Innovative Characteristic Assessment of Air Pollution in Bangkok

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Abstract

In Thailand, the major air pollutants include Sulfur dioxide, Nitrogen dioxide, Carbon monoxide, Ozone, and Particulate matter. At present, the air pollutant that remains a major problem is particulate matter. Especially in areas with heavy traffic in Bangkok. The study findings of the trend of air pollution in Bangkok for the past 10 years, revealed that, in most air quality measuring stations, sulfur dioxide and nitrogen dioxide tended to decrease whereas carbon monoxide, ozone, and PM_{10} tended to be different depending on stations. The primary pollutants tended to have positive relationships. Ozone, the secondary pollutant, could not see a positive relationship with other parameters. PM_{10} attended to increase, exceeding standards, in the winter of every year. In winter, the weather was dry, and the relative humidity decreased, resulting in the long lingering dust in the air. The emission of primary pollutants revealed that they would have the highest concentration in the morning and gradually decrease until the evening, mainly depending on traffic congestion. The concentration of air pollution was high at each time of congested traffic. A positive relation was found between nitrogen dioxide and the amount of traffic as nitrogen dioxide came from direct fuel combustion in cars.

Keyword: Major air pollutants, Primary pollutants, Secondary pollutant

Introduction

Air pollution is an environmental problem in large communities and developed areas with rapid expansion due to industrial activities, transport, traffic, and construction. In Thailand, the major air pollutants include Sulfurdioxide, Nitrogendioxide, Carbonmonoxide, Ozone, and Particulate matter, which are regularly and continuously measured by Pollution Control Department (PCD). At present, the air pollutant that remains a major problem is particulate matter. Especially in areas with heavy traffic in Bangkok, it is found that the concentration is 3-5 times higher than the air quality standards. As for other pollutants such as lead, Sulfurdioxide, Nitrogendioxide, and Carbonmonoxide, they do not normally exceed the standards of air quality in the atmosphere. According to the statistics of the registered accumulated cars the Department of Land Transport in 2019, Bangkok had as high as 10 million registered accumulated cars (information as of 31 May 2019). As a result, the main causes of the air pollution problems in Bangkok are from car exhaust are traffic. Fuel combustion in cars depends on 3 major factors namely fuel, air, and heat. The complete combustion and will generate only carbondioxide and water. However, most combustion is incomplete combustion will emit air other pollution, and dust causing air pollution, especially in urban areas with heavy traffic.

Air pollution this air with contaminants in sufficient quantity and duration that can cause harmful health to humans, animals, plants, and materials. The pollutants may be natural or man-made elements or compounds, and can be in the form of gas, liquid, or solid particles (Textbook of air pollution treatment system 2004, Department of Industrial Works). Air pollutants are divided into (1) Primary Air

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Pollutants which can also be divided into air pollutants that form and are directly emitted from the origins such as sulfurdioxide, carbonmonoxide, oxide of nitrogen, ash, and soot from fuel combustion in vehicles and ovens in industrial plants, etc. and (2) Secondary Air Pollutants which are air pollutants that do not occur and are emitted from any origins but occur in the general atmosphere from chemical reaction between Primary Air Pollutants and other compounds in the atmosphere such as ozone that comes from Photochemical Oxidation between oxide of nitrogen and hydrocarbon, as well as inorganic air pollutants (Textbook of air pollution treatment system 2004, Department of Industrial Works).

As Bangkok is the capital, center of administration, education, national prosperity communication and transport in Thailand, rapid growth of Bangkok renders insufficient basic infrastructure. Bangkok is also the most populated province in Thailand and most registered number of cars. The limited number of roads and wide use of passenger cars cause traffic congestion and air pollution. Until now, the government has formulated a policy to limit the usage of smoke-emitting diesel cars that fail to meet the standards which has helped reduce the amount of PM_{10} and $PM_{2.5}$ along road curbs. In 2012, the government stipulated that small diesel cars and benzene cars, as well as fuel, must comply with the Euro 4 standards. Sources of PM_{10} in Bangkok can be divided into anthropogenic sources, which include incomplete combustion from vehicles, dust generated by construction activities, open burning, and emissions from industrial production processes, and natural origins such as soil-derived particulate matter carried by wind and the transport of particulate matter from other regions to Bangkok. Health impacts from PM_{10} exposure can be diverse, as it can enter the respiratory system through inhalation. Health effects can arise from both short-term and long-term exposure, including respiratory illnesses, cardiovascular diseases, exacerbation of respiratory disease symptoms, and increased mortality rates associated with cardiovascular diseases, respiratory ailments, and lung cancer.

Effective management strategies to improve air quality are essential to minimize health risks. These measures encompass enforcing legal regulations and adhering to air quality standards, mitigating pollution at its source, embracing structural changes such as reducing energy consumption (particularly fuel combustion), modifying transportation or logistical methods, and land-use planning. Personal behavioral adjustments, such as choosing less environmentally impactful transportation methods, altering residential energy consumption to decrease energy usage and adopt cleaner energy sources, are also of paramount importance. Therefore, there was a research interest to study the direction of air pollution in Bangkok with the objective to explain the trend and Characteristics of air pollution in the areas of congested traffic for the past 10 years. Analysis was then conducted to find the factors impacting air pollution in Bangkok, leading to the formulation of management policy and decisions in control, prevention, and surveillance of air quality for more efficient and effective operation.

Research Objectives

1. Explain the characteristics of the generation of air pollution in Bangkok for the past ten years

2. Analyze the factors that impact the generation and the spread of PM10 in Bangkok

Literature Review

Air pollution means the conditions of the air with contaminants in sufficient quantity and duration to harm health of humans, animals, plants, and various materials. The contaminants can be natural or man-made substances or compounds or in the form of gas, liquid drops, or solid particles. The major air pollutants include Particulate Matter, lead (Pb), carbon monoxide, sulfur dioxide, nitrogen oxide, and ozone.

Types of Air Pollutants

1. Primary Air Pollutants are air pollutants directly generated and emitted from sources such as sulfur dioxide, carbon monoxide, nitrogen oxide, ash, and black smoke derived from combustion of fuel in vehicles and incinerators in industrial plants, etc.

2. Secondary Air Pollutants are air pollutants not generated or emitted from any source but take place in the atmosphere in general through chemical

reaction between primary air pollutants and other compounds in the atmosphere such as ozone is derived from Photochemical Oxidation between nitrogen oxide and other hydro carbon compounds and inorganic air pollutants such as hydrogen sulfide and lead dust, etc.

