SIMULATING THE EFFECTS OF EURO 4 DIESEL-POWERED ENGINE JEEPNEYS ON AIR QUALITY AND UNDERSTANDING ESTIMATED HEALTH RISK TOWARDS SUSTAINABLE TRANSPORTATION

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KEY WORDS: PUVMP, Euro 4, Pollutant Concentration, Jeepney Emissions, Health Risk Assessment, AERMOD, AirQ+

ABSTRACT:

The Euro-4 diesel-powered engines are the current industry standard in the Philippines as indicated in the Public Utility Vehicle Modernization Program (PUVMP) Omnibus Guidelines Department Order 2017-011. Based on the National Emissions Inventory report of the Environmental Management Bureau in 2018, 74% of air pollutant concentrations were produced by mobile sources including jeepneys. The PUVMP is focused on enhancing environmental sustainability, air quality, and in providing a reliable and effective public transportation system. The potential advantages to air quality and health from the full implementation of the program especially the Euro 4 diesel-powered engine jeepneys in Trece Martires City are assessed in this paper. The study aims to estimate the impact of the possible enforcement of Euro 4 diesel-powered engine jeepneys on the reduction of air pollution in the research locale. Four pollutants were assessed particularly Carbon Monoxide (CO), Nitrogen Oxide (NOx), Sulfur Oxide (SOx) and Particulate Matter 2.5 (PM2.5) using AERMOD Air Dispersion Modeling Software in five (5) different scenarios: (1) baseline engine jeepneys, (2) 25% implementation of Euro 4 diesel-powered engine jeepneys, (3) 50% implementation of Euro 4 diesel-powered engine jeepney, (4) 75% implementation of Euro 4 diesel-powered engine jeepneys and (5) full implementation of Euro 4 diesel-powered engine jeepneys. AirQ+ was utilized to evaluate the health risk of Euro 4 diesel-powered engine jeepneys to the drivers and commuters in the vicinity. Result shows that the Scenario 5 or the full implementation of Euro 4 diesel-powered engines relatively reduces CO by 84.30% (8.355 μg/cu.m to 1.31 μg/cu.m), NOx by 21.76% (10.6 μg/cu.m to 8.27 μg/cu.m), and PM2.5 by 83.36% (2.69 μg/cu.m to 0.447 μg/cu.m), by its maximum estimated concentrations. However, an increase by 14.14% of SOx emissions (0.091 μg/cu.m to 0.104 μg/cu.m) were seen on the simulation from Scenario 1 to Scenario 5. In terms of health risk assessment, higher levels of PM2.5 exposure exhibit an increase in health hazard with respect to mortality rate. Simulation outputs indicate that transitioning of jeepneys from current technology to Euro 4 models reduces pollution levels and lowers health risk, hence, can be used as basis in enhancing transport plans and health monitoring strategies in the city.

1. INTRODUCTION

1.1 Background of Study

One of the immediate concerns in developing countries, including the Philippines, is the ambient air quality or the actual concentration of pollution in the atmosphere. In order to describe the atmospheric pollution in a specific area, the concentration of pollutants in the environment is determined using the Air Quality Index (AQI). Based on the National Emissions Inventory report of the Environmental Management Bureau in 2018, 86.92% of air pollutant concentrations were produced by mobile sources in Region IV-A including jeepneys.

Health implications of transportation-related ambient air pollution, which can deteriorate the environment and human health, have become a substantial issue in the transportation industry. Thus, formulating initiatives like the modernization of public transportation can be vital in achieving substantial air quality supported by high-quality data and extensive study.

The Public Utility Vehicle Modernization Program (PUVMP) is enclosed to the Omnibus Guidelines Department Order 2017-011 of the Department of Transportation (DOTr) that seeks a dynamic, effective, and environmentally friendly mode of transportation in the Philippines. The program also anticipates where commuters can travel to their destinations safely and comfortably and where public transportation operators and drivers may earn stable and sufficient. The Omnibus Guidelines on the Planning and Identification of Public Road Transportation Services and Franchise Issuance states that Euro 4 diesel-powered engine is the current industry standard in the Philippines. Studies have shown that the replacement of Euro 4 automobiles would significantly reduce transportation air pollution on both roadways and in cities across the European Union (Serrano, et al., 2018). Moreover, it is reported that advantages of using Euro 4 Emission Standard over the previous standard (Euro 2) were the possibility to significantly cut pollution, save fuel subsidies, and increase automobile manufacturing and market share worldwide (Maulidya, 2019). In the study conducted by the Department of Environment and Natural Resources and De La Salle University (DENR-DLSU, 2021), the implementation of new engines relatively proves to decrease pollutant emissions.

