Urban Air Pollution Monitoring System for Mapping Areas Based on Pollutant Level

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Abstract. This paper presents an explanation of the design of Carepol, an air pollution monitoring system in urban areas, using ISPU standard calculations (air pollution standards index of Indonesia) based on the internet of thing's (IoT). ISPU is a standard of air quality determination recognized by the government of the Republic of Indonesia through the Ministry of Environment. This IoT-based air pollution monitoring system is focused on measuring carbon monoxide (CO) levels as the highest pollutants in the world today, and analyzing and estimating the value of these pollutants in real-time and continuously. By using Carepol, society can actively engage in the control of urban air quality, and contribute to improving the environment and public health. For the government, Carepol can serve as a reference platform for proper policy-making in environmental issues, especially air pollution, and as well as the realization of Smart City for better life.

1. Introduction
Air has a very important meaning in life, so the air is a natural resource that must be protected for human life. It means that it is utilization should be wise to take into account the interests of present and future generations. To get air in accordance with the desired level of quality, air pollution control becomes very important to do. Air pollution is defined by an increase in air pollution levels resulting in decreasing air quality, which can ultimately lead to disruption to human health. Since the past few decades, urbanization has led to the fact that human population intensively grows in specific areas. Intensive industrial development and transportation have a direct effect on air quality [1]. Air quality can be expressed by the concentration of several pollutants such as carbon monoxide (CO), sulfur dioxide, nitrogen dioxide, and ozone. The threshold values specified by the European Environment Agency for these pollutants are 10, 350, 40, and 120 µg/m³, respectively [2]. Traditionally, bulky air quality monitoring stations are used for collecting various gases concentrations. These stations include many reference analyzers where each analyzer measures one gas. Although these analyzers produce measurements with high level of accuracy, such stations require frequent calibration and maintenance, and they need access to power socket mainly for air conditioning. This inevitably limits their use on large scale. Nowadays, and because of the recent advances in micro-electro-mechanical (MEMS) systems, research and industrial bodies are focusing on developing new generation of sensing stations with low cost, smaller size, and more mobility features [3].
Increased human population in the world, demands the creation of good environmental management, clean, comfortable and orderly. As in urban areas, the layout of residential buildings, green spaces, modern and traditional shopping centers, must be carefully managed and monitored, prevent the destruction of natural ecosystems/environments. Many of the industrial areas are an urban development phenomenon that cannot be avoided, because with a high population in Indonesia, must be balanced with the increase of industrial growth by providing jobs, to create an independent and prosperous society. A large number of industrial estate developments with an increase the number of vehicles in urban areas will certainly create a significant impact on the air quality environment. Public awareness to maintain the air quality and diseases that can be generated from the phenomenon of air pollution is an important step against air pollution, and improve the quality of public health. The increase in vehicles reaching 80%, it makes transportation as the main reason for the air pollution problem in the cities [1]. As a result, people are looking for better ways to monitor the quality of air in their immediate environment in order to take appropriate actions such as wearing masks or staying at home [4]. The health effects of air pollution have been subject to intense study in recent years. Exposure to pollutants such as airborne particulate matter and ozone has been associated with increases in mortality and hospital admissions due to respiratory and cardiovascular disease. These effects have been found in short-term studies, which relate day-to-day variations in air pollution and health, and long-term studies, which have followed cohorts of exposed individuals over time. Effects have been seen at very low levels of exposure, and it is unclear whether a threshold concentration exists for particulate matter and ozone below which no effects on health are likely. In this review, we discuss the evidence for adverse effects on the health of selected air pollutants [5].

