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Assessment of Ambient Air Quality in Terms of $PM_{2.5}$ and PM_{10} at Batangas Port Phase I

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Abstract

Air is one of the most essential compositions of Earth. It is a mixture of invisible gases such as nitrogen and oxygen that freely travels in the atmosphere. In addition, with these gases, air also contains dust particles, pollen grains, bacteria, ashes, soot, and some other fine particles. Air has no definite shape or volume nor color and smell. A good quality of air is needed to keep humans, animals and even plants alive. Atmospheric dust from natural sources are innately present in the atmosphere including those from volcanoes, smoke, ash from fires and pollens from plants and even meteorite dust that enters the Earth upper layer of atmosphere are rarely harmful and partly beneficial. Air pollution is said to be one of the serious problem in the world today. Particulate matter is a composition of air pollution that triggers not just the natural environment but even human's health. It is classified as course particles and fine particles. Fine 2.5µm particulate matter ($PM_{2.5}$) is a type of air pollutant that can harm human health when presence in air is very high. When in open air, fine particles can be found primarily from truck, bus and off-road vehicle (e.g., construction equipment, snowmobile, locomotive) exhausts, and other operations that involve the burning of fuels such as wood, heating oil or coal and natural sources such as forest and grass fires. Particulate matters that pass in the $PM_{2.5}$ can travel into the respiratory tract, reaching the lungs. When exposed to fine particles it can cause short term illness such as nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. It can also affect lung condition and worse medical conditions like asthma and heart disease. Scientific studies show that daily exposure to $PM_{2.5}$ increases respiratory and cardiovascular hospital admissions. Coarse particulate matter (PM_{10}) are inhalable particles, with diameters that are generally 10 micrometers and smaller. Particles in this size range make up a large proportion of dust that can be drawn deep into the lungs. Larger particles tend to be trapped in the nose, mouth or throat.

Introduction

Air is most abundant element contained by Earth. It is composed of 78.09% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide, and small amounts of other gases. Some small amounts of other gases contain dust particles, pollen grains, bacteria, ashes, and some fine particles. One of the major problems still experienced today is air pollution. Pollution in air makes it harmful to the health of the public. It is regained by volcanic eruptions, wind erosion, pollen dispersal, emissions from industries and manufacturing activities and burning fossil fuels. Air Quality issues are extremely important for both occupational and environmental health. In port cities and coastal areas, many sources of air pollution can be found. Only little is known about the magnitude and effects of air pollution due to marine vessels. According to WHO (2013), outdoor air pollution is carcinogenic to human. Findings from the Global Burden of Diseases, Injuries and Risk Factors Study (2010) shows that air pollution is a major health risk factor. Ports have long been gateways for global trade and are critical to economies around the world; they are also a contributor of major air pollution in the world. Shipping vessels have an engine that runs heavy fuel oil. Heavy fuel oil is much cheaper than the petrol used in land transport.

The sulfur dioxide (SO_2) content of Heavy Fuel Oil is 2700 times higher than the road fuel. In addition, ports contain a vast array of diesel powered machinery: straddle carriers, terminal tractors and, reach lifters. Diesel powered engines result in elevated emission of various pollutants. This pollution causes an array of environmental impacts that can seriously affect the health of workers, and passengers, and it contributes significantly to regional air pollution. Major air pollutants generated by port activities include carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM). The health effects of prolonged exposure to these compounds include respiratory diseases, cardiovascular disease, lung cancer and premature death. Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets that get into the air. Some particles, such as dirt, dust, soot, or smoke, are large or dark enough to be seen with the naked eye. Once inhaled, these particles can affect the heart and lungs and may cause serious health effects. In Europe, sulfate and organic matter are the main components of particulate matter. On days when the level of particulate matter in air are high (PM_{10} exceeds 50 μg/m^3), nitrate is also major component of PM_{10} and $PM_{2.5}$.

Objectives of the Study

This study aims to assess the ambient air quality of the Batangas Port Phase I handled by the Asian Terminals Incorporated – Batangas.Furthermore, the following objectives are to be achieved:

a. Determine the concentration of Particulate Matter 10μm (PM_{10}) and Particulate Matter 2.5μm ($PM_{2.5}$) at the Batangas Port Phase I.

b. Determine the correlation of the concentration of particulate matter with the following:

i. Populace in the area

ii. Traffic volume

iii. Wind speed

iv. Humidity

c. Assess the air quality compliance with that of the WHO, USEPA and DAO standards.