As one of the progressing cities in the province in terms of economy, the demand for public transportation increases with the rise of different establishments in Trece Martires City.

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https://doi.org/10.5194/isprs-archives-XLVIII-4-W8-2023-149-2024 | © Author(s) 2024. CC BY 4.0 License.

Report states that nearly half of the casualties associated with ambient air pollution from public transportation are attributable to diesel emissions (Climate and Clean Air Coalition, 2019). Thus, the amount of pollutant concentrations is expected to escalate as the city continues to develop. Health implications are among the fundamental issues where public transportation emitted pollutants are concerned (Manasilidis, 2020). With the help of PUVMP, cities like Trece Martires can achieve a resilient and sustainable transportation where no one is left behind which is projected by the United Nations (UN) for Sustainable Development Goals (SGDs).

1.2 Research Objectives and Significance

The study aims to estimate and quantify the impact of regulating the use of Euro 4 diesel-powered engine jeepneys on the reduction of air pollution in Trece Martires City, Cavite. Drivers and commuters play a vital role in the economic stability of the city. Ensuring the health and safety of the citizens has always been the main goal of every community. Thus, simulation outputs indicate that transitioning of jeepneys from current technology to Euro 4 models can reduces pollution levels and lowers health risk, hence, can be used as basis in enhancing transport plans and health monitoring strategies in the city.

1.3 Scope and Limitations

Researchers delimited the study to a 1.5 km radius from a road intersection with geographical coordinates 14.282231, 120.868386 latitude and longitude, respectively. The origin point of the receptor was the location of the main intersection of the research locale – which was considered as the busiest road network in the area (City Government of Trece Martires, 2023). As shown in Figure 1, barangay boundaries including Cabuco, Conchu, Gregorio, Lapidario, Luciano, and San Agustin were incorporated in the study because of its proximity to the origin point.

Figure 1. Model coverage showing 1.5-km buffer zone in yellow region (Base map source: Google Earth, 2023)

1.4 Review of Related Literature

1.4.1. Public Utility Vehicle Modernization Program (PUVMP): The PUVMP is expected to completely transform the road sector since it is a broad system reform that emphasizes regulatory reform and develops new guidelines for highway public transportation franchise allocation. Local government units planned the route considering their knowledge of the necessities of their passengers within the provincial authority. Under the modernization program, traditional jeepneys will be replaced with Euro 4-compliant engines with solar panels. To be environmentally sustainable, safe, and convenient for passengers with disabilities, these modern jeepneys will be outfitted with an automatic fare collection system, dashboard cameras, a navigation system, closed-circuit television cameras (CCTV), dashboard cameras, speed limiters, and Wi-Fi (LTFRB, 2017).

Section 21 of the R.A. 8749, commonly called the Philippine Clean Air Act, requires the DOTr to develop an action plan for controlling and managing air pollution from motor vehicles that is compliant with the Integrated Air Quality Framework. R.A. 6969, also known as the "Toxic Substances and Hazardous and Nuclear Wastes Control Act of 1990," requires the regulation and management of toxic substances, as well as hazardous and nuclear wastes, in terms of import, manufacturing, processing, distribution, use, transportation, treatment, and disposal within the country.

Under Department Order No. 011, issued in 2017 and referred to as the "Omnibus Guidelines on the Planning and Identification of Public Road Transportation Services and Franchise Issuance" or Omnibus Franchising Guidelines (OFG), its objective is to establish nationwide reliable, safe, accessible, environmentally friendly, efficient, and comfortable public road transportation services. As stated in Department Order No. 16, titled "Guidelines on the Availment of the Equity Subsidy under the Public Utility Vehicle Modernization Program", all Public Utility Jeepneys (PUJs) that are replaced and substituted to avail of the subsidy must be surrendered for demolition. Given the implementation of the OFG, the DOTr acknowledges the need to involve the private sector in implementing the scrapping program, particularly concerning the valuable vehicle life component of the PUV modernization program.

1.4.2. Euro 4 Engines: On March 24, 2015, the "Implementation of Vehicle Emission Limits for Euro 4 and In-Use Vehicle Emission Standards" was under DENR Administrative Order No. 2015-04. To address worsening air pollution in the country and in accordance with Article 4 Section 21 of Republic Act 8749, vehicles loaded with Euro 4 fuel must follow the respective emissions standards starting July 1, 2015.

