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Impact of traffic conditions on $PM_{2.5}$ Concentrations at two distinct traffic junctions in Bangkok Thailand.

Miss Walaipan Yeemadarlee

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Title	Impact of traffic conditions on $PM_{2.5}$ Concentrations at two distinct traffic junctions in Bangkok Thailand.
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ABSTRACT

The impact of traffic flow on $PM_{2.5}$ emissions at two types of different traffic junctions were examined, at Phathum Wan intersection site (13.44’46 "N, 100.31’51" E) and Odeon Circle Yaowarat roundabout, site (13.44’13 "N, 100.30’46" E). Ambient $PM_{2.5}$ concentrations was collected 12 hours/day within working hours day-time. While the traffic flow and number of vehicles were recorded by video camera simultaneously. The relationship between concentration of $PM_{2.5}$ and traffic conditions were compared between these two sites. At Phathum Wan intersection, the linear regression is significantly related between $PM_{2.5}$ and traffic flow and number of vehicles, r = 0.84. However, at the Odeon Circle Yaowarat with high traffic flow, r = 0.48, showed a moderate level in the same direction. The concentration of $PM_{2.5}$ in ambient and the emission of the passenger-car and medium-utility vehicles-car,van (PC-MUV) and three-wheel-auto rickshaw (3WH) are associated with $PM_{2.5}$ levels, at Phathum Wan intersection.

Keywords $PM_{2.5}$**,** Emission of vehicles, Traffic, Bangkok

หัวเรื่อง	ผลกระทบของสภาพการจราจร ต่อความเข้มข้น $PM_{2.5}$ ที่แยกการจราจรสองแห่งในกรุงเทพประเทศไทย
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บทคัดย่อ

การศึกษาผลกระทบของการไหลของการจราจรต่อการปลดปล่อย $PM_{2.5}$ ที่แยกการจราจรสองแห่งที่แตกต่างกัน บริเวณแยกปทุมวัน(13.44’46”N, 100.31’51”E) และบริเวณวงเวียนโอเดียน เยาวราช (13.44’13”N, 100.30’46”E) โดยความเข้มข้นของ $PM_{2.5}$ ในอากาศถูกเก็บเป็นเวลา 12 ชั่วโมง / วัน ในชั่วโมงทำงานเวลากลางวัน ทราบการไหลของการจราจรและจำนวนยานพาหนะโดยการบันทึกด้วยกล้องวิดีโอ เปรียบเทียบความสัมพันธ์ระหว่างความเข้มข้นของ $PM_{2.5}$ กับสภาพการจราจรระหว่างสองสถานที่นี้ มีความสัมพันธ์เชิงเส้นตรงที่ระดับนัยสำคัญ ระหว่าง $PM_{2.5}$ กับการไหลของการจราจรและจำนวนยานพาหนะ r = 0.84 อย่างไรก็ตามที่วงเวียนโอเดียน เยาวราช ที่มีการไหลของการจราจรดี มีค่า r = 0.48 มีความสัมพันธ์กันในระดับปานกลางในทิศทางเดียวกัน และความความสัมพันธ์ของปริมาณ $PM_{2.5}$ กับค่าการปลดปล่อยมลพิษของรถยนต์นั่งส่วนบุคคลและรถสามล้อ มีความสัมพันธ์กับระดับ $PM_{2.5}$ ในอากาศ ที่แยกปทุมวัน

คำสำคัญ ฝุ่นละอองขนาดเล็กไม่เกิน2.5ไมครอน, ค่าการปลดปล่อยมลพิษจากยานพาหนะ, การจราจร, กรุงเทพมหานคร

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CHAPTER I

INTRODUCTION

1.1 Introduction

Traffic is a major source of air pollution in urban areas worldwide (Colvile et al., 2001). In Asian developing countries, a fast increase in vehicle population in conjunction with a slow increase in road surface areas and improper traffic management often lead to traffic congestion, which can further seriously deteriorate urban air quality.

Urban areas in developing countries experienced a rapid growth of vehicle fleets in recent years. In Bangkok, the capital city of Thailand, around 9 million people live there, which has long faced serious air pollution problems and Bangkok is a city with the most serious traffic problems in Southeast Asia. The amount of vehicles that growing number of vehicles each year, speed of traffic flow, density of buildings and street structures. Bangkok urban were increasing demand for using personal vehicle, this city has faced with serious overcrowded traffic problem for a decade (BMA data center, 2018). Consequently, Traffic emission from overcrowded traffic cause serious problem in air pollution, especially Particulate matter (Jinsart et al., 2011).

In 2018 there are more than 970,000 new vehicles (348,728 passenger car; above 12,600 heavy duty diesel; 472,808 motorcycles; and others), were registered in the city (DLT, 2018), Traffic contributes the majority (50–90%) of the NOx, CO, PM, and nonmethane hydrocarbon (HC) emissions. During the dry and more polluted season, $PM_{2.5}$ seasonal annual is 50 μg/m^3, the US EPA 24-h standard of 35 μg/m^3. PM2.5 constitutes most of PM_{10}, i.e. 58–66% (Kim Oanh et al., 2006). $PM_{2.5}$ from road transportation emission is generated from 2 main sources that is exhaust and non-exhaust emission. Exhaust emission are emitted from fuel combustion, which are petrol exhaust and diesel exhaust. In case of non-exhaust emission, it is emitted from brake wear, resuspension, road surface wear (Lawrence *et al*.,) For Bangkok transportation, although there are many choices for commuters to transport, the public transports are insufficient to support whole commuters, which including immigrant workers. Bangkok citizens prefer to use their private vehicles than the public transport together with increasing in a number of cars; as a result, Bangkok suffers from overcrowded traffic (BMA center data, 2018). These reasons also confirm that automobiles at traffic area are the main source for PM emission.

There is an increasing recognition that the adverse health effects from environmental exposure to airborne particulate matter (PM) are more significant than those from exposure to gaseous pollutants. The proportion of smaller particles is especially important in the estimation of health risk. $PM_{2.5}$ (PM with an aerodynamic diameter of less than 2.5 μm), in particular, has been shown to be more strongly related to adverse health effects. Fine particles ($PM_{2.5}$) are the main cause of impaired visibility (haze) (Pope et al., 1991; Schwartz, J., & Neas, L. M., 2000; Khodarahmi et al., 2016). Small particulate pollution has health impacts even at very low concentrations-indeed no threshold has been identified below which no damage to health is observed. By exposure to PM, it causes many diseases such as cardiovascular, cerebrovascular, respiratory impacts. Moreover, World Health Organization's International Agency for Research on Cancer (IARC) classified PM as a lung carcinogen (WHO, 2018). As $PM_{2.5}$ are the causes of adverse health effects to human and air depress air quality, PM annual standard and 24-hours standard in Thailand was set at 25 $\mu g/m^3$ and 50 $\mu g/m^3$ for $PM_{2.5}$, while WHO set them at 10 $\mu g/m^3$and 25 $\mu g/m^3$. However, Bangkok sometimes faces the challenge that $PM_{2.5}$ value exceeds the air quality index (AQI). Thus, this issue need to find an effective mitigation strategies and policies to assist Bangkok air quality meets the WHO PM guideline.

AQI Calculation:

$$I = \frac{Ij - Ii}{Xj - Xi}(X - Xi) + Ii$$

For; I = the air quality Index

X= the pollutant concentration

Xj = the concentration breakpoint that is ≥ X

Xi = the concentration breakpoint that is ≤ X

Ij = the index breakpoint corresponding to Xi

Ii = the index breakpoint corresponding to Xj

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0 - 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
51 -100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
300+	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor exertion

Figure 1.1 Bangkok air quality Index

Source : Bangkok air quality lndex (AQI) by the US-EPA 2016 standard

The major problems of air pollution in Bangkok is from traffic. These rapidly increasing cities tend to have significantly more traffic jam than others. The pollution creates from incomplete fossil fuel combustion, the composition is very complicated and some elements are carcinogenic in human (Janssen et al., 2003; Nakatsuka et al., 1991; Oftedal et al., 2003; van Vliet et al., 1997). The problem of emission is most critical at traffic junctions like intersections and roundabouts of urban centers. Vehicles undergo different modal events and speeds with frequent interruptions while maneuvering the junctions and thus relationship of emissions to traffic-flow characteristics varies. That the number of vehicles at different values and type affect the different emissions. In Bangkok, The most critical at traffic junctions like Pathum Wan intersection. There are approximately 69,083 vehicles per day. And a non-signalized roundabout that traffic-flow characteristics is Odeon Circle Yaowarat, Charoen Krung, Bangkok. There are approximately 27,989 vehicles per day. (DLT, 2018). In this paper, describes the vehicular pollution studies carried out at Phathum Wan Intersection a heavily trafficked intersection in Bangkok and a non-signalized roundabout in Odeon Circle Yaowarat, Charoen Krung, Bangkok Thailand that different number of vehicles and emission $PM_{2.5}$ of vehicles.