The 1972 UN Conference on the Environment in Stockholm called for a concerted attack on all global environmental pollution problems. The United Nations Environment Programme (UNEP) was created, and in partnership with the World Health Organization (WHO) began to address the problems of urban air pollution which were exemplified by the 1952 London Fog in which over 3000 people died (Ministry of Health, 1954). In 1974, UNEP and WHO collaborated in the initiation of a Global Environment Monitoring System (GEMS) urban air pollution monitoring network (GEMS/Air). This network has provided air monitoring equipment to developing countries and has collected air quality data in over 50 cities in 35 countries throughout the world. The initial network focused on sulfur dioxide (SO2), suspended particulate matter (SPM) by the high-volume sampler method (TSP), and lead (Pb) analyses of the TSP filters, as these pollutants were identified as the most important for developing countries [6]. WHO, states that exposure to air pollution has a major influence on determining the quality of public health and shortening human life expectancy [7]. Each year, the concentration of ambient pollutants in the world is always increasing; the highest pollutants are in the Asian region [8]. By 2015, over 90% of humans, living in areas with poor air quality, exceed the air quality minimum standards of WHO [7].

Associations have been found between long-term exposure to ambient air pollution and cardiovascular morbidity and mortality. The contribution of air pollution to atherosclerosis that underlies many cardiovascular diseases has not been investigated. Animal data suggest that ambient particulate matter (PM) may contribute to atherogenesis. We used data on 798 participants from two clinical trials to investigate the association between atherosclerosis and long-term exposure to ambient PM up to 2.5 μm in aerodynamic diameter (PM2.5). Baseline data included assessment of the carotid intima-media thickness (CIMT), a measure of subclinical atherosclerosis. We geocoded subjects’ residential areas to assign annual mean concentrations of ambient PM2.5. Exposure values were assigned from a PM2.5 surface derived from a geostatistical model. Individually assigned annual mean PM2.5 concentrations ranged from 5.2 to 26.9 μg/m3 (mean, 20.3). For a cross-sectional exposure contrast of 10 μg/m3 PM2.5, CIMT increased by 5.9% (95% confidence interval, 1–11%) [6].

Primary pollutants are components that have a major influence in the spread of humans disease; it is pollutants exist from the combustion of fuel vehicles. An example of a dangerous primary pollutant is Carbon monoxide (CO) [4]. Primary pollutants such as CO, have microscopic particle sizes, so they can enter the human respiratory organs until they reach the human vital organs. CO is harmful because
of the characteristics of this pollutant, colorless and odorless, making it difficult to identify the levels of CO content of the environment. According to the National Fire Protection Association (NFPA), CO enters the body through breathing. CO poisoning can be confused with flu symptoms, food poisoning, and other illnesses. Some symptoms include shortness of breath, nausea, dizziness, lightheadedness or headaches. High levels of CO can be fatal, causing death within minutes. Thus, it is very important to monitor the CO concentration [1]. Existing particulate matter monitors fall into roughly two categories: 1) microbalance PM monitoring stations that are very accurate, but are large and expensive (on the order of 50K-100K dollars), and 2) portable light-scattering based PM monitors with varying accuracies and costs between 300-10K dollars, which are still too expensive for most individuals or deployment at scale [9]. To solve this problem, we need a system capable of real-time monitoring pollutants and involves the participation of the society to care and be active. The environmental problems are growing rapidly. Air pollutants from cars, buses, and trucks, particularly ground-level ozone, and particulate matter can worsen respiratory diseases and trigger asthma attacks. Transportation can be responsible for more than 50 percent of carbon monoxide in the air. This carbon monoxide can play havoc on human health [10].

In this paper will be presented about the design of Carepol, a system consisting of hardware and software to monitor air pollutants Carbon monoxide (CO) to mapping areas potentially have high pollutant levels, in urban areas.

2. Method
Carepol is an integrated air quality monitoring system, designed to monitor Carbon monoxide (CO) pollutants. Hardware system Carepol, has been equipped with sensor modules and microcontroller data processing. Carepol device already has internet access, so it makes the system possible to deliver data to the server automatically. The system works refers to the IoT. This figure bellow 3D design of hardware to measure pollutant level (See Figure 1).

