Assessment of the Air Quality of C.P. Garcia Avenue Along the Institute of Civil Engineering (ICE) Compound

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Abstract: This study assessed the air quality of C.P. Garcia Avenue along the I.C.E. Compound. The air quality, Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Particulate Matter 2.5 ($PM_{2.5}$) concentrations, were observed for compliance with Philippine Clean Air Act of 1999, and the DENR Administrative Order 2013-13 standards for CO and NO_2, and $PM_{2.5}$ respectively. Data such as wind velocity, traffic speed and volume, and vehicle type were correlated to determine the factors that greatly affect the air quality using simple and multiple linear regressions. The 10-minute lag regression model was developed for CO, the 30-minute lag regression model for NO_2, and the no lag regression model for $PM_{2.5}$. These results were checked with the computed pollutant transport aided regression models and it was found that the multiple R values were close to each other. The traffic volume and speed were proven significant using P-test of 95% confidence with values less than 0.05.

Keywords: Air Quality, Pollutant Concentration Standards, Traffic Characteristics, Wind Velocity, Regression Analysis

1. INTRODUCTION

Traffic volume increases together with the rising vehicle registration rate throughout the Philippines. For the year 2013, there was an increase of 3.08% from the total of 7,460,185 registered vehicles in 2012 where most increase was attributed to SUV with a rate of increase of 11.55%, followed by trailers with 7.17%, trucks with 4.94%, motorcycles/tricycles with 3.25%, cars with 2.25%, and UV with 1.31% (LTO, 2013).

Most types of road transportation are run with internal combustion engines which are classified mobile sources of air pollution. Due to combustion, gases in the form of carbon monoxide (CO), oxides of nitrogen (NO_x), in particular nitrogen dioxide (NO_2), and particulate matter 2.5 are emitted which increases the ambient concentration of these gases and suspended particles in the air which in turn causes health problems in the respiratory system especially during long term exposures. Furthermore, with the increasing number of vehicles traversing the roads, traffic speed will decrease thus, increasing the concentration of air pollutants released in the atmosphere (Xue, Jiang, & Liang 2013).

Buildings housing student population such as the Centennial Residence Halls situated at the corner of C.P. Garcia Avenue and E. Jacinto Street were exposed to high concentrations of air pollutants especially $PM_{2.5}$ which was recorded with a highest concentration of 55.52 μg/NCM last March 19, 2015 (Perez, 2015). Such concentrations were found to be greater than the set standards, 50 μg/NCM, of the DAO 2013-13.

Similarly, since the ICE building is situated along the C.P. Garcia Avenue, it would be vital to determine the compliance of the ambient air present in the vicinity of the compound for CO, NO_2, and $PM_{2.5}$ since the building houses the bulk of the civil engineering students together with other students taking courses in the building. It would also be necessary to determine an empirical equation which can relate traffic volume and speed, together with wind properties to help facilitate predictions of pollutant concentrations.

1.1 Problem Statement

What was status of the concentrations of CO, NO_2, and $PM_{2.5}$ in the vicinity along the ICE Compound especially the conformity with the Philippine Clean Air Act of 1999 (R.A. 8749) for CO and NO_2 and D.A.O. 2013-13 for $PM_{2.5}$?

How did the factors of wind velocity and direction, traffic volume composition and speed, and diesel and gasoline-powered vehicles affect the concentration of air pollutants such as CO, NO_2, and $PM_{2.5}$ in the surrounding air?

1.2 Objectives

The study assessed the air quality of the area around ICE Compound along C.P. Garcia Avenue and whether the concentration of previously mentioned pollutants conformed to the approved concentrations set by the Philippine Clean Air Act of 1999 and D.A.O. 2013-13.

The study aimed to determine the 24-hour concentration of air pollutants within three days especially during traffic peak hours and the time of maximum student and faculty occupancy of the compound. The data were used to determine how the characteristics of a given traffic flow (vehicle engine type and traffic flow speed) and how the velocity of the prevailing wind affect the air quality.

1.3 Significance of the Study

With the increasing amount of registered motorized vehicles, pollutants, due to emission, also increases causing serious health problems. Suspended particulate matter and pollutant gases could cause illness upon exposure and since the ICE Compound was in close proximity to the roadway, possible health hazards could be experienced by students, faculty, and staff. Acquiring the quantity of the pollutant concentrations and correlation with the traffic variables of speed and volume, and prevailing wind velocity and direction were performed. The obtained data were then checked with the standards set by R.A. 8749 and mathematical models were determined from the correlation in order to determine the possible air quality in future time in such a way that mitigations to the problem of air pollution could be addressed along the ICE Compound near the C.P. Garcia Avenue.

1.4 Scope and Limitations

The study was limited to the analysis of two gases namely CO, NO_2, and one suspended solid, $PM_{2.5}$. The concentrations of these pollutants were correlated with only three independent variables namely: traffic volume, traffic speed and wind velocity. Spot speed analysis was done using the trap length method recorded on video clips to which speed observations were done every ten minutes from 7:00 AM – 5:30 PM for three days. Analysis for the pollutants was done in accordance to the short-term procedures specified by the Philippine Clean Air Act of 1999 with additional provisions from the DENR Administrative Order 2013-13 for $PM_{2.5}$.

2. REVIEW OF RELATED LITERATURE

A study performed by Buonocore, et al. (2009) on the effects of traffic parameters of volume and speed together with wind speed and direction with the pollutant concentrations particularly black carbon, ultrafine particles and $PM_{2.5}$ was performed on Mission Hill neighborhood, Boston, Massachusetts. The study involved two methods of data gathering wherein fixed equipment such as water-based condensation particle counter for ultrafine particles, laser photometer for $PM_{2.5}$, and aethalometer for black carbon were housed indoors with the polyvinyl chloride and polytetrafluoroethylene tubing collecting data from the outside environment while the mobile equipment consisting of portable versions of the devices were encased inside a backpack. From their study, black carbon concentrations peaked during the morning rush followed by a steady decline while ultrafine particles showed initial increases during the early afternoon. Notably, diesel vehicles increased during the morning followed by a peak during the noon with decline at the afternoon in which from which it was found that diesel vehicles are associated with ultrafine particles, and black carbon whereas non-diesel vehicles are for $PM_{2.5}$. Speeds higher than 15 mph tend to be associated with ultrafine particles and black carbon while slower vehicles than 15 mph were associated with $PM_{2.5}$ with notable observations of significantly greater concentrations during downwind conditions under low speeds of wind especially for ultrafine particles and black carbon but inconsistent effects were found for $PM_{2.5}$. The mobile method was used to verify the pollutant concentrations depending on its distance from the roadside.