1.2 Objective

1.2.1 The aim of calculation $PM_{2.5}$ emission in two different sites at traffic junction Pathum Wan Intersection and Odeon Circle Yaowarat roundabout.

1.2.2. Identify the association of $PM_{2.5}$ concentration and the traffic conditions in two different sites.

1.3 Scope of the study

1.3.1 Period of study during January,2019 - May,2019

1.3.2. Sampling at two traffic junction Pathum Wan Intersection a heavily traffic intersection in Bangkok and a non-signalized roundabout in Odeon Circle Yaowarat, Charoen Krung, Bangkok Thailand.

1.3.3. The twelve hours $PM_{2.5}$ samples were collected by collected on PTFE filters using a Personal Modular Impactor® (PMI) (SKC: Eighty Four, PA, USA) connected to personal air pump (Gillian GilAir5).

1.4 Expected outcomes

1.4.1. To know the difference of pollutant emissions vehicle in Pathum Wan Intersection and roundabout in Odeon Circle Yaowarat, Charoen Krung, Bangkok Thailand.

1.4.2. To know the relationship of pollutant emission the population of vehicles in the area.

1.4.3. Applied the data to air quality management.

CHAPTER II

THEORIES AND LITERATURES REVIEWS

2.1 Description of study area

2.1.1 Geography

Bangkok is the capital city of Thailand. The landscape of Bangkok is a lowland. The city's latitude and longitude coordinates are 13°45'14.33"N, 100°30'5.18"E. Bangkok has an area of 1,569 square kilometers. The vicinities of Bangkok include Nonthaburi, Pathum Thani, Samut Prakan, Samut Sakhon and Nakhon Pathom (BMA data center, 2018). Bangkok is the capital and having a large population in Thailand. The number of vehicles in Bangkok has increased every year (Praditphet C et al., 2013). The major problems of air pollution in Bangkok is from traffic. These rapidly increasing cities tend to have significantly more traffic jam than others. In Bangkok, Thailand, areas around the Phathum Wan Intersection were selected for the study because this intersection has the most serious traffic problems in the city. There are 2 roads that cross that are Phaya Thai Road and RAMA I Road that overcrowded traffic area.

A non-signalized roundabout in Odeon Circle Yaowarat, Charoen Krung, which are located in Bangkok, Thailand. These area located near 2 travel famous place are The golden Buddha Temple and Chiana Town Bangkok that is shopping plaza, where many people go there. This roundabout has 2 famous road that are Yaowarat Road and Charoen Krung Road. Two locations are different of road and total of vehicles that representing roadside sampling criteria by the area have collecting of $PM_{2.5}$ for study.

2.2 $PM_{2.5}$

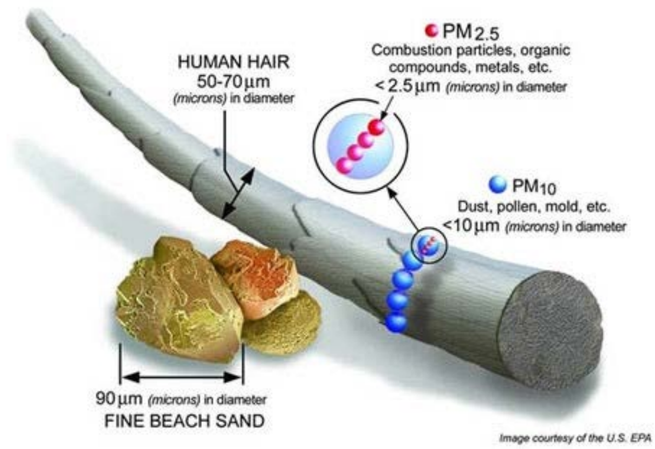

Figure2.1 PM_{10} and $PM_{2.5}$ characterizations (USEPA, 2016)

Particulate Matter is the term for a mixture of solid particles and liquid droplets found in the air such as nitrates, ammonia, sodium chloride, black carbon, dust and water. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye (USEPA, 2016).

$PM_{2.5}$ is a fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller (USEPA, 2017). $PM_{2.5}$ is from the exhaust of the car, fuel combustion process, power plants processes in various industries, using firewood and It can also be caused by the reaction of VOCs with other substances in the atmosphere, sulfur dioxide and oxide of nitrogen.

Particulate Matter have affected to people more than another pollutant that they can be smell and cause health problems. Particles less than 10 micrometers in diameter (PM10) announce as a big problems, because they can go deep into your lungs, and may get into your bloodstream. Many scientific studies tell that particulate matter exposure run to various problems, include death of people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing. However, Fine particles ($PM_{2.5}$) are the main cause of impaired visibility (haze) (Pope et al., 1991; Schwartz, J., & Neas, L. M., 2000; Khodarahmi et al., 2016).

Small particulate pollution has health impacts even at very low concentrations-indeed no threshold has been identified below which no damage to health is observed.

2.3 Emission Factor

Emission factors (EFs) are empirical functional relations between pollutant emissions and the activity that causes of road vehicle emissions that depend on many parameters. Emission models are used to perform the calculations of road transport emissions. (Smit et al.,2007) proposed a classification of these models in five major categories according to the input data required. These range from models which only require mean travelling speed to estimate emissions (e.g. COPERT, EMFAC) and models that need traffic situations (i.e., qualitative assessments of driving conditions) to express emissions (e.g. HBEFA), to models which require second-by-second engine or vehicle state data (e.g. PHEM, MOVES) to derive emission information for the complete driving profile. Regardless of the specific implementation, each model aims to provide appropriate EFs.

Road vehicle EFs are functional relations that predict the quantity of a pollutant that is emitted per distance driven, energy consumed, or amount of fuel used. EFs are typically derived for vehicle categories (but they also exist for single vehicles, or even an entire fleet), and they depend on many parameters such as vehicle characteristics and emission control technology, fuel specifications, and ambient and operating conditions (cold-start, cruising, acceleration, etc.). The quality of the application of any road vehicle emission model largely depends on the representativeness of the EFs it contains. This refers to the accuracy with which the EF can describe the actual emission level of the particular vehicle type and driving condition it is applied to. EFs are usually developed on the basis of experimental data collected in vehicle emission measurement campaigns. The measurement technique selected, along with other specifics of each campaign including the criteria for vehicle selection and the driving conditions imposed all have an impact on the quality of the EFs later derived.

Pollution Control Department operates the project together with Division of the Industrial factory Industrial of Thailand and Japan International Cooperation Agency (JICA) have developed emission factors and various variables related to the assessment of pollutants from vehicles. (The Development of PRTR System in the Kingdom of Thailand,2016).

Table 2.1 Emission Factor of each vehicles

Type	$PM_{2.5}$ (g/km)
Two Wheeler	0.0035
Three Wheeler	0.0114
Passenger car	0.0011
Heavy commercial vehicles	0.0783

Source : EMEP/EEA Guidebook, 2006 IPPC Guidelines.

2.3 Literature Review

Jinsart et al. (2011) studied the particle air pollution, which are $PM_{2.5}$ and PM_{10}, at roadside in Bangkok. By focusing in high polluted areas (busy intersection and average 70,000 vehicles/day) and low polluted areas (suburban area and average 40,000 vehicles/day), almost high polluted areas exceeded the National Ambient Air Quality Standards (NAAQS). Moreover, the correlation coefficient of $PM_{2.5}$ and PM_{10} in high polluted areas are involved to automobile sources. It can be concluded that, with their measurement, automobile exhaust was the main source of particulate air pollution. For future study, the existing monitoring procedures and standards need to be revised to include specific measurement of the fine particles as $PM_{2.5}$

Huong Giang, N. T. and N. T. Kim Oanh. (2014) characterized roadside levels of $PM_{2.5}$ and BTEX in Ho Chi Minh City, Vietnam. Residential areas and business activities are found along the heavy traffic roads, and air pollution are emitted more when the traffic jam. Samples were collected both weekends and weekdays including 284 hourly BTEX samples, 24 8-hr samples $PM_{2.5}$ and 42 24-hr $PM_{2.5}$ samples using Minivolume air sampler. There were 8 sampling points on both side of the street that has average traffic flow. The results showed that 24-hr $PM_{2.5}$ on weekdays was higher than weekends. By using Principal component analysis, the association between roadside pollution levels and traffic were confirmed. At roadside, urban background, other sources than traffic in the street, was removed by calculation algorithm. The main urban background was $PM_{2.5}$ (90- 98%) and BTEX (67- 97%) influenced by upwind side of the street and at late evening hours when less traffic was observed. Monitoring at different times also required in this study to get significant variations in the street traffic composition.

Sharad Gokhale. (2012) studied the impact of traffic-flow on CO, NO2 and PM emissions at two distinct traffic junctions and evaluates the use of emission factors. The problem of emissions is generally most critical at traffic junctions like intersections and roundabouts of urban centers. Vehicles undergo different modal events and speeds with frequent interruptions while maneuvering the junctions. Emissions at two distinct traffic junctions types relating them to traffic-flow and heterogeneity in traffic characteristics using different methods of density and emission calculations. The results showed that the proportion of diesel- or petrol-driven vehicles significantly affect the pollutant emissions at different junction types.

