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Monitoring the Air Quality and Microclimate in a Semi-urban Area Using a Smartphone

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Abstract: In most developing countries, the air quality index is a relevant issue since it directly impacts human health and mobility. Commercial devices have already been used to describe the relationship between the air quality index and associated risks. But these results are not readily accessible to the general public, especially in semi-urban areas where threats of air pollution lurk with rapid urbanisation. The main idea is to use open-source wireless technologies for real-time monitoring of outdoor pollutants where free access to data on air pollution is not available. The result of the study shows the mean concentration of nitrous oxide ranges from 1.50 μg/m^3 to 3.83 μg/m^3 with the maximum being 6 μg/m^3 and the minimum being 0 μg/m^3. The average daily concentration of P.M$_{10}$ ranges from 20.58 μg/m^3 to 38.43 μg/m^3 with a maximum 46 μg/m^3 and the minimum 13 μg/m^3. The average concentration of particulate matter P.M$_{2.5}$ ranges from 30.04 μg/m^3 to 53.39 μg/m^3 with the maximum concentration being 59 μg/m^3 and the minimum concentration being 2 μg/m^3 in the study period. Similarly, the daily mean concentration of ozone varied between 19.87 μg/m^3 and 34.75 μg/m^3 with a maximum 52 μg/m^3 and the minimum 5 μg/m^3. The mean AQI value ranges from 34.54 to 54.30 with a maximum value of 91 and a minimum being 24. PM$_{2.5}$ and PM$_{10}$ showed a positive correlation ($r^2 = 0.998$) with each other, indicating they came from the same source. Both PM$_{2.5}$ and PM$_{10}$ were negatively and weakly correlated with temperature and humidity. In the study, it is shown that PM$_{10}$ acts as a single variable that affects the air quality index as a result of the combined effects of multiple factors.

Keywords: Developing countries; Semi-urban area; Air quality monitoring app; Air quality index; Microclimate.

Introduction

Health is a component of a nation's sustainable development (Acharya et al., 2018). It is of utmost importance for a nation to have a healthy populace, as a hazardous environment undermines both health and economic development. The poor are regularly exposed to health-harming environmental hazards, such as contaminated water and air pollution. Every day, the global population increases. Since the industrial revolution of the eighteenth century, this process has been ongoing. A region with high per capita earnings is more urbanised, while a location with low per capita wages is less urbanised (WHO, 2019). Thus, an urbanized location, such as a city, offers distinct living choices due to its economic and political prospects. And people are drawn to these urban regions. In the next 30 years, the urban population in Africa and Asia is projected to rise (Neierud, 2015). In Asia, 34.93 percent of India's population will reside in urban regions (https://www.statista.com/statistics/271312/urbanization-in-india/). In the past, when the rate of development was slower, there were two types of societies: urban and rural. As the economic level expanded under the influence of technological breakthroughs and industrialisation, semi-urban areas emerged. These regions have a population between 10,000 and one million. Numerous studies examine the distinctions between urban and rural regions without discriminating between varied urban areas. It is difficult to provide an overview of issues that vary by urban agglomeration location. Particularly in India, semi-urbanisation has generated numerous difficulties, such as environmental health issues. Air pollution poses a grave threat to human health (Li et al., 2017; Manisalidis et al., 2020). There are millions of human deaths attributable to outdoor air pollution caused by motor traffic, industry, rubbish burning, or household fuel combustion (https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health). Increasing data suggest that ambient air pollution is a leading cause of death among middle- and low-income groups, primarily in South Asia (https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health). According to the World Health Organization, 13 percent of global deaths are caused by heart disease, followed by paralysis and respiratory disorders. The scientific standard for monitoring air quality is classified as either FRM (federal reference method) or FEM (federal equivalent method). FRM was specifically designed to fulfil air quality monitoring criteria established by regulatory agencies. Whereas FEM monitors use alternative technologies like the smart air quality monitoring system. This system uses stationary or mobile IoT-enabled sensors to map and monitor air quality in small and large geographical areas. The system will send an instant alert if an air quality risk is detected.