A study performed by Xue, et al. (2013) about the effect of traffic flow on the vehicle exhaust emissions particularly CO, NO_x and hydrocarbons (HC) was performed at the road rings of Beijing, China. The methods used involved the study of five vehicle brands namely Volkswagen, Ford, GM, Nissan and Honda to which their emission rates were determined using SEMTECHDS gas analysis system where it was found out that during increased accelerations during high speed conditions showed a quick increase in emission amplitudes. During acceleration $<-6m/s^2$, slow increase in emission during increasing acceleration. During $>-6m/s^2$ but $<0.3m/s^2$ rapid increase in emission amplitude is observed at increasing acceleration while rapid decrease in emission amplitude was observed at $>0.3m/s^2$ but $<1m/s^2$ with increasing acceleration. Acceleration $>1m/s^2$ increase in emission amplitude was observed at increasing acceleration. From the relationship derived using speed to that of vehicle emission, Greenshield equation was used to relate volume to that of emission. From the derived model, it was found that a decrease in the number of vehicles introduced in the road system will induce an increase in vehicle speed reducing travel time. Simulations were performed where it was found out that a 27% volume decrease results in a 24% speed improvement with 19.4% less commuting time particularly for cabs which further results in decrease of 29.3% for NO_x, 42.2% for CO, and 40.9% for HC.

A study done by Padilla and Sakurai (2012) within the road section of the Academic Oval of the University of the Philippines – Diliman Campus showed that there is a correlation between traffic volume and pollutant concentrations particularly CO, NO_2, and PM_{10}. From their study, traffic and pedestrian count was done from 6:30 AM to 8:00 PM within a span of two days. They were able to derive empirical equations relating traffic volume segregated into gasoline and diesel vehicles wherein the former showed greater correlation with CO while the latter showed greater correlation with NO_2 and PM_{10}. It was also found out that during periods of traffic rush particularly early morning and early evening to which vehicle counts were greater, pollutant concentration also tend to increase within these periods.

3. METHODOLOGY

3.1 Analysis of ICE Main Building Population

Population analysis especially for the student body inside the ICE Main Building was performed to determine the most probable day/days to which maximum occupancy was reached within a given week. Data for analysis was obtained from the list of classes shown in the Computerized Registration System of the University of the Philippines-Diliman for the second semester of the Academic Year 2016-2017 to which it was verified using the official class list procured from the Institute Course Programming Committee to determine the cases for overbooked classes. The counting of students was done initially on a per 30 minute time interval to accommodate deviations from the standard one and half hour lecture class which is the case for laboratory classes done in a span of three hours or large lecture classes done in a span of two hours. Shown in Table 1 was the per-30 minute variation of the student population within one week and the daily variation in student population. Figure 1 showed the per 30 minute variation per day while Figure 2 showed the daily student populations.

Table 1. Average 30-minute student population within one week

Day	Average Student Population (Student per 30 minutes)
Monday	85.6
Tuesday	293.1
Wednesday	187.4
Thursday	394.3
Friday	264.8
Saturday	39.2

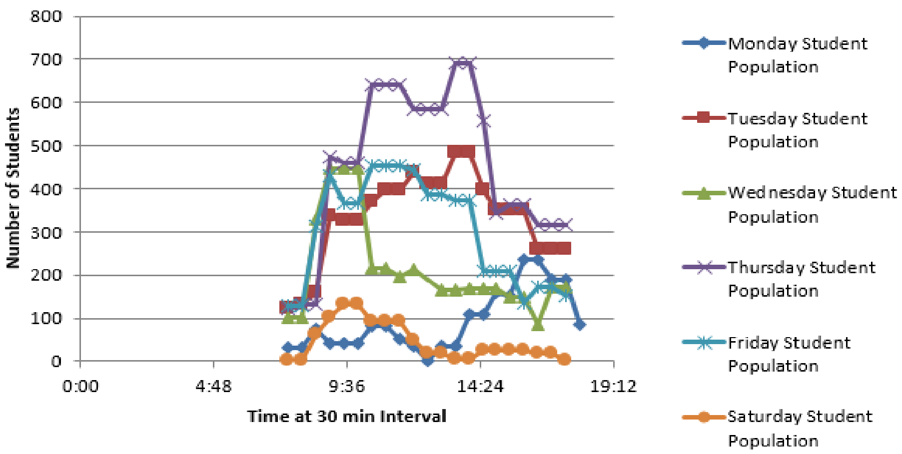

Figure 1. Variation in Student Population within a Week

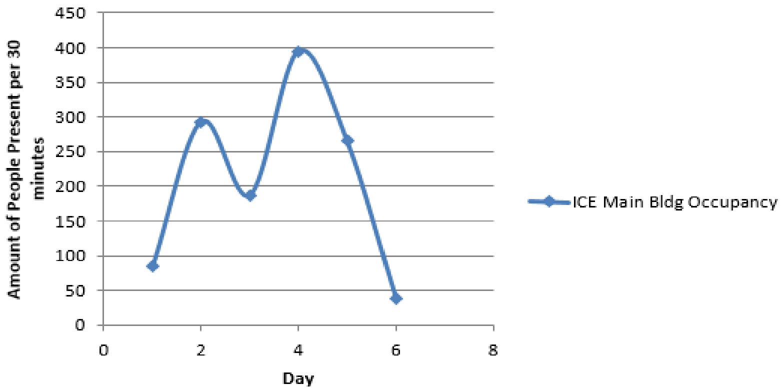

Figure 2. Average Daily Variation in Student Population

Table 1 showed the average student population within one week in which the number of students peaks at Thursday. Excluding Monday and Saturday which both have relatively lower population compared to Tuesday to Friday, Wednesday would be the day with the lowest student population. From this analysis, data gathering was decided to commence during Thursday, February 16, 2017, as the representative for the day with the maximum population; Wednesday, February 15, 2017, as the representative for the minimum population. Friday, February 17, 2017, was used to represent the day when the likelihood for traffic congestion happened being a pre-weekend day which may cause congestion due to people going home to their provinces.