Seong Suk Park et al. (2012) Fuel-based emission factors for 143 light-duty gasoline vehicles (LDGVs) and 93 heavy-duty diesel trucks (HDDTs) were measured in Wilmington, CA using a zero-emission mobile measurement platform (MMP). The frequency distributions of emission factors of carbon monoxide (CO), nitrogen oxides (NOx), and particle mass with aerodynamic diameter below 2.5 mm (PM2.5) varied widely, whereas the average of the individual vehicle emission factors were comparable to those reported in previous tunnel and remote sensing studies as well as the predictions by Emission Factors (EMFAC) 2007 mobile source emission model for Los Angeles County. Variation in emissions due to different driving modes (idle, low- and high-speed acceleration, low- and high-speed cruise) was found to be relatively small in comparison to intervehicle variability and did not appear to interfere with the identification of high emitters, defined as the vehicles whose emissions were more than 5 times the fleet-average values.

Ferm, M. and K, Sjöberg. (2015) Studied emission factors for PM_{10} and $PM_{2.5}$ were estimated using NO_X as a tracer. NO_X emissions were estimated from the traffic flow and emission factors calculated from the HBEFA3.1 model. $PM_{2.5}$ constitutes the finer part of PM10. Emissions of the coarser part of PM_{10} (PM_{10}–$PM_{2.5}$) are suppressed when roads are wet and show a maximum during spring when the roads dry up and studded tyres are still used. Less than 1% of the road wear caused by studded tyres give rise to airborne $PM_{2.5–10}$ particles. The NO_X emission factors decrease with time in the used model, due to the renewal of the vehicle fleet. However, the NO_X concentrations resulting from the roads show no clear trend. The air dispersion is an important factor controlling the PM concentration near the road. The dispersion has a minimum in winter and during midnight. The average street level concentrations of PM_{10} and $PM_{2.5}$ in Gothenburg were 21 ± 20 and 8 ± 6 $\mu g/m^3$ respectively, which is 36% and 22% higher than the urban background concentrations. Despite the four times lower traffic flow in Umeå compared to Gothenburg, the average particle concentrations were very similar; 21 ± 31 and 7 ± 5 $\mu g/m^3$ for PM_{10} and $PM_{2.5}$ respectively. These concentrations were, however, 108% and 55% higher than the urban background concentrations in Umeå. The emission factors for PM10 decreased with time, and the average factor was 0.06 g km^{-1} $vehichle^{-1}$. The emission factors for $PM_{2.5}$ are very uncertain due to the small increments in $PM_{2.5}$ concentration at the thorough fares, and were on average 0.02 g km^{-1} $vehichle^{-1}$.

Qiu, Z et al. (2017) To investigate the pedestrian exposure to fine particulate on various typical urban roadways, mass concentration of PM_{10}, $PM_{2.5}$, PM_1 and particle number concentrations in the given size distribution were obtained at four types of urban roads in Xi'an City: urban expressway, arterial road, collector road, and local road. The principal component analysis (PCA) was used. Measurement and analysis results showed that the mean particle number concentration for the size range of 0.25–32 μm on the urban expressway was 9%, 29% and 32% higher than those on the arterial road, the collector road and the local road, respectively. However, the mass concentration of particles, especially for $PM_{2.5}$ and PM1, varied little. Traffic volumes on the urban expressway, the collector road and the local road all had important influences on PM particle-number concentration, but at different size ranges.

Additionally, the results discussion indicated that PM_{10}, $PM_{2.5}$ and PM_1 were generated from the same emission source (i.e. vehicles) on the urban expressway, yet on the other types of roads PM (especially PM_{10} and PM_1) emissions were generated from different sources (i.e. vehicles, pedestrians, or road dust).

Hoogendoorn, S. and Knoop,V. (2013) Traditional definitions of flow, density and speed In general, the flow q (also referred to as intensity or volume) is tradition- ally defined by the average number of vehicles (n) that pass a cross-section during a unit of time (T). According to this definition, flow is a local variable (since it is defined at a cross-section).

$$q = \frac{n}{T}$$

This expression shows that the flow can be computed easily by taking the number of vehicles n that have passed the measurement location during a period of length T.

CHAPTER III

METHODOLOGY

3.1 Site description

3.1.1 Study area and sampling sites.

Bangkok (capital city of Thailand) is located in central of Thailand. Due to the fact that there are a lot of people stay in Bangkok and the migrants come to the metropolis make a problem in transportation system and air pollution. The transportation system cannot accommodate the rapid population growth. Most mass transit systems also share routes with private cars.

The data were collected in Phathum Wan Intersection a heavily trafficked intersection and a non-signalized roundabout in Odeon Circle Yaowarat, Charoen Krung, which are located in Bangkok, Thailand. Two locations, representing roadside sampling criteria by the area have collecting of $PM_{2.5}$ for study. There are 4 sampling points in Phathum Wan Intersection and 2 sampling points in Odeon Circle Yaowarat roundabout. Sampling at each point will be performed on Wednesday, Friday (weekday) and Sunday (weekend) for 12 hours (working hours).

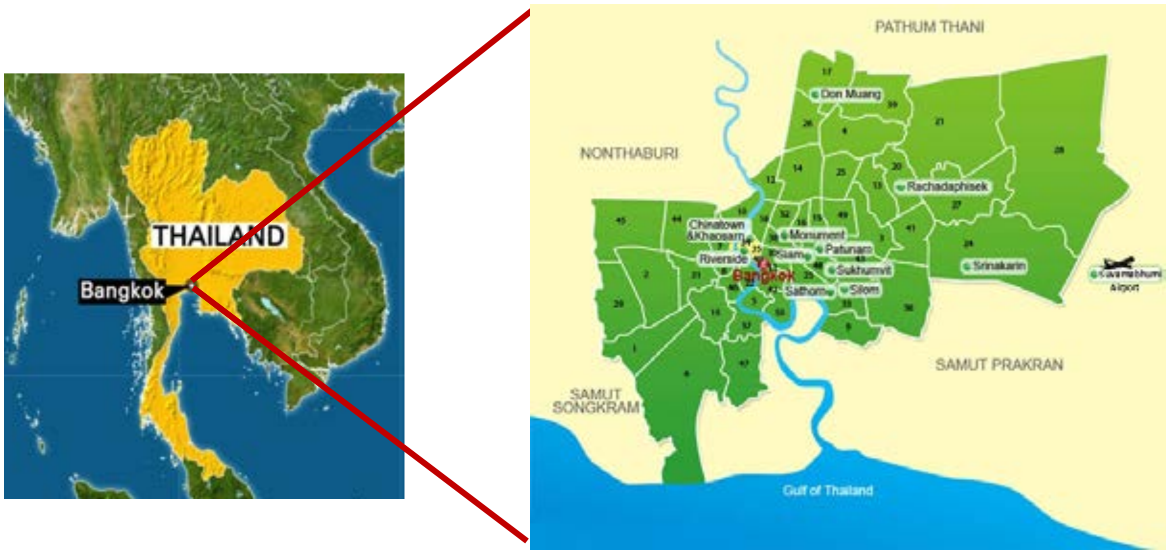

Figure3.1: Location and districts of Bangkok, Thailand

source : http://bangkokwow.blogspot.com/2008/12/bangkok-map-50-districts.html

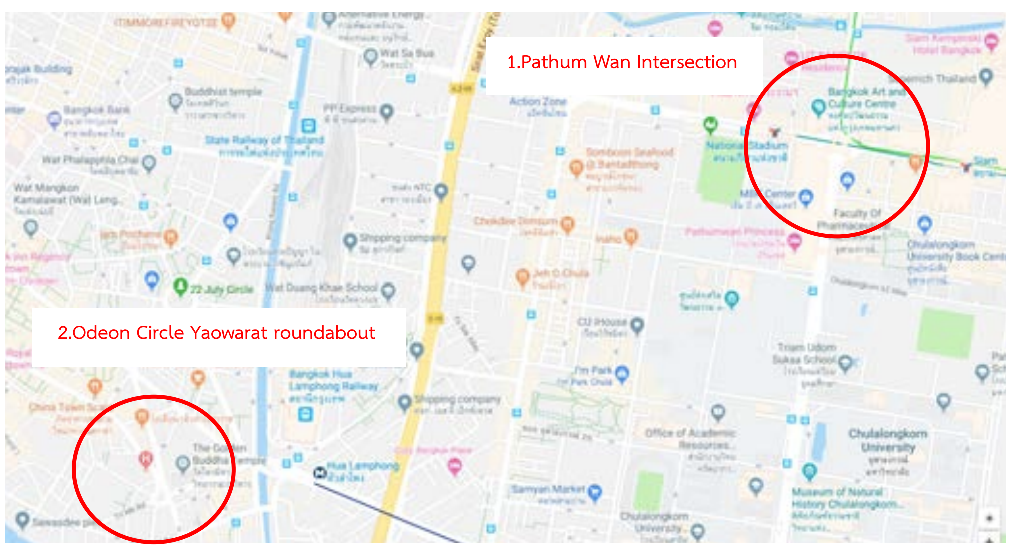

Figure 3.2 Location of sampling sites in Bangkok

Site 1 Phathum Wan Intersection

Site 2 Odeon Circle Yaowarat roundabout.