In Thailand, there was notification on the volume of pollutants permitted for emission into the atmosphere in order to control 7 types of main pollutants, composing mainly of primary air pollutants namely carbon monoxide, nitrogen dioxide, sulfur dioxide, total suspended particulate, lead, particulate matter (PM10), and ozone which are secondary air pollutants. Moreover, there are Hazardous Air Pollutants (HAPs) or Toxic Air Pollutants (Air Toxic) which are carcinogens and with long-term impact on health through destruction of immunity of nervous system and abnormality in reproductive and endocrine systems, etc. In US, 189 types of hazardous air pollutants are identified with major sources being chemical industrial plants, pesticides, combustion, etc. At present, in US, the standard of HAPs has not been established from sources as many as possible. As for Thailand, the standard of HAPs in the atmosphere has not been established but there is a policy formulated to control the HAPs from sources by using the measures to control the emission from sources such as pollution prevention or clean technology, etc.

Major Air Pollutants

1. Particulate Matter the definition covers solid particles and liquid drops suspended in the air. Some of the particles are big and black soot. But some are so small they are invisible to the naked eyes. In general, the particulate matter suspended in the air has the size of not exceeding 100 microns. The particulate matter impacts health of humans, animals, and plants damaging residential buildings, causing troubles to people, obscuring vision, and obstructing transport. Many countries therefore have devised the standards of the particulate matter in the atmosphere. In US, the United States Environmental Protection Agency (US EPA) has devised the standards of the total suspended particulate and

PM_{10} according to the definition of US EPA means Coarse Particle with the radius of 2.5-10 microns generated from traffic on unpaved roads according to the transport of particle from stone crushing activities.

$PM_{2.5}$ according to the definition of US EPA means Fine Particles with the radius smaller than 2.5 microns. Fine particles are generated from exhaust fumes, power plants, industrial plants, and smoke from cooking using firewood. Moreover, SO_2, NO_x, and VOC can interact with other substances in the air causing fine particles.

2. Carbon monoxide (CO) has no color, flavor, or smell. It is slightly lighter than general air. When inhaling, it will combine with Hemoglobin in red blood with 200-250 times more than oxygen. It will result in carboxyhemoglobin (COHb) which reduces the ability of blood to become the oxygen conductor from the lungs to various tissues. In general, the main component causing the large or small amount of carboxyhemoglobin depends on the concentration of carbon monoxide in the air that people breath in and the duration of the condition. Human reaction mainly depends on the percentage of carboxyhemoglobin and individual susceptibility.

3. Nitrogen oxide (NO_X) oxide consists of nitrus oxide (N_2O), nitric oxide (NO), dinitrogen trioxide (N_2O_3), nitrogen dioxide (NO_2), dinitrogen tetroxide (N_2O_4), and dinitrogen pentoxide (N_2O_5). Generally, the types of gas that generate air pollutants include nitrogen dioxide (NO_2) and nitric oxide (NO) which are inert gas with the anesthetic properties and without color or smell. In nature, generally, they are found in the amount which is smaller than 0.5 ppm. It is also slightly soluble. As for nitrogen dioxide (NO_2), it is brown gas. If in sufficient large volume, it is visible. Both types of gas can exist in nature such as lightning, volcanic eruption, or microorganic mechanism. Moreover, they are caused by human activities such as industries namely nitric acid or sulfur acid manufacturing industries, explosive manufacturing factories, and engine combustion, etc.

4. Sulfur oxide (SO_x)

Sulfur oxide consists of SO_2 and SO_3. It is generally referred as SO_x. Sulfur oxide (SO_2) has no color. It is nonflammable and has sharp smell that irritates the nose. It is highly soluble and is changed into sulfuric acid. Generally, in nature, it is found in small quality in the atmosphere between 0.02-0.1 ppm. But if found in large quantity, it is generated mostly from combustion using fuel or material with sulfur as composition. The reaction generates Sulfur dioxide (SO_2).

Sulfur oxide (SO_x) in the atmosphere is mostly found in the form of sulfur dioxide (SO2) which has no color. It is nonflammable and nonexplosive. It can have flavor if found in large quantity. With time, sulfur dioxide will be changed into sulfur oxide, sulfuric acid, and sulfate salt through the catalytic reaction or photochemical reaction in the air. Sulfur dioxide generally is derived from the combustion of sulfur in the fuel from petroleum and coal. It is toxic gas that is mainly generated from industrial plants and diesel engine.

5. Ozone (O_3)

Ozone is a type of photochemical oxidant from the photochemical oxidation between hydro carbon and nitrogen oxide with sunlight as catalyst. Other photochemicals include aldehyde, ketone, and peroxyacetyl Nitrate (PAN) causing the condition called photochemical smog. It is white fog widely spread in the air. In general, ozone will cause irritation of the eyes and the respiratory system, reducing the function of the lungs.

6. Lead (Pb)

Lead in the air especially in cities comes from benzene-run vehicles as benzene consists of tertrathyl Lead or tetramethyl Lead which is mixed to increase octane to the benzene to prevent engine knock. Lead will be emitted through the exhaust pipe in the form of solid matter. Lead is a heavy metal with high toxicity, especially in children. It is seriously harmful to people's health. For example, it will destroy bone marrow and red blood cells, causing anemia, and can be transmitted from mother to fetus through the placenta.