Euro 4 is made available with the help of oil companies, automobile manufacturers, and transportation associations, which are all doing their part to minimize air pollution and its impacts (Paje, 2016). In 2016, Paje issued DENR Administrative Order (DAO) No. 2015-04, which establishes more stringent requirements for new passenger, light- to heavy-duty vehicles to meet in terms of their emissions of carbon monoxide (CO), nitrogen oxides, hydrocarbons, and particulate matter (PM). According to the Department of Energy (DOE), by January 1, 2016, all new vehicles sold or established in the Philippine market must be powered with Euro 4 engines and meet Euro 4 or IV emission limits. Afterwards, the Environmental Management Bureau (EMB) will only issue Certificates of Conformity (COC) for these types of cars.

The replacement of Euro 4 automobiles would significantly reduce transportation air pollution on both roadways and in cities across the European Union (Serrano et al., 2019). The advantages of using the Euro 4 Emission Standard over the previous standard (Euro 2) were the possibility to significantly cut pollution, save fuel subsidies, and increase automobile manufacturing and market share worldwide (Maulidya, 2019). It is impossible to achieve Euro 4 compliance by simply replacing a used overstock diesel engine with a Euro 4 diesel engine. (Orbos, 2018).

In terms of safety and environmental sustainability, the majority of jeepneys are of substandard quality (Tugade, 2017). In 2019, Senator Grace Poe introduced Senate No. 867 Sec. 4. The establishment of a PUVMP, usually referred to as "the program," is to improve the safety, efficiency, and reliability of public land transport. In addition, under Senate No. 867, Sec. 5, PUVs that have been evaluated and confirmed street legal by the DOTr and the Department of Trade and Industry, Bureau of Philippine Standards (DTI-BPS) will just need to have their engines replaced to be Euro 4 certified.

1.4.3. Air Pollution due to Diesel-Engine Vehicles: Vehicle pollution is hazardous to human health and emits greenhouse gases, contributing to climate change. When diesel fuel is burned, hazardous byproducts such as nitrogen oxide and carbon monoxide are produced. Moreover, when diesel fuel is consumed in an engine, the volume of sulfur in the fuel is directly proportional to the number of pollutants created. Pollution levels rise as sulfur levels rise. The pollutants produced when diesel fuel is consumed in engines contribute to air pollution, which has significant environmental and health consequences (United States Environmental Protection Agency, 2022). According to the Department of Environment and Natural Resources - Environmental Management Bureau (DENR - EMB) Emissions Inventory for 2018, public utility jeepneys were the leading source of air pollution among other mobile sources. In an emissions inventory conducted by GIZ in Iloilo City, PUJs emit 18% of CO, 58% of NOx, 80% of particulate matter, and 54% of SOx from all mobile sources of air pollution.

Transportation makes a major contribution to Carbon Monoxide (CO), Non-methane Volatile Organic Compound (NMVOCs), Nitrogen Oxide (NOx), Particulate Matter (PM), and Sulfur Oxide (Sox) emissions (European Environment Agency, 2021). The study excludes volatile organic compounds (VOCs) and non-methane volatile compounds (NMVOCs) since many VOC concentration levels are ten times higher indoors than outdoors (United States Environmental Protection Agency, 2022). According to the Total Exposure Assessment Methodology of the U.S. According to the EPA, levels of a dozen common organic contaminants are two to five times higher inside homes than outside, whether the house is in rural or industrial areas. Non-methane volatile organic compounds (NMVOCs) are similar to VOCs but do not contain methane. They are a group of organic compounds that vary in chemical components but act similarly in the atmosphere. Only a few NMVOC components are responsible for at least all the harmful effects (ION Science, 2021). Thus, four (4) pollutant concentrations were suggested by Yu et al. (2021) as major contributors to the air pollution from the traditional diesel engines in the Philippines which are CO, NOx, SOX, and PM2.5.

2. MATERIALS AND METHODS

2.1 Data Collection

First-hand data from specified government agencies were utilized to ensure the credibility and reliability of the research findings, the most recent primary data was put into priority.

One year daily meteorological data from January 2022 – 2023 were obtained from Philippine Atmospheric, Geophysical and Astronomical Administration (PAGASA). In terms of Emission Estimate/Inventory, researchers adapted the emission factor from EMEP/EEA Emission Inventory Guidebook and formulated an equation with the guidance and expertise of the Technical Staff under Air Quality Management in DENR, and a mechanical engineer. Data related to registered and unregistered jeepneys were obtained from Land Transportation Franchising and Regulatory Board (LTFRB), Land Transportation Office (LTO) Region IV-A, and Trece Dasma Imus Zapote Jeepney Operator's and Driver's Association (TREDIZJODA). Local government and City Health Office of Trece Martires were the main source of datasets utilized in road and health assessment, respectively.