Several studies provide real-time examples of the effects of various contaminants on public health in underdeveloped nations, utilising commercial devices rather than open-source software. The use of open source technologies along with geographic information systems is on the rise. Such technologies refer to computer software for which the source code or the base code is available for usage, modification, and distribution with the original rights for re-use. In addition, open source software is not restricted to software development tools and technologies. The majority of open-source programs provide cheaper data than proprietary ones (Saini et al., 2020). These applications exhibit exceptional precision with respect to a wide range of environmental conditions. Through the use of an AQI, public data can be shown quickly and easily. It can demystify data that is readily scaled and colour-coded without units and concentrations, and it can provide crucial information regarding the air quality in their area and how it may influence their health. Scholars can improve the accuracy of air quality statistics by analysing local air quality data. This will allow them to produce the essential data for establishing an integrated air quality management program and establishing air quality regulations for the city. However, no research has been conducted utilising wireless technology to monitor the air quality index and microclimate in a semi-urban location. The Plume app enables users to modify their outdoor activities based on ambient air quality. The Plume application provides a summary of what we are breathing. Clear greens represent clean air, whereas intense violets depict deadly smog on pollution maps.

Based on our hypothesis, meteorological parameters influence the concentration of pollutants in the air. It examines the relationship between air pollutants and meteorological factors in a semi-urban area.

Materials and Methods

Study Area

The current work selects Tezpur, one of the many towns in Assam, as the research area (26°41’55.9716” and E92°50’11.1876”). The town is situated in Assam, a state in the northeast. On the North Bank of the massive Brahmaputra, its terrain is sprinkled with green slopes and water features and has an average elevation of a few meters. Tezpur has a pleasant, temperate climate. Tezpur experiences an average annual rainfall of 3867 mm and a temperature of 24°C. In Figure 1, the study site map is displayed.

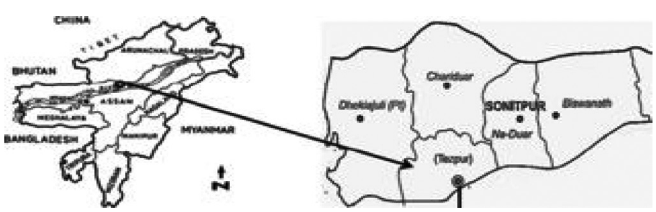


Figure 1: Map of the study area with monitoring site (Tezpur) pointed on it.

Data Resources and Statistical Analysis

Nine parameters’ real-time data are taken into consideration. A total of 14 days, or from September 8 to September 21, were used to gather data on NO_2, $PM_{2.5}$, PM_{10}, O_3, AQI, temperature, wind speed, UV index, and humidity. Per measurement was made once every hour over a 24-hour period. Data was collected with the goal of having a 5% level of missing values.

In an experimental investigation carried out in a town, basic yet dependable open-source device technology was utilised to monitor pollutants and meteorological parameters including temperature, wind speed, UV Index, and humidity, and create correlations between them. The first set of elements that are thought to influence the AQI is the nine monitoring parameters. Second, these factors are the subject of correlation analysis. The relationship between each independent factor and the connection between the independent factor and the dependent factor is calculated using the Pearson coefficient. Multicollinearity, according to a sensible method to select out the variables, using SPSS software to carry out stepwise regression analysis, obtain multiple regression coefficients and obtain multiple regression equations, using the resulting model calculations, not only boost efficiency but also improve AQI interpretability and accuracy. This solves the inefficiency that the original model only reflects the monitoring index with the top degree of pollution as the assessment index of AQI, and the outcome is biased and large. The factor selection after the multivariate regression model not only completely studies all the impact of pollutants on AQI but also greatly eases the intricacy of the model. The recommended values for the investigated air quality parameters are listed in Table 1.

