Real Time Air Quality Monitoring System in Three Sites (Bogor, Cibeureum and Serpong)

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Abstract. Center for Climate Risk and Opportunity Management of Bogor Agricultural University in collaboration with National Institute for Environmental Studies-Japan developed an on-line system to monitor real time air quality and greenhouse gases for three sites surrounding Jakarta area, i.e. Bogor (Center of Bogor city), Serpong (Jakarta suburb) and Cibeureum (mountainous area, background-like site). The system uses standards air-quality monitoring equipped with an array of gaseous and meteorological sensors. The system records data every minute and stores in local storage and sent automatically to a Dropbox every 6 hours. The data in the Dropbox is accessed using API and being processed and analysed using several modules to be converted into useful information and presented in a website. The website will display real time air quality for ozone (O$_3$) and particulate matters (PM$_{2.5}$ and PM$_{10}$) and greenhouse gas data (CO$_2$, CH$_4$), Carbon monoxide (CO) Nitrogen Oxide (NO$_x$), and Sulfur Dioxide (SO$_2$), in the past 30-day including local weather data for the past 7 days. These data are then converted into an index indicating the status of the quality of the air surrounding the stations. The index is divided into five categories based on EPA air quality standard, namely good, moderate, unhealthy for sensitive group, unhealthy and very unhealthy. The system can provide the status of air quality index on a six hours basis and easy to be accessed by any stakeholder. The system allows local authorities, communities and industries to easily access and use the information for air quality management purposes and early warning.

Keywords : air quality, ozone, CO, SO$_2$, NO$_x$, CH$_4$, PM.

1. Introduction

The presence of air quality monitoring system is very important for air pollution management, particularly in the big cities. It provides information about the status of air quality for the city authorities and helps the cities’ authorities in formulating the mitigation policies and developing air pollution management. It also provides information to warn people when pollution levels reach harmful level and help communities to do actions in limiting the impact of poor air quality on bad days. Jakarta, Bogor,
Depok, Tangerang and Bekasi (Jabodetabek), the growing and the biggest cities in Indonesia, have installed air quality monitoring system. However, many of them do not function well and only monitor a few air quality parameters [1]. In addition, the air quality information is also not processed and disseminated to public informatively.

Center for Climate Risk and Opportunity Management in Southeast Asia Pacific (CCROM-SEAP) of Bogor Agricultural University (IPB), Agency for the Assessment and Application of Technology (BPPT) and National Agency for Meteorology, Climatology, and Geophysics (BMKG) are implementing a joint monitoring of air pollutants and greenhouse gases with the National Institute for Environmental Studies (NIES) Japan. The monitoring systems are ground base system installed at three sites in Jabodetabek, i.e., Bogor (Center of Bogor City), Serpong (Jakarta suburb), and Cibeureum (mountainous area, background-like site) in 2016-2017. The system monitors many air quality parameters continuously consisting of GHGs and air pollutants (CO2, CH4, O3, CO, NOx, SO2, aerosol concentrations PM2.5, PM10, Black Carbon, chemical components and flask sampling of air) [2]. Measurement of CO2 and CH4 uses G2301 from Picarro, CO using CO-30i from Los Gatos Research, NOx using Model 42i-TL from Thermo, SO2 using Model 43i-TLE from Thermo, O3 using OA-787 from Kimoto Electric, aerosol concentrations (PM2.5, PM10, BC) and chemical components using ACSA-14 from Kimoto Electric, and automatic flask sampler of air from Koshin-RS. The system uses standards air-quality monitoring equipped with an array of gaseous and meteorological sensors.

We developed a website air quality monitoring system to display the processed air quality data measured by the monitoring system from the three sites in the form of air quality index information. This paper introduces the web-based air quality monitoring system along with its capabilities in analyzing the air quality data to produce real time air quality status along with the archive data in the past few hours and days.

2. Architecture of the Web-Based Air Quality Monitoring System

We developed the web-based air quality monitoring through two steps (Figure 1). The first is establishing a database of the air quality data from the local storage and the second is building a web service from the database that will display the real time and data archived from the past hours and days on the website.