2.2 Derivation of Emission Rate

In this study, jeepney emissions were assumed to be uniformly distributed throughout the transport route, with emissions calculated using the derived formula approved by the Department of Environment and Natural Resources (DENR) Region IV-A through its Air Quality Management Section. The emission rate (ER), in grams per second, is calculated using Equation 1 adapted from DENR-EMB (2021):

$$ER = EF \times FC \times FS \tag{1}$$

where ER = emission rate, g/s
EF = emission factor, g/kg
FC = fuel consumption, kg/hr
FS = fleet size

In accordance with the EMEP/EEA Emissions Inventory Guidebook, the researchers adapted the emission factor (g/kg) as shown in Table 1, developed in the study Public Utility Jeepney Modernization Health Impact/Benefit Assessment by DLSU-Manila and DENR-EMB.

Technology	**CO**	**SOx**	**NOx**	**PM2.5**
Baseline Jeepney	9.17	0.10	11.60	2.95
Euro 4 Diesel	1.26	0.10	7.95	0.43

Table 1. Vehicle specification emission factors (g/kg)

In terms of fuel consumption, researchers utilized the developed and approved formula of DENR Region 4A, with consultation from the technical staff of the Air Quality Management Section. To get the fuel volume of the jeepneys, the researchers used the average fuel economy at a 10-to-15-kilometer route length (DENR-DLSU, 2019). Additionally, the researchers consulted with a mechanical engineering instructor at Lyceum of the Philippines University – Cavite to correlate the values to the total length of the road network and to understand the limitations of converting values. Thus, it is applied to acquire the total consumed liter per time, and a conversion factor of 60 minutes was used to have a result of lb/hr, using Equation 2:

$$FC = (V \times 60) / t \tag{2}$$

where FC = fuel consumption, kg/hr
V = fuel volume per kilometer
t = operating time

To generate the required parameter in the AERMOD software, the researchers used the mass over 3600 seconds to have the g/s unit of emission rate, considering that only mobile source emissions from the jeepneys are included in the modelling process.

Listed below are the computed source emission rate (g/s) per scenario and pollutant concentration considering all jeepneys (Table 2), peak hour conditions (Table 3), and normal traffic conditions (Table 4). The values obtained were utilized as input parameters in the AERMOD software simulation. Moreover, the source parameters used are the four (4) major road networks in the study area as shown in Figure 1. AADT from the DPWH Road Traffic Information was utilized to quantify the estimated number of jeepneys passing through the road network.

Scenario	CO	SOx	NOx	PM2.5
Scenario 1	4.6444	0.0506	5.8751	1.4941
Scenario 2	3.6656	0.0525	5.5567	1.1828
Scenario 3	2.6868	0.0543	5.2384	0.8715
Scenario 4	1.7081	0.0561	4.9200	0.5602
Scenario 5	0.7293	0.0579	4.6017	0.2489

Table 2. Summary of estimated emission rate considering all jeepneys (g/s)

Scenario	CO	SOx	NOx	PM2.5
Scenario 1	0.9632	0.0105	1.2185	0.3099
Scenario 2	0.7591	0.0109	1.1521	0.2450
Scenario 3	0.5572	0.0113	1.0864	0.1807
Scenario 4	0.3554	0.0116	1.0208	0.1165
Scenario 5	0.1513	0.0120	0.9544	0.0516

Table 3. Summary of estimated emission rate considering the peak hour condition (g/s)

Scenario	CO	SOx	NOx	PM2.5
Scenario 1	0.5024	0.0055	0.6356	0.1616
Scenario 2	0.3971	0.0057	0.6013	0.1281
Scenario 3	0.2892	0.0058	0.5638	0.0938
Scenario 4	0.1842	0.0061	0.5321	0.0604
Scenario 5	0.1191	0.0063	0.4978	0.0269

Table 4. Summary of estimated emission rate considering the normal hour condition (g/s)

2.3 Air Dispersion Modeling Simulations

Data gathered were set as input parameters on the software utilized in the study – AERMET, AERMOD, and AirQ+.