Significance of the Study

This will be information to know about the air quality with regards to $PM_{2.5}$ and PM_{10} concentration within the Port area and for them to know what actions or preventions should be taken to maintain or improve the present air quality in the area. For future researchers to have an awareness on the air quality of the port area and what are the best actions or improvements should be undergo to secure the health of their passengers and employees that are exposed to this kind of air quality in Port area.

Conceptual Framework

The conceptual framework of the study on the assessment of air quality in Batangas City Port Phase I. The input will be the determination of Site characteristics and site development plan on the proposed location of the study. Process includes ocular inspection for sampling stations, air sampling, comparison to WHO, USEPA, and DENR standards, and statistical analysis of the results obtained. The output of the study will be Ambient Air Quality concentration of PM2.5 and PM10. , then the correlation of concentration with the selected factors, lastly, the compliance of the acquired concentration to WHO, USEPA and DENR. Standards.

Scope and Delimitation

This study will investigate the concentration of particulate matter 10μm (PM_{10}) and particulate matter 2.5μm ($PM_{2.5}$) which are major components of air pollution that could threaten both health and environment. The study was conducted at the Phase I of Batangas City Port. The air sampling was done in four (4) days from October 31 to November 3, 2017 with 20 minutes sampling per hour for twelve hours per day. The instrument used for the study was a handheld particle counter, the Aerotrak Handheld Particle Counter 9306-V2. This study only covers the PM10 and PM2.5 outside concentration of the area of Batangas Port Phase I and does not include the restricted areas of the port.

Conceptual Literature

Particulate Matter

Particulate Matter is a mixture of solid particles and liquid droplets found in the air. Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Particles less than 10 micrometers in diameter pose the greatest problems, they can get deep into your lungs, and some may even get into your bloodstream. Fine particles ($PM_{2.5}$) are the main cause of reduced visibility. These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles from in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles.

Exposure over both the short term (hours, days) and long term (months, years) include respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions, mortality for cardiovascular and respiratory diseases and from lung cancer. All cause daily mortality is estimated to increases by 0.2-0.6% per 10μg/$m^3$of PM_{10}. Long term exposures to $PM_{2.5}$ are associated with an increase in the long term risk of cardiopulmonary mortality by 6-3% per 10μg/$m^3$of $PM_{2.5}$. The chemical properties vary depending on sources of particles. It is important to note that particulates are not one particular chemical substance but a classification of particles by size rather then chemical properties. Figure 1 shows the comparison $PM_{2.5}$ and PM_{10} to human hair and fine beach sand.

Coarse Particulate Matter (PM_{10}): Coarse particulate matter (PM_{10}) are inhalable particles, with diameters that are generally 10 micrometers and smaller. Particles in this size range make up a large proportion of dust that can be drawn deep into the lungs. Larger particles tend to be trapped in the nose, mouth or throat (Figure 1).

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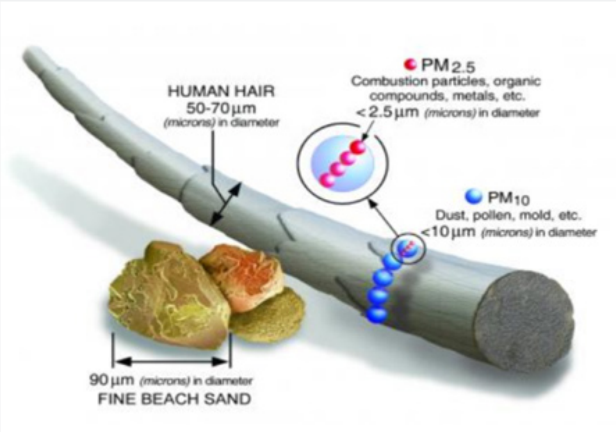

Figure 1: Human Hair size and Fine beach sand comparison to the size of PM 10µm and PM 2.5µm.

Fine Particulate Matter ($PM_{2.5}$): Fine particulate matter ($PM_{2.5}$) is an air pollutant that is a concern for people's health when levels in air are high. $PM_{2.5}$ are tiny particles in the air that reduce visibility and cause the air to appear hazy when levels are elevated. Outdoor $PM_{2.5}$ levels are most likely to be elevated on days with little or no wind or air mixing. $PM_{2.5}$ refers to the tiny particles or droplets in the air that are two and a half microns or less in size. Particles in the $PM_{2.5}$ size range are able to travel deeply into the respiratory tract, reaching the lungs. Exposure to fine particles can cause short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. Exposure to fine particles can also affect lung function and worsen medical conditions such as asthma and heart disease. Scientific studies have linked increases in daily $PM_{2.5}$ exposure with increased respiratory and cardiovascular hospital admissions, emergency department visits and deaths.