The Phathum Wan Intersection sampling site 1 (PTW1), site 2 (PTW2), site 3 (PTW3) and site 4 (PTW4) (13.44'46"N, 100.31'51"E) locates near center of Phathum Wan Intersection that set up at the footpath, it is the same road separated by Phaya thai road and Rama I conjunction.

Figure 3.3 Sampling points at site 1, The Phathum Wan Intersection (PTW)

The roundabout in Odeon Circle (13.44'13"N, 100.30'46"E) sampling site 1 (OCY1) locates at roundabout beside Charoen Krung Road and Odeon Circle Yaowarat sampling site 2 (OCY2) locates at footpath of roundabout beside Yaowarat Road.

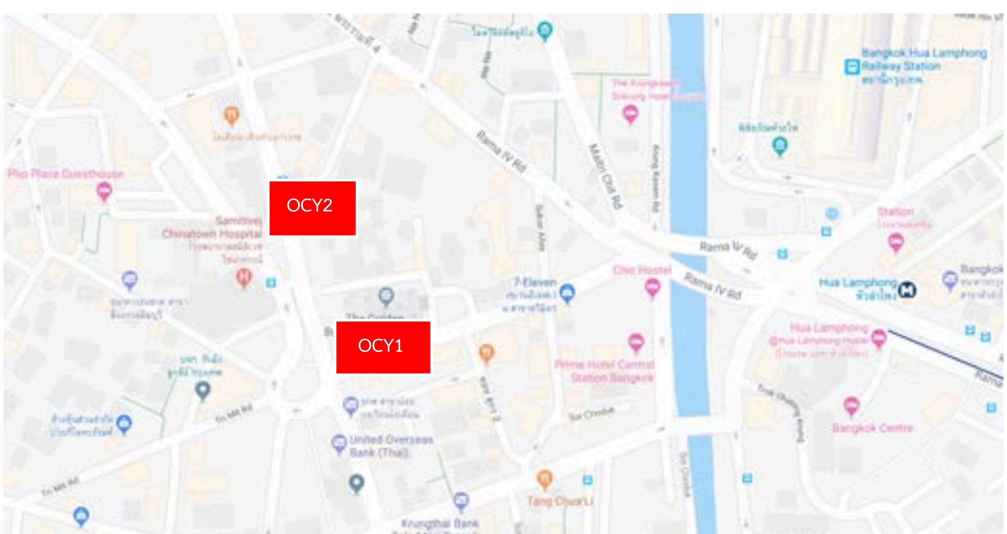

Figure 3.4 Sampling points at site 2, The Odeon Circle Yaowarat roundabout (OCY)

3.2 Measurement data

3.2.1 Equipment

- Microbalance with 7 decimals (UMX2, Mettler-Toledo, Mettler- Toledo International Inc, USA)
- Personal air pump (Gillian GilAir5)
- Personal Modular Impactor® (PMI) (SKC: Eighty Four, PA, USA)
- PFTE filter Ø 37 mm, 1.0 µm for $PM_{2.5}$ (R2PJ037, PALL, Pall Corporation Filtration & Separations (Thailand) Ltd)
- Defender volumetric flow rate calibrator (D-150-L, Casella, JJS Technical Services, USA)
- Desiccator

Figure 3.5 Personal Modular Impactor® (PMI)

Source: https://www.skcinc.com/catalog/product_info.php?products_id=399

3.2.2. Gravimetric method

This study used Gravimetric method to measure the data. First, brought the filters into desiccator for 24 hours and weighted the filters. Then, kept the filters in zip bag to protect from contamination. To start measurement, put filters on dust separator head (Personal modular impactor) and connected it to personal pump with flow rate 3.0 liter/min. Flow rate, date and time were recorded before and after measurement at each measurement sites for 12 hours. When finishing measurement, shut down personal pump and kept filters in zip bag to analyze at laboratory. After that, brought filters into desiccator for 12 hours and weighted of filters. After the collected samples were stored in desiccator, $PM_{2.5}$ mass was determined by gravimetric method using Personal Modular Impactor (PMI) which is able to weight 7 decimals with temperature and humidity- controlled.

The concentration of $PM_{2.5}$ is calculated using the equation 1 and 2:
Air volume (V) are calculated using;

$$V = Q \times T \times 10^{-3} \qquad (1)$$

For; V = air volume (m^3)
Q = air flow rate (L/min)
T = sampling time (min)

$$C = \frac{W_f - W_i}{V} \times 10^3 \qquad (2)$$

For; C = concentration of particulate matter ($\mu g/m^3$)
W_f = filter weight after sampling (mg)
W_i = filter weight before sampling (mg)
V = air volume (m^3)

Vehicle emissions of $PM_{2.5}$ in Pathum Wan Intersection a heavily traffic intersection and a non-signalized roundabout in Odeon Circle Yaowarat, Charoen Krung, which are located in Bangkok, Thailand. Estimated using the following

Emission Inventory equation 3:

$$Ep = N_i \times Ef \qquad (3)$$

For; Ep = The Pollutant mass emission per day.

Ef = The pollutant's emission factor of vehicle (g/km).

N = Number of each type of vehicle.

i = The vehicle category.

3.2.3. Data collection

3.2.3.1. $PM_{2.5}$ samples

$PM_{2.5}$ samples were collected by collected on PFTE filter Ø 37 mm,1.0 µm for $PM_{2.5}$ using a Personal Modular Impactor® (PMI) connected to personal air pump (Gillian GilAir5). The $PM_{2.5}$ was collected once per day, 12 hours/day (8am - 20pm) for 3 days including weekdays and weekends. For equipment installation, The Gillian GilAir5 is calibrated to a flow rate of 3 L/min on the footpath with approximately 1.6 m above the ground where it was around 1 m from the nearest lane of the road. The PMI with pumps were placed approximately 1.6 m above the ground.

Figure 3.6 Personal Air Sampler

3.2.3.2 Traffic conditions

Traffic flow and number of vehicles were recorded daily by using video recorder (CCTV), at the same date and time with sample collection period, included 2 weekdays and 1 weekends (Wednesday, Friday and Sunday). The traffic data from The Traffic and Transportation Department, Bangkok were obtained from the monitoring sites at the sampling point. The data are then classified the vehicle types such as two-wheelers-motorcycle (2WH), three-wheel-auto rickshaw (3WH), passenger-car and medium-utility vehicles-car,van (PC-MUV) and light and heavy commercial vehicles (LHCV).
Traffic flow was calculated using the equation:

$$q = \frac{N}{T}$$

For; q = traffic Flow rate
N = the number of vehicles
T = time

3.2.3.3. Emission factors (EFs)

Data Emission Factor of motorcycle, three-wheel, passenger-car and heavy commercial vehicles. (g/km), as standard values from the Pollution Control Department operates the project together with Division of the Industrial factory Industrial of Thailand and Japan International Cooperation Agency (JICA) have developed emission factors and various variables related to the assessment of pollutants from vehicles. (The Development of PRTR System in the Kingdom of Thailand,2016).

3.2.3.4. Meteorological data

The meteorological data were recorded from the monitor station. The data were included the weather conditions such as temperature, humidity, pressure, wind speed and direction, rain. The weather information is nearly real-time. After the data were obtained, the meteorological data were average in 12 hours during at the same sampling period.

3.3 Data analysis

Data analyses used Microsoft Excel (Microsoft Corporation, Redmond, Washington, U.S.), SPSS (IBM, Inc., New York, USA) for regression analyses and find the association between each factor. The linear regression used to measure the strength and direction of association between two variables, while the linear regression is used to study about the relationship between several independent or predictor variables and a dependent variable. The association in this project are determined traffic, and $PM_{2.5}$ concentration was analyst by Linear regression. And the relationship between concentration of $PM_{2.5}$ in ambient from measurement and emission each type of vehicles by calculate use Multiple linear regression.

3.4 Study frame work

Data collecting

- Roadside measurement $PM_{2.5}$
- Traffic data
- PCD monitoring station data
- Meteorological data (TMD)
- Emission Factor in each vehicles type

Sample analysis

Quantify $PM_{2.5}$ concentration that related the impact of traffic volume.

Data analysis

Statistical analysis to identify association of $PM_{2.5}$ from roadside that related with emission $PM_{2.5}$ of vehicles by emission factor using SPSS program.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 $PM_{2.5}$ concentration and number of vehicles.