3.2 Pre-Data Gathering

3.2.1 Field Reconnaissance

Reconnaissance was performed in the vicinity of the ICE Main Building to determine the best possible spot for equipment setup (Air quality monitoring van beside the Construction Laboratory Building, and video camera for traffic flow recording on the fourth floor level of the building).

3.2.2 Materials, Equipment, and Personnel Deployment

The following were used for air pollutant data collection: HORIBA APMA 370 for carbon monoxide, HORIBA APNA 370 for oxides of nitrogen, particularly nitrogen dioxide, and EBAM for particulate matter 2.5.

Traffic surveyors equipped with handheld traffic counters were assigned on each traffic direction to record traffic volume, and another surveyor with portable handheld anemometer was assigned for wind monitoring. Both traffic volume and wind velocity data were recorded manually per 10 minutes for traffic volume and per five minutes for wind velocity.

Survey forms for traffic volume were segregated into two classifications: gasoline (cars, van, motorcycles, tricycles) and diesel (SUV, pickups, jeepneys, buses, trucks & heavy equipment) since gasoline-powered vehicles emit more CO while NO_2 and $PM_{2.5}$ were attributed to diesel-powered vehicles (UK National Air Quality Strategy, 2002).

3.2.3 Equipment Set up

The trap length to be used for spot speed analysis was first set up which spans about 38.6 m.

It started at the halfway portion of the ICE Compound gate demarcated by asphalt lining to the other end which is demarcated by a street lamp post and also by an asphalt lining. Measurement of the study length was done using a measuring wheel.

According to RA no. 4136 or the Land Transportation and Traffic Code of 1964 and the QC speed limit ordinance, since this portion of CP Garcia Avenue passes through a school zone, the designated maximum speed will be set to 20 kph. Table 2 showed the traffic speed and trap length classification provided by the Center of Transportation Research and Education of Iowa State University as shown below:

Table 2. Study Length Values from Center of Transportation Research and Education, Iowa State University

Traffic Stream Average Speed	Recommended Study Length (ft)
<25 mph	88
25-40 mph	176
>40 mph	264

The speed limit was <25mph or <40.23kph which then the recommended length was to be 88 feet or 26.82 m. The researchers extended the trap length to 38.6m to be easily visible from the fourth floor window and to provide enough reaction time especially during almost free flow traffic regime. Figure 3 showed the trap length as seen from the fourth floor level.

Figure 3. Demarcation of the Study Length marked by the black lines (encircled by yellow ellipses)

The video camera was mounted on a tripod overlooking the established trap length in which was ensured that both lanes can be seen clearly.

For the setting up of the Air Monitoring van for air pollutant concentration gathering, three parameters were used in the selection of the location. First was its proximity to the roadside band second was that it should represent the actual air that is about to enter the main building. Third criterion used was its proximity to a readily available power source which is within reach of the equipment power cord to avoid any possible hazards due to the possibility of short circuiting and moisture problems due to rain. Due to these criteria, the chosen location is that of the sidewalk beside the Construction Laboratory wherein there is a readily available power source from the nearby building. It also satisfied the criteria for representative air about to enter the main building since it was positioned almost a meter from the building's edge but also not that far from the roadside of about 23 m distance. The EBAM on the other hand was installed above the van for safety reasons with its power supply coming from the van. A wind vane setup was also placed on top of the van. Furthermore, distance from trees was also accounted to which the selected position was not adjacent to any trees which might affect the pollutant concentration approaching the monitoring receptor.

The directions for the wind vane were set using a lensatic compass aided by Google Maps application. The eight directions namely: N, NE, E, SE, S, SW, W, and NW were labeled on the wind vane's base. Final checks on all instruments were done prior to data gathering.

3.5 Data Gathering

Data gathering was done for four days for the air pollutant concentrations and three days for the traffic volume and speed, and wind speed and directions.

Air pollutant data was recorded using ENVIDAS software connected to the APMA 370 & APNA 370 of the Air Monitoring Van while the $PM_{2.5}$ was recorded by EBAM software. The pollutant data were retrieved on a daily basis every 6:00 PM. These data were to be used for the per 10 minute pollutant correlation as a dependent variable.

Traffic volume counting started daily at 7:00 AM and ends at 5:30 PM since all undergraduate classes were held during this period. Furthermore, two surveyors were deployed at a location facing C.P. Garcia Avenue and were issued with two traffic counters for easier and efficient counting, and traffic count forms each for recording. Prior to traffic volume recording, the surveyors were oriented on the different vehicle types to be surveyed to avoid any confusion in counting which in turn affect the recorded volume data. Traffic counts were done at 10-minute intervals to have similar time period with the averaging of the Air Monitoring equipments. The third surveyor was deployed above the Air Monitoring to record wind velocity per 10 minutes of observation with readings to be done during the 0^{th}, 5^{th}, and 10^{th} minute since manual observation was performed. The surveyor was oriented to first determine the wind direction and face the anemometer's blades parallel to that direction with readings be done every five minutes. This method was used to ensure that the recorded wind speed was at its maximum for that instance. In cases of no blade rotation and arrow movement of the wind vane, the surveyor was instructed to write C for calm condition. All traffic and wind data gathering were collected between 5:30 -5:40 PM on a daily basis.