Shipping Port/Sea Port

A port can be defined as a harbor or an area that is able to provide shelter to numerous boats and vessels, and can also allow constant or periodic transaction of shipment. The port can be a natural establishment or an artificial construction, which provides a place for the loading and unloading of cargo. Sea ports are the most common types of ports around the world which are used for commercial shipping activities. These ports are built on a sea location and enable the accommodation of both small and large vessels. Numerous seaports are situated along the coastline and actively handle the ongoing cargo transactions.

Related Readings

Republic Act 8749: Also known as "Philippine Clean Air Act of 1999." An act that provides quality framework for the country's air quality management program. This act aims to uphold the rights of every citizen to breathe clean air by addressing the air pollution from stationary and mobile sources.

DENR Administrative Order 2000–81 and 2013–13: DAO 2000-81 is known as the "Implementing Rules and Regulation of the Philippine Clean Air Act of 1999." Its purpose is to provide guidelines on the operationalization of RA 8749. This administrative order provides the guideline values for coarse particulate matter (PM_{10}) and other pollutants aside from fine particulate matter ($PM_{2.5}$). DAO 2013-13 is another administrative order released by DENR to provide a provisional guideline value for fine particulate matter ($PM_{2.5}$) for the evaluation of outdoor air quality in a surrounding area.

US Environmental Protection Agency Standard for Particulate Matter: The Clean Air Act of the US, which was last amended in 1990, required the EPA to set standards for pollutants which are considered harmful to public health and environment. Those standards are known as the NAAQS or National Ambient Air Quality Standards. There are also two types of national ambient air quality standards as identified by the Clean Air act: Primary and Secondary standards. Primary standards provide public health protection while Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animal, crops, vegetation, and buildings. The Tables 1 & 2 below states the standards given by the USEPA.

Table 1: USEPA Standard for Particulate Matter in 24-hr concentrations.

Pollutant		Primary/ Secondary	Averaging Time	Level
Particle Pollution (PM)	$PM_{2.5}$	primary and secondary	24 hours	35 µg/m3
	PM_{10}	primary and secondary	24 hours	150 µg/m3

Table below shows the standards for $PM_{2.5}$ and PM_{10} set by WHO.

Table 2: WHO Standard for Particulate Matter in 24-hr concentrations.

	PM10 ($\mu g/m^3$)	PM2.5 ($\mu g/m^3$)	Basis for the selected level
Air quality guideline(AQG)	50	25	Based on relationship between 24-hour and annual PM levels

Foreign Literature

The study of Bathmanabhan, et. al (2010) entitled "Analysis and interpretation of particulate matter - PM10, PM2.5 and PM1 emissions from the heterogeneous traffic near an urban roadway" conducted an analysis and interpretation of the daily, weekly and seasonal cycles of particulate matter (PM_{10}, $PM_{2.5}$, and PM_1) concentrations in a roadway located in Chennai city, India within a 1 hour average. According to the study, the daily highest concentrations of particulate matter were observed during

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the peak traffic hours while the light traffic hours showed the lowest concentrations. The seasonal analysis showed that higher concentrations were observed in the post monsoon season with results of PM_{10} = 189 µg/m³ $PM_{2.5}$ = 84 µg/m³ PM_1 = 66 µg/m³ compared to results obtained during winter season (PM_{10} = 135 µg/m³ $PM_{2.5}$ = 73 µg/m³ PM_1 = 59 µg/m³) and summer season (PM_{10} = 102 µg/m³ $PM_{2.5}$ = 50 µg/m³ PM_1 = 34 µg/m³). A study done by Pandolfi, et al. (2011) entitled "Source apportionment of PM_{10} and $PM_{2.5}$ at multiple sites at the strait of Gibraltar by PMF: impact of shipping emissions" done in 2010 studied the effect of shipping emissions on surrounding urban settlements of major ports and vessel routes. The study was done in a multi-year data collection of PM_{10} and $PM_{2.5}$ at four sampling locations located around the Bay of Algericas and positive factorization matrix which is used to identify major PM sources with particular attention paid to the qualification of total shipping emissions. It was found that the direct contribution from shipping in the Bay of Algericas was estimated at 1.4–2.6µg PM_{10}/m³ (3-7%) and 1.2–2.3µg $PM_{2.5}$/m³ (5-10%). The study of Polla Mattiot, et al. (1999) entitled " The effect of rain on suspended particulate matter and other pollutants in an urban area" done in 1999 focused on the effects of rain on atmospheric pollutants in the city of Rome from 1994 to 1996 by using the data from government monitoring stations situated in different parts of the city. It is found that abatement in the three years is about 10% and that in a single event of heavily rainy days showed a 50% reduction on the hourly concentration. Particulate matter, CO and NOx concentrations were correlated to precipitation using working days and low wind speed conditions.