Raw meteorological data were used as input values in the meteorological processor called AERMET. It is a separate software that converts acquired met data to ".SFC" and ".PFL" file format needed in AERMOD. Once data were converted, the researchers utilized the US Environmental Protection Agency (EPA)-approved air dispersion modeling AERMOD to assess and simulate the behaviour of the pollutants. Four (4) air pollutants were assessed particularly carbon monoxide (CO), nitrogen oxide (NOx), sulfur oxide (SOx), and fine particulate matter (PM2.5). The modelling simulations involve five (5) different scenarios: (1) baseline engine jeepneys, (2) 25% implementation of Euro 4 diesel-powered engine jeepneys, (3) 50% implementation of Euro 4 diesel-powered engine jeepneys, (4) 75% implementation of Euro 4 diesel-powered engine jeepneys and (5) full implementation of Euro 4 diesel-powered engine jeepneys. Source and control pathways are essential for the modeling simulations since it is a user-defined type of program.

In terms of health assessment, the emission estimates acquired in AERMOD were set as one of the input parameters in AirQ+. The software evaluates the health risk of Euro 4 diesel-powered engine jeepneys to the drivers and commuters in the vicinity using the PM2.5 simulated results.

3. RESULTS AND DISCUSSIONS

3.1 Effects of Euro 4 Diesel-Powered Engine Jeepneys

To determine the overall air ambient concentration in the study area, the researchers used the number of jeepneys, registered and unregistered, that theoretically passed through the road networks within the 1.5 km radius of Trece Martires City. Moreover, the source emission utilized in the simulation was limited to road networks only, excluding the possible effects of building emission concentrations in the area. Baseline jeepney emissions using the same setting were also simulated as a basis for comparison. The resulting values were remodeled by the researchers so that the contour map of the estimated concentrations was as accurate as possible.

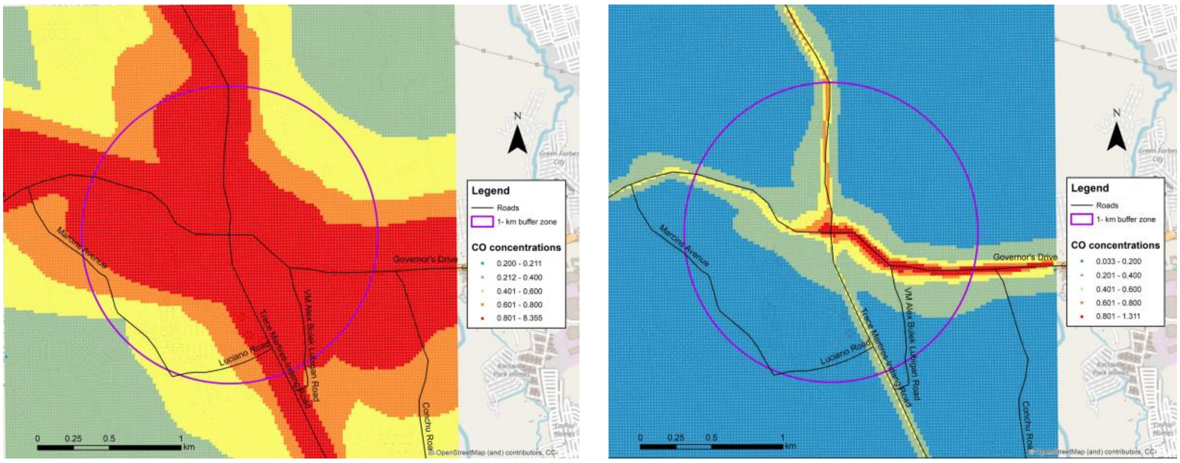
Figure 2 shows that under (a) full implementation of Euro 4 diesel-powered engines, carbon monoxide pollutant concentration in the area ranges from 0.033 µg/cu.m to 1.311 µg/cu.m which is six (6) times lesser compared to the simulated value, 0.2 µg/cu.m to 8.355 µg/cu.m, in (b) baseline jeepney emissions. In terms of pollutant concentration nitrogen oxide, the simulated heat map in Figure 3 (a) displays the accumulated minimum emission value of 0.21 µg/cu.m and 8.28 µg/cu.m as its maximum emission. On the other hand, (b) emission ranges from 0.27 µg/cu.m to 10.57 µg/cu.m which is 1.28% higher than the emissions in the full implementation of Euro 4 engine.

The sulfur oxide concentration in Figure 4 (b) has a minimum value of 0.003 µg/cu.m and a maximum value of 0.104 µg/cu.m. In comparison to the accumulated values in Figure 4 (a), which only ranges from 0.002 µg/cu.m to 0.091 µg/cu.m, it was 1.14 times higher and was the only pollutant concentration that increased in value upon the implementation of Euro 4 engines. Emissions of the pollutant PM2.5 in Figure 5 (a) ranges from 0.068 – 2.688 µg/cu.m. As compared to emissions shown in Figure (b), the resulted values were six (6) times lower, with a minimum value of 0.011 µg/cu.m and a maximum value of 0.448 µg/cu.m.

