International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 7, 2020
ISSN: 1475-7192

The Impact of Air Particulate Concentration on Health and Economic Conditions of Residents in Surabaya

Dewi Resti Mayangsari[1], Vindi Elsa Fatikasari[1], Febdilau Dwi Melati Ningrum[1], Gigih Prihantono[2] and Luthfi Nur Rosyidi[3]

***Abstract*---*Air pollution can be defined as the infiltration of substance, energy, or other components into the ambient air due to human activities to the point that the quality of the air is descending into a certain a level, causing ambient air's inability to fulfill its function which can affect human's health. This study is conducted in Surabaya to review the impact of air particulate concentration toward people's health and economic condition from October 2012 through February, 2014. Air pollution indicator used is particulate matter 10 (PM10) and PM2.5. Methods done for this study is literature study, descriptive research, sampling collection, and calculation of economic impact. This study is conducted to find out the effect of air pollution, particularly concentration of PM10 and PM2.5, towards health and economic condition of residents in Surabaya. The economic impact is measure by the amount of money spent due to health problems which includes mortality and morbidity. The technique used in this research involves two approaches which are epidemiology to assess the causality of PM10 and PM2.5 concentration level against health risks that occur, and economic valuation to estimate value in monetary unit against those healthy risks. The result of this study indicates that the quality of air in Surabaya contains PM2.5 concentrations which has exceeds its annual standard value according to Government Regulation No. 41 in 1999, which is 15.05 μg/m3 and 30.41 μg/m3 of PM10 concentration. Air pollution caused by PM10 and PM2.5 impacts residents of Surabaya in terms of the quality of health which is proven by the emergence of health cases suffered by residents of Surabaya. This impacts the economic sector in which every resident needs to endure health costs of 4.1% from their income as the negative effect (externality) of economic development.*

***Keywords*---*air pollution, concentration, PM2.5, PM10, air particulate, Surabaya city*.

I. Preface

Air pollution can be defined as the infiltration of substance, energy, or other components into the ambient air due to human activities to the point that the quality of the air is descending into a certain a level, causing ambient air inability to fulfill its function which can affect human's health [1]. The total greenhouse gas emissions obtained from burning biomass can cause an increase in the surface temperature of the earth, which can have an impact on climate and sea level [2]. Not only that, air pollution has become one of global environmental issues which attracts the attention of the world. A survey conducted by World Health Organization (WHO) in 2002 in 1,600 cities of 91 countries around the world pointed out that

[1]*Department of Environmental Engineering, Faculty of Science and Technology, Universitas Airlangga, 60115, Indonesia*
[2]*Department of Economics, Faculty of Economics and Business, Universitas Airlangga*
[3]*Department of Islamic Economics, Faculty of Economics and Business, Universitas Airlangga*
vindielsa99@gmail.com

almost 90% of people who live in urban areas inhale unsanitary air. Air pollution might come from various substances of air pollutants, which include concentration of PM2.5, PM10, and Pb. Pollutants themselves might be originated from biomass, vehicle, soil, industrial Pb, industrial Zn, and industrial Fe.

Pollutants bear great impact to health problems. Exposure to PM10 in short amount of time might impact health as it might cause lungs inflammation, upper respiratory tract infection (URI), and cardiovascular system disorder. PM10 might affect health in the long-run by causing symptoms of lower respiratory tract disorder, exacerbation of asthma, decreased lung function in children and adults, chronic obstructive increase of lungs, probability of lungs cancer, and death caused by cardiopulmonary disease [3].

The impact of air pollution also includes economic burden that society must endure. This economic burden from a certain disease include three cost component which are direct costs, indirect costs, and intangible costs. Direct costs come in the form of resources used to take care of and treat the sufferer. Direct costs are categorized into two groups, which are medical cost, such as the costs of treatments and medical consultation, and non-medical costs, such as the transportation mode and accommodation used while receiving the treatment. Indirect costs are the value of resources which are worn out. They include the cost of morbidity and mortality, informal treatment, and costs of loss due to criminal acts. Intangible costs are the kind of costs which are rather hard ot be measures as they include feelings, both physical and psychological, such as soreness, pain, or feelings of discomfort [4]. In addition, utilization of natural resources for business purposes can also cause some losses, such as loss or damage of biological authenticity of these resources [5].