Local Literature

The study of Claveria, et al. (1998) entitled "Quantitative Determination of Selected Air Pollutants in Ambient Air in Agricultural and Industrial Areas of Batangas City" focused on the air quality agricultural and industrial areas in Batangas City during the time of its growth and development and was at an accelerating point of trading, commercial and industrial activities in the locality. The study determined the concentrations of selected air pollutants namely, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), total suspended particulates (TSP), and lead (Pb), in Batangas City among the stations located along the agricultural areas and industrial areas. The air quality was evaluated by comparing it with the limits or standards set by the DENR. Air sampling was done from three (3) different stations in agricultural areas and four (4) different stations in industrial areas. Sampling was done from August 1997 to November 1997 between the time ranges of 6:30 AM to 6:30 PM. Analysis was done at the Environmental Fuel Laboratory of NPC – Batangas Coal-Fired Thermal Power Plant located in Calaca, Batangas. With the results of the study, it was concluded that the concentration of SO_2, NO_2, and TSP in both agricultural and industrial areas fall within the set limit of the DENR while the lead concentration exceeded that of the standard.

Another study done by Ilagan, et. al. (2013) entitled " Ambient Air Quality Analysis of Selected Areas in Lipa City" assessed the ambient air quality of selected areas of Lipa City in terms of total suspended particulates (TSP),sulfur dioxide (SO_2), carbon monoxide (CO), lead (Pb), and nitrogen dioxide (NO_2). The study was conducted at three (3) sampling points known as the "Hotspot environments" namely, Highway Bugtong na Pulo, Marauoy and Balintawak. Factors considered was the population density in the area, number and type of vehicle, and number and type of industrial establishments per location. The ambient air quality was compared to the air quality standards set by the Department of Natural Resources (DENR). Sampling was done from January 15 to January 16, 2013 with a one (1) hour sampling time done three (3) times per day; morning (5am – 6am), noontime (12pm – 1pm), and afternoon (5pm – 6pm). The methods of sampling used were the TE-5000 High-volume Air Sampler for TSP and Pb, SKC Handy Sampler for SO_2 and NO_2, and Bacharach CO meter for CO. It was found that the ambient air quality in Lipa city can be affected by population density, number of vehicles and number of establishments located in the area. It was also determined that the air quality can still be considered of god quality in terms of SO_2, NO_2, Pb and CO except for TSP which exceeded the standards set by the DENR.

A study conducted by De Jesus, Tuiza, and Yabyabin (2017) entitled "Investigation of $PM_{2.5}$Concentration in Batangas State University Main Campus" focused on the concentration of PM2.5 at Batangas State University Main Campus during the time of construction and renovation of the campus. They monitored the effects and correlation of PM concentrations to the number of pedestrians, temperature, humidity, and traffic volume in the said area. The study was conducted by setting five (5) sampling points in the area and collecting air samples for five (5) days. The results obtained from the five (5) sampling points in average concentration are as follows: 70µg/m³, 80 µg/m³, 30 µg/m³, 30 µg/m³, 30µg/m³, respectively. It was found that the concentrations obtained from the station points did not conform to the standards.

Synthesis

The study of Claveria, et. al. was done in the agricultural and industrial areas of Batangas City and with the parameters of SO_2, NO_2, TSP and lead while the current study was done in the coastal area of Batangas City and only particulate matters size 2.5µg and 10µg in consideration for the ambient air quality classification. The current study uses the photometric method or light scattering method in the detection of particulate matter concentration in contrast to the study which used the gravimetric method for the analysis of concentration. The study of Claveria, et. al. and the current study was both done in the same time of 6:30 AM to 6:30 PM except this study was done in a much shorter timeframe of four (4) days. The study of Ilagan, et al. assessed the air quality in terms of TSP, CO, SO_2, NO_2, and lead while the current study assessed the air quality in terms of PM10 and PM2.5 only. Ilagan's, et. al. study was done in an urban area of Lipa City with a sampling done three (3) times per day for two (2) days while this study was done in the coastal area of Batangas City with the sampling done from 6:30 AM to 6:30 PM for four (4) days. The study of Ilagan, et al. and Claveria, et al. both used the gravimetric method of analysis for TSP. The study conducted by De Jesus, Tuiza and Yabyabin focused on the concentration of $PM_{2.5}$ and its effects and correlation with

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the number of pedestrians, temperature, humidity, and traffic volume at Batangas State University Main Campus with five (5) sampling stations and a sampling time of 15 minutes per hour in the time of 6 am to 6 pm while the current study added another particle size in consideration and was done at four (4) sampling points with a 30 minute sampling time per hour from 6:30 am to 6:30 pm. The considered factors for correlation in the current study were the population in the area, traffic volume, wind speed and humidity.