$PM_{2.5}$ concentrations were measured by two roadside: Phathum Wan intersection (13.44'46"N, 100.31'51"E) and Odeon Circle Yaowarat roundabout (13.44'13"N, 100.30'46"E). The 12 hours (working hours) $PM_{2.5}$ concentration in ambient was ranged from 24.00 – 57.17 $\mu g/m^3$. In Phathum Wan intersection, the average of $PM_{2.5}$ concentrations on weekday and weekend were 45.32±11.90 $\mu g/m^3$ and 36.62±8.17$\mu g/m^3$ respectively. In Odeon Circle Yaowarat roundabout, the average of $PM_{2.5}$ concentrations on weekday and weekend were 32.66±7.97 $\mu g/m^3$ and 33.83±5.60 $\mu g/m^3$ respectively as shown in the Table 4.1. The highest concentration of $PM_{2.5}$ was found in Phathum Wan intersection it located near Phaya thai road and Rama I road which had heavy traffic all day and this intersection was a center of transportation such as bus, motorcycle and taxi that could be the source of fine particulate matter (Karra et al, 2017). The average number of vehicles on weekday and weekend were 77,487 and 59,886 respectively. The minimum concentration of $PM_{2.5}$ was found in Odeon Circle Yaowarat roundabout because the number of vehicles is less than in Pathum Wan intersection. The average number of vehicles on weekday and weekend were 45,937 and 31,693 respectively. Detail of measurement data and Number of vehicles are shown Table 4.2. In additions, the $PM_{2.5}$ concentrations at each site were depended upon the atmospheric conditions such as temperature, wind, pressure, humidity impact and the different activities on weekday and weekend.

For example, The atmospheric conditions from monitor station, at Phathum Wan intersection and Odeon Circle Yaowarat roundabout. The atmospheric conditions of these two sites were not much different. There was one station that represented the same of this two site. However, in this study we concerned only the traffic concentrations, which are the major impact of $PM_{2.5}$ emission.

Table 4.1 The comparison $PM_{2.5}$ concentration of number of vehicles on weekday and weekend.

Site	Particulate matter	Day	Average concentrations ($\mu g/m^3$)	Number of vehicles				Total Vehicles
				2WH	3WH	PC-MUV	LHCV	
*Phathum Wan intersection	$PM_{2.5}$	Weekday	45.32 ± 11.90	33,605	2,947	39,360	1,574	77,487
		Weekend	36.62 ± 8.17	19,884	2,674	35,710	1,618	59,886
**Odeon Circle Yaowarat roundabout		Weekday	32.66 ± 7.97	19,147	2,213	22,592	1,986	45,937
		Weekend	33.83 ± 5.60	10,151	1,953	17,892	1,697	31,693

*Weekday: Sampling 4 days, 16 points //Weekend: Sampling 2 days, 8 points

** Weekday: Sampling 4 days, 8 points //Weekend: Sampling 2 days, 4 points

The example of vehicles daily, distribution profile was shown in figure 4.1. The traffic conjunction occurred during the peak time 7am. and 11.00-12.00 am. The comparison of $PM_{2.5}$ concentration and number of vehicles on weekend and weekday were shown in Table 4.1

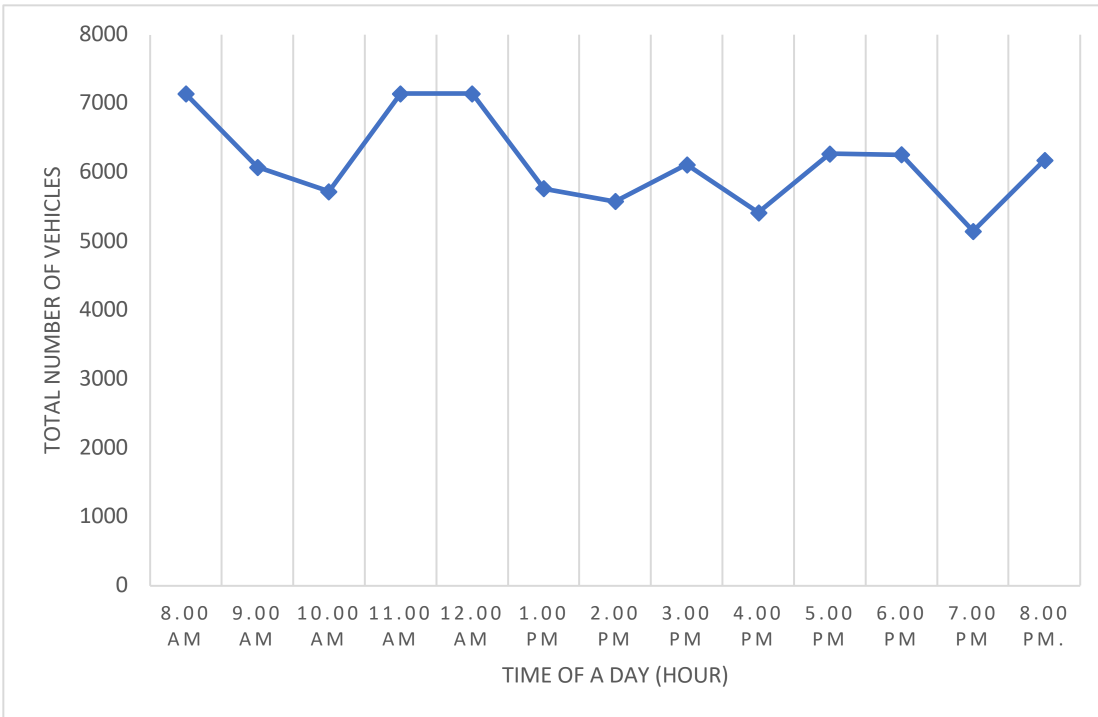

Figure 4.1 Vehicles daily, distribution profile at Phathum Wan intersection

Table 4.2 $PM_{2.5}$ concentrations, Number of vehicles and Traffic flow.

Date	Sites	Concentration $PM_{2.5}$ ($\mu g/m^3$)	Average $PM_{2.5}$ ($\mu g/m^3$)	Number of vehicles (N)	Traffic flow (N/12hr)
W27/02/19	PTW1	48.23	55.59	83,815	6,985
	PTW2	62.29			
	PTW3	36.31			
	PTW4	56.25			
F010/03/19	PTW1	46.74	57.17	82,426	6,869
	PTW2	53.10			
	PTW3	65.78			
	PTW4	63.05			
S03/03/19	PTW1	32.16	42.11	62,978	5,248
	PTW2	41.20			
	PTW3	50.22			
	PTW4	44.86			
W06/03/19	PTW1	36.80	40.6	72,625	6,052
	PTW2	38.22			
	PTW3	47.08			
	PTW4	40.31			
F08/03/19	PTW1	27.68	32.75	71,062	5,922
	PTW2	32.30			
	PTW3	37.19			
	PTW4	33.84			
S10/03/19	PTW1	25.72	31.12	56,794	4,733
	PTW2	30.10			
	PTW3	35.27			
	PTW4	33.39			
W13/03/19	OCY1	41.37	37.12	46,047	3,837
	OCY2	32.88			
F15/03/19	OCY1	25.50	24.00	45,663	3,805
	OCY2	22.49			
S17/03/19	OCY1	40.08	39.41	32,324	2,693
	OCY2	38.74			
W20/03/19	OCY1	29.59	26.95	43,263	3,605
	OCY2	24.32			
F22/03/19	OCY1	41.89	42.59	31,305	2,609
	OCY2	43.28			
S24/03/19	OCY1	28.31	28.24	31,060	2,588
	OCY2	28.18			

4.2 Traffic survey data of various vehicle in Phathum Wan intersection and Odeon Circle Yaowarat roundabout

The average daily patterns of flow of two-wheelers-motorcycle(2WH), three-wheel-auto rickshaw (3WH), passenger-car and medium-utility vehicles-car,van (PC-MUV) and light and heavy commercial vehicles (LHCV). Throughout the day are shown in Table 4.1. during Feb 27, 2019 to March 24, 2019. In 12 hours (working time), the number of PC-MUV is high during the day. The vehicle count considering both major and minor lanes was found to be 71,167 and 38,277 per day in Phathum Wan intersection and Odeon Circle Yaowarat roundabout respectively. The percentage of PC-MUV was the most of other vehicles in Phathum Wan intersection and Odeon Circle Yaowarat roundabout were shown in Figure 4.2 and 4.3.

