Low Cost Air Quality Monitoring Sensor (AQMS) for Particulate Matter Measurement of Light Emitting Diode LiDAR System

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Abstract

The unsustainable rapid growth of urbanization in Manila is becoming a problem as the number of vehicles continue to increase. The top contributor to poor air quality in the city is vehicular emissions. Light Emitting Diode (LED) LiDAR system is applicable for such application as traffic aerosol measurement as it is intended for near range measurement from 0 m ~ 500 m. In order to correlate LED lidar signal of traffic aerosols to particulate matter concentration an additional in situ device is needed. A low-cost air quality monitoring sensor was developed that can measure PM concentration and other criteria pollutant gases. These sensors can be placed along the lidar path to be able to correlate the LED lidar signal with the PM concentration at several points and be able to obtain an empirical formula to convert the lidar signal to PM concentration.

Keywords: low cost sensors, led lidar, particulate matter, air quality, portable

1. INTRODUCTION

The unsustainable rapid growth of urbanization in Manila is becoming a problem as the number of vehicles continue to increase. The top contributor to poor air quality in the city is vehicular emissions. Light Emitting Diode (LED) LiDAR system is applicable for such application as traffic aerosol measurement as it is intended for near range measurement from 0 m ~ 500 m (Koyama and Shiina, 2011; Fukuchi and Shiina, 2012; Shiina, 2013; Shiina, 2014). In 2015, the Environment And RemoTe Sensing ResearcH (EARTH) Laboratory, Physics Department, De La Salle University started to collaborate with Dr. Tatsuo Shiina to learn the LED LiDAR technology to be able to make the affordable LiDAR technology in the Philippines through our EARTH laboratory (Ong et al., 2016). We plan to develop an LED LiDAR system for traffic aerosol measurement along Taft Avenue which is in front of our university. It is one of the major and busy thoroughfares in the city of Manila. Synergy of lidar and PM measurement can provide a basis for characterizing air quality (Mazzoleni, C., 2010). Multiple PM measurements along the lidar path can provide a better characterization of air quality. Shown in Figure 1 is the synergy set up of LED Lidar and the EARTH AQMS. Low cost air quality sensors are becoming popular in monitoring urban air quality. In the Philippines, low-cost air quality monitor is not yet popular. Most reported air quality measurement comes from the accepted standard AQMS and/or expensive monitoring instruments. Our group developed a portable low-cost Arduino and Raspberry PI based air quality monitoring device that may help on cutting the cost to a very affordable price, making the data accessible to everyone. The EARTH Air Quality Monitoring Sensors (EARTH AQMS) device can be place along the LED lidar path to provide a basis for air quality characterization. It is designed to measure criteria pollutants such Particulate matter, Carbon Dioxide, Carbon Monoxide, Nitrogen Dioxide, Sulfur Dioxide, and Ozone. A powerbank or a 5V DC adaptor can be used to provide the 5V DC voltage needed by the device. The measured variables of developed device were compared with a commercial particle counter and gas sensor.

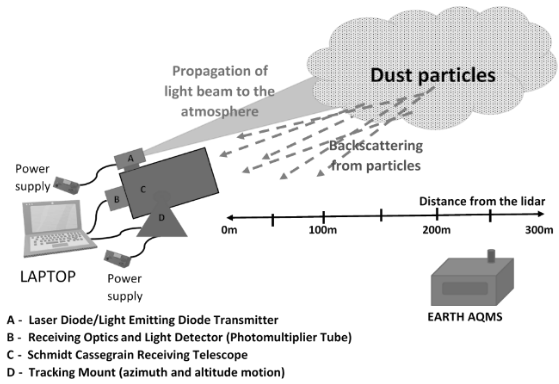

Figure 1. The synergy set up of LED Lidar and the EARTH AQMS.

2. THE DESIGN OF THE PROTOTYPE

Figure 2 shows a block diagram of the EARTH AQMS. It consists of five gas sensors (Ozone, NO2, SO2, CO, and CO2), a PM sensor, and a temperature and humidity sensor. The gas sensors, except for CO2, are electrochemical sensor that detect gas concentration by measuring the current based on the electrochemical principle. The CO2 sensor used non-dispersive infrared (NDIR) principle to detect the existence of CO2 in the air. The PM sensor used laser scattering principle to detect the dust particles in air.