Research Design

The study uses quantitative method to obtain data related to air quality at Batangas Port Phase I as it requires data collection and analysis method, objectives, possible outcomes, actions, and time concern (Figure 2).

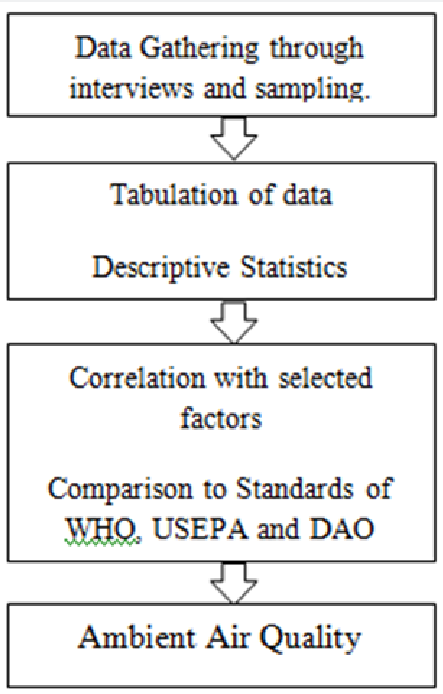

Figure 2: Research Process Diagram.

Sampling Period

The researchers collected the samples last October 31, 2017 to November 3, 2017. The sampling was started from 6:30 a.m. to 6:30 p.m. with twenty minutes (20mins.) running time each hour.

Sampling Method

Photometric method was used for the analysis of data. Photometer was already installed in the instrument, Aerotrak Handheld Particle Counter Model 9306-V2, which was used in the study. It shows the intensity of a beam of light once it passes through the paper, and the fall in the intensity is the degree of dust concentration.

Statistical Treatment of Data

The data determined at four (4) sampling stations were compared with the standards of WHO for health standard and, DAO and USEPA for environmental standards of $PM_{2.5}$and PM_{10}. Using Pearson's formula for correlation with the aid of Microsoft Excel software, the datawas correlated to temperature, humidity, pedestrians, vehicle count and wind speed to determine the relationship of the following variables to the concentration of $PM_{2.5}$ and PM_{10}. The Pearson formula for computing correlation, where r is the range of correlation, x represents the concentration, y as the variables and n is the number of hours.

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2) - (\sum x)^2][(\sum y^2 - (y)^2]}}$$

The Table 3 below shows the verbal interpretation of the computed range (r) including the behavior through signs.

Table 3.

Interpretation of "r"	
Coefficients	**Verbal Interpretations**
Exactly -1.00	A perfect downhill (negative) linear relationship
-0.7	A strong downhill (negative) linear relationship
-0.5	A moderate downhill (negative) linear relationship
-0.3	A weak downhill (negative) linear relationship
0	No Linear Relationship
0.3	A weak uphill (positive) linear relationship
0.5	A moderate uphill (positive) linear relationship
0.7	A strong uphill (positive) linear relationship
Exactly +1.00	A perfect uphill (positive) linear relationship

Sampling Location

The researchers set four (4) sampling stations for air monitoring comprising the coordinates and some description of locations. USEPA guidelines were used for locating sample stations which states that the monitoring should be done at outside zone of influence of sources located within the designated area of representation for the monitoring location and at a suitable distance from any direct pollution source including traffic and pedestrians. The stations were as follows (Figure 3):