Results of the model simulations, as seen in Table 5, indicate that the implementation of Euro 4 jeepneys in Trece Martires City were observed to reduce CO, NOx, and PM2.5 emissions production by 84.30 %, 21.76 %, and 83.36 %, respectively. On the other hand, there is a 14.14% increase in SOx emissions.

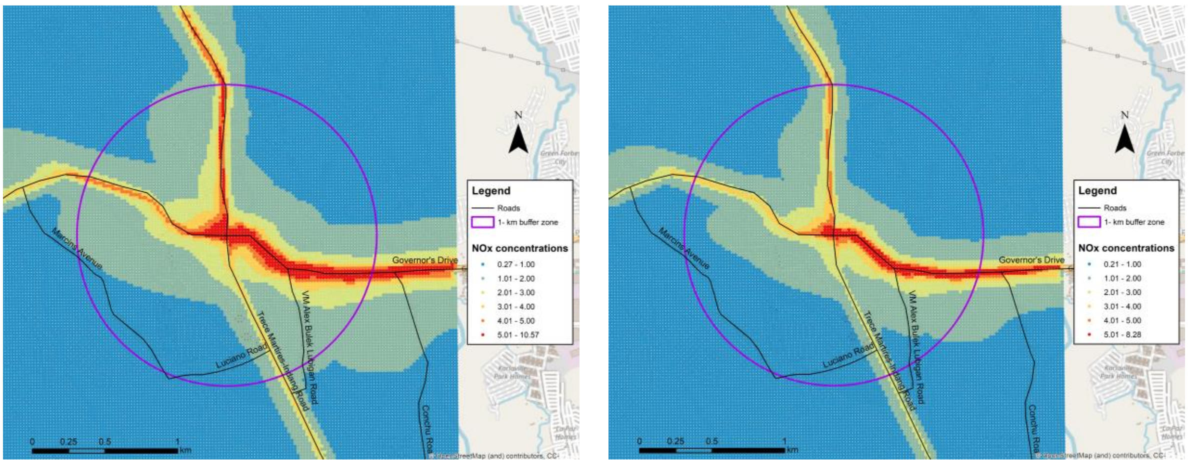
Simulated Emission (µg/cu.m)		All Jeepneys	
		Baseline	Euro 4
CO	Min	0.21	0.03
	Max	8.35	1.31
NOx	Min	0.3	0.21
	Max	10.6	8.27
SOx	Min	0.0022	0.003
	Max	0.091	0.104
PM2.5	Min	0.07	0.011
	Max	2.69	0.447

Table 5. Estimated pollutant concentration considering all jeepneys



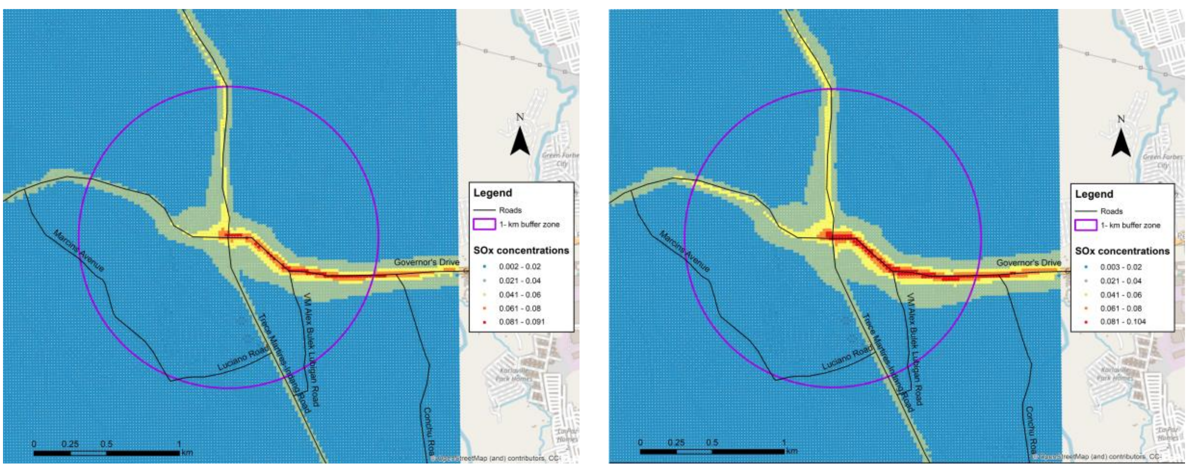
(a) (b)