Spot Speed Analysis was done with the aid of a video camera to which vehicles' speeds were recorded by measuring the time required for a vehicle to pass the whole study length. Time measurements were done using stopwatches with a 1/10 s chronograph accuracy. Each of the researchers performed spot speed analysis on the assigned traffic direction to them. Time recordings are done during 0-3 min, 3-6 min, and 6-9 min periods. 30 vehicles randomly selected were used for spot speed analysis with a weighted distribution of 18 vehicles bound to Katipunan Avenue and 12 vehicles bound to Philcoa area. Such distributions were done due to observations from field reconnaissance that the direction to Katipunan Avenue tends have build-up which in effect provide a longer duration of stay at the study length. A basis for such classification was done using the concept of directional derivative wherein from the total of 30 vehicles, the direction which most likely to contain queuing was multiplied by 0.6 factor to determine the total number of vehicles' speed as its representative which in this case was the Katipunan bound direction while the remaining 40 % of the speed will be determined from the Philcoa bound direction.

3.6 Post Processing

Post processing of all the data was done after the three days of data gathering. Traffic volumes for each vehicle type were recorded in a workbook with delineations for gasoline and diesel powered engines. Gasoline-powered engines were those of the passenger cars, vans, motorcycles and tricycles while the rest were classified into diesel-powered with recordings still done on a 10-minute interval.

Spot speed data were organized according to the destination the vehicles were bound per ten minute interval in a worksheet per direction. The average of the 30 vehicles, 12 going to PhilCoA and 18 going to Katipunan Ave. was obtained at ten minute intervals.

Similarly, wind data were converted into a ten minute interval to be able to perform analysis since all of the previous observed data were in per 10-minute readings. Directions expressed in cardinal direction were converted into azimuth from the North measured in clockwise orientation to be able to express in numerical values.

4. RESULTS AND DISCUSSION

4.1 Analysis of Air Pollutants

4.1.1 Compliance Check with the Philippine Clean Air Act and DAO 2013-13

Compliance for the concentration of air pollutants was checked using two Philippine standards namely: Republic 8749 or the Philippine Clean Air Act of 1999 and the Department of Environment and Natural Resources Department Administrative Order (DENR DAO) no. 2013-13 or the Establishment of the National Ambient Air Provisions for Particulate Matter (PM) 2.5.

The 10-minute variation in the concentration of CO per day from February 14-17, 2017 is shown in Figure 4 below.

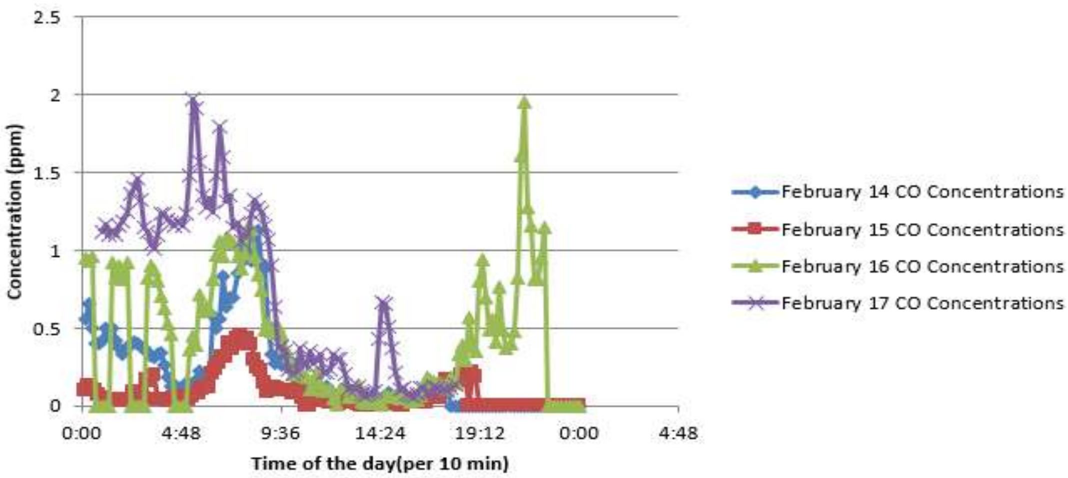

Figure 4. Daily CO Concentrations

Evaluation of CO concentrations is divided into short term (24-hour averaging) and long term (1 year averaging). Since the study was conducted on a span of almost four days, the former averaging will be used. It was given in the law that acceptable concentrations will be 9 ppm for eight hour averaging. Shown in Table 3 and Figure 5 were the daily concentrations of CO from February 14 (Tuesday) to February 17 (Friday), 2017.

Table 3. Eight-hour average of CO Pollutant Concentration

CO	14-Feb	15-Feb	16-Feb	17-Feb
Time	Concentration	Concentration	Concentration	Concentration
0:00-8:00	0.420208	0.13375	0.814412	1.280698
8:00-16:00	0.207083	0.063478	0.220833	0.389792
16:00-24:00	0.096667	0.108235	0.549211	0.11

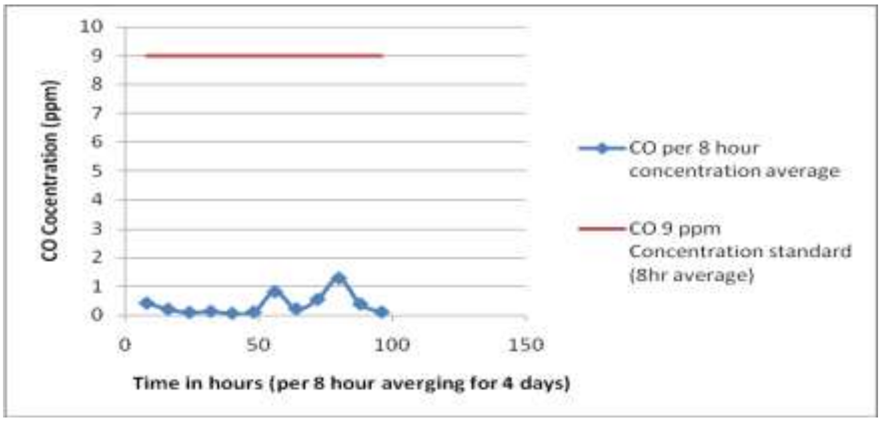

Figure 5. Comparison of 8-hour concentration average and concentration standards for CO

The pollutant concentrations for each day were seen to be relatively lower to the set standard values using the eight hour averaging of pollutant concentration.

