European Journal of Public Health Studies
ISSN: 2668 - 1056
ISSN-L:2668 - 1056
Available on-line at: www.oapub.org/hlt

DOI: 10.46827/ejphs.v7i3.193 Volume 7 | Issue 3 | 2024

INTERACTIONS WITH POPULACES' PERCEPTIONS OF THE POLICY FOR SOLVING PROBLEMS OF THE PM2.5 DUST TOXIC POLLUTION ON HEALTH AND THE IMPACT CONTAMINATION TO AFFECTED RESPIRATORY SYSTEM DISEASES

Prachayakul Tulachom[1i],
Jumnean Wongsrikaeo[2],
Toansakul T. Santiboon[3],
Gregory S. Alexander[4]
[1]Independent Academic in Environmental Studies (PhD),
Mueang Sa Kaeo District, Sa Kaeo 27000,
Thailand
PhD, Environmental Education,
Valaya Alongkorn Rajabhat University under Royal Patronage,
Pathum Thani, 13180,
Thailand
orcid.org/0009-0000-6796-6131
[2]Deputy Director of Administration (PhD),
Phutthasothon Hospital, Mueang District,
Chachoengsao Province, 24000,
Thailand
PhD, Environmental Education,
Pathumthani University,
Thailand
orcid.org/0009-0005-7687-8471
[3]Professor of Research and Post-Doctorate Administrator,
(Post Doctorate Degree),
Queen University Belfast,
Belfast, Northern Ireland,
United Kingdom
orcid.org/0000-0003-0577-9423
[4]Professor of Graduate Studies (PhD),
Department of Post-Graduate Studies,
Faculty of Humanities,
Central University of Technology,
Bloemfontein, Free State,
South Africa

Abstract:
Science 2008, keep an eye on the Particulate Matter (PM 2.5) toxic dust situation including any chemical, physical, or biological agent mixture of solid and liquid particles

[i] Correspondence: email dr.prachayakul@hotmail.com,

suspended in the air. It has affected the health of Thai people with over 10 million patients each period in a year. The Thai government needs to solve the problem of PM2.5 dust pollution at its sources seriously. The effects of global and climate change are affected to impact the threat to human health by human activities in short-middle-and long terms: Spiration System Affected, Lung Cancer, Carcinogenicity, Brain Threats, Heart Hazards diseases. Creative the Document Research Methodology data was reviewed, the Qualitative Research method data was interviewed and observed, and the independent and dependent variables were associated with 400 populaces who used to be sick with PM2.5 dust in 2023. Creating The 36-item Questionnaire on Populaces and PM2.5 Affected Interaction (QPPAI) in six scales; each scale consisted of 6 items in five options (Never-Always); and the 10-item Attitudes on Solving-Problem PM2.5 Toxic Dust (ASPTD). These instruments are valid and reliable. The participants' responses reveal that they know how to protect themselves from PM2.5 dust and get support from the government (KPSG), they understand the effects of PM2.5 toxic dust, which can be inhaled deep into the respiratory tract and lungs (UETD), their receiving care from the government for being a patient with PM2.5 dust pollution (RCGP), most of the participants are understanding of effects of PM2.5 toxic dust (UETD), however, their awareness of news from the media or government organizations for groups at risk of danger from PM2.5 dust, receiving advice on care and treatment (AGAT), and this situation has in shock because they don't yet understand the health effects of PM2.5 dust on the respiratory system and lungs (UHER), respectively. The results have found that the R2 value indicates that 61% of the variance in populaces' perceptions of their attitudes to the government policies was attributable to their perceptions of the health effects of the PM2.5 toxic dust pollution in the air environment. They are supported significantly by government policies.

Keywords: PM25 toxic fine dust, global and climate changes, respiration system affected, populaces' perceptions, independent and dependent variables associated

1. Introduction

Keep an eye on the PM 2.5 dust situation affecting the health of Thai people. The National Economic and Social Development Board revealed the figures for 2023 that 10.5 million Thai people would be sick, while from January 1 to February 13, 2024, 910,000 people were found to be sick with diseases related to air pollution. The fourth quarter of Thai society and the overall picture of 2023 for March 2024, on issues related to the health of Thai people, especially the PM 2.5 dust situation, from the Health Data Center system of the Ministry of Public Health in 2023, it was found that up to 10.5 million Thai people were sick with diseases related to air pollution, an increase of 3.6 percent from 2022. Most of them suffer from respiratory diseases, dermatitis, and eye inflammation, most commonly found in the North, followed by the Northeastern, the Southern, and Bangkok.

When considering each major disease from PM 2.5 dust and each province in 2023, it was found that the number of patients with chronic bronchitis increased by 39.1 percent from 2022. The most patients were found in Nakhon Ratchasima Province, followed by lung cancer, which increased by 19.7 percent, especially in Bangkok. Cerebrovascular disease increased by 16.8 percent, most commonly found in Bangkok, where most patients were aged 60 years and over. PM2.5 Dust situation in 2024 Data from January 1 - February 13, 2024, found 910,000 patients with diseases related to air pollution, with the North having more patients than other areas (Than Settakij News, 2024). Based on the statistics of the 2019 readings of Thailand's air quality index, on statistical average, the whole country has a yearly rating of being 'moderately' polluted. The PM2.5 concentration is two times above the WHO's recommended guideline for annual PM2.5 exposure (10 μg/m3), coming in at a reading of 24.3 μg/m3 (Air Quality in Thailand, 2024).

Thailand as a country can be counted as a place that has numerous polluted cities and is famous for its levels of smoke and haze. Bangkok has always topped the list of polluted cities, and even Chiang Mai, once renowned and hailed as a cleaner and less densely populated version of Bangkok, has in recent years exploded in terms of the level of pollution, having overtaken Bangkok in 2019, with the readings of PM2.5 sitting at a yearly average of 32.3 μg/m3, as opposed to Bangkok's 22.8 μg/m3. Amongst all its major cities, these increases in dangerous particles and chemicals in the air push the AQI rating up to potentially hazardous levels. It is affected for reasons such as this, such as Thailand being considered very polluted. In 2019, Thailand was ranked as the 28th most polluted country out of the 98 countries ranked in IQAir's 2019 World Air Quality Report, with a yearly PM2.5 rating of 24.3 μg/m3, putting it at a rating of moderate risk to health according to the US Air Quality Index. This is not particularly terrible when compared to the world's biggest offenders, it is still 2 times over the WHO's exposure recommendation of PM2.5 and other dangerous chemicals such as nitrogen dioxide (NO_2) sulfur dioxide (SO_2) and carbon monoxide (CO) to name a few (Thailand Air Quality Data Attribution, 2023).

