied by their corresponding frequency or weight (Satya, 2018). The researchers implemented the above Five-Point Likert Scale (Gade, 2013) during the evaluation of the project.

Table 3. Five-Point Likert Scale

Scale	Range	Descriptive Evaluation
5	4.50 – 5.00	Highly Acceptable
4	3.50 – 4.49	Very Acceptable
3	2.50 – 3.49	Acceptable
2	1.50 – 2.49	Moderately Acceptable
1	1.00 – 1.49	Unacceptable

$$WM = \frac{\sum (w_i - N_i)}{n_x} \qquad \textit{Equation 1}$$

where

w = sum of data set
N_i = sub-criteria
n_x = number of sub-criteria

RESULTS AND DISCUSSIONS

Project Evaluation

Table 4 below shows the summary of the weighted mean from the IT Experts' evaluation. The system received the highest mark of 4.80 – Highly Acceptable – on Reliability while it received the lowest mark of 4.10 – Very Acceptable – on Portability. Overall, IT Expert's evaluation obtained a 4.49 overall mean that proves its strengths in the different criteria mentioned below.

Table 4. IT Experts' evaluation

Criteria	Mean	Interpretation
Functionality	4.67	Highly Acceptable
Reliability	4.80	Highly Acceptable
Usability	4.73	Highly Acceptable
Efficiency	4.50	Highly Acceptable
Maintainability	4.13	Very Acceptable
Portability	4.10	Very Acceptable
Overall IT Experts' mean	4.49	Very Acceptable

Table 5 shows the summary of the weighted mean from the end users' evaluation. Table 6 shows that the system is functional at a mean of 4.53 which means it is highly acceptable. The project is also usable at a mean of 4.53 and highly acceptable as gathered from the respondents. The system received the lowest mean of 3.90 – Very Acceptable – on portability due to the fact that the system will be installed on selected areas only. Overall, the system gained a 4.33 overall mean that proves its strengths in the different criteria mentioned above.

Table 5. End-users' evaluation

Criteria	Mean	Interpretation
Functionality	4.40	Very Acceptable
Reliability	4.20	Very Acceptable
Usability	4.33	Very Acceptable
Efficiency	4.40	Very Acceptable
Maintainability	4.00	Very Acceptable
Portability	3.70	Very Acceptable
Overall end-users' mean	4.17	Very Acceptable

Table 6.Summary of the combined weighted mean of respondents

Criteria	Mean	Interpretation
Functionality	4.53	Highly Acceptable
Reliability	4.50	Highly Acceptable
Usability	4.53	Highly Acceptable
Efficiency	4.45	Very Acceptable
Maintainability	4.07	Very Acceptable
Portability	3.90	Very Acceptable
Overall mean	4.33	Very Acceptable

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Pollution is very much disregarded when it is not given any attention. But, with the help of the system, users can have a glimpse of the current situation of the air quality that surrounds them. The system most notably detected Carbon Dioxide (CO_2), which the city government's existing system did not detect.

With proper dissemination of data derived from the monitoring system and with the help of the internet, the project can raise awareness and can help people reduce air pollution by giving them insights of what bad air may cause them so they can come up with an action plan.

Conclusions

Pollutants in the four selected locations varied from each other. The amount of pollutants also varied in different time schedules. For example, the amount of air pollutants reached its highest point at about 400+ ppm of carbon during rush hours or 4:00PM to 8:00PM. A graphical representation of the data gathered from the system further justified that the selected areas are not always polluted but only on certain time schedules. Implementing the system in these selected locations can further give insights to the city government about their possible plan of action to lessen the pollutants during the said hours.

Recommendations

Through observations, meticulous testing of the system, and software evaluation – a rating of 4.33 (Highly Acceptable) – the researchers are now able to give their final recommendations to the users, beneficiary and future developers to further improve the project:

- Users must sign up for the system to receive a notification if ever the air quality reaches the dangerous level;
- The city government – as the beneficiary of the said system – should provide a stable internet connection to the system to enable real-time monitoring of the air quality along McArthur Highway;
- The city government may allow the developers to connect the system to the city's power connection, i.e. lamppost, to keep the air monitoring system running;
- The city government may implement this system by expanding it to more than four locations to further analyze the air pollution in the city;
- The future developers must integrate more sensors to further improve the accuracy of the current system; and
- Future developers may opt to integrate a renewable power source such as solar panel for the system so it can run even without the city's electric power supply.

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