![Figure 1. Architecture of the system](image)

2.1. Database

The air quality monitoring system in the three sites records data every minute and stores the data in their local storage and sent automatically to a Dropbox every 6 hours. We developed modules using Application Programming Interface (API) to transfer the data from the Dropbox (cloud storage) to Database, The API is a protocol that forms an interface to allow for inter-programs to access and to analyze the data from the background. The Dropbox provides the v2 API through OAuth 2, in which
the access requires tokens generated from https://www.dropbox.com/developers site. Module for the database facilitate the process for receiving, storing, pre-processing and converting the data into useful information and presenting the information in the website. The module uses Data reader daemon that checks raw data (.csv) in a group files in Dropbox into the database (PostgreSQL) [4]. Data readers are built using python v3.6.4 with the following requirements:

- Dropbox library: Reads the structure and content of files stored in the Dropbox.
- Psycopg2 library: Facilitates interaction between the Dropbox and the database (PostgreSQL DBMS)
- Temporary folder (tmp): Temporary location for storing the data during the synchronization process.

During the synchronization process, the module scans all data in the Dropbox and retrieves the query list of files that have been synchronized in the database, so that they get a list of the data that is not in the database, and transfer the data to the database. The module can be run periodically using the scheduler on the operating system or on the website using ‘cronjob feature’ that is run every 6 hours.

2.2. Web Service

Modules for the web services run using PHP7.2.4 with Laravel Framework 5.6 requires the php-pgsql [5]. The web services accommodate the following data feature:

a) **Real time Air quality monitoring (O₃, PM₂.₅ and PM₁₀ and Weather**, Air quality monitoring (O₃, PM₂.₅ and PM₁₀) and weather are placed on the main page of the website as this information is considered as the main important information. Like the weather, the O₃, PM₂.₅ and PM₁₀ vary considerably between times (hour to hour, day to day etc.). The module will develop Air Quality Index (AQI) based on the condition of the concentration of the O₃, PM₂.₅ and PM₁₀ in the air using EPA standard [6]. AQI provides simple information about status of the air quality, whether the index is at the stage of ‘unhealthy’ or any status as presented in Table 1 and Figure 3, so that people can mitigate the impact on their health. The AQI is calculated using the last 6 hours data from eight time periods, i.e. from 01:00 to 07:00, 04:00 to 10:00, 07:00 to 13:00, 10:00 to 16:00, 13:00 to 19:00, 16:00 to 22:00, 19:00 to 01:00 and 22:00 to 04:00. Thus, if the page is accessed at 09:00, the information displayed is an average between 01:00 and 07:00 of the day before the data accessed. Each data has a flag indicating the status of the data, i.e. ‘A’ indicating the data obtained during adjustment mode of the instruments, ‘X’ indicating data error, and ‘N’ indicating normal (the data can be used for the calculation of the AQI).

| Classification | Color | O₃ (ppb) | PM₂.₅ (ug/m³) | PM₁₀ (ug/m³) | Health Concern |
|----------------|-------|----------|----------------|---------------|----------------|
| 1 Good         | Green | 0-54     | 0-12           | 0-0.54        | None           |
| 2 Moderate     | Yellow| 55-70    | 12.1-35.4      | 55-154        | Unusually sensitive people should consider reducing prolonged or heavy exertion. |
| 3 Unhealthy for Sensitive Group | Orange | 71-85    | 35.5-55.4      | 155-254       | People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion. |
| 4 Unhealthy    | Red   | 86-105   | 55.5-150.4     | 255-354       | People with heart or lung disease, older adults, and children should avoid prolonging or heavy exertion. Everyone else should reduce prolonged or heavy exertion. |
| 5 Very Unhealthy | Purple | >= 106   | >= 150.5       | >= 355        | People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion. |
Figure 2. Bogor City AQI for Ozone

Similar with AQI, weather data is also grouped into eight time periods (segments), i.e. 01:00 to 07:00, 04:00 to 10:00, 07:00 to 13:00, 10:00 to 16:00, 13:00 to 19:00, 16:00 to 22:00, 19:00 to 01:00 and 22:00 to 04:00. The weather information presented in the front page of the web page consists of:

- Wind speed in m/s
- Wind direction in arc degree (DEG)
- Temperature (°C), average air temperature for the eight segments,
- Relative humidity (%), average relative humidity for the eight segments,
- Rainfall (mm), total rainfall for the eight segments.