The IQAir 2023 World Air Quality Report, the sixth in its series, analyzes scientists' work to present PM2.5 air quality data from more than 30,000 air quality monitoring stations in 7,812 locations, covering 134 countries and regions. Looking back at statistics from 2023, we can see that air quality in Thailand has been getting worse and worse, with air quality ranked 5th out of 9 countries in the ASEAN region for the second consecutive year and ranked 36th out of 134 countries worldwide, up from 57th in 2022. In recent years, the particularly worth air quality of Bangkok, as well as its other cities, has sent the government shuffling quickly to come up with some fast solutions to help ease the issue, as well as looking at long-term goals that can be implemented to lessen the environmental crisis that their country and many major cities are undergoing. Thailand's air quality is ranked 36th in the world and 5th in Southeast Asia, 4.7 times higher than the WHO air quality guidelines, and the annual average PM2.5 dust level has increased by 28%. Bangkok is ranked 37th among the world's most polluted cities, with an average mean

PM2.5 of 21.7 micrograms per cubic meter. Chiang Rai Province and Pai District in Mae Hong Son Province are ranked in the top 5 areas with the worst PM2.5 dust pollution in Southeast Asia. In 2023, February – April was the period with the worst air quality, with Chiang Mai province seeing its monthly PM2.5 average increase from 53.4 to 106.4 micrograms per cubic meter, an increase of more than 150% compared to the monthly average for the same period in 2022 (Rujirawat, 2024).

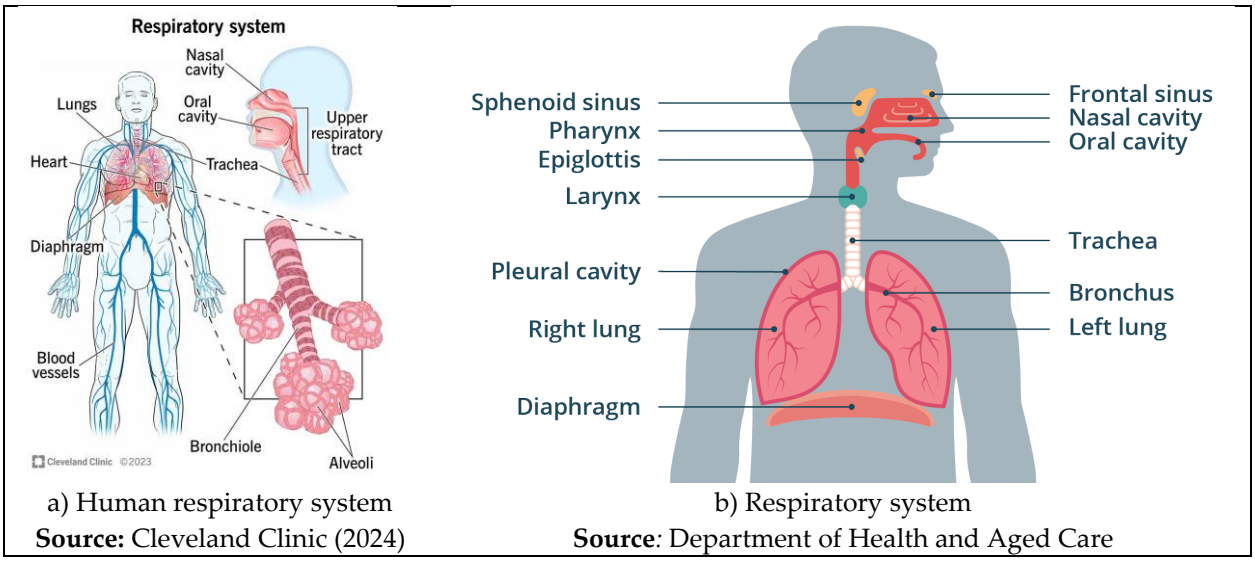
Transboundary PM2.5 pollution has been a health crisis that has plagued people in the North for almost 20 years. People in the North unanimously said that the dust of PM2.5 in 2023 was the worst year for PM2.5 pollution. This can be seen from the report's findings that from February to April, Chiang Rai and Mae Hong Son provinces had the highest average hourly PM2.5 values, exceeding 300 AQI, and became the most polluted cities in the world. Civil society networks have joined forces to campaign for the PRTR law to disclose information on pollutant emissions from sources, which is an important tool for effective pollution management. The World Air Quality Report 2023 shows that the government needs to seriously focus on solving the problem of PM 2.5 dust pollution at its source. It needs to set policies, and budgets, and elevate it to a national agenda. It needs to be implemented urgently and efficiently in the interests of the people over the industrial capital groups because access to clean air is a basic right of the people (Thai PBS: Policy Watch, 2024).

The Thai government has set a policy to solve the PM 2.5 dust problem, emphasizing that the government prioritizes this issue by establishing a national committee to prevent and solve forest fires, open burning, smog, and dust problems by management mechanisms at both the national and local levels. It also promotes Chiang Mai as a model province because the PM 2.5 dust problem has decreased, especially in January. The accounting of the dust PM2.5 10 years ago and this year, Chiang Mai people say that the dust problem has improved and the amount of dust has decreased a lot compared. However, the area of Bangkok and its vicinity has still increased, including set target areas for solving the problem, focusing on repetitive burning fire wild areas by 50%, reducing burning in agricultural areas of 3.25 million rai from 2023, which has a burning area of 66% or 6.5 million rai, in 10 conservation forests and 10 national reserve forests by creating firebreaks and people barriers. The PM2.5 dust problem has returned to the cause of the PM2.5 problems. Although the previous government designated it as a national agenda in 2019, it seemed to improve to be started for solving this case. However, after the government plan policy was ended, the dust and smoke became more severe. Meanwhile, the current government does not have a clear plan and only has measures from the cabinet as orders. However, after the government plan policy was ended, the dust and smoke became more severe. Meanwhile, the current government does not have a clear plan and only has measures from the cabinet as orders (Nagarani *et al.*, 2021).