Figure 2. Simulated levels for CO in Trece Martires City using
(a) baseline jeepney emissions, and (b) full implementation of Euro 4 engine



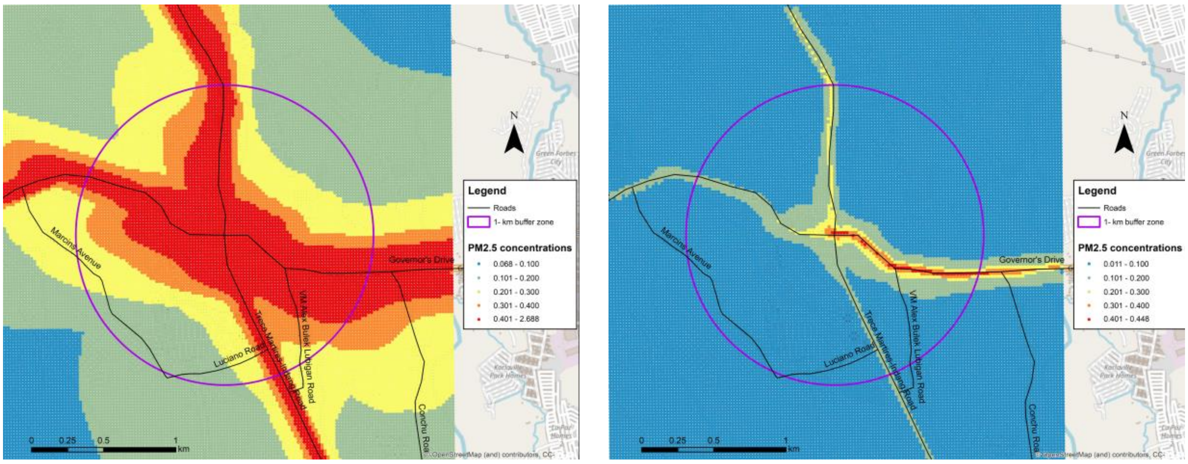
(a) (b)

Figure 3. Simulated levels for NOx in Trece Martires City using
(a) baseline jeepney emissions, and (b) full implementation of Euro 4 engine



(a) (b)

Figure 4. Simulated levels for SOx in Trece Martires City using
(a) baseline jeepney emissions, and (b) full implementation of Euro 4 engine



(a) (b)

Figure 5. Simulated levels for PM2.5 in Trece Martires City using (a) baseline jeepney emissions, and (b) full implementation of Euro 4 engine

3.2 Evaluation of Euro 4 Diesel-Powered Engine Jeepneys During Peak Hours

The peak hours in the Trece Martires are based on the traffic volume count conducted by the researchers. Results show that the peak hours within the study area are 7:00-9:00 a.m. and 5:00-7:00 p.m. The mean average number of jeepneys that pass through the CCTV footage is 370 jeepneys, and the researchers utilized this value to compute the predicted ambient air pollutants in the study area.

Simulated Emission (µg/cu.m)		Scenario				
		1	2	3	4	5
CO	Min	0.395	0.312	0.229	0.145	0.062
	Max	15.593	12.307	9.02	5.734	2.448
NOx	Min	0.5	0.47	0.45	0.42	0.39
	Max	19.72	18.66	17.59	16.52	15.45
SOx	Min	0.004	0.004	0.004	0.005	0.005
	Max	0.168	0.176	0.18	0.187	0.195
PM2.5	Min	0.127	0.101	0.074	0.048	0.021
	Max	5.016	3.973	2.926	1.882	0.835

Table 6. Estimated pollutant concentration during peak hours

As shown in Table 6, except for SOx, the remaining three (3) pollutants show that there are significant changes per modelling scenario. For CO, there is a reduction of 80.11% if the number of jeepneys implemented is from 25% to 100%. At the same time, the NOx will have a 21.65% reduction if the Euro 4 diesel-powered jeepney is gradually implemented in the Trece Martires. Lastly, PM2.5 shows that 83.35% has been reduced for the study area. Because the SOx of the diesel engine has been lowered to 50 ppm with the introduction of Euro 4 fuel standards, this is anticipated to increase the SOx releases, and the specific emission factor of both baseline and Euro 4 technology is the same based on the derivation of the DENR-DLSU study.