4.3 Comparison of $PM_{2.5}$ emission of vehicles in Phathum Wan intersection and Odeon Circle Yaowarat roundabout.

The average emission factor $PM_{2.5}$ from different vehicles groups were 0.0035 g/km (2WH), 0.0114 g/km (3WH), 0.0011 g/km (PC-MUV) and 0.0783 g/km (LHCV) (EMEP/EEA Guidebook, 2006). In Phathum Wan intersection, the date contribution of different vehicle category in above pollutants emission is shown in Table 4.3 In case of 2WH, the emission average of $PM_{2.5}$ was 101.61 g/km It was more as the PC-MUV emission average of $PM_{2.5}$ was 41.96 g/km. The LHCV has high the emission average of $PM_{2.5}$ was 124.39 g/km. The 3WH was 3.26 g/km. It's very less value. And Odeon Circle Yaowarat roundabout, the date contribution of different vehicle category in above pollutants emission is shown in Table 4.4. In case is 2WH, the emission average of $PM_{2.5}$ was 56.52 g/km. It was more as the PC-MUV emission average of $PM_{2.5}$ was 23.13 g/km. The LHCV has high the emission average of $PM_{2.5}$ was 147.95 g/km. The 3WH was 2.42 g/km.

The $PM_{2.5}$ emission of LHCV higher then other vehicles, which the EF of elements are low with the highest values obtained for Fe and Al though still below 2.3–2.5 mg/km for LHCV vehicles and 2 mg/km for PC-MUV vehicles. This is in line with a previous study (Gillies and Gertler, 2000) which shows an insignificant contribution of elements to the $PM_{2.5}$ mass. The Comparison of $PM_{2.5}$ emission of vehicles in Phathum Wan intersection and Odeon Circle Yaowarat roundabout that show in

Fingure 4.4. In Phathum Wan intersection, the value of emission $PM_{2.5}$ of LHCV less more than In Odeon Circle Yaowarat roundabout. The emission of LHCV showed the highest emission of $PM_{2.5}$ because LHCV had the highest emission factor (EF) value, although it showed the lowest number of vehicles, so it was the main source of $PM_{2.5}$ in these two sites. The second highest emission of $PM_{2.5}$ was from 2WH because it showed high number of vehicles while its EF was low. So these two types of vehicles were main contributors to $PM_{2.5}$ emission in this study.

So the emission PM2.5 of LHCV that effect to air pollution in Bangkok.

Table 4.3 $PM_{2.5}$ concentrations and emission of vehicles in Phathum Wan intersection

Date	Avg $PM_{2.5}$ (ug/m3)	Total Vehicles	Emission of Vehicles (g/km)				Total Emission (g/km)
			2WH	3WH	PC-MUV	LHCV	
W27/02/19	55.59	83,815	125.85	3.50	47.36	136.48	313.20
F01/03/19	57.17	82,426	128.00	3.20	45.58	126.61	303.39
S03/03/19	42.11	62,978	75.04	3.29	40.68	130.76	249.77
W06/03/19	40.6	72,625	111.25	3.13	40.19	121.44	276.02
F08/03/19	32.75	71,062	105.36	3.60	40.06	108.52	257.54
S10/03/19	31.12	56,794	64.14	2.81	37.89	122.54	227.37
Avg. Emission of Vehicles (g/km)			101.61	3.26	41.96	124.39	

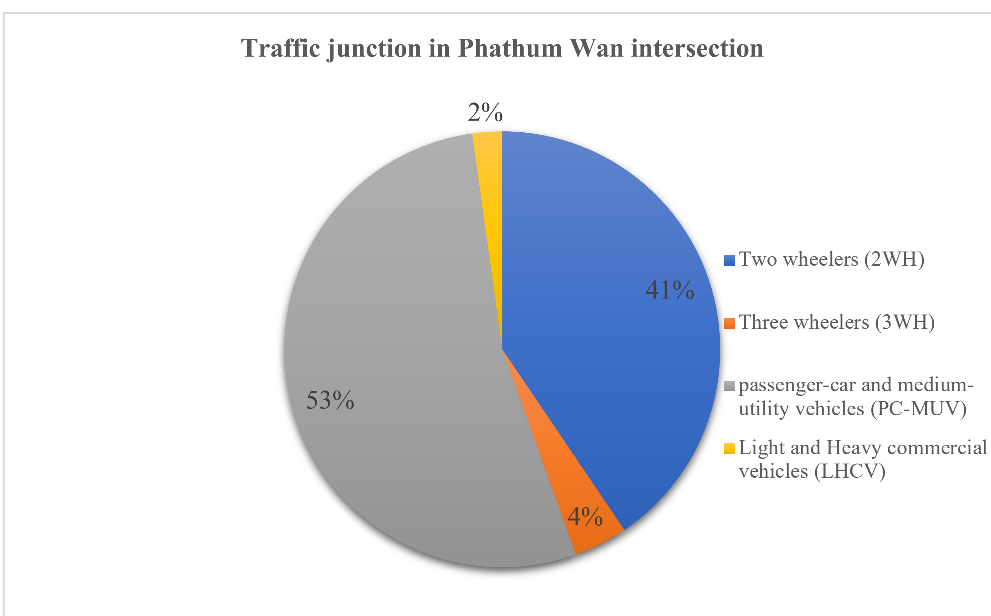

Figure 4.2 Traffic junction in Phathum Wan intersection

Table 4.4 $PM_{2.5}$ concentrations and emission of vehicles in Odeon Circle Yaowarat roundabout.

Date	Avg $PM_{2.5}$ (ug/m^3)	Total Vehicles	Emission of Vehicles (g/km)				Total Emission of vehicles (g/km)
			2WH	3WH	PC-MUV	LHCV	
W13/03/19	37.12	46,047	69.89	2.16	24.34	160.67	257.07
F15/03/19	24.00	45,663	70.84	2.48	23.58	141.64	238.55
S17/03/19	39.41	32,324	36.30	2.72	19.60	136.71	195.34
W20/03/19	26.95	43,263	59.38	2.64	24.23	153.39	239.63
F22/03/19	42.59	31,305	67.94	2.80	27.26	166.31	264.31
S24/03/19	28.24	31,060	34.75	1.73	19.76	128.96	185.20
Avg. Emission of Vehicles (g/km)			56.52	2.24	23.13	147.95	