Surabaya is one of large cities in Indonesia with the daily mean amount of concentration in particulate matter (PM) 10 μm is 150 $\mu g/m^3$ during 2001, 240 $\mu g/m^3$ during 2002, and 170 $\mu g/m^3$ during 2003 [6]. The quality of air in Surabaya has surpassed the anual standard quality value according to Government Regulation No. 41 in 1999, which are 15.05 $\mu g/m^3$ of PM2.5 and 30.41 $\mu g/m^3$ of PM10. Air pollution due to PM2.5 and PM10 may cause various health disorders that will impact health quality and economic condition of residents in Surabaya, which means that every resident needs to endure a certain amount of health cost. Surabaya government needs to undertake pollution management to solve air pollution problems to reduce the negative impact it causes such as the inability to perform its function that will impact the health of Surabaya residents greatly.

II. Fundamental Theory

Air Pollution

According to Government Regulations No. 41 in 1999 about Air Pollution Control, air pollution can be defined as the infiltration of substance, energy, or other component into the ambient air due to human activities to the point that the quality of the air is descending into a certain a level, causing ambient air's inability to fulfill its function.

Types of Air Pollution Based on Its Form

a. Gas is fumes originated from solid or liquid substance which evaporates or is heated, i.e. CO_2, CO, Sox, and NOx.
b. Particle is one form of air pollution originated from tiny flecks which are dispersed into the air, either from solid, liquid, or solid and liquid substance altogether, i.e. dust, smoke, fog, et cetera.

Particulate Matter (PM)

Particulate Matter (PM) or material/particulate material, also referred to as dust, is liquid substance in the form of smoke, dust, or fume which will settle in the atmosphere for a long time. Particulate matter in large size that is inhaled will settle in upper respiratory system for a long time while one in smaller size (inhalable) will infiltrate lungs and damage respiratory function. Small particulate can be measured under 10 μm (PM-10) or the even smaller one has the size of smaller than 2.5 μm (PM-2.5). Particulate-10 (PM-10) is the main cause of death for people with heart and lungs disease [7].

Basic Concept of Environmental Measurement

In general, environmental measurement can be categorized into two groups, instrumental or use value and intrinsic or non-use value. Instrumental value indicates the ability of an environment when used to fulfill various needs while intrinsic value is values inherent to the environment. Instrumental value itself is differentiated by direct use value, indirect use value, option use value, and bequest value. Intrinsic value, on the other hand, can be differentiated by bequest value and existence value [8].

III. Research Methods

Literature Study

This research is a literature study research, conducted by reviewing several journals with concern regarding pollution caused by air particulate and its effect to Surabaya areal as well as to Indonesia in general. Results originated from these various literature studies will be used to identify the impact of air particulate concentration on health and economic condition to Surabaya areal.

Descriptive Research Method

Method used in this study is descriptive research method. According to Arikunto, descriptive is a research method to identify situation, condition, and so forth that has been mentioned, to which the result will be elaborated in the form of research report. In research, researchers do not change, add, or manipulate objects or areas in research. In conducting research, researchers merely capture current situation within examined objects or areas which is elaborated into research report as it is. Moreover, Lexy Moleong stated that descriptive method is not limited to collection and compiling data, but also includes analyzing and interpreting the meaning of the data. All data collected has the possibility to be the key factor to what is being examined. In the meantime, design used for this research is library studies design in which researcher conducted research on literature before conducting the study.

Sampling Method and Measurement of Economic Impact According to Reference

Sampling method used for this study is Gent Sampler system who is in the rooftop for 24 hours with the flow rate of ± 18 L/min. The work principle of Gent Sampler is to collect sample of air particulate. Material filter used is polycarbonate with 47 mm diameter and pore a size of 4 μm. Analysis measurement for particulate is gravimetric method to determine mass weight of PM sample by measuring the difference between mass weight and specific gravity before and after sampling method is applies in a controlled room with temperature of 18-23^{o}c and humidity of 45-55 g/m^{3}. This method is performed to stabilize water content within dust. BC measurement is carried out using EEL 43D Smoke Stain Reflactometer. Analysis of metal content in this research is carried out using EDXRF 3D Epsilon 5. The advantage from using EDXRF method is that it contains multiple elements, is non-destructive, and can perform high sensitivity and selectivity. The source of pollutant is determined through positive matrix factorization (PMF) [9].

This research is conducted using quantitative approach with emphasis on analysis of numerical data or quantified facts. Economic impact from air pollution on health is measured by economic cost of health disorders cause by air particulate concentration. The amount of health disorders cases caused by air particulate concentration is estimated by Dose Response Function (DRF) function. Dose Response Function approach elaborates the possibility and the level of intensity from health impact (response) regarding the amount and concentration of the pollutant (dose). The main principle from this approach is ambient quality level changes in each pollutant that might be related statistically with the changes in each health impact. That relationship is defined in dose response coefficient gained through regression and cohort analysis [10].