Conceptual Framework

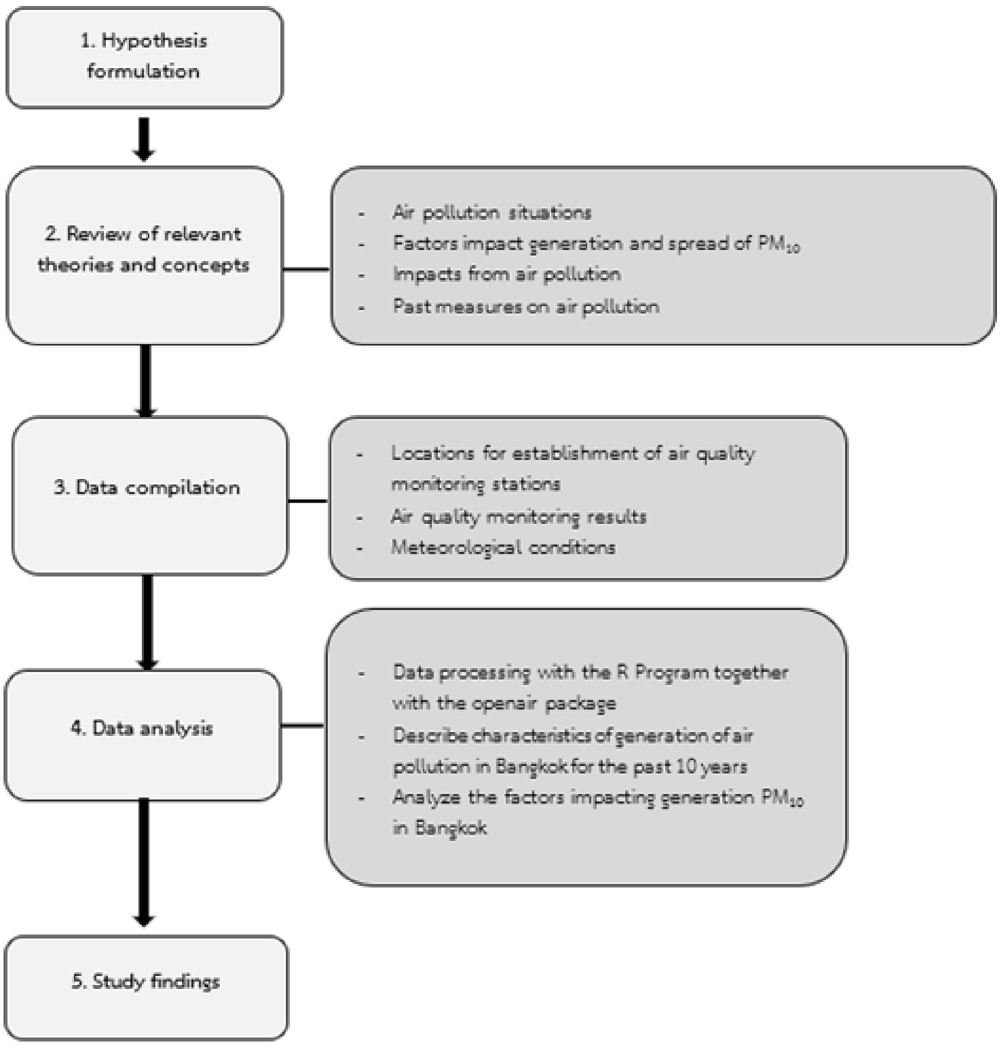

Figure 1. Research Conceptual Framework

Research Methodology

1. Air Pollution Data use in this work are from Air Quality and Noise Management Office, Pollution Control Department between 2007-2016 and consist of the parameters of the study consisted of the following:

1) Sulfur dioxide measured by UV fluorescence detector

2) Nitrogen dioxide measured by chemiluminescence detector

3) Ozone measured by ultraviolet absorption photometry

4) Carbon monoxide measured by Gas Chromatography/Mass Spectrometry (GCMS)

5) PM_{10} measured by Beta Ray Attenuation and in accordance with Federal Equivalent Method (FEM) as determined by US Environmental Protection Agency (US EPA)

6) Wind speed and wind direction

2. Study Area data are from monitoring 6 air quality measuring stations along road curbs in Bangkok namely Ministry of Science and Technology station (MST) on Rama 6 Road, Department of Land Transport station (DLT) on Phahon Yothin Road, Chulalongkorn Hospital station (CUH) on Rama 4 Road, Thonburi power sub-station (TBP) on Intarapitak Road, Chok Chai Metropolitan Police Station (CCP) on Ladprao Road, and Din Daeng Community Housing station (DDC) on Din Daeng Road as illustrated in Figure 2.

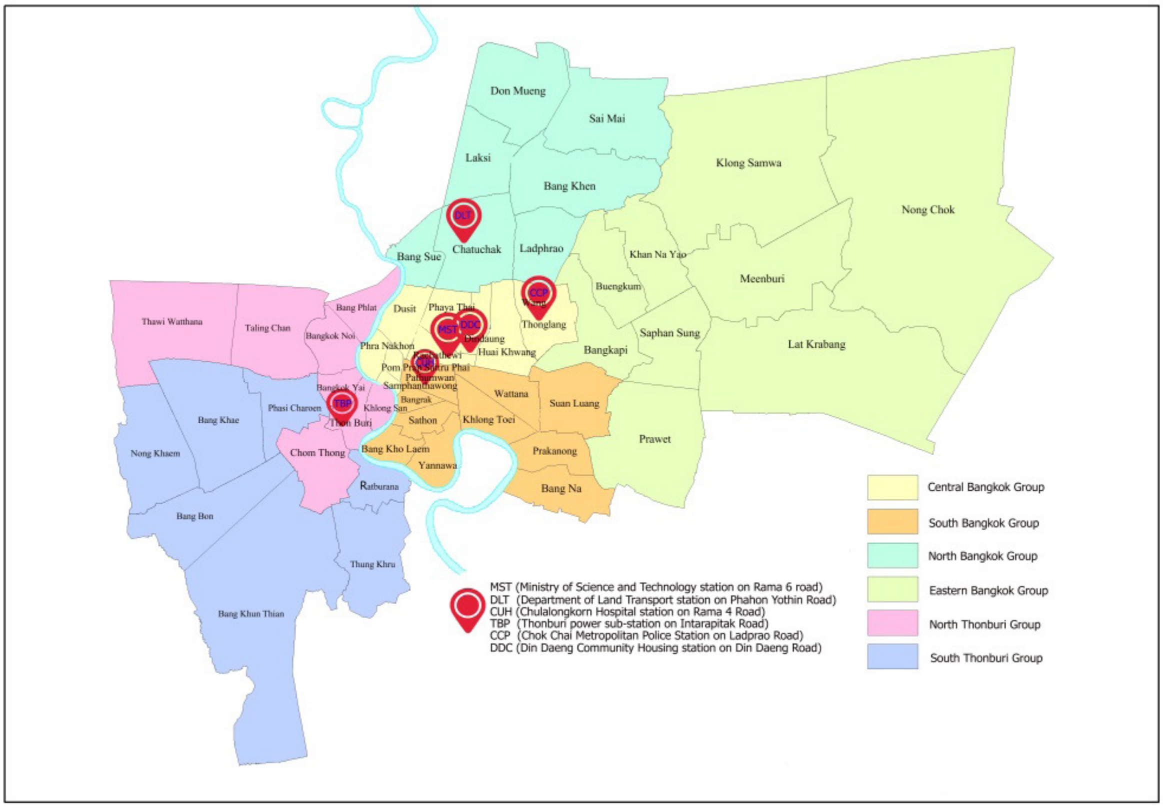

Figure 2. Locations of Air Quality Measuring Stations Along Road Curbs in Bangkok of Pollution Control Department

3. Analysis Tool we use the R statistical program in conjuncture with the Openair package to analyze the data of air quality. The statistical package was constructed to analyze data and draw graphs model, for exam of hourly air quality measuring from DDC as shown in Figure 3.