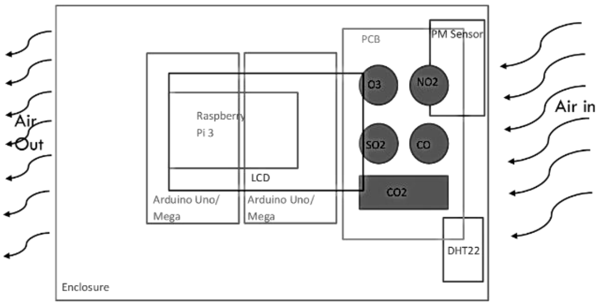

Figure 2. Block diagram of the EARTH AQMS

Arduino Mega is the microcontroller responsible for collecting data from all the gas sensors, the PM sensor and the temperature and humidity sensors. Once data is collected it will be converted into a single string and will be transferred to the raspberry pi data string every minute, once data has been transferred to raspberry pi data will be displayed to the LCD screen, it will be presented with a GUI interface program. Data will also be backed up in a sd card which is installed in the raspberry pi. Data will then be transferred to the web server once internet connection is established. The working flow chart for the AQMS code is illustrated in Figure 3.

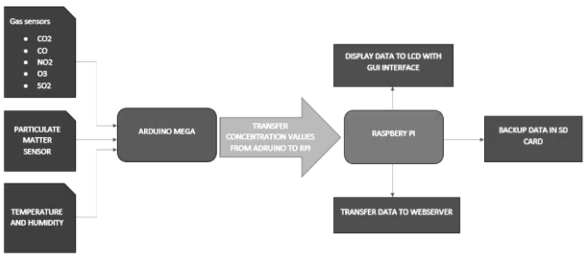

Figure 3. Flowchart for the EARTH AQMS code.

3. MEASUREMENT COMPARISON BETWEEN EARTH AQMS AND COMMERCIAL INSTRUMENTS

EARTH AQMS measurement was compared with commercial calibrated sensors because of difficulty of finding reference method. For gases, we used AEROQUAL gas sensors for comparison, while for Particulate matter LIGHTHOUSE Handheld 3016-IAQ and DustTrak™ DRX Aerosol Monitor 8533. These commercial sensors were calibrated against a reference method. Figures 4 show the comparison of the gas and PM sensors of AQMS with the commercial instruments. There is a good agreement between the EARTH AQMS and Aeroqual with regards to Ozone and SO2 measurement. For PM2.5, the PM sensor of the AQMS has almost the same concentration as the Lighthouse and same trend as the TSI. The EARTH AQMS was placed in front of De La Salle University, which is near a major thoroughfare in Manila. The developed EARTH AQMS device can provide real time continuous monitoring of criteria pollutants especially PM1.0, PM2.5, and PM10. When the LED LiDAR is developed, a synergy of the LiDAR system and the EARTH AQMS can provide a better characterization of the air quality near a busy thoroughfare.

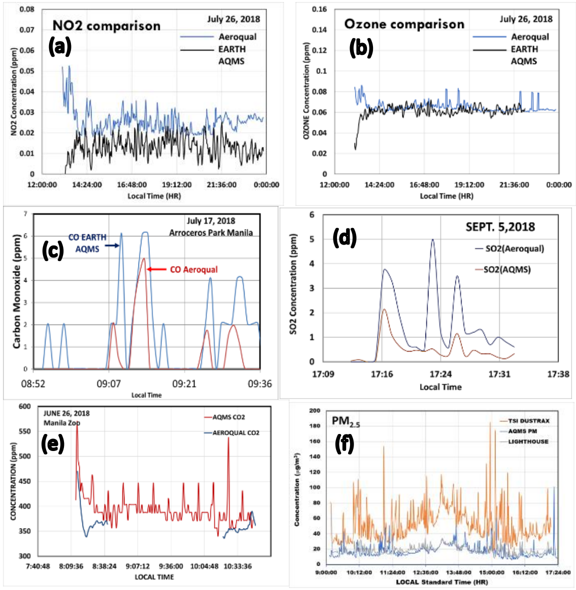

Figure 4. Comparison of EARTH AQMS measurement with expensive commercial instruments. (a) NO_2; (b) O_3; (c) CO; (d) SO_2; (e) CO_2; (f) $PM_{2.5}$.

4. ACKNOWLEDGEMENT

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