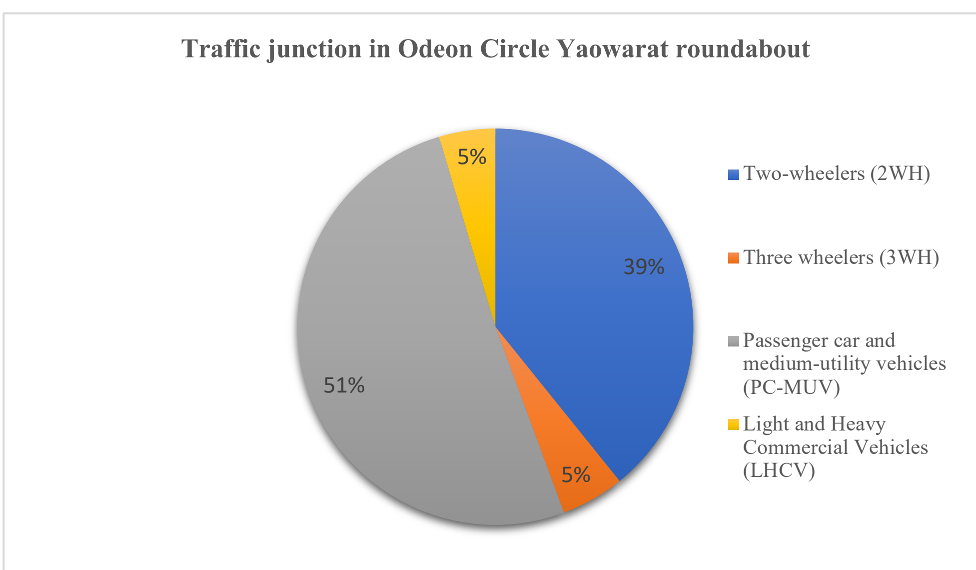

Figure4.3 Traffic junction in Odeon Circle Yaowarat roundabount

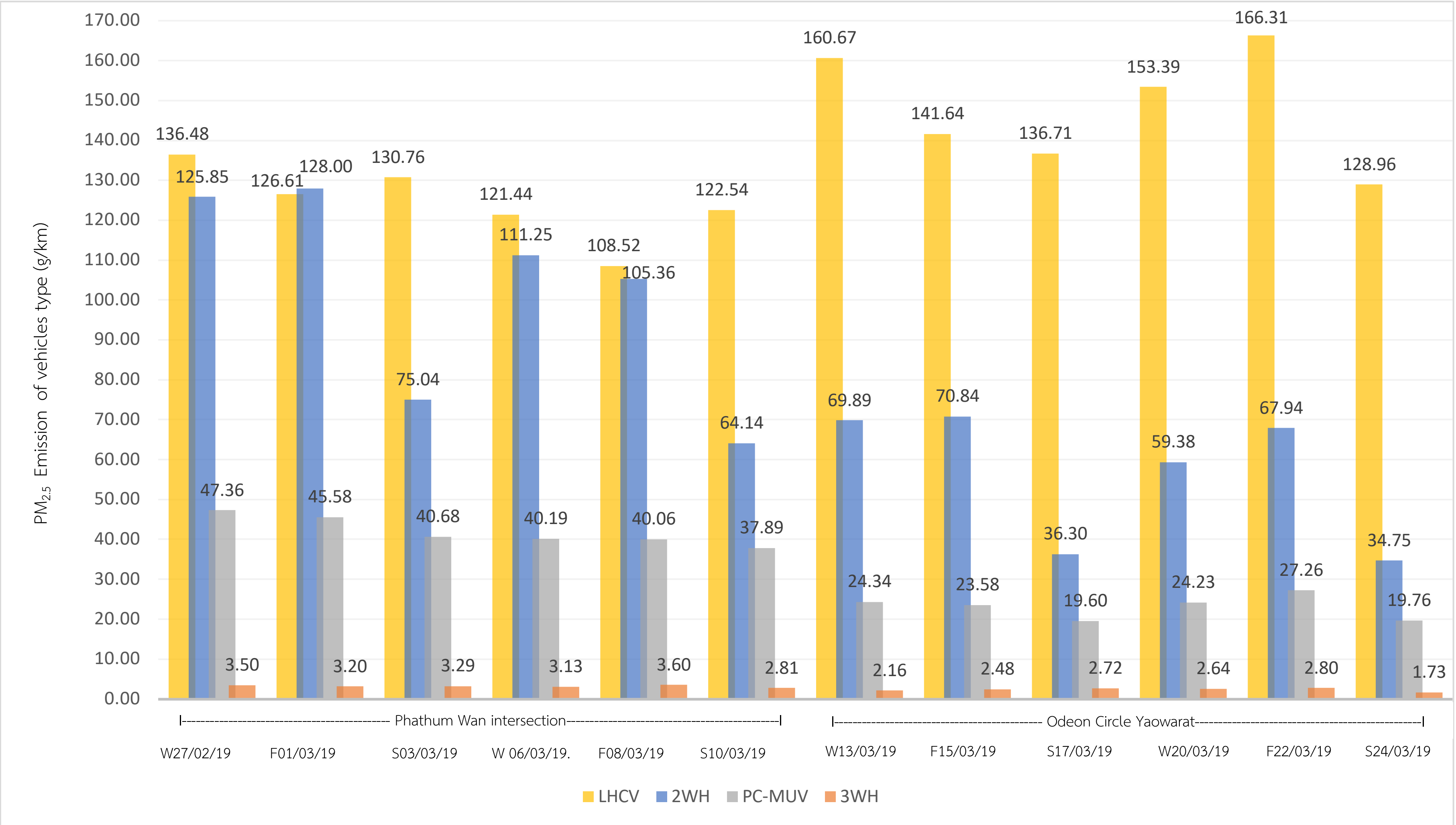

Figure4.4 Comparison of $PM_{2.5}$ emission of vehicles types in Phathum Wan intersection and Odeon Circle Yaowarat roundabount

4.4 Correlation between $PM_{2.5}$ in ambient concentration, the traffic conditions and emission each type of vehicles.

From data in Table 4.2, Linear regression was used to modelling the relationship between concentration of $PM_{2.5}$ in ambient from measurement and traffic conditions by video recorder. Linear regression showed a significant relationship between $PM_{2.5}$ and traffic conditions from Phathum Wan intersection ($p < 0.05$). Figure 4.5. The r value was 0.84 so 84% of the a $PM_{2.5}$ in ambient variable that's explained by the number of vehicles variable, showing good relation. $PM_{2.5}$ in this site was covered by Phathum Wan sky walk, traffic flow factors were directly related to $PM_{2.5}$ levels in covered area. (Sahanavin et al.,2018). And linear regression from Odeon Circle Yaowarat roundabout showed in Figure 4.6 did not show significant relationship between $PM_{2.5}$ and traffic volume ($p > 0.05$) The r value was 0.48 so 48% of the a $PM_{2.5}$ in ambient variable that's explained by the number of vehicles variable in ambient. The number of vehicles has weak relation to $PM_{2.5}$. Because the roundabout has free-flow point to no-stop conditions.

Multiple linear regression was used to modelling the relationship between concentration of $PM_{2.5}$ in ambient from measurement and emission each type of vehicles by calculate. In Phathum Wan intersection, the emission value of PC-MUV and 3WH can be explained by $PM_{2.5}$ in ambient. A significant relationship between $PM_{2.5}$ vehicles type PC-MUV and 3WH. In Odeon Circle Yaowarat roundabout, the emission each type of vehicles can not explained by $PM_{2.5}$ in ambient. A not significant relationship between $PM_{2.5}$ and traffic emission each type of vehicles. According to the results of linear regression, the volume of vehicles has no relation to $PM_{2.5}$ in ambient because the uncontrollable atmospheric conditions, temperature inversion impact and the different activities.

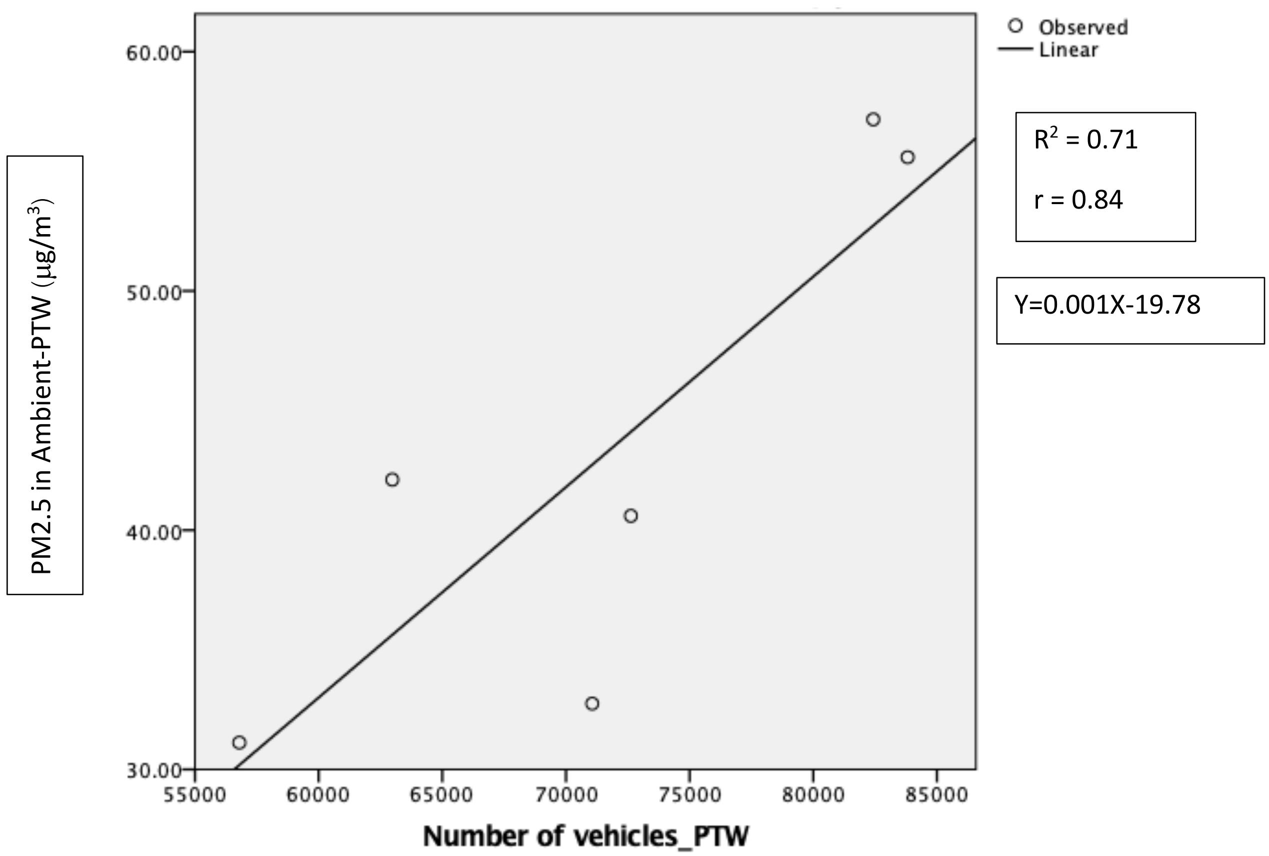

Figure 4.5 Linear regression of $PM_{2.5}$ in ambient and number of vehicles in Phathum Wan intersection.