Table 1: Air quality level as per WHO guidelines

Pollutant	*Averaging time*	*Air quality level*
NO_2, µg/m^3	**1-hour**	**200**
SO_2, µg/m^3	**10-minute**	**500**
CO, mg/m^3	**8-hour**	**10**
	1-hour	35
	15-minute	100
$PM_{2.5}$, µg/m^3	24-hour	15
PM_{10}, µg/m^3	24-hour	45
O_3, µg/m^3	8-hour	100

Results and Discussion

Diurnal Profiles of the Pollutants

The study also finds the diurnal profiles of the pollutants, shown in Add-on Table 2. $PM_{2.5}$ has a higher concentration than PM_{10}. In general, PM_{10} and $PM_{2.5}$ concentrations follow almost a bimodal pattern during the day. The dawn surge in PM_{10} is usually logged at 6 to 7 a.m. on the 1st, 3rd, 5th, 7th, 8th and 12th day of the study, while the peak can occur from 0.00 a.m to 7 a.m. PM_{10} concentrations increase around 0.00 a.m., indicating that the values rise as traffic on the roads gains momentum. These roads are crowded with light and heavy vehicles, as well as buses that transport people to and from work.

Ozone helps protect us from the harmful rays of the sun by blocking out the UV rays. However, tropospheric ozone is toxic to human health. It is produced when sunlight reacts with certain chemical emissions. These chemicals can come from manufacturing facilities, car emissions, fuel vapours and other places of origin. The higher concentration of ozone observed between 10 a.m and 2 p.m may be induced by the meteorological conditions that are commonly linked with the formation of river land breeze circulations and that favour the creation of O_3 (Agudelo-Castañeda et al., 2020). In addition, high temperatures and powerful sunlight speed up the reactions that produce O_3 and the constant replenishment of the town's air that comes from the

Table 2: A correlation study of air pollutants and air quality index with meteorological variables

	NO_2	*$PM_{2.5}$*	*PM_{10}*	*O_3*	*AQI*	*Temperature*	*Wind speed*	*UV Index*	*Humidity*
NO_2	1	0.680**	0.694**	-0.585*	0.678**	0.478	-0.441	0.735**	-0.754**
$PM_{2.5}$		1	0.993**	-0.011	0.973**	0.106	-0.120	0.359	-0.362
PM_{10}			1	-0.016	0.983**	0.151	-0.175	0.411	-0.412
O_3				1	0.084	-0.376	0.277	-0.561*	0.635*
AQI					1	0.184	-0.198	0.397	-0.390
Temperature						1	-0.317	0.658*	-0.806**
Wind speed							1	-0.631*	0.588*
UVIndex								1	-0.877**
Humidity									1

AQI-Air quality index

river (Additional Table 2). Further, the vehicular traffic in the town area is quite thick and there is frequent sluggishness at night. This process can also be responsible for the formation of ozone. This occurs because traffic jams result in reduced driving speeds, reduced traffic capacities and increased releases of contaminants related to vehicle exhaust (Tang et al., 2019). Observations from the study show that the temperature and wind speed is lower at night. The humidity is higher at night. In addition, the UV index is lower in the late afternoon and even zero at night.

The air quality index (AQI) is a numerical scale that is used to describe daily air quality. The AQI functions as a scale that ranges from 0 to 500. The AQI is a technique to see changes in the quantity of pollution in the air, rather than temperature changes. After 14 days of monitoring the AQI, it was discovered that the AQI was lower in the morning. It does, however, gradually rise in the afternoon and then rise once more in the evening. The fact that the readings of AQI are higher at night than during the day is another of the most intriguing facts. Since there is less breeze at night, contaminants like smoke can condense closer to the ground.