IV. RESULT AND DISCUSSION

Measurement of Air Particulate Concentration in Surabaya

The end result of air particulate concentration measurement is gathered from literature study from various references in measuring air particulate concentration. This literature study is done by collecting samples of air particulate in Technical Implementation Unit of Environmental Quality Test Laboratory of the Environmental Agency for Eastern Java in Rd. Wisata Menanggal No. 38, Surabaya. Data gathering process is started from October, 2012 through February, 2014. PM2.5 concentration is generated from fine filter particle while PM10 concentration is generated from fine filter and coarse filter. The generated concentration is used to compare existing standard and to determine whether or not the air PM concentration in Surabaya has surpassed the threshold. The result can be seen in Table 1.

Table 1. Concentration PM2.5 and PM10 (annual mean) in Surabaya.

Parameter	Mean (μg/m3)	Range (μg/m3)	Deviation Standard (μg/m3)
PM 10	30.41	18.35 – 50.65	9.37
PM 2.5	15.25	8.53 – 26.38	4.77

The range of particulate for PM10 and PM2.5 shows both high and low fluctuated result. Concentration in PM2.5 and PM10 is highly influenced by seasons. Sampling collection during raining season might cause particulate concentration in the air is low since air particulate will be captured by raindrops. During dry season, rainfall volume is anywhere near 100 to 150 mm per month, showing that rain might happen but with varied intensity.

According to Government Regulations No. 41 in 1999 about Ambient Air Standard in Particulate Matter, the result of PM2.5 measurement in Surabaya during October, 2012 and February, 2017 is 15.05 $\mu g/m^3$ which had surpassed annual standard value of 15 $\mu g/m^3$ according to literature study for this research. It can be concluded that daily air pollution in Surabaya has surpassed PM2.5 quality standard. PM2.5 in Surabaya during October, 2012 and February, 2017 had also surpassed annual mean standard set by WHO which is 10 $\mu g/m^3$ and US EPA which is 50 $\mu g/m^3$. PM10 in Surabaya during October, 2012 and February, 2017 had not surpassed the threshold of quality standard set by Government Regulations No. 41 in 1999 with the amount of 150 $\mu g/m^3$, US EPA with the amount of $\mu g/m^3$, and WHO with the amount of 50 $\mu g/m^3$. PM2.5 high contribution to air pollution is caused by the increasing amount of motor vehicles as well as fossil fuels for industrial purposes.

Impact of Air Particulate Concentration on Health Quality of Surabaya Residents

The impact of particulate concentrate can be estimate through various variables. Estimation technique involves several research variables with operational definition and the measurements of them are shown in Table 2. Data used for this estimation are macro-scale data in national level, which is Indonesia for one year in 2011 as the last data available. The data used are secondary data from previous reports and researches published by various institutions.

Table 2. Variables in estimating technique for impact of air particulate concentration.

Variabel	Definisi dan Pengukuran	Sumber
Air Particulate Concentration	Suspensed small particles with diameter less than 10 microns are measured from annual mean exposure of outdoor pollution in urban area of a country with µg/m3 unit (microgram per meter cubic).	[11]
Total Population	Total population with risks of suffering from the impact of particular diseases from exposure to air particulate concentrate is stated in people.	[11,12]
Costs of illness (COI)	All kinds of costs of health treatment (health care costs) which is stated in US$ unit.	[13]
Value of statistical life (VSL)	The value of statistical life is measured by the willingness to pay in terms of decreasing level of death in US$ unit	[13]
Buying Power Parity	Comparison of buying power level between two countries is measured by gross national income product per capita on price valid in 2011.	[11]

Source: WHO, 2000

The impact of large amount of air particulate concentrate might cause various diseases that fall upon residents in Surabaya. The impacts might cause health disorders suffered by residents of Surabaya that will also influence their day-to-day activities. The impact that is most significant is the decrease in economic condition of several middle and lower classes of society. Health cases generated from air particulate concentrate can be seen in Table 3.

Table 3. Health disorder cases caused by air particulate concentration in Surabaya.

Different Types of Health Impact	Economic Cost per capita (in Rupiah)
Mortality: early death	931.671.16
Morbidity	598.695.88

Health treatments in hospital due to cardiovascular diseases	205.197.60
Health treatments in hospital due to respiratory system diseases	293.548.61
Acute bronchitis	86.619.53
Asthma	1.939.79
Respiratory system disorders	949.86
Total non-working days	10.440.49

Sourse: WHO,(2000).