2. Literature Review

2.1 Human Respiratory System

The human respiratory system consists of the body's organs and structures that allow humans to breathe. It includes your lungs, nose, mouth, and the tubelike structures (airways) that connect them. You also have muscles and blood vessels that support your respiratory system and ribs to protect it. These parts work together to bring oxygen into the human body when humans inhale and eliminate carbon dioxide when they exhale. The main function of your respiratory system is to pull in oxygen for your body's cells and get rid of carbon dioxide, a waste product. You do this by breathing in and out and through gas exchange between the small air sacs of your lungs (alveoli) and the blood vessels running nearby. It moisturizes the air to bring it to the humidity level your body needs. Parts of the human respiratory system can block harmful germs and irritants from getting in or push them out if they do get in. The air vibrates its vocal cords, which make sounds. Breathing in the air moves its molecules past the human olfactory nerve, which sends messages to your brain about the position something smells. Balance's level of acidity in the human body too much carbon dioxide lowers their blood's pH, making it acidic. By removing carbon dioxide, the respiratory system helps maintain the acid-base balance in the human body. The main organs of your respiratory system are your lungs. However, the respiratory system has many different parts that the body works to help them breathe together. Parts of the respiratory system include the human: nose and nasal cavity; mouth and oral cavity; sinuses; pharynx (throat); larynx (voice box); trachea (windpipe); bronchi (large airways); lungs; and diaphragm (Figure 1).



a) Human respiratory system
Source: Cleveland Clinic (2024)

b) Respiratory system
Source: Department of Health and Aged Care

Figure 1: Human respiratory system

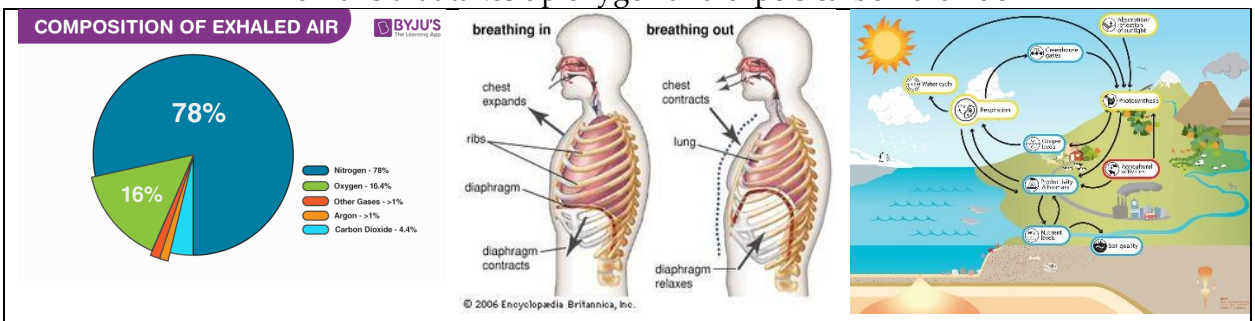
2.2 Clean Air for Human Respiration

Inhaled air is by volume 78% nitrogen, 20.95% oxygen, and small amounts of other gases including argon, carbon dioxide, neon, helium, and hydrogen. The gas exhaled is 4% to

5% by volume of carbon dioxide, about a hundredfold increase over the inhaled amount. The volume of oxygen is reduced by about a quarter, 4% to 5%, of total air volume. The typical composition is 5.0–6.3% water vapor; 79% nitrogen; 13.6–16.0% oxygen; 4.0–5.3% carbon dioxide, and 1% argon parts per million (ppm) of hydrogen, from the metabolic activity of microorganisms in the large intestine. Clarification needed ppm of carbon monoxide from degradation of heme proteins; 4.5 ppm of methanol; and 1 ppm of ammonia. Trace many hundreds of volatile organic compounds, especially isoprene and acetone. The presence of certain organic compounds indicates disease (Turner, 2006). However, most humans stay in a room, cleanrooms are classified according to the number and size of particles permitted per volume of air. Large numbers like "class 100" or "class 1000" refer to FED_STD-209E, and denote the number of particles of size 0.5 mm or larger permitted per cubic foot of air. The standard also allows interpolation, so it is possible to describe e.g., "class 2000" (International Organization for Standardization Logo, 2020).

Air in its purest state is best suited for the essential task of sustaining life. Air pollution is a major environmental risk to health. Air pollution can trigger heart attacks or strokes. One in three Americans has heart disease, which can be worsened by air pollution. Breathing clean air can lessen the possibility of diseases from stroke, heart disease, and lung cancer, as well as chronic and acute respiratory illnesses such as asthma. Lower levels of air pollution are better for heart and respiratory health, both long- and short-term. The Air Quality Index (AQI) is an indexing indicator for reporting daily air quality. It tells you how clean or polluted your air is and what associated health effects might concern human respiration. The AQI focuses on health effects humans may experience within a few hours or days after breathing polluted air. The AQI focuses on health effects humans may experience within a few hours or days after breathing polluted air (Department of Health, 2021). Breathing clean air can lessen the possibility of diseases from stroke, heart disease, and lung cancer, as well as chronic and acute respiratory illnesses such as asthma. Lower levels of air pollution are better for heart and respiratory health, both long- and short-term. Fresh air not only cleans your lungs, but it can also boost your mood, lower your heart rate, increase energy levels, and even improve digestion (yes, that's right). Florence Nightingale knew the benefits of fresh air long before any scientific study. The oxygen in the air is then transported to all of the cells in the human body. It is used to produce energy. The carbon dioxide produced by the human cells is then transported back to the lungs and exhaled. Air is necessary for breathing because it provides the human respiratory system with the oxygen humans need to produce energy (Grossman, 2024) (Figure 2).