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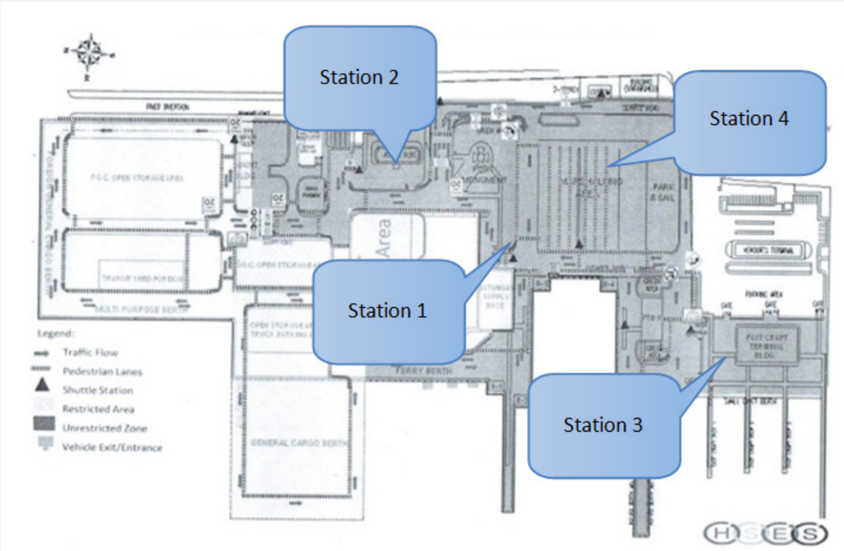

Figure 3: Batangas Port Phase 1 showing the four (4) sampling station.

Station 1

Description: Entrance of Batangas Supply Base

Coordinates: 13°45'17.25713'' N, 121°02'32.94864''E

Traffic Data Point Source: Entrance point going to parking and inspection area

Station 2

Description: Old Admin Building

Coordinates: 13°25'22.57744'' N, 121°02'32.628844'' E

Traffic Data Point Source: Entrance/Exit point going to Terminal 2 and inspection area

Station 3

Description: Fast Craft Terminal

Coordinates: 13°45'8.34412" N, 121°02'34.37766" E

Traffic Data Point Source: Entrance/Exit point at Terminal 3

Station 4

Description: Marshalling Area

Coordinates: 13°45'15.25964" N, 121°02'37.23422" E

Traffic Data Point Source: Parking Area

Presentation, Analysis and Interpretation of Data

Mean Concentration of PM 2.5 and Standard

Figure 4 shows the concentration of $PM_{2.5}$ present on the sampling stations at Batangas Port Phase I including the standards set by the WHO, USEPA and DENR in concentrations of μg/m³. A 36μg/m³mean concentration was acquired at sampling station 1 located at the entrance of Batangas Supply Base, a mean concentration of 20μg/m³ were determined at sampling stations 2 and 3 located at old administration building and Fast craft terminal, and at sampling station 4 which is located at marshalling area, a mean concentration of 47μg/m³ was determined. Standard concentration set by WHO standard was 25μg/m³, USEPA standard with 35μg/m³ and DENR standard with 50 μg/m³is given for the comparison with the obtained mean concentration for each station.

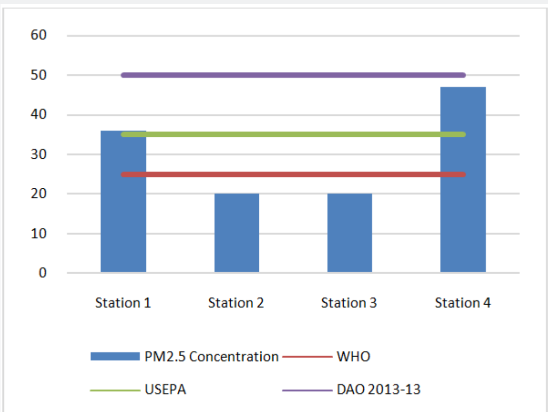

Figure 4: Mean $PM_{2.5}$ Concentrations and WHO, USEPA and DENR standards.

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Mean Concentration of PM10 and Standard

Figure 5 shows the concentration of PM_{10} present on the sampling stations at Batangas Port Phase I including the standards set by the WHO, USEPA and DENR in concentrations of µg/m³. A 12µg/m³mean concentration was determined at sampling station 1, mean concentrations of 5µg/m³and 6µg/m³were obtained at sampling station 2 and 3, respectively, and at sampling station 4, a mean concentration of 16µg/m³ was obtained. Standard concentrations set by WHO health standard was 50µg/m³, USEPA environmental standard with 150µg/m³ and DENR standard with 150 µg/m³were given for the comparison with the obtained mean concentration for each station.