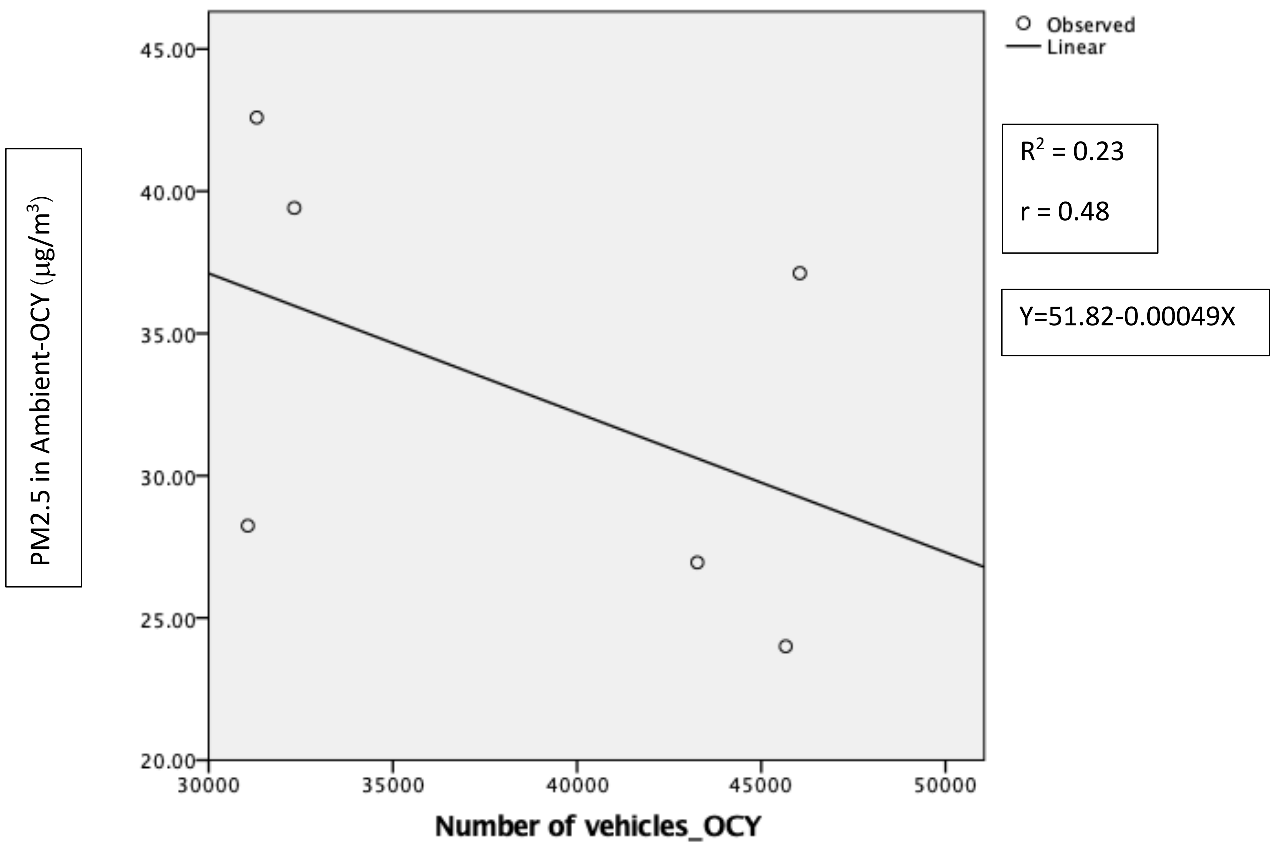

Figure 4.6 Linear regression of $PM_{2.5}$ in ambient and number of vehicles in Odeon Circle Yaowarat roundabout.

CHAPTER V

CONCLUSIONS

$PM_{2.5}$ concentrations were measured from Phathum Wan intersection and Odeon Circle Yaowarat roundabout. The results showed that the average concentration of $PM_{2.5}$ on weekday was higher than the average concentration on weekend. The minimum average concentration of $PM_{2.5}$ were showed in Odeon Circle Yaowarat roundabout. while the maximum concentration of $PM_{2.5}$ were showed in Phathum Wan intersection.

At Phathum Wan intersection, which a high number of vehicles that cause of emission vehicles in this site. Traffic flow and number of vehicles was related the $PM_{2.5}$ in ambient. So high traffic flow and number of vehicles, that effect to $PM_{2.5}$ in ambient. The emission of PC-MUV and 3WH are associated with $PM_{2.5}$ levels

At Odeon Circle Yaowarat roundabout, which a number of vehicles less then Phathum Wan intersection. Traffic conditions not significant relationship $PM_{2.5}$ in ambient and the emission each type of vehicles can not explained by $PM_{2.5}$ in ambient.

The traffic flow from two sites on weekday is higher than on weekend. At Phathum Wan intersection, traffic flow rate (h^{-1}), vehicles number and $PM_{2.5}$ concentration are higher than at Odeon Circle Yaowarat roundabout. So the ambient $PM_{2.5}$ concentration is depend on site location and traffic activity.

From this result study we recommend to continues agent measure $PM_{2.5}$ increasing number of site and frequently. The future study, that we should concern about the related junction extensively study the relationship between vehicle speed and emission $PM_{2.5}$.

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APPENDICES

Correlation Linear regression

1.Linear regression of $PM_{2.5}$ in ambient and number of vehicles in Phathum Wan intersection.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-19.780	20.310		-.974	.385
	Number of vehicles_PTW	.001	.000	.843	3.130	.035

a. Dependent Variable: PM2.5 in Ambient_PTW (μg/m3)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.843[a]	.710	.638	6.65855877

a. Predictors: (Constant), Number of vehicles_PTW

b. Dependent Variable: PM2.5 in Ambient_PTW (μg/m3)

2. Linear regression of $PM_{2.5}$ in ambient and number of vehicles in Odeon Circle Yaowarat roundabout.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	51.820	17.510		2.959	.042
	Number of vehicles_OCY	.000	.000	-.478	-1.089	.338

a. Dependent Variable: PM2.5 in Ambient_OCY (µg/m3)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.478[a]	.229	.036	7.48221723

a. Predictors: (Constant), Number of vehicles_OCY

b. Dependent Variable: PM2.5 in Ambient_OCY (µg/m3)

Correlation Multiple linear regression

1. Correlation Multiple Linear regression of $PM_{2.5}$ in ambient (PM_PTW) and emission each type of vehicles (Ep) in Phathum Wan intersection.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	582.436	4	145.609	4.968	.323[b]
	Residual	29.311	1	29.311		
	Total	611.747	5			
2	Regression	576.313	3	192.104	10.843	.086[c]
	Residual	35.434	2	17.717		
	Total	611.747	5			
3	Regression	575.219	2	287.610	23.621	.015[d]
	Residual	36.527	3	12.176		
	Total	611.747	5			
4	Regression	551.318	1	551.318	36.494	.004[e]
	Residual	60.429	4	15.107		
	Total	611.747	5			

a. Dependent Variable: PM_PTW c. Predictors: Ep_LHCV e. Predictors: Ep_PC

b. Predictors: Ep_2WH. d. Predictors: Ep_3WH

2.Correlation Multiple Linear regression of $PM_{2.5}$ in ambient (PM_OYC) and emission

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	195.855	4	48.964	.519	.763[b]
	Residual	94.419	1	94.419		
	Total	290.275	5			
2	Regression	189.721	3	63.240	1.258	.472[c]
	Residual	100.553	2	50.277		
	Total	290.275	5			
3	Regression	181.614	2	90.807	2.507	.229[d]
	Residual	108.661	3	36.220		
	Total	290.275	5			
4	Regression	69.442	1	69.442	1.258	.325[e]
	Residual	220.832	4	55.208		
	Total	290.275	5			
5	Regression	.000	0	.000	.	.[f]
	Residual	290.275	5	58.055		
	Total	290.275	5			

a. Dependent Variable: OYC_PM. b. Predictors: (Constant), Ep_3WH.

c. Predictors: (Constant), Ep_PC, d. Predictors: (Constant), Ep_2WH

e. Predictors: (Constant), Ep_LHCV

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Impact of traffic conditions on $PM_{2.5}$ Concentrations At two distinct traffic junctions in Bangkok Thailand.

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ABSTRACT

The impact of traffic flow on $PM_{2.5}$ emissions at two types of different traffic junctions were examined, at Phathum Wan intersection site (13.44’46 "N, 100.31’51" E) and Odeon Circle Yaowarat roundabout, site (13.44’13 "N, 100.30’46" E). Ambient $PM_{2.5}$ concentrations was collected 12 hours/day within working hours day-time. While the traffic flow and number of vehicles were recorded by video camera simultaneously. The relationship between concentration of $PM_{2.5}$ and traffic conditions were compared between these two sites. At Phathum Wan intersection, the linear regression is significantly related between $PM_{2.5}$ and traffic flow and number of vehicles, r = 0.84. However, at the Odeon Circle Yaowarat with high traffic flow, r = 0.48, showed a moderate level in the same direction. The concentration of $PM_{2.5}$ in ambient and the emission of the passenger-car and medium-utility vehicles-car,van (PC-MUV) and three-wheel-auto rickshaw (3WH) are associated with $PM_{2.5}$ levels, at Phathum Wan intersection.

Keywords $PM_{2.5}$**,** Emission of vehicles, Traffic, Bangkok

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