Figure 2: The human respiratory system, the system in humans that takes up oxygen and expels carbon dioxide



a) Gasses humans breathe in and breathe out the composition of air

b) Role of the diaphragm in respiration

c) Respiration - Understanding Global Change

Source: Lindholm & Lundgren (2009) (a); Weibel & Burri (2018) (b): and the University of California Museum of Paleontology (2024) (c)

Fresh Air is a mixing of 78.09% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide, and other gases in meager amounts. Water vapor is also a constituent of air in varying amounts of dust particles. The molar mass of dry air or air with no/low quantity of water vapor in it is 28.97g/mol. Clean air is fundamental to health. Compared to 15 years ago, when the previous edition of these guidelines was published, there is now a much stronger body of evidence to show how air pollution affects different aspects of health at even lower concentrations than previously understood. But here's what hasn't changed: every year, exposure to air pollution is still estimated to cause millions of deaths and the loss of healthy years of life (The World Health Organization, 2021).

2.3 Global Change

In the last 250 years, human-caused change has accelerated and caused climate change, widespread species extinctions, fish-stock collapse, desertification, ocean acidification, ozone depletion, pollution, and other large-scale shifts (Dahms *et al.*, 2018). While Earth's climate has changed throughout its history, the current warming is happening at a rate not seen in the past 10,000 years. According to the Intergovernmental Panel on Climate Change (IPCC), "Since systematic scientific assessments began in the 1970s, the influence of human activity on the warming of the climate system has evolved from theory to fact. Scientific information taken from natural sources (such as ice cores, rocks, and tree rings) and modern equipment (like satellites and instruments) all show the signs of a changing climate, global temperature raised to melting ice sheets, the evidence of a warming planet abounds, exactly (National Aeronautics and Space Administration, 2023).

2.3.1 The Rate of Change since the Mid-20th Century Is Unprecedented over Millennia

Earth's climate has changed throughout history. Just in the last 800,000 years, there have been eight cycles of ice ages and warmer periods, with the end of the last ice age about 11,700 years ago marking the beginning of the modern climate era and of human civilization. Most of these climate changes are attributed to small variations in Earth's

orbit that change the amount of solar energy our planet receives. The current warming trend is different because it has affected the result of human activities since the mid-1800s, and is proceeding at a rate not seen over recent millennia.1 It is undeniable that human activities have produced the atmospheric gases that have trapped more of the Sun's energy in the Earth's system. This extra energy has warmed the atmosphere, ocean, and land, and widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred (National Aeronautics and Space Administration, 2023).

2.3.2 Understanding Global Change

The Earth is a dynamic system of many parts that interact to shape our climate and ecosystems. Explaining the causes and effects of global change phenomena requires an interdisciplinary understanding of essential biology, chemistry, physics, and Earth science content that can be explored. Generally, people understand global change to comprise a wide range of biophysical, ecosystem, and socio-economic changes that alter the functioning of Earth as a system on a planetary scale (changes in climate, land and ocean productivity, atmospheric chemistry, ecosystems). Global change is not a matter of faith, but rather of scientific knowledge. It can, therefore, be evidenced in many ways – the disequilibrium in Earth's energy balance, rise in greenhouse gas concentrations, increase in ocean temperatures, declining biodiversity, and the like. All these parameters can be mathematically calculated. Global climate change is "*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods*." Thus, when discussing global climate change, we are always talking about changes caused by humans (The United Nations Framework Convention on Climate Change (UNFCCC), 2023).

2.4 Climate Change

Climate change refers to long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions. Since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels, including coal, oil, and gas. Burning fossil fuels generates greenhouse gas emissions, that act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures (United Nations, 2019). The impacts of climate change include warming temperatures, changes in precipitation, increases in the frequency or intensity of extreme weather events, and rising sea levels. These impacts threaten our health by affecting the food we eat, the water we drink, the air we breathe, and the weather we experience. People in developing countries may be the most vulnerable to health risks globally, but climate change poses significant health threats even in wealthy nations such as the United States. Certain populations, such as children, pregnant women, older adults, and poor people with low incomes, face increased risks;

see the section below on Populations of Concern (United States Environmental Protection Agency, 2018).

2.4.1 Effects of Climate Change

Humans and wild animals face new challenges for survival because of climate change. More frequent and intense droughts, storms, heat waves, rising sea levels, melting glaciers, and warming oceans can directly harm animals, destroy the places they live, and wreak havoc on people's livelihoods and communities. As climate change worsens, dangerous weather events have become more frequent or severe. People in cities and towns around the world are facing the impact of the consequences, from heat waves and wildfires to coastal storms and flooding (World Wildlife Fund, 2020). Climate change is the single biggest health threat facing humanity. Climate impacts are already harming health, through air pollution, disease, extreme weather events, forced displacement, pressures on mental health, and increased hunger and poor nutrition in places where people cannot grow or find sufficient food (United Nations, 2019).

Carbon dioxide and other heat-trapping gases are the main drivers of global warming. While climate change cannot be stopped, it can be slowed. To avoid the worst consequences of climate change, we will need to reach "net zero" carbon emissions by 2050 or sooner. Droughts, floods, and extreme weather disasters have damaged people's communities (The Union of Concerned Scientists, 2020). The oceans are changing. With 70 percent of the planet covered in water, the seas are important drivers of the global climate. Nevertheless, increasing greenhouse gases from human activities are altering the ocean before our eyes. NASA and its partners are on a mission to find out more. There is unequivocal evidence that Earth is warming at an unprecedented rate. Human activity is the principal cause. Earth-orbiting satellites and new technologies have helped scientists see the big picture, collecting many different types of information about our planet and its climate change over the world effect. These data, collected over many years, reveal the signs and patterns of changing climate atmospheres (National Aeronautics and Space Administration, 2023).