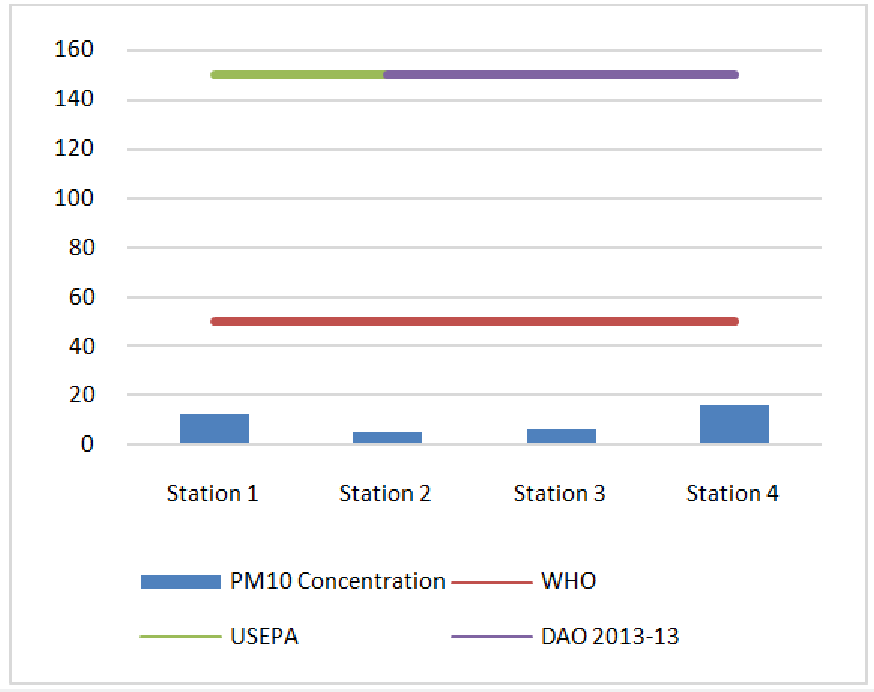

Figure 5: Mean PM_{10} Concentrations and WHO, USEPA and DENR standards.

Findings

This study was conducted for the purpose of investigating the concentration level of Particulate Matter 2.5µm and 10µm at Batangas Port Phase I. The mean level of 2.5µm and 10µm Particulate Matter acquired from October 31, 2017 to November 3, 2017 from 4 different sampling stations at Batangas Port Phase I was 31µg/m³ and10µg/m³ respectively. From Sampling Station 1 which is located near at entrance of Batangas Supply Base, the determined level of concentrations of Particulate Matter 2.5 µm was 48 µg/m³, 33 µg/m³, 33µg/m³, 33 µg/m³, 25 µg/m³, 31 µg/m³, 19 µg/m³, 39 µg/m³, 33 µg/m³, 54 µg/m³, 45 µg/m³, and 41 µg/m³ while the determined concentration of Particulate Matter 10 µm was 19 µg/m³, 12 µg/m³, 14 µg/m³, 13 µg/m³, 7 µg/m³, 10 µg/m³, 6 µg/m³, 16 µg/m³, 13 µg/m³, 18 µg/m³, 8 µg/m³, and 11 µg/m³. From 6:30am-6:30pm these levels of concentration were determined for each hour respectively. The highest level of concentration of $PM_{2.5}$ and PM_{10} were determined from 3:30pm to 4:30pmand 6:30am to 7:30am respectively and the lowest concentration was determined from 12:30pm-1:30pm for each concentration.

From Sampling Station 2 which is located near Admin Building, the determined level of concentrations of Particulate Matter 2.5µmwas25 µg/m³, 20 µg/m³, 16 µg/m³, 36 µg/m³, 18 µg/m³, 12 µg/m³, 8 µg/m³, 43 µg/m³, 15 µg/m³, 14 µg/m³, 17 µg/m³, 18 µg/m³ while the determined level of concentrations of Particulate Matter 10µm was 8 µg/m³, 6 µg/m³, 4, µg/m³ 16 µg/m³, 8 µg/m³, 2 µg/m³, 2 µg/m³, 5 µg/m³, 3 µg/m³, 3 µg/m³, 3 µg/m³, 3 µg/m³. From 6:30am-6:30pmtheselevels of concentration were determined for each hour respectively. The highest level of concentrations of $PM_{2.5}$and PM_{10} was determined from 1:30pm-2:30pm and 9:30am-10:30am respectively and the lowest was determined from 12:30pm-1:30pm and11:30am- 1:30pm respectively. From Sampling Station 3 which is located at Fastcraft Terminal, the determined level of concentrations of Particulate Matter 2.5µmwas16µg/m³, 16µg/m³, 21µg/m³, 20µg/m³, 15µg/m³, 17µg/m³, 15µg/m³, 13µg/m³, 20µg/m³, 24µg/m³, 21µg/m³and 37µg/m³while the determined level of concentrations of Particulate Matter 10µm was 3µg/m³, 4µg/m³, 4µg/m³, 5µg/m³, 5µg/m³, 6µg/m³, 4µg/m³, 5µg/m³, 7µg/m³, 10µg/m³, 7µg/m³ and 14µg/m³.From6:30am-6:30pm these levels of concentration were determined for each hour respectively. The highest level of concentrations of $PM_{2.5}$and PM_{10} was determined from 5:30pm-6:30pmand the lowest concentrations were determined from 1:30pm-2:30pmand 5:30pm-6:30pm respectively.