The per-10 minute concentrations of nitrogen dioxide throughout the day from February 14-17 were shown by Figure 6 below.

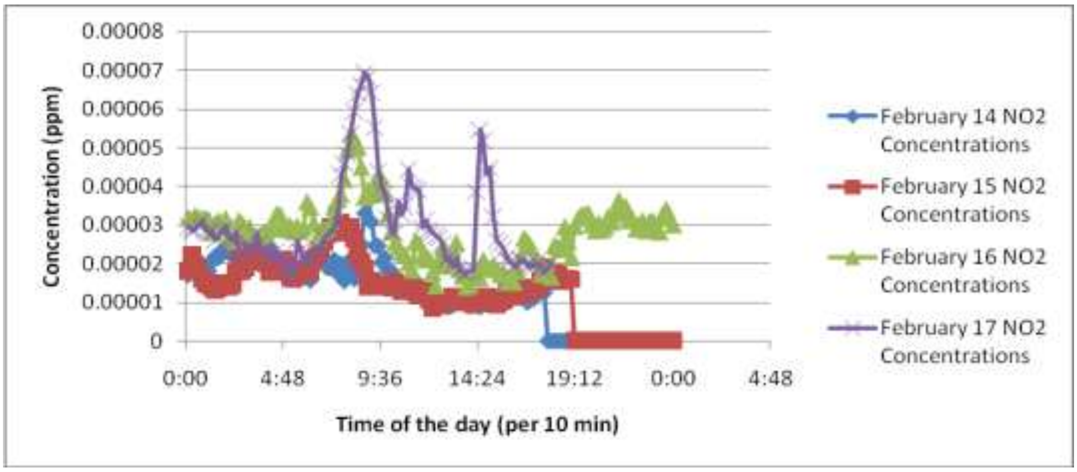

Figure 6. Daily Nitrogen Dioxide Concentration

Evaluation for nitrogen dioxide was also divided into short and long term averaging with durations similar to those above. However, only one standard concentration was established for NO_2 which was 0.08 ppm. Table 4 and Figure 7 showed the 24-hour average of nitrogen dioxide concentrations.

Table 4. 24-hour average concentration of NO_2

NO2	14-Feb	15-Feb	16-Feb	17-Feb
Time	Concentration	Concentration	Concentration	Concentration
0:00-24:00	0.000016904	0.000016493	0.000028113	0.00003002

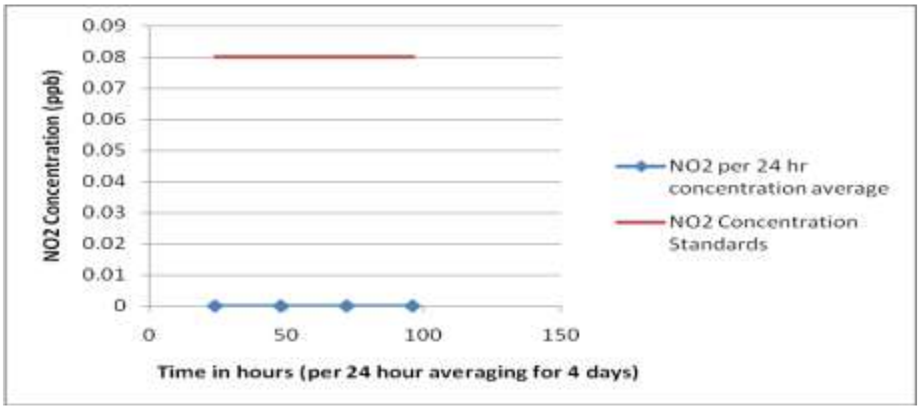

Figure 7. Comparison of per-24 hour concentration average and concentration standards for NO_2

As what was shown by Figure 7, the concentration levels were below to that of the standards set using the 24-hour short term averaging for the pollutant, it can also be seen that it still passed the standard as shown on the table and graph above.

The DENR DAO no. 2013-13 was used for the evaluation of $PM_{2.5}$ since no provision was given by RA 8749. The department order, it was also divided into short and long term averaging with standards given as 0.050mg/NCM. Daily concentrations from February 14-17, 2017 were shown by Figure 8.