Established in 2014, this NASA-sponsored team works to improve the understanding of regional relative sea-level change on timescales. They work with partners to translate the latest science and research into actionable information and to communicate how impacts are increasing at the coast. NASA Earth Exchange (NEX) (2023) combines state-of-the-art supercomputing, Earth system modeling, and NASA remote sensing data feeds to deliver a work environment for exploring and analyzing terabyte- to petabyte-scale datasets covering large regions, continents, or the globe. NASA Earth Observatory has produced a collection of image series showing some features of Earth to explore. She has changed over time due to natural and human-induced causes of the World of change. NASA explores the unknown in air and space, innovates for the benefit of humanity, inspires the world through discovery, and assembles one of the world's most trusted global temperature records, using a

combination of surface air temperature data acquired by tens of thousands of meteorological stations, as well as sea surface temperature data from the ship- and buoy-based instruments.

2.5 Factors Causing Pollution Problems in the Atmosphere

Air pollution is contamination of the indoor or outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities, and forest fires are common sources of air pollution. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide. Outdoor and indoor air pollution cause respiratory and other diseases and are important sources of morbidity and mortality. WHO data show that almost all of the global population (99%) breathe air that exceeds WHO guideline limits and contains high levels of pollutants, with low- and middle-income countries suffering from the highest exposures. Air quality is closely linked to the earth's climate and ecosystems globally. Many of the drivers of air pollution (i.e. combustion of fossil fuels) are also sources of greenhouse gas emissions. Therefore, there are policies to reduce air pollution, offer a win-win strategy for both climate and health, lower the burden of disease attributable to air pollution, and contribute to the near- and long-term mitigation of climate change (World Health Organization, 2024).

The rising number of air pollutants has made breathing fresh, clean air shortly to well done impossible. The causes of air pollution have left everyone worried about their health. Air pollution, being built as the largest environmental killer, kills over 17 billion people worldwide. While calculating, that's up to 2.2 years lost on average. As pollutants in the air cannot be seen with human naked eyes, we don't realize the sources of the increasing pollution levels. Humans must understand the sources of air pollution and need to first go through the basic causes of air pollution. The list of 10 common air pollution has been caused along with their effects. They have serious implications for and their loved ones' health daily, including the burning of fossil fuels, industrial emissions, indoor air pollution, wildfires, microbial decaying process, transportation, open burning of garbage waste, construction and demolition, agricultural activities, and use of chemical and synthetic products (The National Air Quality Index (AQI) of the Purelogic Labs India Ltd., 2019).

2.6 Air pollution

Air pollution is one of the biggest environmental threats to human health. In 2005, the World Health Organization (WHO) released its first global air quality guidelines (AQGs) for particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). On September 22, 2021, the WHO updated its AQGs, providing clear evidence of the adverse health effects of air pollution at even lower concentrations than previously understood (For instance, the WHO AQGs 2021 recommend annual mean concentrations

of PM2.5 not exceeding 5μg/m^3 and NO2 not exceeding 10μg/m3 and the peak season mean 8-h O3 concentration not exceeding 60μg/m. As a comparison, the corresponding WHO AQGs 2005 values were 10μg/m^3 for PM2.5 and 40μg/m^3 for NO^2, with no recommendation for long-term O_3 concentrations (The World Health Organization, 2021).

Air pollution is an affecting impact threat to human health in all countries, but its impact in low- and middle-income countries is the greatest. As the largest developing country, China has been changing rapidly over the past four decades, and its economic expansion is largely driven by the use of fossil fuels, leading to a dramatic increase in emissions of both air pollutants and greenhouse gases.[4] The same origin of air pollution and climate change. Any continuous air quality improvement actions will help low-carbon development, and vice versa. Air pollution and climate change are now among the top risk factors for mortality and morbidity of the Chinese population. The global burden official of disease was studied and reported that air pollution and non-optimal temperature contributed to over 1.8 and 0.6 million deaths, in 2019 in China, respectively. After China's AQS included PM2.5 for the first time in 2012, the Chinese government implemented the Air Pollution Prevention and Control Action Plan (APPCAP) from 2013 to 2017, requiring that by 2017, the concentration of PM2.5 in the Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta regions would decrease by 25%, 20%, and 15%, respectively (Dimitriou, Christidou, & Khallaf, 2021).

2.7 Particulate Matter (PM)

Particulate Matter (PM) is a mixture of solid and liquid particles suspended in the air. These are categorized into coarse, fine, and ultrafine. PM2.5 are fine particles that measure size as a diameter of fewer than 2.5 micrometers (more than 100 times thinner than a human hair) and remain suspended in the air for longer durations. The health risk with PM2.5 is that it can travel deep into the respiratory tract, reaching the lungs and entering the bloodstream (Indoor Air Hygiene Institute, 2024). Outdoor air pollution is typically caused by PM2.5, increasing. These particles are created from emissions from cars, trucks, buses, power plants, and other activities such as burning fuels from wood and coal. Natural events such as wildfires can also contribute Fine Dust to the air. Fine Dust in outdoor air can easily travel long distances, so activities that create PM2.5 can impact the surrounding area for miles.

The World Health Organization (WHO) has set the average level of PM 2.5 dust in the air as being hazardous to health if it exceeds 25 micrograms per cubic meter, while Thailand has set the level of PM 2.5 dust danger at 50 micrograms per cubic meter. The Ministry of Natural Resources and Environment, through the Pollution Control Department, has revised the standard values for particulate matter measuring no more than 2.5 microns, or PM2.5, and the National Environment Board announced it in the Royal Gazette on July 8, 2022: The 24-hour average was adjusted from 50 to 37.5 micrograms/cubic meter, effective from June 1, 2023; and The annual average has been

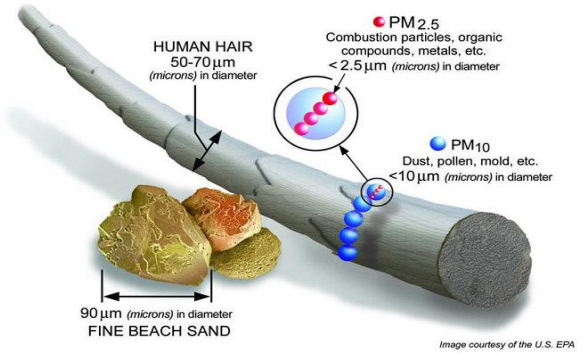
reduced from 25 to 15 micrograms/cubic meter, effective from the day following the announcement in the Government Gazette (Srihawan, 2024) (Figure 3).