Statistic on Air Pollutants

Figures 2a, 2b, 3a and 3b show the fluctuation of the daily mean concentrations of nitrous oxide, PM_{10} and $PM_{2.5}$ and Ozone. These concentrations were observed for 14 days in the town. The mean concentration of nitrous oxide ranges from 1.50 μg/m^3 to 3.83 μg/m^3 with the maximum being 6 μg/m^3 and the minimum being 0 μg/m^3. The average daily concentration of PM_{10} ranges from 20.58 μg/m^3 to 38.43 μg/m^3 with a maximum 46 μg/m^3 and the minimum 13 μg/m^3. The average concentration of particulate matter $PM_{2.5}$ ranges from 30.04 μg/m^3 to 53.39 μg/m^3 with the maximum concentration being 59 μg/m^3 and the minimum concentration being 2 μg/m^3 in the study period. Similarly, the daily mean concentration of ozone varied between 19.87 μg/m^3 and 34.75 μg/m^3 with a maximum 52 μg/m^3 and a minimum of 5 μg/m^3.

Air quality index (shown in Figure 4), the mean AQI value ranges from 34.54 to 54.30 with a maximum value 91 and a minimum being 24.

The Environmental Condition

The 14-day temperature (25.26-29.12°C), minimum (18-25°C) and maximum temperatures (29-34°C), humidity (78.1-90.08%), minimum (24%) and maximum (42%), Wind speed (3.26-9.1 km/hr) minimum (1-4km/hr) and maximum (5-14km/hr), UV index (1.22-2.12) minimum (0) and maximum (6-10) differed (Figures 5 and 6). This difference was attributed to changes in weather patterns and fluctuations in outdoor environmental parameters. Pollutants are dispersed by high winds, which can dilute their concentrations. However, stagnant conditions or