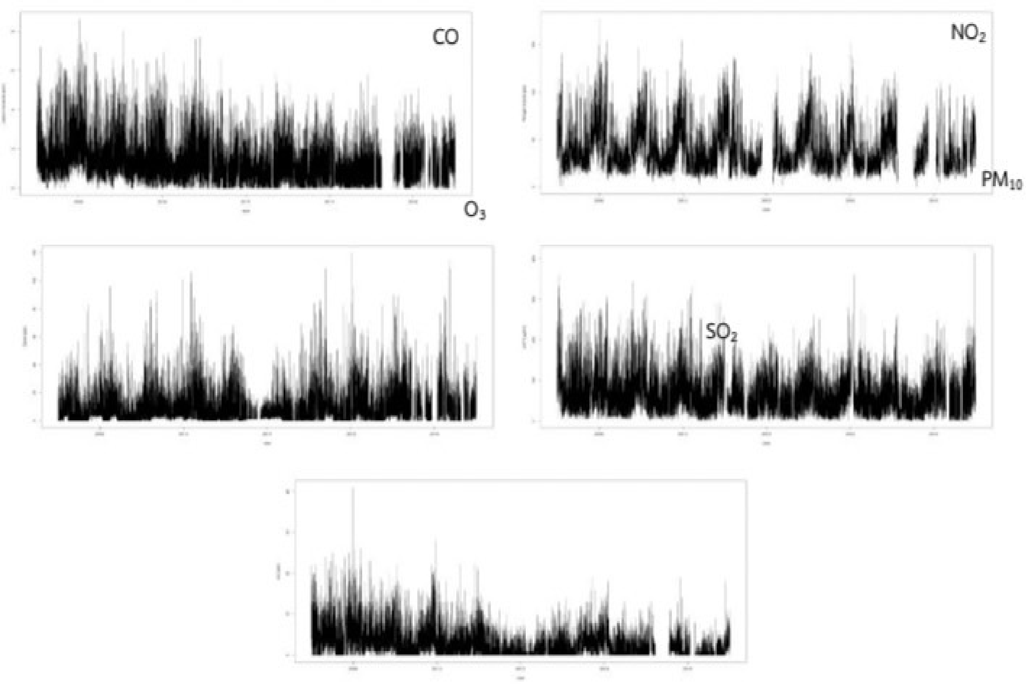

Figure 3. Results of Hourly Air Quality Measuring from DDC between 2007-2016

Research Results

1. Trend of Air Pollution in Bangkok

The analysis of Air Quality data from Air Quality station the results of the measuring of air quality from air quality measuring stations along road curbs in Bangkok for the past 10 years revealed that, in most air quality measuring stations, sulfurdioxide and nitrogendioxide tended to decrease. Carbonmonoxide, Ozone, and PM_{10} tended to be different according to stations as shown in Table 1 and Figure 3. Limit the usage of smoke-emitting diesel cars that fail to meet the standards could decrease the amount of PM_{10} along road curbs. In 2004, Department of Energy Business formulated the policy to improve Euro 3 vehicle emission and diesel quality standards, by determining the characteristics and the quality of fuel in various dimensions appropriate to the functioning of engine in order to control the emission of pollution especially dust, black smoke, and sulfurdioxide. Therefore, the reduction of sulfur in diesel would reduce car exhaust containing sulfurdioxide and reduce formation of sulfate dust. Importantly, the reduction of sulfur must be undertaken in parallel and following by Euro 4 vehicle emission standards which would also help reduce the amount of PM_{10}. From Table 1, in some stations, there was increased trend concentration of Carbonmonoxide and PM_{10} such as Stations DLT, CCP, and MST due to the characteristics of such stations with regular traffic congestion, as well as the orientation of the buildings in the areas which obstructed the movement of horizontal air (Advection). It was one reason that caused air pollution problems in the areas.

Table 1. Results of Air Quality from Air Quality Measuring Stations Along Road Curbs in Bangkok between 2007-2016

Stations	Parameters				
	CO	NO_2	O_3	PM_{10}	SO_2
1. TPB	Decrease	Decrease	**Increase**	Decrease	Decrease
2. CCP	**Increase**	Decrease	Decrease	Decrease	Decrease
3. DDC	Decrease	Decrease	**Increase**	Decrease	Decrease
4. MST	**Increase**	-	-	Decrease	-
5. DLT	Decrease	Decrease	**Increase**	**Increase**	Decrease
6. CUH	No change	-	-	No change	-