The large amount of health disorder cases caused by air particulate concentration will bring great impact on various activities in economic sector. Using information from buying power parity, exchange rate, and inflation rate, it can be concluded that, in the end, economic costs caused by air particulate concentration needs to be endured by the residents as negative impact (external) from economic development or, usually called as, development costs and gas emission from vehicles. Total population of residents in Surabaya, according to Ministry of Internal Affairs are 2,827,892 people. Therefore, the amount of costs that each resident endures (per capita) is Rp 1,530,367.04 or around US$ 174.5, which includes mortality costs of Rp 931,671.16 or around US$ 106.2, morbidity costs of Rp 598,695.88 or around US$ 68.3, health treatments costs due to cardiovascular diseases of Rp 205.197,60 or around US$ 14.36, health treatments costs due to respiratory system diseases of Rp 293.548, 61 or around US$ 20.55, health treatments cost due to acute bronchitis of Rp 86,619.53 or around US$ 6.06, health treatments costs due to asthma of Rp 1,939.79 or around US$ 0.14, and economic costs of non-working days of Rp 10.440,49 or around US$ 0.73. With income per capita in Surabaya within the same year of Rp 62,456.21, each resident of Surabaya needs to endure health costs of around 4.1% from their income. This fact shows that pollution costs that each resident needs to endure are correlated and linked to the existence of air pollutant concentration that bring great impact to economic condition of residents in Surabaya.

V. Conclusion

The quality of air in Surabaya contains PM2.5 concentration that has surpassed the annual standard quality according to Government Regulations No. 41 in 1999, which is $\mu g/m^3$ and PM10 concentration of 30.41 $\mu g/m^3$. Air pollution caused by air particulate such as PM2.5 and PM10 causes various health disorder cases that bring great impact in terms of health quality and economic condition of residents in Surabaya in which each resident must endure health costs of 4.1% of their income.

REFERENCES

[1] Cooper C D and Alley F C 1994 *Air Pollution Control A Design Approach Second Edition* Illionis: Waveland Press Inc

[2] Nasih M, Harymawan I, Paramitasari Y I and Handayani A 2019 Carbon Emissions, Firm Size, and Corporate Governance Structure: Evidence from the Mining and Agricultural Industries in Indonesia. *Sustainability* **11** (9) 2483

[3] Nurjanah K L and Mufid A 2014 *Gangguan FungsiPAru dan Kadar Continine pada Urin Karyawan yang Terpapar Asap Rokok Orang Lain* Jurnal Kemas **10** p1

[4] Sengkey S L, Jansen F and Wallah S 2011 *Tingkat Pencemaran Udara CO Akibat Lalu Lintas dengan Model Prediksi Polusi Udara Skala Mikro* Jurnal Kemas **1** (2) 119-126
[5] Handriana T and Ambara R 2016 Responsible environmental behavior intention of travelers on ecotourism sites. *Tourism and hospitality management* **22** (2) 135-150
[6] Chamidha 2004 *Policy for air pollution control strategy by using the air pollutant dispersion model (PM10) in Surabaya* Surabaya: Dinas Lingkungan Hidup Kota Surabaya
[7] Wilyusdinik R 2012 *Realisasi Alat Ukur Particulate Matter (PM) Gas Buang Kendaraan Bermotor Menggunakan Sensor Fotodioda* Skripsi Bandar Lampung: Jurusan Fisika FMIPA Universitas Lampung
[8] Suparmoko and Suparmoko M R 2000 *Ekonomika Lingkungan* Yogyakarta: BPFE
[9] Ahmad E F and Santoso M 2016 *Analisis Karakterisasi Konsentrasi dan Komposisi Partikukat Udara (Studi Case: Surabaya)* Jakarta: Jurnal Kimia Valensi p 97-103
[10] Mursinto D and Kusmawardani D 2016 Estimasi Dampak Ekonomi dari Pencemaran Udara Terhadap Kesehatan di Indonesia Semarang *Jurnal Kesehatan Masyarakat Kemas* **11** (2) p 163-172
[11] World Bank 2014 *GDP Ranking* Retreived in 28 Mei 2019 Retreived from http://data.worldbank.org/data-catalog/GDP-ranking-table.
[12] Badan Pusat Statistik Jakarta Pusat 2013 *Statistik Indonesia Tahun 2013* Jakarta: Pusat Badan Pusat Statistik
[13] US EPA 2011 *Reducing Greenhouse Gas Emissions through Recycling and Composting* Seattle WA US EPA Region 10