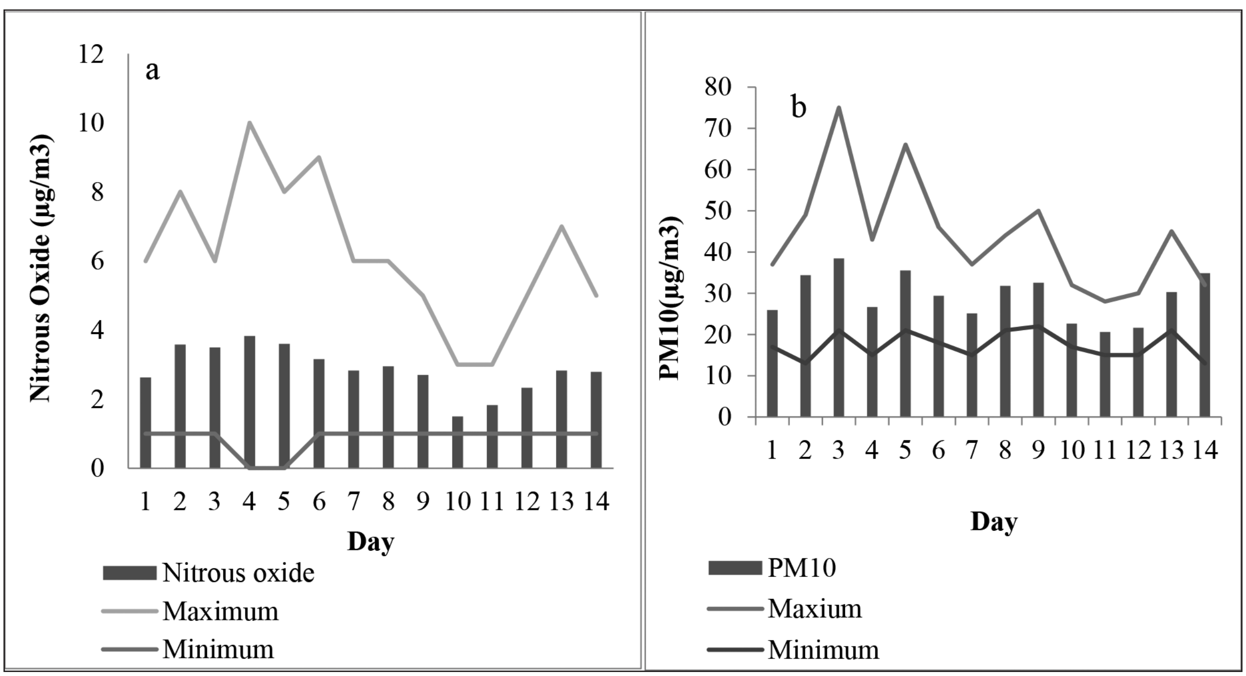
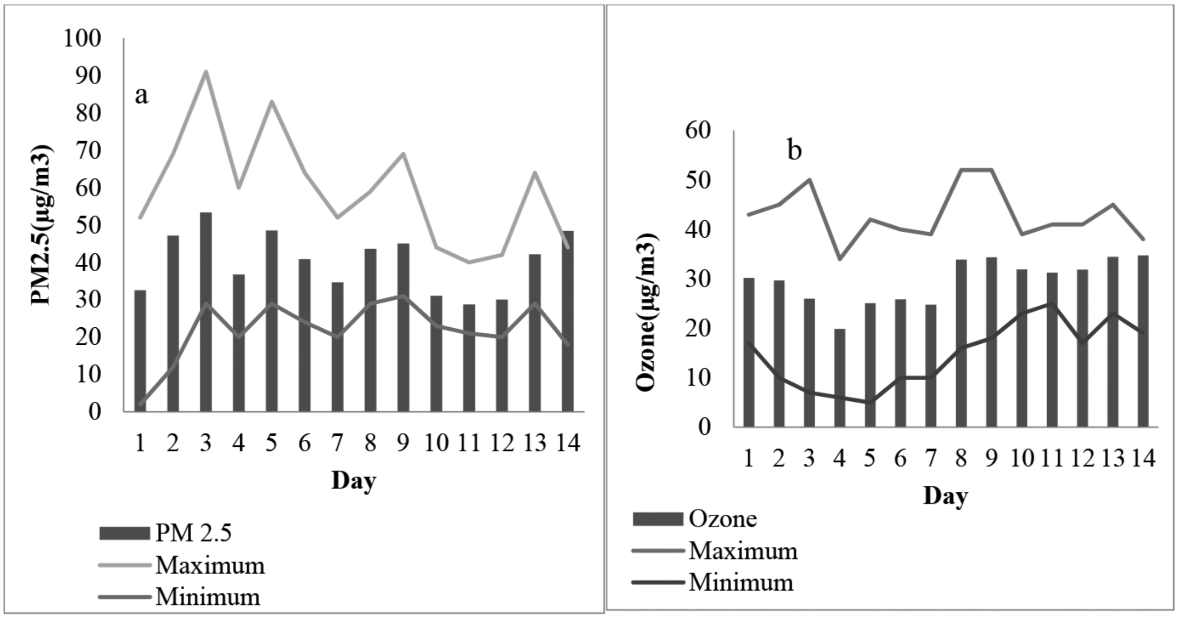


Figure: 2a and 2b. Fluctuation of daily mean concentration of the of nitrous oxide and particulate matter, PM_{10} for 14 days



Figures 3a and 3b: Fluctuation of daily mean concentration of the particulate matter $PM_{2.5}$ and ozone for 14 days.

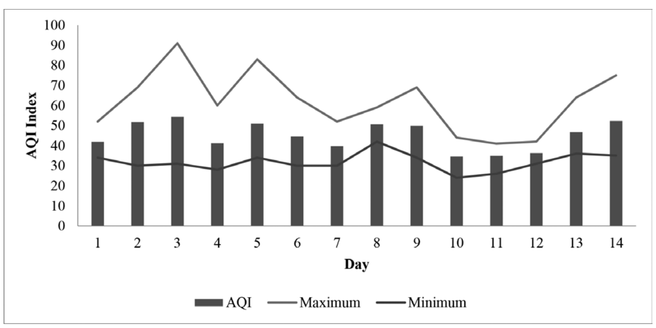


Figure 4: Mean air quality index (AQI) value for 14 days study.