![Figure 1. Hardware design for measure pollutant level.](image)

Sensors contained in the device used to get data by sensing process. Sensing is the mechanism of the sensor to detect environmental parameters. The sensors in the Carepol system are DHT 11 (temperature and humidity), MQ7 (carbon monoxide), GPS module. Each component is integrated to optimize the performance of the Carepol system. All component connected to microcontroller for data processing, and communication to send data to cloud by internet connection. Then, android application received data and show in interface. This figure explains the hardware connectivity in block diagram system (See Figure 2).
Carepol hardware system works in 5-volt DC voltage. The sensing mechanism is performed by the sensor module components such as DHT11, MQ7. Set location system by UBLOX GPS that’s installed in the device. For internet access to connect to the database server, the GSM module works as a data exchange platform (GET and POST). The user can get data monitoring system by android application, it’s make society possible to involve in carepol system. All component placed on the electrical board / PCB, we used eagle application for make board design, this figure is result of board Carepol (See Figure 3).

The Carepol system has a separate working mechanism between hardware and software, but both integrate each other be intelligent systems capable of analyzing the air pollutant levels. Hardware has the main function of detecting pollutants using sensors attached to the device, while the software is designed to perform processing and analysis of data stored in the database so it can be a conclusion/information for the society. Carepol device’s will detect positions with GPS; it’s to determine the location of the latitude-longitude of Carepol. Then the sensors detect environment parameter data. The data will deliver automatically to the carepol database by internet connection on the device via the SIM module. The information can be reference for government to take policy, based on situation. Each stage is detailed in the following subsection (See Figure 4).
3. Result and Discussion
In this section, will explain about full part of the system carepol (hardware, software user application, and cloud/database system).

3.1. Hardware
Hardware is contained many sensors, has main function to measure and detection pollutant level in the city has internet connection for sending data to server. The Internet connection can get from smartphone (shared connection access), besides the hardware has many functions to support sensing process performance, are (See Figure 5):

- Detect temperature and humidity environment
- It has a solar panel as a backup battery
- GPS system for position detection
- Detect primary pollutant like CO
- We can place a device in indoor or outdoor
- Easy and portable

The image below is result of hardware design.
3.2. Website and Database
Website in Carepol system as an information platform for the society, but in addition, equipped with additional features for optimizing data processing, there are:
- Center of data storage
- Digital mapping city areas, based on pollutant level
- Information center for society
- Promotion and selling media of product

Dissemination of the measured information is performed via client-side applications running on computers or mobile devices, e.g. smartphones. These applications access the network via the server, which forwards the stored data received from the sensors. The applications could include a periodically updated web site with data summaries and statistics, data visualization with the display of sensor locations on a map (See Figure 6).

3.3. User Application
Carepol also has user application for society; it makes people’s possible to access, share, and monitoring environment status in around the city. It is a social contribution of all elements to keep healthy and fresh air quality to increase life quality. User can download the application on PlayStore. Feature of application are:
• Real-time monitoring system
• Spread information about pollutant level in the city
• Digital mapping system

3.4. ISPU Methodology
Air quality delivered to the community in the form of the Air Pollutant Standards Index (ISPU). ISPU is the air quality report to the community to explain how clean or polluted our air quality and how it impacts our health after breathing air for several hours or several days. Determination ISPU considers the level of air quality on human health, animals, plants, buildings, and aesthetic value. Based on the Decree of the Environmental Impact Management Agency (Bapedal) Number KEP-107/Kabapedal/11/1997, ISPU delivery to the community can be done through mass media and electronic boards and displays in public places. ISPU determined based on five major pollutants, namely: CO, SO2, NO2, surface ozone (O3), and dust particles (PM10) [13].