3.3 Evaluation of Euro 4 Diesel-Powered Engine Jeepneys During Normal Condition

Based on the observations, the regular traffic hours are 12:00-2:00 PM and 9:00-11:00 PM. Additionally, the researchers used 193 jeepneys as the mean average number of vehicles shown on the CCTV footage to compute the expected levels of ambient air pollutants in the study area. The contour map and resulting data were produced using four specific contaminants. AERMOD was utilized to evaluate the effects of the different scenarios during normal traffic conditions in Trece Martires City. Table 7 shows the simulated values.

Simulated Emission (µg/cu.m)		Scenario				
		1	2	3	4	5
CO	Min	0.208	0.164	0.12	0.076	0.033
	Max	8.143	6.427	4.711	2.996	1.28
NOx	Min	0.26	0.25	0.23	0.22	0.21
	Max	10.3	9.74	9.19	8.63	8.07
SOx	Min	0.002	0.002	0.002	0.002	0.002
	Max	0.089	0.09	0.094	0.098	0.101
PM2.5	Min	0.067	0.053	0.039	0.025	0.011
	Max	2.618	2.073	1.527	0.962	0.436

Table 7. Estimated pollutant concentration during normal condition

Other than SOx, the other three (3) pollutants indicate that the scenario resulted in sizable changes. If the number of jeepneys used is from 25% to 100%, Table 7 shows that CO will be reduced by 80.08%, while NOx will be reduced by 17.15% if the Euro 4 diesel-powered jeepney is used in the Trece Martires progressively. Furthermore, the reduction in the research area for PM2.5 is 78.97% while the SOx emission will increase by 13.48%.

3.4 Simulated Results in Comparison to Air Quality Index

According to the National Air Quality Status Report of 2019/2020, different initiatives are being undertaken in terms of collecting data on mobile source emissions since they are the most prevalent source of air pollution in the Philippines. The DENR – EMB is currently partnering with different agencies and local government units in terms of monitoring roadside emissions known as "anti-smoke belching operations." The result of this study can pave way for different agencies involved and future researchers in roadside emissions to use it as a baseline for estimating pollutant concentrations in specific areas since precise data for mobile emissions is currently not available in every agency in the Philippines, including the

DENR-EMB and research institutions like the UP National Center for Transportation Studies (UP – NCTS).

3.5 Health Assessment

The researchers utilized the resulted PM2.5 values for all jeepneys to estimate the mortality in the respiratory in the study area. The graph shows the resulting relative risk of the simulated values. Relative risk is likelihood of disease to happen due to exposure to a pollutant. The higher the relative risks, the exposure will likely happen. As seen in the graph, the relative risk is gradually decreasing by implementing the Euro 4 diesel-powered engine jeepneys.

In terms of health risk assessment, higher levels of PM2.5 exposure exhibit an increase in health hazard with respect to mortality rate. PM2.5 values were utilized for all jeepneys to estimate the mortality in the respiratory in the study area. The Table 8 shows the resulting relative risk of the simulated values.

Estimated Attributable per 100,000 population at risk	Scenario				
	1	2	3	4	5
Lower	2.03	1.58	1.14	0.69	0.25
Central	6.51	5.08	3.66	2.23	0.79
Upper	11.26	8.79	6.35	3.68	1.38

Table 8. Mortality, respiratory, adults age 30+ of all jeepneys in 24 hours

4. CONCLUSION

The modeling simulations conducted in this study indicate that the implementation of Euro 4 jeepneys in Trece Martires City was expected to reduce CO, NOx, and PM2.5 emissions production by 84.30 %, 21.76 %, and 83.36 %, respectively. On the other hand, there is an increase in SOx emission, which is 14.14 %.

Peak and normal hour conditions also show a substantial decrease in the predicted ambient air pollutant emissions. The emissions are projected to be lowered in three (3) pollutants, namely CO by 84.30 % for peak hour and 84.28 % for normal conditions, 21.66 % for peak hour and 21.65 % for normal conditions in NOx, and 83.35 % and 83.34 % in PM2.5 for peak and normal conditions, respectively. On the other hand, SOx increase by 13.85 % during peak hours, and 11.88 % in normal traffic conditions.

In terms of health assessment, higher levels of exposure to PM2.5 exhibit an increase in health hazard with respect to mortality rate. It has been proven that Euro 4 engine jeepneys decreased fatality rates in all conditions.

The adoption of Euro 4 diesel-powered engine jeepneys will help the road network in Trece Martires City to reduce the mobile source emissions that can deteriorate the environment and the health of both drivers and commuters. Moreover, it will help the local government of Trece Martires City to conduct more analysis to implement the program for the benefit of the transportation sector in the city.

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