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From Sampling Station 4 which is located at Marshalling Area, the determined level of concentrations of Particulate Matter 2.5μmwas48μg/m^3, 35μg/m^3, 43μg/m^3, 33μg/m^3, 55μg/m^3, 41μg/m^3, 28μg/m^3, 50μg/m^3, 69μg/m^3, 35μg/m3, 60μg/m^3 and 70μg/m^{3}while the determined level of concentrations of Particulate Matter 10μm was 15μg/m^3, 11μg/m^3, 14μg/m3, 12μg/m^3, 22μg/m^3, 15μg/m^3, 9μg/m3, 14μg/m^3, 17μg/m^3, 13μg/m^3, 26μg/m^3 and 27μg/m^3. From6:30am-6:30pm these levels of concentration were determined for each hour respectively. The highest level of concentrations of $PM_{2.5}$and PM_{10} was determined from 5:30pm-6:30pm and the lowest concentration was 12:30pm-1:30pm. The obtained correlations (r) with respect to different factors were: the average pedestrian has moderate downhill linear correlation with $PM_{2.5}$ while a weak downhill linear correlation with PM_{10}. No linear correlation was obtained within the relationship of temperature to $PM_{2.5}$ and a weak downhill linear correlation to PM_{10}. Humidity is found to have a moderate uphill linear correlation to $PM_{2.5}$ and a weak uphill linear correlation PM_{10}. A weak downhill linear correlation is found on vehicular count and wind speed with respect to $PM_{2.5}$ and PM_{10} concentrations. The average $PM_{2.5}$ concentration obtained at Batangas Port Phase I is 31μg/m^3 which exceeded the WHO standard but falls within the USEPA and DENR standard while the average PM10 concentration obtained is 10μg/m^3 which is within the standards set by WHO, USEPA and DENR.

Conclusion

The researchers came up to the following conclusions.

a. The average concentration of 2.5μm Particulate Matter obtained at Batangas Port Phase I was 31 μg/m3.The average concentration of 10μm Particulate Matter obtained at Batangas Port Phase I was 10 μg/m3

b. The correlations of PM2.5 and PM10concentrations with respect to the following variables were:

i. Temperature has no linear correlation with respect to PM2.5 while there is a weak downhill linear correlation of temperature with the PM10 concentrations

ii. Humidity has a weak uphill linear correlation with respect to PM2.5 and PM10 concentrations

iii. Pedestrian count and PM2.5 concentrations has a moderate downhill linear correlation while

there is a weak downhill linear correlation of pedestrian count with PM10¬ concentrations.

iv. Vehicle count has a weak downhill linear correlation with respect to PM2.5 and PM10 concentrations

v. Wind speed has a weak downhill linear correlation with respect to PM2.5 and PM10 concentrations.

c. The average PM2.5 concentration obtained at Batangas Port Phase I is 31 μg/m3 which exceeded the standards set by WHO health standard with the standard of 25μg/m3 but still in within the standard set by USEPA and DENR which is 35 μg/m3 and 50 μg/m3, respectively. The average PM10concentration obtained at Batangas Port Phase I is 10 μg/m3 which is within the standards set by DENR, WHO and USEPA which is 150 μg/m3, 50μg/m3and 150μg/m3, respectively.

Recommendations

For further study, the following are the recommendations of the researchers.

a. The study recommend for the management to conduct experiment for the concentration of Particulate Matter 2.5 within the Phase 1 of Batangas Port to compare the result of this study which exceeded the WHO health standards.

b. The researchers suggest to have a moderate air sampling monitoring within the whole Batangas Port to continuously monitor the concentration of Particulate matter 2.5 and other parameters.

c. Recommend assessment of air quality during off-season of passengers for the differential of result of Particulate matter 2.5 and 10 during holiday season.

d. Conduct another study concerning air quality with parameters such as NOx and SOx.

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