*No measuring

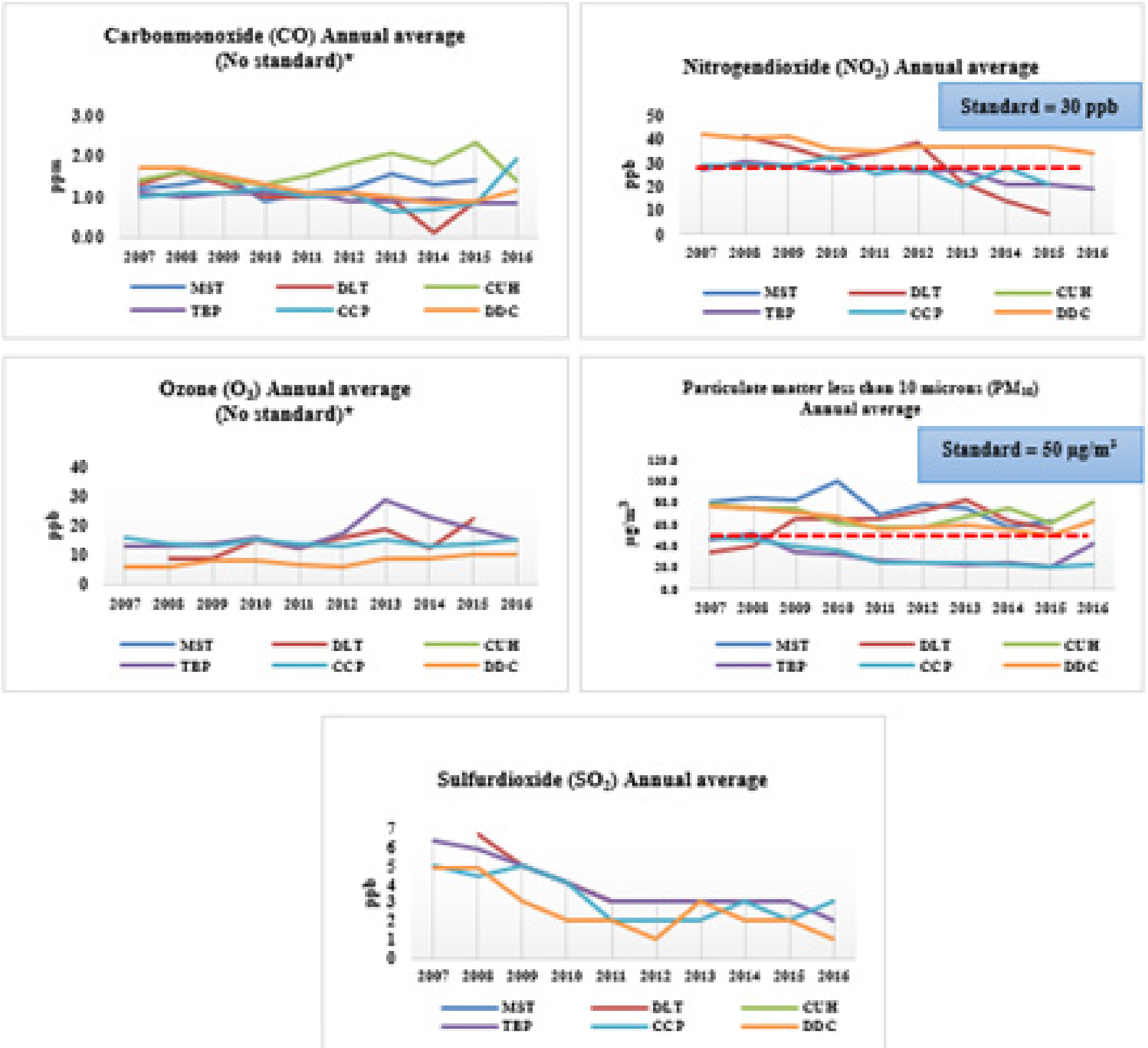

Figure 4. Average Annual Concentrations from Measuring Stations Along Road Curbs in Bangkok Divided by Monitored Parameters between 2007-2016

2. Correlation

The correlation between various parameters as shown in Figure 4 revealed that the primary pollutants tended to have positive relation such as nitrogendioxide with carbonmonoxide, nitrogendioxide with sulfurdioxide, and carbonmonoxide with PM_{10} etc. as the primary pollutants were usually from the same sources. As ozone was the secondary pollutant, positive correlation with other parameters could not be observed, consistent with the study of Thanikan Lapapipatt, 2006 was conducted to find the present and past amount of concentration of ozone at the ground level from human activities in Bangkok and to find the relation between ozone with substrates and meteorological factors such as pressure, amount of rainfall, relative humidity, and sun radiation. Information was compiled for 5 years between 1999-2005 from the total of 11 air quality measuring stations from various parts in Bangkok, divided into 3 types of stations namely 3 stations along road curbs, 5 stations in urban areas, and 3 stations in suburban areas. It was found that the occurrence of ozone was in high relation with sun radiation.

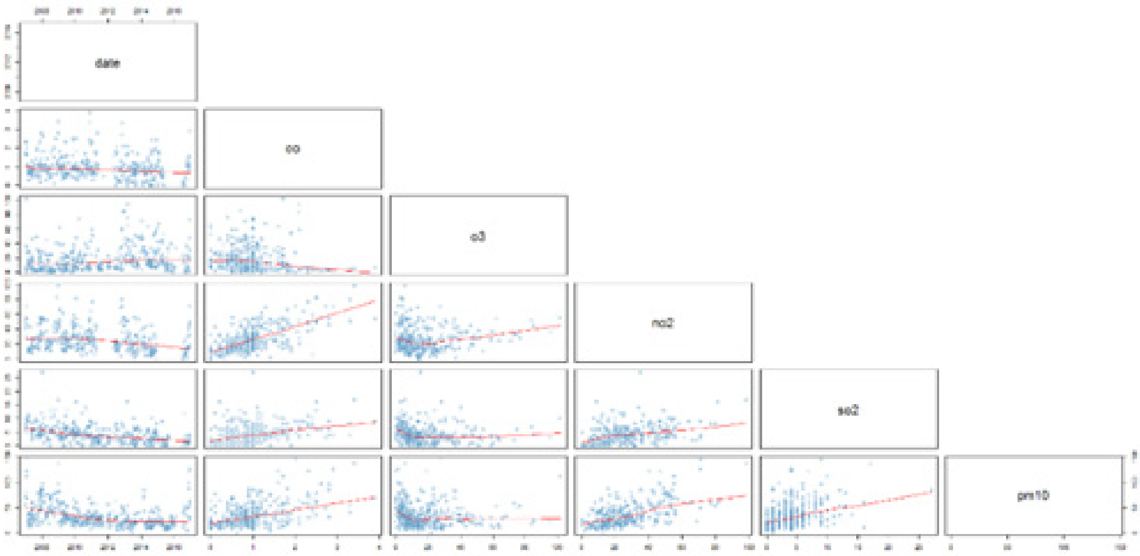

Figure 5. Relation between Various Parameters from Data Random Sampling of 500 Hours from TPB

3. Air pollution Changes According to Different Time from Data

3.1 Seasonal change. The analysis of air quality data air pollution changes road curbs in Bangkok for the past 10 years revealed that sulfur dioxide, nitrogen dioxide, and carbonmonoxide had high concentration in the winter of each year, especially PM_{10} as we found the air pollution episode with higher concentration exceeding the standards many times, notably in winter every year, between November-February. Due to the dry weather in winter, relative humidity would decrease, resulting in longer resident time hanging of dust in the air. Moreover, calm weather and inverse atmospheric inversion near the ground would cause air pollutants to accumulate in a large amount. In rainy seasons, between May-September, all types of air pollutants tend to be lower than the air quality standard as rainfall would increase relative humidity in the air and cleanse pollutants in the atmosphere as well.