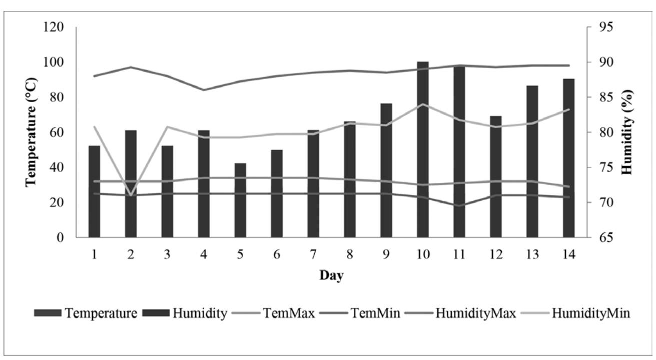


Figure 5: Variations of temperature and humidity for 14-days.

a lack of air movement cause pollution levels to build up. Since elevated near-ground temperatures speed up upright air jets, which drastically lessen near-ground contaminants and also the hotter the temperature, the

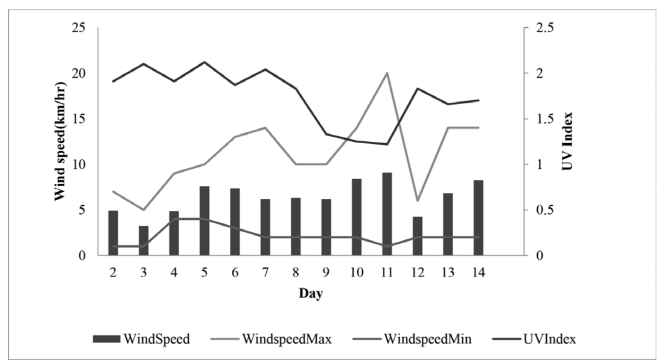


Figure 6: Illustrates wind speed and UV index variation over a 14-day period.

better the air quality. However, high humidity does not result in better air quality, according to the study. This is partly based on the fact that droplets in the air can unite solid particles like $PM_{2.5}$ to create air suspension.

Relations Between Air Pollutants and the AQI and Meteorological Variables

Correlation Analysis

Correlation is a numerical calculation that expresses the degree to which two factors are linearly related (meaning they vary together at a steady rate). It is a general tool for defining simple relationships without making a report about cause and effect.

The correlation between PM_{10} and $PM_{2.5}$ ($p = 0.993$) indicates that these contaminants originate from identical starting points, such as biomass burning, industrial sources, automotive fleets, loading, unloading, and urban activities. In the case of meteorological variables, statistically significant negative correlations were found between pollutants and humidity. It is suggested from this study that the influence of humidity is much more effective at subsiding pollutants in a region.

The relationship of particulate matter (PM_{10} and $PM_{2.5}$) with temperature was positive and not significant. The association between O_3 and particulate matter (PM_{10} and $PM_{2.5}$) and between O_3 and NO_2 was negative (Table 2). In this case, the absence of periods with high ozone concentrations may be mainly linked with the low presence of precursors, especially NO_2, which presented low concentrations (Agudelo-Castañeda et al., 2020). The presence of slight quantities of water vapour has a harmful effect on ozone formation. Moisture prevailing in the atmosphere with harsh sunlight causes the synthesis of hydroxyl (OH^-) and hydroperoxy (HO_2^-) ions resulting in enhanced ozone destruction which results in a negative correlation with ozone. In this case, however, O_3 is mainly linked to humidity positively, indicating rainy days without a reduction in precursor emissions. Also, a negative UV index is observed in the study area. The excess amount of O_3 has significantly contributed to trapping harmful UV radiation, thereby lowering UV Index. No significant clear link was found between ozone and wind speed, which shows that no ozone was possibly transferred from other areas, supporting the local formation of this pollutant. When the sun is higher in the sky, UV radiation levels are higher. Thus, UV radiation levels vary with time of day. Temperature and UV index are positively related (p=0.658). The AQI is computed for four major air contaminants controlled by the Clean Air Act: tropospheric ozone, particle pollution, ozone and nitrous oxide. PM_{10}, $PM_{2.5}$, and NO_2 are positively correlated with AQI in the study area.