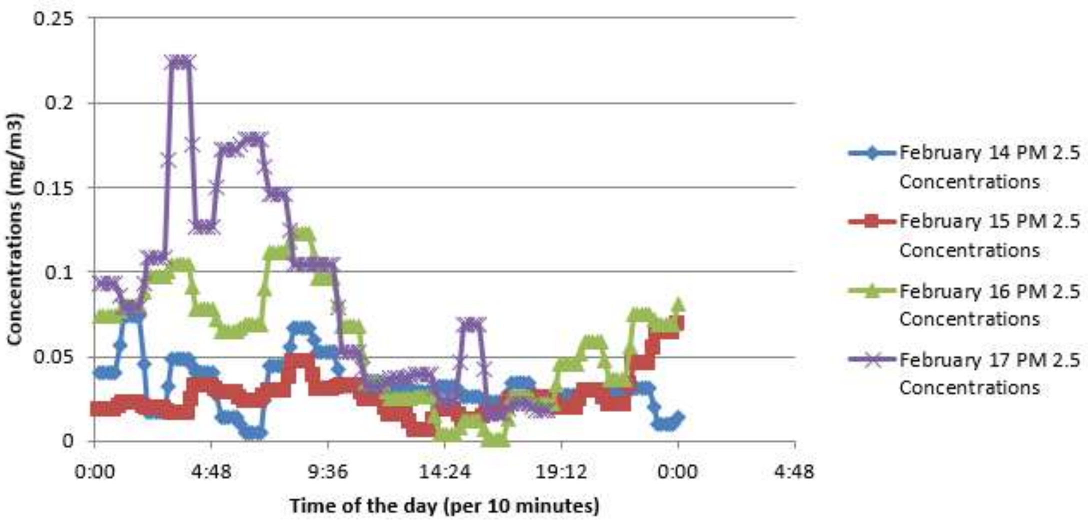

Figure 8. Daily Particulate Matter 2.5 Concentrations

From Figure 8, the high values of $PM_{2.5}$ concentrations happened during early dawn periods up to morning periods. A possible reason for these values above the standard during these periods may be attributed to the Metro Manila Development Authority (MMDA) Truck Ban Ordinance which prohibits the passage of trucks during 6-9 AM and 5-9 PM in major road arterials and combined by the “No window hour scheme” from 7 AM to 8 PM which includes C.P. Garcia Avenue to those included which makes trucks and other cargo and freight transports to travel during the periods outside of the two road ordinances. The additional higher values during 6-9 AM and 5-7 or 8 PM were possibly attributed to the bulk of people in their vehicles rushing to their schools and workplaces.

Table 5 and Figure 9 showed the per 24-hour averaging of $PM_{2.5}$. It can be seen that at some point, the concentration of $PM_{2.5}$ exceeded those set by the standard, 0.05mg/NCM. These happened mostly during Thursday (February 16) and Friday (February 17).

Table 5. Per-24 hour $PM_{2.5}$ Averages

PM2.5	14-Feb	15-Feb	16-Feb	17-Feb
Time	Concentration	Concentration	Concentration	Concentration
0:00-24:00	0.03309	0.025736	0.058358	0.087469

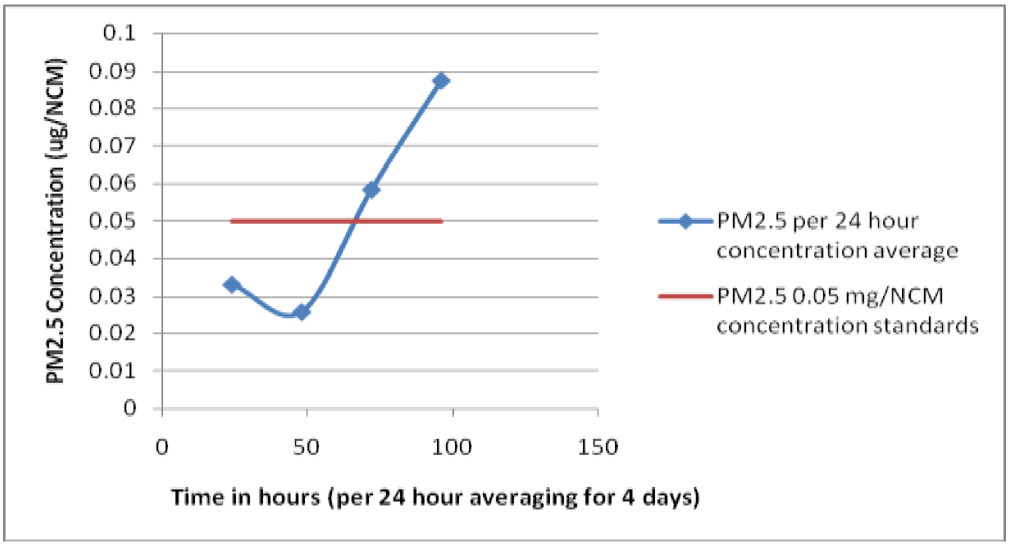

Figure 9. Comparison of 24-hour average concentration and concentration standards for $PM_{2.5}$

4.1.2 Population and Pollutant Concentrations

Figure 10 below showed the comparison of the occurrences of CO concentrations throughout the day with that of student population particularly shown was that of February 16 since it represents the highest number of students inside the building.

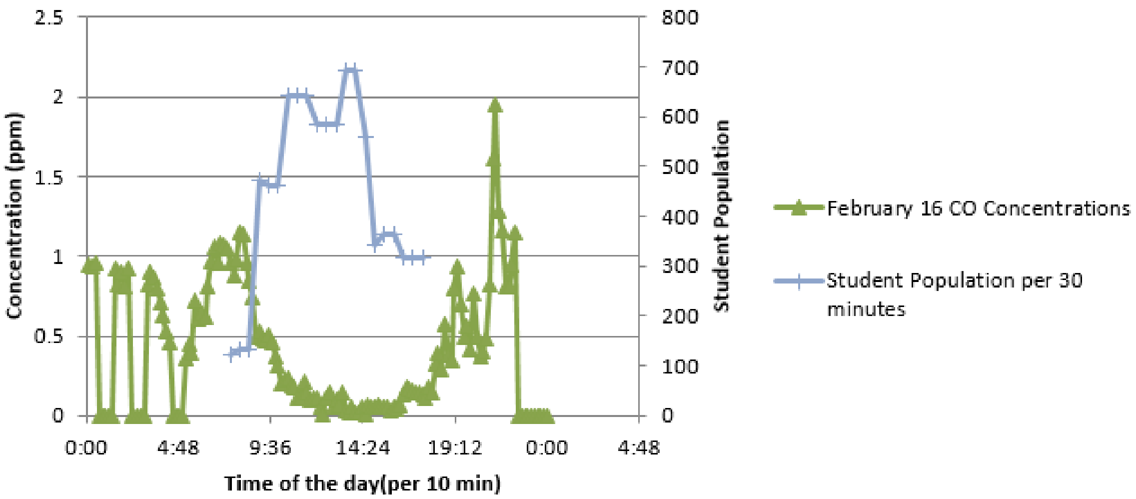

Figure 10. Student Population by Time of Day vs. CO Concentrations (February 16)

Since it was shown in Figure 5 and Table 3 that CO complied with CO concentration standards of R.A. 8749, likelihood of exposure to high CO concentrations were less likely to happen.

Similarly, Figure 11 showed the comparison of NO_2 Concentrations throughout the day together with student population still using the data obtained during February 16.