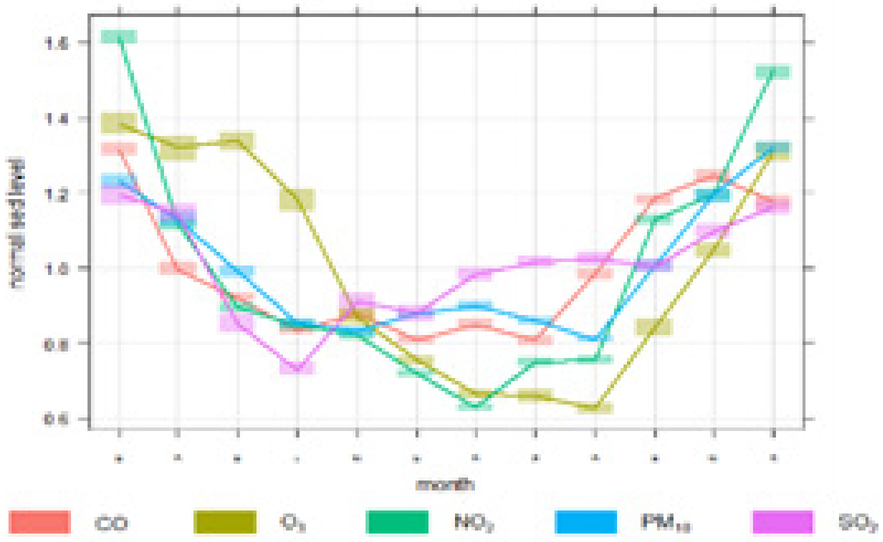

Figure 6. Results of Monthly Air Quality Measuring from TPB between 2007-2

3.2 Diurnal change. Diurnal validation in air pollution is show in Figure 6. The pollution emission of primary pollutants such as sulfurdioxide, nitrogendioxide, carbonmonoxide and PM_{10} would have the highest concentration in the morning, gradually decreasing in the afternoon, and then increasing again in the evening and into the night, mainly depending on the congestion of traffic. Ozone had the highest concentration in the afternoon as form Photochemical reaction.

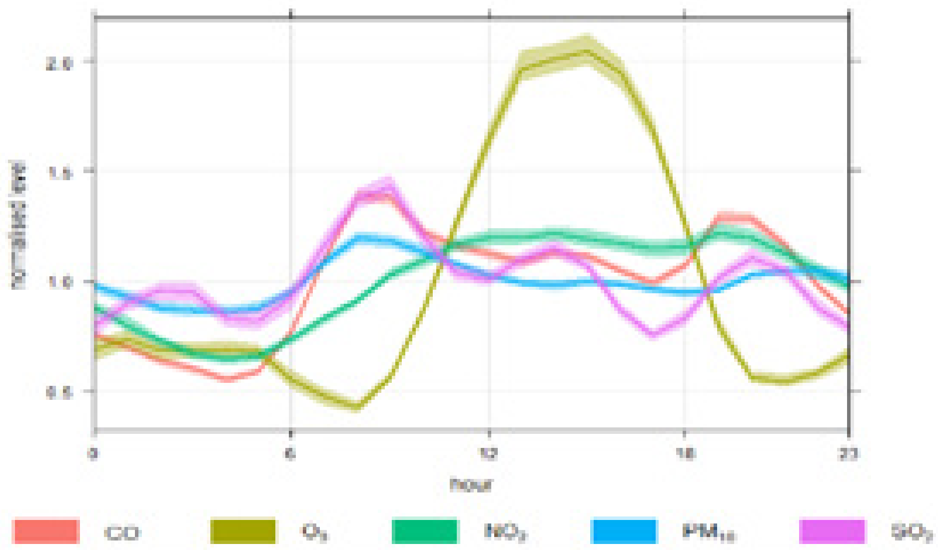

Figure 7. Results of Hourly Air Quality Measuring from DLT between 2007-2016

3.3 Weekend-Weekday change. From Figure 7, it can be seen that, in each day, the concentration of each type of pollutant was different: sulfurdioxide, nitrogendioxide, carbonmonoxide and PM_{10} were the lowest on Sundays (weekly holidays) and highest during weekday deference depending on the pollutant however ozone was clearly the highest on Sundays and the lowest on Wednesdays and Thursdays as ozone was the secondary pollutant derived from the reaction between primary pollutants from the study of Brechler (2000) found the highest concentration of primary pollutants at mid-week and revealed that the amount of nitrogenoxide would increase if the amount of traffic increased consistent with the study of Mäkelä, Kanner, and Laurikko (1996) the emission of pollution from traffic would depend of the concentration of the amount of traffic and car speed especially nitrogenoxide and nitrogendioxide would continuously increase when car speed increased from 40-120 kms/hr. Pollution Control Department, 2000 are found relation of road pollution which revealed that the speed of each type of car would impact the emission rate of carbonmonoxide and oxide of nitrogen in the form of nitrogendioxide. The emission rate of carbonmonoxide was high when a car ran at low speed. In the case of oxide of nitrogen in the form of nitrogendioxide, the emission rate would gradually increase in line with the increased speed. But once constant speed was reached, the emission rate would increase as a result of the temperature in combustion and the amount of air with nitrogen as compound during combustion.