2.7.1 What are the fine specks of dust PM2.5?

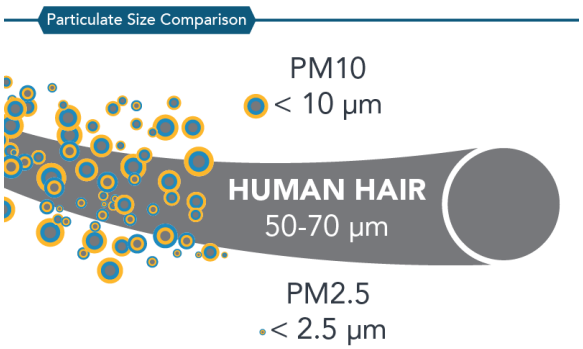
Airborne particulate matter (PM) is not a single pollutant but a mixture of many chemical species. It is a complex mixture of solids and aerosols composed of small droplets of liquid, dry solid fragments, and solid cores with liquid coatings. Particles vary widely in size, shape, and chemical composition and may contain inorganic ions, metallic compounds, elemental carbon, organic compounds, and compounds from the earth's crust. Particles are defined by their diameter for air quality regulatory purposes. Those with a diameter of 10 microns or less (PM10) are inhalable into the lungs and can induce adverse health effects. Fine particulate matter is defined as particles that are 2.5 microns or less in diameter (PM2.5). Therefore, PM2.5 comprises a portion of PM10. PM may be either directly emitted from sources (primary particles) or formed in the atmosphere through chemical reactions of gases (secondary particles) such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and certain organic compounds. These organic compounds can be emitted by natural sources, such as trees and vegetation, as well as man-made (anthropogenic) sources, such as industrial processes and motor vehicle exhaust. The relative sizes of PM10 and PM2.5 particles are compared in Figure 1c) as above (California Air Resource Broad, 2021).

Several adverse health impacts have been associated with exposure to both PM2.5 and PM10. For PM2.5, short-term exposures (up to 24 hours duration) have been associated with premature mortality, increased hospital admissions for heart or lung causes, acute and chronic bronchitis, asthma attacks, emergency room visits, respiratory symptoms, and restricted activity days. These adverse health effects have been reported primarily in infants, children, and older adults with preexisting heart or lung diseases. In addition, of all the common air pollutants, PM2.5 is associated with the greatest proportion of adverse health effects related to air pollution, both in the United States and worldwide, based on the World Health Organization's Global Burden of Disease Project. The WHO guidelines state that annual average concentrations of PM2.5 should not exceed 5 $\mu g/m^3$, while 24-hour average exposures should not exceed 15 μg/m3 more than 3 - 4 days per year. The guidelines provide evidenced, health-based standards for specific air pollutants that cities should adopt as air quality targets. Initially set in 2005, they were updated in 2021 to reflect far-reaching evidence that shows how air pollution affects many aspects of health, even at low levels (The World Health Organization, 2022) (Figure 3).

a) PM 2.5 is a tiny particle that has a huge negative (health) impact in 2019.
Source: Photo by Chananya Srihawan (2024)



b) Fine Dust size renders it practically invisible; it can only be detected with an electron microscope.
Source: Indoor Air Hygiene Institute. (2024)



c) The relative sizes of PM10 and PM2.5 particles are compared
Source: California Air Resource Board (2022)

d) Wildfire Map Spotlight: Bridge Fire, California
Source: Air Quality Index (AQI) (2023)

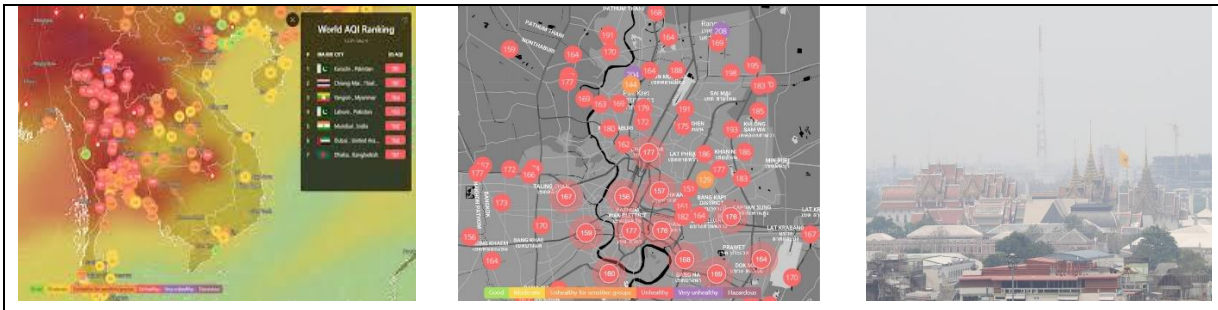
Figure 3: The tiny particle air pollution in Bangkok Environment with tiny particles (PM2.5) was covered in 2019 (left), and the Fine Dust size renders it practically invisible compared

2.7.2 Effects and Dangers from PM2.5 Dust Pollution

Aggravation of Respiratory Diseases: PM 2.5 can exacerbate respiratory conditions like asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). It increases the frequency and severity of asthma attacks and can lead to the development of chronic bronchitis. The health effects of PM 2.5 exposure are significant and multifaceted, affecting various systems in the body: Respiratory and Cardiovascular Impacts. Cardiovascular Problems: Exposure to PM 2.5 is associated with an increased risk of heart attacks, strokes, arrhythmias, and heart disease. These particles can induce inflammation and oxidative stress in the cardiovascular system, forming arterial plaque (Bumrungrad International Hospital, Thailand 2024).