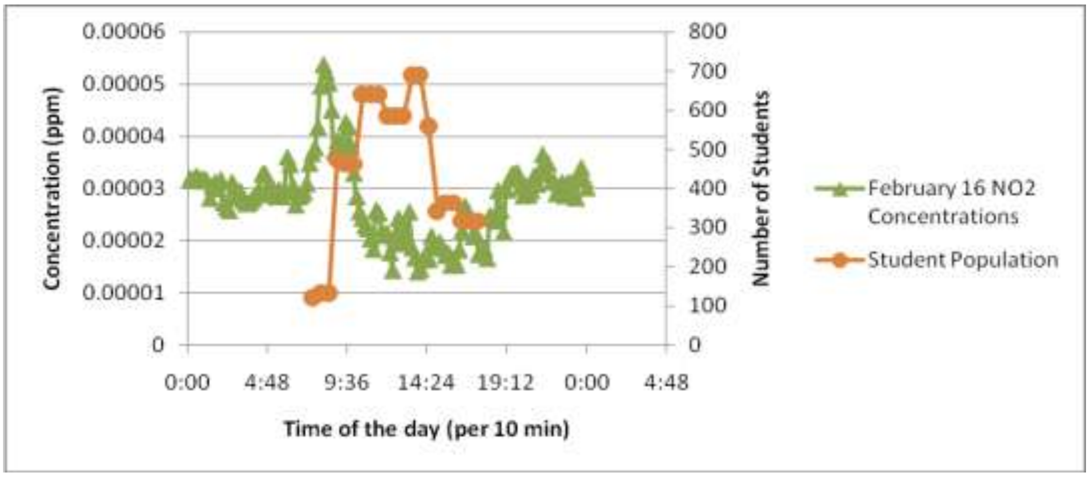

Figure 11. Student Population by Time of Day vs. NO_2 Concentrations

Similarly, health hazards brought by high NO_2 exposure were also less likely to happen to the low levels of pollutant concentrations all throughout the day as what was shown by Figure 6 and Table 4.

Figure 12 showed the concentrations of $PM_{2.5}$ at the February 16 observation day (most number of students).

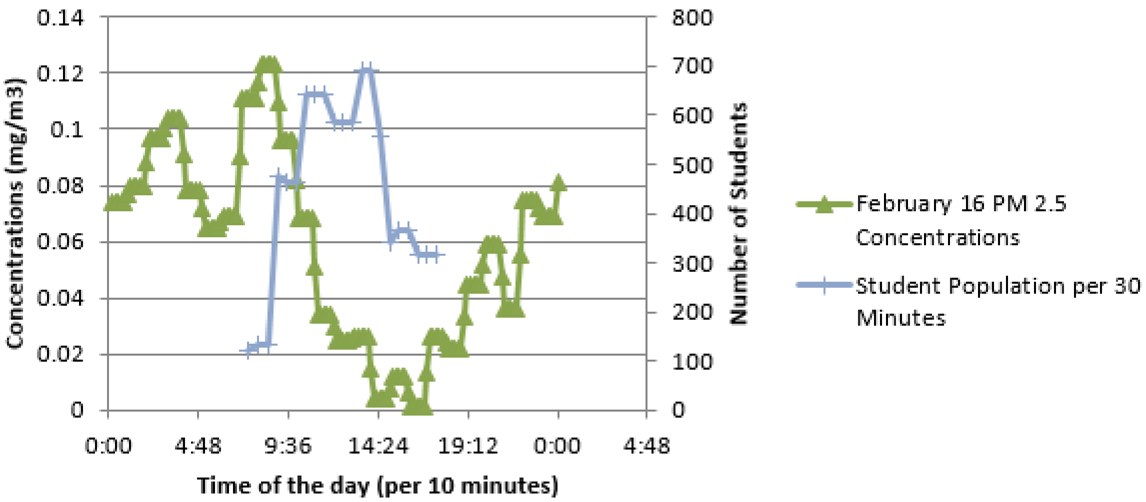

Figure 12. Student Population by Time of Day vs. $PM_{2.5}$ Concentrations

Non-compliances were observed for $PM_{2.5}$ particularly during the February 16 which had the highest number of students and having 0.058 mg/NCM, and February 17 with 0.087 which were both above the 0.050mg/NCM standard of D.A.O. 2013-13 for 24-hour averaging which could expose the student population in high concentrations of $PM_{2.5}$ and the corresponding health hazards.

4.2 Regression Model for Traffic Volume, Traffic Speed, Wind, and Pollutant Concentration

Traffic volume (TV), traffic speed (TS), and wind velocity (W) were assigned to be independent variables while pollutant concentration were the dependent variable. Simple linear regression was used to relate either traffic volume or traffic speed to that of the pollutant concentration while multiple linear regression was used when wind velocity was applied to either the said variables. Additionally, multiple linear regression was also used when relating all independent variables to that of the pollutant concentration.

A summary of the regression results were shown in Table 6 for CO, Table 7 for NO_2, and Table 8 for $PM_{2.5}$.

Table 6. Correlation of CO with Independent Variable

	No Lag	10 min Lag	20 min Lag	30 min Lag	40 min Lag	50 min Lag	60 min Lag
TV	0.250	0.275	0.272	0.281	0.281	0.271	0.281
TS	0.104	0.108	0.104	0.107	0.104	0.111	0.107
TV+W	0.503	0.526	0.526	0.536	0.534	0.523	0.520
TS+W	0.328	0.332	0.335	0.341	0.332	0.339	0.335
TV+TS+W	0.547	0.578	0.575	0.577	0.582	0.577	0.574

Table 7. Correlation of NO_2 with Independent Variable

	No Lag	10 min Lag	20 min Lag	30 min Lag	40 min Lag	50 min Lag	60 min Lag
TV	0.078	0.099	0.105	0.108	0.118	0.121	0.121