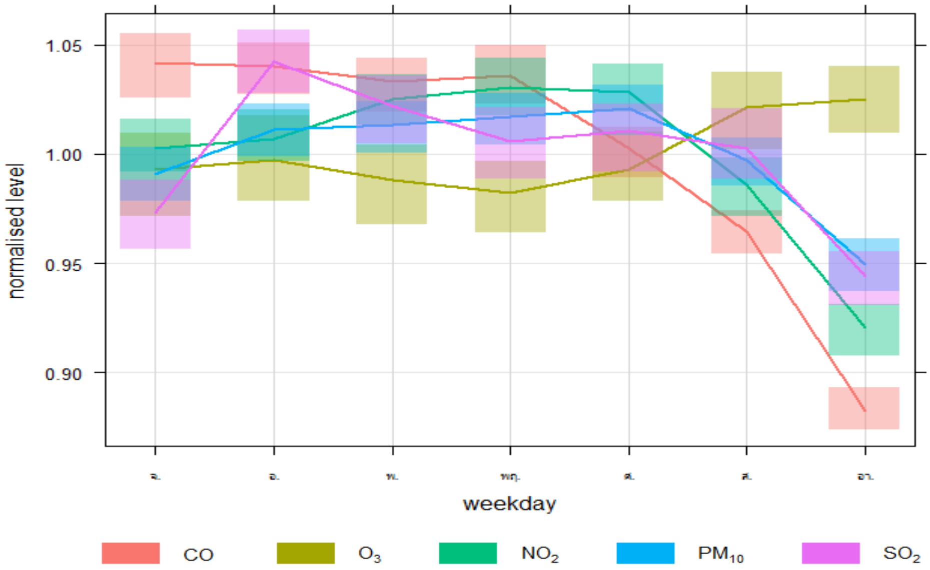

Figure 8. Results of Weekly Air Quality Monitoring from TPB between 2007-2016

4. Other Meteorological Factors

The comparison of the wind direction of the 6 air quality measuring stations along road curbs in Bangkok revealed that mostly wind came from the north (N) or southwest (SW) except at DDC station on Din Daeng Road where the wind came from south southwest (SSW) as shown in Figure 8. The study of the relation between air pollution and wind speed revealed that in calm wind, there would be fluctuations of wind causing directness movement of wind and uncertainty, further causing bad diffusion of air pollution and accumulation of air pollution. Therefore, the concentration of such condition was high, causing seriousness and high health risks. The risk of the emitted it's not found that substances tend to increase when the wind speed subsided (Deaves & Lines, 1998). Generally, low wind speed or calm wind occurred in tropical zones at night (Sharan, Yadav, & Singh, 1995) with clear skies and stable weather. Sometimes, it could be found early in the morning. The case of calm wind in the afternoon would occur in the center of a wide space with high air pressure in winter or summer (Smith, 1992). Therefore, when air pollution was released from its sources, wind direction would influence the movement direction of air pollution and the diffused areas of air pollution. It would determine the direction of the diffusions of air pollution as wind did not move in the same direction all the time and was quite unstable. The average of wind direction was important to consider the area that might receive air pollution from sources as it determined the movement direction of plume (Bouble, Fox, Turner, & Sterm, 1994). Wind speed was therefore yet another important factor for the diffusion of the emitted air pollution from sources similarly to wind direction. Air pollution would be diluted by higher wind speed and longer distance from the source. The impact of wind speed came from horizontal air pressure and differences of temperature (differences of high air pressure, higher wind speed). Generally, wind speed would increase at be high of approximately 200-300 meters near the earth surface as about the ground friction which would decrease wind speed near the ground. The differences of pollution in each station might result from the differences in local meteorological factors. Urban topography characteristic in each area in differences the amount of pollution concentration in the same city, In the case of relatively low wind speed, PM_{10} would be blown from high to low concentration (high accumulation), as well as the factors of traffics that were not equal as shown in Table 2

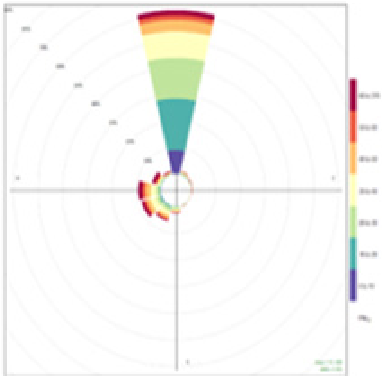

Figure 9 (A) Shows Wind Direction Impacting PM_{10} at CCP

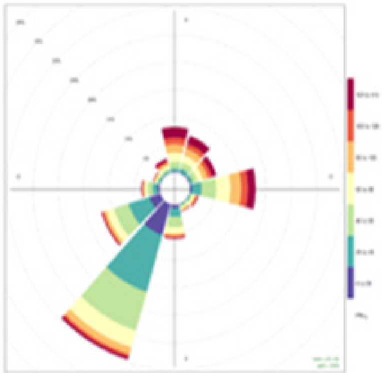

Figure 9 (B) Shows Wind Direction Impacting PM_{10} at DDC

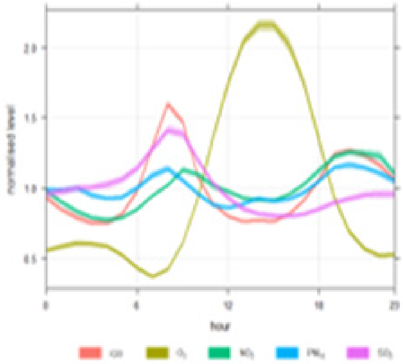

Figure 9 (C) Results of Hourly Air Quality Measuring from TBP

Figure 9. Shows Wind Direction Impacting and Results of Hourly Air Quality Measuring

Table 2 Statistics of The Amount of Traffic in Bangkok between 2008-2016 Nearby Monitoring Stations

Stations	Roads	Intersections/Surveyed Locations	Surveyed Years								
			2008	2009	2010	2011	2012	2013	2014	2015	2016
MST	Phaya Thaiw	Victory Monument	35,603	37,486	***	37,516	33,788	***	39,058	***	28,610
		Phaya Thai	41,287	39,575	36,264	37,190	38,927	***	38,790	***	36,401
		Tuek Chai	43,785	51,991	51,970	43,371	42,581	***	43,540	***	39,188
		Si Ayutthaya	47,435	42,258	37,961	41,598	***	***	39,938	***	46,132
DLT	Phahon Yothin	Ha Yaek Ladprao	***	70,834	***	***	87,076	***	***	83,957	***
		Kamphaeng Phet	71,885	70,192	75,407	68,649	67,785	70,676	62,774	60,237	***
		Saphan Khwai	34,142	34,357	34,890	33,404	34,713	33,360	31,935	***	29,471
CUH	Rama 4	Henri Dunant	52,566	52,691	***	53,660	***	***	40,809	47,384	***
		Rama 4	***	***	40,202	***	36,436	31,673	37,510	***	36,884
		Rajdamri	***	29,337	***	23,510	28,945	28,697	***	28,814	***
TPB	Intarapi-tak-Petch-kasem	Bang Yi Ruea	42,349	***	***	39,228	***	38,760	***	30,785	***
CCP	Ladprao	Chok Chai 4	46,127	44,835	***	47,220	48,710	49,780	50,241	***	43,211
		Pawana	56,796	51,130	57,106	55,751	53,485	61,643	***	52,944	***
DDC	Asoke Din Daeng	Din Daeng intersection	83,905	77,569	76,570	76,074	78,789	72,016	***	67,082	***
		Pracha Songkhro	67,032	60,621	61,550	59,323	62,756	***	54,202	***	56,763