Figure 4(a) shows the map from the Ministry of Publish Health, Thailand, which said that air pollution led to 200,000 hospital admissions on March 6-13, 2024. Toxic dust levels above safe limits persisted in the North, the Northeast, Bangkok, and surrounding provinces, adding to already severe health risks caused by air pollution. More than 1.3

million people have fallen sick in the kingdom since the start of the year as a result of air pollution, AFP quoted a ministry official as saying (Air Quality in Thailand, 2024).



a) Dust above safe limits in North, Northeast, and Greater Bangkok
Source: Bangkok Post (2024)

b) Why doesn't the Thailand Air Quality Index tell us the current air quality?
Source: Buakhamsri (2019)

c) Heavy fine dust covers the historic Rattanakosin Island district of Bangkok on Thursday.
Source: Chatpattarasill (2024)

Figure 4: Dust above safe limits in North, Northeast, and Greater Bangkok

Figure 4(b) reported that Thailand has been using a new Air Quality Index (AQI) that includes PM2.5 since October 2018. The AQI tells us what the average air quality is like over the past 24 hours. Thailand's AQI is differentiated from the more stringent U.S. Environmental Protection Agency Air Quality Index (U.S. AQI). At any given time, if Thailand's AQI indicates "moderate" air quality, the U.S.AQI would indicate "*air is unhealthy for vulnerable groups such as children and the elderly*." On the day when PM2.5 dust covered Bangkok and surrounding areas, there was a question of why the air quality reports by the Pollution Control Department and other applications such as IQAir AirVisual were different. The Air Quality Index of Thailand is divided into 5 levels, from 0 to 201 and above. If the Air Quality Index is higher than 100 that means the standardized of the AQI will begin to affect public health (Buakhamsri, 2019).

2.7.3 How Does the AQI Work?

The U.S. Air Quality Index (AQI) is EPA's tool for communicating about outdoor air quality and health. The AQI includes six color-coded categories, each corresponding to a range of index values. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 or below represents good air quality, while an AQI value over 300 represents hazardous air quality. The AQI is divided into six categories. Each category corresponds to a different level of health concern. Each category also has a specific color. The color makes it easy for people to quickly determine whether air quality is reaching unhealthy levels in their communities (Table 1).

Table 1: AQI basics for ozone and particle pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: the risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Source: The U.S. Air Quality Index (AQI) (2019).

2.7.4 Five Major Pollutants

The United States Environmental Protection Agency (EPA) establishes an AQI for five major air pollutants regulated by the Clean Air Act. Each of these pollutants has a national air quality standard set by EPA to protect public health: Ground-level ozone; Particle pollution (also known as particulate matter, including PM2.5 and PM10); Carbon monoxide; Sulfur dioxide; and Nitrogen dioxide.

Thus, PM2.5 has increasingly become a new challenge to Thailand, especially in the North, where forest fires, which usually start in mid-January, pose a variety of impacts to people's health. The World Health Organization (WHO) notes that PM2.5 is a fine particulate matter with a diameter of 2.5 microns or less that has been classified as carcinogenic since 2013, and along with other fine dust, they are capable of penetrating deep into the lungs, causing cardiovascular and respiratory impacts and also affecting other organs. The Geo-Informatics and Space Technology Development Agency (GISTDA) reported that 14 provinces were facing red (seriously harmful) levels of particulate matter 2.5 and less in diameter (PM2.5), ranging from 75.9 to 173.6 μg/m3 of air over the past 24 hours.

3. Research Methodology

Air pollution is again reaching concerning levels, which poses serious health risks. Among its components, particulate matter 2.5 (PM 2.5) is particularly hazardous. PM 2.5 refers to fine particles that are 2.5 micrometers or smaller in diameter, making them about 30 times smaller than the width of a human hair. This minuscule size allows these particles to pass the body's natural defense systems and enter deep into the lungs and,

potentially, the bloodstream. The PM 2.5 dust pollution consists of various components, including acids (such as nitrates and sulfates), organic chemicals, metals, soil or dust particles, and allergens. These particles originate from various sources, such as burning fossil fuels, industrial processes, construction sites, natural wildfires, slash-and-burn, and even household cooking. The main concern with PM 2.5 is its small size. While larger particles are typically filtered out in the nose and throat, PM 2.5 can evade these filters, enter the lung alveoli, and even enter the blood. This can lead to a myriad of health issues, some of which can be life-threatening to the respiration system of humans.

3.1 Research Objectives

To investigate and review the effects of particulate matter 2.5 (PM 2.5) dust pollution that caused the Thai populaces have posed a risk of stimulating the respiration system due to stroke, heart disease, lung cancer, and acute and chronic respiratory diseases to premature deaths using document research methodology, qualitative and quantitative research methods.

3.2 Research Procedures

Thailand's government has greenlighted incentives worth 8 billion THB (225 million USD) for sugarcane farmers who agree to cut fresh sugarcane without burning the residue, a move aimed at helping reduce the amount of PM2.5 dust in the 2022-2023 harvest year, funding to support the scheme will be sourced from the state-owned Bank for Agriculture and Agricultural Cooperatives. Under the scheme, the government will offer farmers who agree to cut fresh sugarcane without burning the residue 120 THB (3.4 USD) per Ton. Thailand's sugar cane output is estimated at 82.4 million Tons in the 2023-2024 crop year, with domestic sugar consumption projected at 25.7 million sacks, which represents 2.57 million Tons (World News, 2024).

Step I: Reviews of the PM2.5 Dust Situation in Thailand

Particulate pollution, especially PM 2.5 from biomass burning, affects public and human health throughout Thailand during the dry season. Therefore, PM 2.5 exposure increases the incidence of non-communicable diseases and mortality. Compared to April last year, in April 2023, the average PM2.5 dust value was 37.3 micrograms/cubic meter, and in 2024 the PM2.5 dust value was 25.5 micrograms/cubic meter, that is, reduced by 32%. Data from GISTDA's satellites report cumulative burning points in 2023, found 43,117 burning points, and in 2024, it decreased to 38,078 points, a decrease of 12% as well. The Ministry of Higher Education, Science, Research and Innovation (MHESI), through the Geo-Informatics and Space Technology Development Agency (Public Organization) or GISTDA, in collaboration with the National Research Office, the Pollution Control Department, Kasetsart University and Chiang Mai University, is monitoring the PM 2.5 dust situation hourly using satellite data via the "Check Dust" application. At 8:00 a.m. on March 29, 2024, 11 northern provinces had dust values exceeding the standard at the

red level. that have an impact on health and the respiratory system include Mae Hong Son 242.2 micrograms, Chiang Mai 169.9 micrograms, Lamphun 147.3 micrograms, Chiang Rai 131.3 micrograms, Phayao 107.4 micrograms, Lampang 103.6 micrograms, Tak 102.6 micrograms, Nan 102.6 micrograms, Uttaradit 89.4 micrograms, Phrae 87.2 micrograms and Sukhothai 85.5 micrograms, while another 21 provinces have values exceeding the orange standard, which is starting to affect health and the respiratory system.