	No Lag	10 min Lag	20 min Lag	30 min Lag	40 min Lag	50 min Lag	60 min Lag
TS	0.082	0.092	0.085	0.093	0.078	0.073	0.064
TV+W	0.287	0.318	0.337	0.325	0.352	0.354	0.354
TS+W	0.292	0.306	0.301	0.316	0.286	0.275	0.258
TV+TS+W	0.398	0.433	0.437	0.449	0.441	0.438	0.428

Table 8. Correlation of $PM_{2.5}$ with Independent Variable

	No Lag	10 min Lag	20 min Lag	30 min Lag	40 min Lag	50 min Lag	60 min Lag
TV	0.093	0.098	0.094	0.101	0.121	0.14	0.136
TS	0.076	0.064	0.055	0.048	0.044	0.043	0.039
TV+W	0.309	0.318	0.325	0.325	0.354	0.379	0.373
TS+W	0.278	0.257	0.240	0.227	0.217	0.213	0.205
TV+TS+W	0.407	0.400	0.384	0.385	0.405	0.425	0.417

It could be seen that as the number of independent variable increased, correlations could also be seen to increase as what was indicated by the R^2 for the simple linear correlation (single independent variable) and multiple R for multiple linear regression (two or more independent variables). With these cases, it could be seen that the multiple linear regression of all the variables would be the most applicable model to be used.

From the values presented by the table 6, 7, and 8 above, it can be seen that first peaks in the regressions using lag time concept occurred at different time lag. For the case of CO, it was 10-minute lag time while NO_2 pertains to a 30-minute lag time. $PM_{2.5}$ exhibited a different behavior wherein the first highest multiple R value occurred at the no lag condition which suggest that particulate solids where transported less than 10 minutes from the source to the receptor. Therefore, the most applicable models for each pollutant would be the 10-minute lag model for CO, the 30-minute lag model for NO_2, and the no lag model for $PM_{2.5}$ since the 50-minute lag model would be a unrealistic scenario given that the distance of the receptor from the roadside was only 23 m which is relatively short.

Also from the result of the multiple linear regression analysis, it was also found out that both traffic volume, and traffic speed are significant variables since both yielded a less than 0.05 P-value using P-test with a confidence of 95 %. Wind velocity exhibited a different behavior where the computed P-values were greater than 0.05.

4.3 Regression Model for Traffic Volume, Traffic Speed, Wind, and Pollutant Concentration with Pollutant Transfer model

Further analysis was done on the data wherein pollutant transport models with the aid of CALINE 4 software were applied on the observed concentrations to model them in a near exhaust condition which removes the need for the use of lag time. Multiple linear regression analysis was also used for the new computed concentrations. Table 9 for CO, table 10 for NO_2, and Table 11 for $PM_{2.5}$ shows the result of the regression.

Table 9. CO Multiple Linear Regression Values

Multiple R	0.569292	
	Coefficients	**P- Value**
Intercept	-0.05638	0.670986
Gas Vehicle Volume	0.004278	8.24E-13
Speed	-8.77987	0.000238
Wind	-0.00604	0.534278

Table 10. NO_2 Multiple Linear Regression Values

Multiple R	0.424159	
	Coefficients	**P- Value**
Intercept	37.49545	0.007072
Diesel Vehicle Volume	0.29911	7.23E-05
Speed	-1125.64	6.48E-06
Wind	-0.64884	-0.63794

Table 11. $PM_{2.5}$ Multiple Linear Regression Value

Multiple R	0.390761	
	Coefficients	**P- Value**
Intercept	0.024852	9.69E-07
Diesel Vehicle Volume	9.19E-05	0.000573
Speed	-0.37108	2.77E-05
Wind	-0.0003	0.409286

From the computed values using multiple linear regression analysis, it could be seen that the obtained multiple R values were close to those of the obtained regression models using the lag time concept.

Additionally, some assumptions were made in the use of the pollutant transport models especially for the case of NO_2 and $PM_{2.5}$ where for the former, the concentration of O_3 was not considered since O_3 can react with NO to produce NO_2which might affect the concentration of NO_2. For $PM_{2.5}$, settling velocity was assumed to be 0 which means that particulate solids were assumed to be suspended all throughout its transport from source to receptor.

It was also found out that traffic volume, and traffic speed are significant variables with their P-values being less than 0.05 using P-test with a confidence of 95 %, hence, significant. This was not the case for wind velocity though, since the computed P-values are greater than 0.05.

5. CONCLUSION

From the study, the concentration for both CO and NO_2 were both found to be compliant with the set standards of RA 8749 wherein the former's concentration were less than 9ppm while the latter were less than 80ppb. Different observation was found for $PM_{2.5}$ since concentration especially during Thursday (0.058mg/NCM) and Friday (0.087mg/NCM) exceeded the set standard of 0.050mg/NCM of DAO 2013-13.

Regression models with each independent variables of traffic volume, traffic speed, wind velocity, and their combinations were established for all pollutants wherein the 10-minute lag regression model was developed for CO, the 30-minute lag model for NO_2, and the no lag model for $PM_{2.5}$ were established in which correlation of the variables were found to be highest when all three independent variables were used. Furthermore, checks using a pollutant transport model aided multiple linear regressions were performed to which closer values for the multiple R were calculated.

The significance of traffic volume, and traffic speed were also proven since the computed P-values for both variables were less than 0.05 using P-test with 95 % confidence while it was not the case for wind velocity with P-values of more than 0.05. This might be cause by the manual method used in recording wind velocity data.

6. RECOMMENDATIONS

As much as possible wind effects must be observed in a near instantaneous method to be able to capture any possible shifts in its speed and direction changes. In cases that pollutant transport models will be implemented, for $PM_{2.5}$, it was suggested that settling velocity must be taken in consideration during observation since it can affect the concentrations during dispersion modeling when the exhaust concentrations is being determined. Furthermore, O_3 concentration must also be taken into account especially if using pollutant transport models since they can affect the NO_2 concentrations if they were able to react with NO. The data used were taken for only a week with only three days' worth of usable values. Thus, acquiring more days of data from different months and from different locations of the roadside is recommended to improve correlation values.

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