Stepwise Regression Analysis

Stepwise regression applies a technique to pick the most suitable collection of predictor variables that score for the observed dependent variable, through a series of tests. Stepwise regression selects the top grouping of predictor variables that accurately predict the outcome (R^2). PM_{10} is the major factor affecting AQI in the study area (Table 3).

Comparison with Other Findings

The comparison of research utilising artificial intelligence technology establishes the concentration of different air contaminants in urban regions. The ROKIDAIR system, for instance, was used to monitor the area's particle matter and send out notifications (Oprea et al., 2015). Kularatna and Sudantha (2008) used an analog device called the ADuC812 to measure various gas concentrations over a small region. A mobile application coupled with the back-end server, the Alpansense OPC-N2 for real-time data collecting, was created by Hojaiji et al. (2017) to monitor particulate matter in an air quality sensor system.

Due to the precipitation of gaseous pollutants, the monsoon season is when gaseous air contaminants cycle and have their lowest concentrations (SO_2, NO_2, O_3, CO) (Mukta et al., 2020). In contrast to spring and autumn, climatological conditions have a greater impact on daily AQI during the summer and winter (Gou and Feng, 2019). Additionally, the AQI values in metropolitan environments exhibit gradient properties.

Additionally, laws for monitoring air quality place a focus on metropolitan and capital districts while ignoring minor cities, rural areas, locations with regular emissions, and other commercial sectors. To develop a successful emissions-control strategy, research on the many sources of air pollutants that cause localized air pollution is necessary (Kawashima et al., 2020).

Conclusion

This work focusses on using a low-cost, practical, durable, and flexible air quality monitoring system for small-scale town air quality monitoring using smart devices and open-source technology. Plume

Table 3: Stepwise regression analysis

Concise Description of the Model[b]					
Model	*R*	*R^2*	*Calibrated R^2*	*Std. Error of the Approximate value*	*Durbin-Watson*
1	0.983[a]	0.967	0.965	1.30001	1.647

a. Predictors: (Constant), PM_{10}

b. Dependent Variable: AQ1

Labs continuously monitors global and local pollution advocating health and modern technology. Users receive live street-by-street pollution maps for the world's major cities, as well as 72-hour air quality projections, similar to a weather forecast.

The daily fluctuations of NO_2, O_3, $PM_{2.5}$, and PM_{10} were measured using Plume continuous air quality monitoring software. The result shows PM_{10} has a lower concentration than $PM_{2.5}$. The levels of PM_{10} and $PM_{2.5}$ vary during the day. $PM_{2.5}$ and PM_{10} levels were associated ($r^2 = 0.998$), indicating that they came from the same source. Temperature and humidity had a negative and weak relationship with $PM_{2.5}$ and PM_{10}. The higher ozone concentration between 10 a.m. and 2 p.m. could be attributable to weather conditions. It is also noticed that the AQI fell in the morning, and then rose in the afternoon and again in the evening. The AQI is also higher at night than during the day. PM_{10} alone has an impact on air quality. The app for this technology offers smartphone pollution monitoring. To quickly restore air quality, a future proposal will compute air pollution concentrations in multiple towns, collect a large amount of data, and strengthen environmental governance.

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