Currently, the air quality index standard in Indonesia is the Indeks Standar Pencemaran Udara (ISPU), in accordance with the Decree of the Minister of Environment, KEP 45 / MENLH / 1997 on the Index of Air Pollution Standards. In the decision that is used as a consideration that is, to provide the convenience of uniformity of ambient air quality information to the society at a certain location and time, and as a reference in making efforts to control air pollution. The Indonesian government has a special policy in determining the limits of pollution values through the ispu method. The following categories are based on ISPU values (See Table 1).

Table 1. ISPU Standard.

| Air Pollutant Standard Index | 24 hours PM10 ug/m³ | 24 hours SO2 ug/m³ | B hours CO ug/m³ | 1 hour O3 mg/m³ | 1 hour NO2 ug/m³ |
|-----------------------------|---------------------|-------------------|-----------------|----------------|-----------------|
| 10                          | 50                  | 80                | 5               | 120            | (2)             |
| 100                         | 150                 | 365               | 10              | 235            | (2)             |
| 200                         | 350                 | 800               | 17              | 400            | 1130            |
| 300                         | 420                 | 1600              | 34              | 800            | 2260            |
| 400                         | 500                 | 2100              | 46              | 1000           | 3000            |
| 500                         | 600                 | 2620              | 57.5            | 1200           | 3750            |

The following is equations if we want to know about ISPU level.

\[ I = \frac{I_a - I_b}{X_a - X_b} (X_x - X_b) + I_b \]  

\[ I_a = \text{ISPU high limit} \]
\[ I_b = \text{ISPU low limit} \]
\[ X_a = \text{Ambient high limit} \]
\[ X_b = \text{Ambient low limit} \]
\[ X_x = \text{Ambient by measurement} \]

In the following table, obtained the result of pollutant measurement data in different places (see Table 2).

Table 2. Result

| No | Location               | Parameter | ISPU Value |
|----|------------------------|-----------|------------|
| 1  | Str.. Gelap Nyawang    | CO        | 325        |
| 2  | Str.. Jend. Ahmad Yani | CO        | 235        |
| 3  | Str.. Kebonwaru Selatan| CO        | 17         |
The value of ISPU, calculated by Carepol system, to automatically mapping on Carepol digital map according to the category of environment standard status of ISPU (See Figure 7).

**Figure 7.** Carepol Digital Mapping Test

In ISPU method, there are several categories of environmental quality statuses, such as GOOD, MEDIUM, UNHEALTHY, VERY UNHEALTHY, and HAZARDOUS. In the following table is the results of measurement refers to ISPU (See Table 3).

| No | Testing Area             | Status       |
|----|--------------------------|--------------|
| 1  | Str.. Gelap Nyawang (325) | Dangerous    |
| 2  | Str.. Jend. Ahmad Yani (235) | Very not health |
| 3  | Str.. Kebonwaru Selatan (17) | Health       |
If the result view on the map like this (See Figure 8):

![Map View](image)

**Figure 8. Carepol Data Status**

The status of test results has been designed according to the ISPU standard categories as follows (See Table 4):

| ISPU INDEX | CATEGORY       |
|------------|----------------|
| 1-50       | Good           |
| 51-100     | Medium         |
| 101-199    | Not Health     |
| 200-299    | Very Not Health|
| >300       | Dangerous      |

High levels of carbon monoxide pollutants are caused by the high flow of vehicles in the area, as well as the lack of green areas. So that pollutants cannot decompose well, it is seen at the location of Str.. Gelap Nyawang with ISPU 325 (Dangerous). The opposite occurs on Str. Kebonwaru Selatan, the number of green spaces and the low flow of vehicles, making the air quality in the location in good quality and healthy. The Carepol system will present pollutant level analysis charts (See Figure 9).
Figure 9. Carepol Chart Analysis

Acknowledgment
The Carepol system still requires further evaluation and development. Especially in the coverage area of the sensor can be further expanded. This can be done by changing the sensor module components that have the best industry standards and quality, and a low error value. The goal is to get data that has high accuracy and quality than using the experimental scale sensor components.

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