Wind speed and wind direction are treated as vector which is calculated using the following formula:

\[
\bar{ws} = \left( \frac{\sum ws \cdot \sin(wd)}{n} \right)^2 + \left( \frac{\sum ws \cdot \cos(wd)}{n} \right)^2 \]

\[
\bar{wd} = \text{atan2} \left( \frac{\sum ws \cdot \sin(wd)}{n}, \frac{\sum ws \cdot \cos(wd)}{n} \right)
\]

\[
\bar{ws} = \text{Average value of wind speed in each 6-hour segments}
\]

\[
\bar{wd} = \text{Average wind direction in each 6-hour segments.}
\]

\[
ws = \text{Average wind speed per minute.}
\]

\[
wd = \text{Average wind direction per minute.}
\]

\[
n = \text{Amount of data in each 6 hours segment.}
\]

b) Archived Data is displayed in two plots, line chart and scatter plot. The line chart shows an average for 8 hours and scatter plots show average for 1 hour but for PM\(_{2.5}\) and PM\(_{10}\) the plot shows average for 24 hours and 3 hours respectively. Only rainfall is displayed in the form of a histogram and the data is using summation instead of the average. The average value presented in the graph is the moving average data (Figure 4). The definition of visualization of each parameter is presented in Table 2.
Table 2. Definition of visualization plot for each parameter

| Parameter                                                                 | Scatter Plot (average of n hours) | Line Chart (average of n hours) |
|--------------------------------------------------------------------------|-----------------------------------|---------------------------------|
| 1. O₃                                                                    | 1                                 | 8                               |
| 2. PM₂.₅ and PM₁₀                                                        | 3                                 | 24                              |
| 3. Weather: Wind Speed, Wind Direction and Humidity                      | 1                                 | 8                               |
| 4. Weather: Temperature                                                  | 1                                 | 8                               |
| 5. Weather: Precipitation*                                               | 1                                 | 8                               |
| 6. CO₂ and CH₄                                                           | 1                                 | 8                               |
| 7. CO                                                                    | 1                                 | 8                               |
| 8. NOₓ, NO, and NO₂                                                      | 1                                 | 8                               |
| 9. SO₂                                                                   | 1                                 | 8                               |

* summation of hourly rainfall over certain periods (1 to 7 days)

Figure 3. CO₂ archived data

c) **Website Widget** is a small application that can be installed and executed within a web page by the user. A widget has a role of a transient or auxiliary application, meaning that it just occupies a portion of a webpage and does something useful with information fetched from other websites and displayed in any position in the screen [8]. Summary of the information can be put on a page of affiliated sites using the iframe tag in HTML4 or the embed tag in HTML5. The url address used in the src attribute is: https://www.sample.com/plugin?f=fitur[&footer=footer&bg=warna].

The widget has two features namely *air* for air quality information, and *weather* for weather-related information. The users can also change the feature of the parameters and also background colors etc. The default color is white and the other colors can be chosen by using encoded value, for example, &bg =%23ffffff for the hex value #ffffff. Example of the visualization of the parameter can be seen in Figure 5.
3. Applications
The presence of the real time air quality monitoring system and also data archive in the last few hours and days allows the user to get the current status of air quality and also trend in the last few hours or days. This information will be useful for local authorities, communities and industries for air quality management purposes and early warning for anticipating the negative impact of the severe air pollution.

4. Conclusion
The system can present a summary of air quality data and weather periodically (updated every 6 hours). The use of flag for data status (normal, error, adjusted) will greatly affects the presentation of the air quality and weather in the form of graphics as the graphs only process and present valid data.

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