5. Relation between the Amount of Annual Traffic and Concentration of Pollutants

Table 2 to show the static of correlation between the pollution concentration as shown in Table 3 revealed that nitrogen dioxide has sulfurdioxide and PM_{10} have positive relation with the amount of traffic some monitoring station, however carbonmonoxide and ozone were found depending on the station as it was a primary pollutant derived from the direct fuel combustion in cars. At the same time, it revealed that ozone has negative correlation with the amount of traffic as it was a secondary pollutant derived from the Photochemical Oxidation between oxide of nitrogen (NO_x) and hydrocarbons (HC) in the atmosphere with sunlight as catalyst. Other pollutants such as sulfurdioxide, carbonmonoxide and PM_{10} had inconsistent correlation with the amount of traffic whereby positive, negative or no correlation were found as shown in Figure 9. However, it must be noted that this analysis was limited by the data the amount of traffic at the annual level only, the locations of monitoring station and traffic amount which were not the same. The researcher used the data of the areas nearest to the air quality measuring stations for analysis.

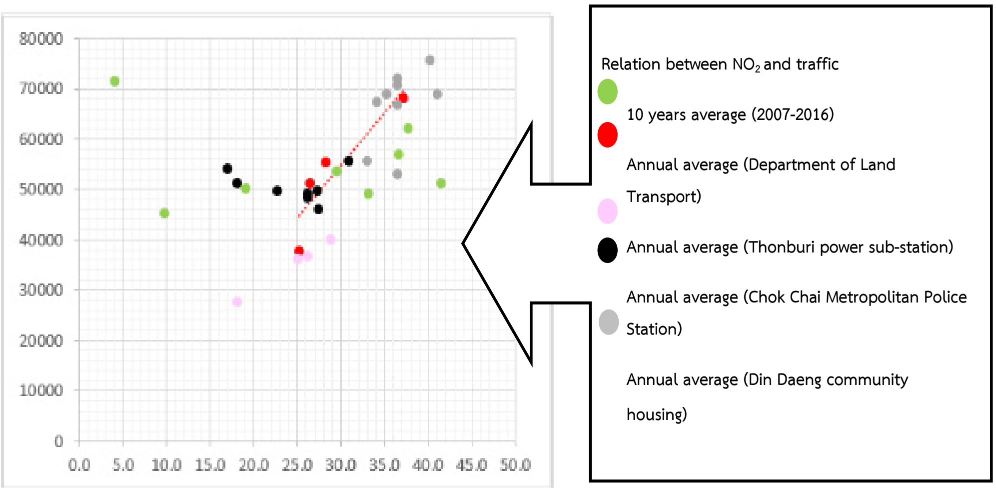

Figure 10. Relation between NO_2 and Traffic

Table 3. Relation between Concentration of Pollutants and Traffic

	Relation between Concentration of Pollutants and Traffic					
	Stations	SO_2	NO_2	CO	O_3	PM_{10}
1	MST	-	-	NR	-	Positive
2	DLT	NR	NR	NR	Positive	NR
3	CUH	-	-	NR	-	NR
4	TPB	Positive	Positive	Positive	NR	Positive
5	CCP	NR	NR	Negative	NR	NR
6	DDC	Positive	Positive	Positive	Negative	Positive
7	All Station	NR	Positive	NR	Negative	NR

NR means No Relation

- means No Data

Research Conclusions

Based on the study findings of the trend of air pollution in the areas of congested traffic for the past 10 years, it revealed that, in most air quality measuring stations, sulfurdioxide and nitrogendioxide tended to decrease whereas carbonmonoxide, ozone, and PM10 tended to be different depending on stations. The primary pollutants tended to have positive relation. Ozone which was the secondary pollutant could not see the positive relation with other parameters. PM10 attended to increase, exceeding standards, in winter of every year. In winter, the weather was dry and the relative humidity decreased, resulting in longer lingering of dust in the air. Calm weather or temperature inversion near the ground resulted in a large amount of accumulated air pollutants. The emission of primary pollutants revealed that they would have the highest concentration in the morning and gradually decreasing until the evening, mainly depending on congestion of traffic. Ozone had the highest concentration in the afternoon as the variables impacting the amount of highest daily concentration of ozone was sun radiation. Every week and every day, concentration of air pollution was high at each time of congested traffic. Positive relation was found between nitrogendioxide and amount of traffic as nitrogendioxide came from direct fuel combustion in cars. At the same time, negative relation was found between ozone and the amount of secondary pollutants derived from Photochemical Oxidation. Conclusion could be reached that the main pollutants found around road curbs in Bangkok were primary pollutants directly emitted from the sources.

Discussion of Results and Recommendations

1. The activity data of emission inventory for on-road transport sector in this study were investigated based on the literature review and secondary data of vehicles. Thus, the primary data should be conducted to implement the upgrading activity data for on-road transport in Bangkok annually. For instance, the vehicle kilometer travelled can be monitored by observing the number of vehicle and the fleet of vehicles running on the specific road to identify the real activities of vehicle in the specific time.

2. The meteorological parameters in this study were collected from the Thai Meteorological Department (TMD) stations simply. As the PM_{10} concentration is highly related to the local meteorological conditions.

3. In this study, the researcher did not use current data due to the research period being between 2013-2014. The data analysis was divided into two timeframes: the past 10 years (2007-2016) to explore air pollution trends in Bangkok, and the period from 2018-2020 for analyzing air pollution patterns in the city. These timeframes have some limitations concerning $PM_{2.5}$ data, such as the number of air quality monitoring stations in Bangkok under the supervision of the Pollution Control Department, and the fact that the city does not yet encompass all 50 districts.

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