Step II: Reviews of PM2.5 Dust Situation in Bangkok 2024

Bangkok residents have been told to expect rising levels of PM2.5, which forecasters at the Pollution Control Department (PCD) have said will continue to worsen from November 2023 to April 2024. The department is urging Bangkok residents to work from home until Wednesday to avoid the worst of the air pollution. The PCD said the rising concentration of PM2.5 pollutants is caused by poor air circulation and wind. The Bangkok Metropolitan Administration (BMA) stepped up its inspections of all pollution sources in the capital. City Hall has also ordered schools to arrange "dust-free" rooms at all kindergartens and schools under BMA's supervision. The Natural Resources and Environment Ministry has also asked ASEAN's secretary-general to urge all countries in the Greater Mekong Subregion to prevent forest fires by cracking down on activities such as slash-and-burn farming. PM2.5 levels fell slightly in some areas. People should take extra caution from March 14-16, as they will be affected by dust that passes over the areas (Bangkok Post, 2024).

Step III: Reviews of PM2.5 Dust Situation in Northern Region 2024

PM2.5 has increasingly become a new challenge to Thailand, especially in the North, where forest fires, which usually start in mid-January pose a variety of impacts to people's health. The World Health Organization (WHO) notes that PM2.5 is a fine particulate matter with a diameter of 2.5 microns or less that has been classified as carcinogenic since 2013, and along with other fine dust, they are capable of penetrating deep into the lungs, causing cardiovascular and respiratory impacts and also affecting other organs. Most provinces in the North were blanketed with dangerous red-coded levels of PM2.5 on Monday morning, with Chiang Mai rated the city with the worst air pollution in the enticement world (Online Reporter, 2024). In Chiang Mai, farmers have been encouraged to stick with just plowing the soil to clear their rice fields instead of burning rice straw, which adds to haze pollution. Summarized, The Geo-Informatics and Space Technology Development Agency (GISTDA) reported that 14 provinces were facing red (seriously harmful) levels of particulate matter 2.5 and less in diameter (PM2.5), ranging from 75.9 to 173.6 $\mu g/m^3$ of air over the past 24 hours. The safe threshold is at 37.5$\mu g/m^3$. PM2.5 levels ranged between 91 and 136 μg/m3 in Chiang Mai, Chiang Rai, Lamphun, Mae Hong Son, Nan, Tak, Sukhothai, Phitsanulok, Kamphaeng Phet and

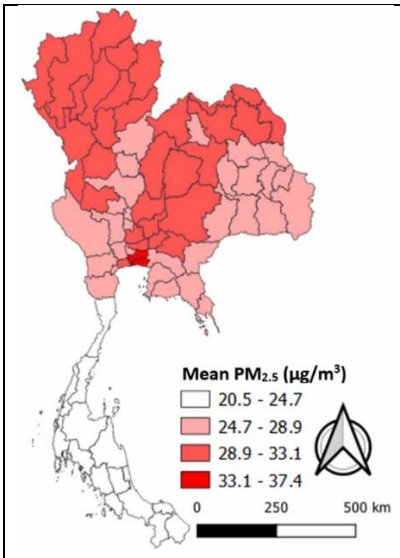
Uthai Thani provinces, with the highest dust levels at Thani Sub-District of Muang district in Sukhothai that affected from the fire-wide (Bangkok Post, 2024).

Step IV: Reviews of PM2.5 Dust Situation in Northeastern Region 2024

Levels of particulate matter 2.5 μg/m^3 or less in diameter (PM2.5) increased in all areas of 17 northern provinces on Thursday morning (March 9th, 2024), according to Pinsak Surasawadi, director-general of the Pollution Control Department (PCD), in his capacity as chairman of the Centre for Air Pollution Mitigation. He blamed the burning of agricultural waste and sugarcane plantations, coupled with weak winds and poor ventilation, for accumulated dust; and urged residents to refrain from burning their agricultural waste before the dust situation eased. The smog is expected to cover the upper and lower North until March 14. In Nakhon Phanom Province, PM2.5 dust levels were over the safe threshold in four districts despite winds blowing away dust above the Mekong River. However, this province was blanketed in smog, with harmful levels of PM2.5 dust measured between 180 and 200 μg/m^3. Authorities advised people to wear masks outdoors and avoid outdoor activities, as they would be at risk of respiratory diseases (Sripiachai & Kongvarakhom, 2024).

Step V: Reviews on Ingestion of PM2.5 Toxic Dust from Air Pollution into the Body

The air pollution problem in Bangkok and other provinces in every region of Thailand, especially fine dust or PM2.5, which has become more severe again, is because the sources of pollution, including cars, industry, construction, and daily activities, have not been controlled. Therefore, people must be prepared, such as wearing N95 or two regular masks stacked together. If not necessary, they should avoid areas with high PM2.5 dust levels because it has immediate effects. The most obvious symptoms are earache, eye ache, throat ache, and itching. However, the long-term effects are still unknown, such as whether PM2.5 dust will stimulate those with coronary artery disease and cerebrovascular disease to develop it earlier because there is no clear data collection in Thailand. Research data from China and the United States found that PM2.5 dust may enter the blood cells and pose a risk of stimulating the disease in this group of patients. According to data collected by Siriraj Hospital, lung diseases, and emphysema have increased between December 2018 and February 2024. In addition, PM2.5 dust is not just small dust, but also includes gases and heavy metals. How does the ingestion of PM2.5 toxic dust from the air pollution into the body (Figure 5).



a) The mean concentrations of PM2.5 by province in Thailand during 1996–2023.
Source: Mueller *et al.*, (2023)

b) PM2.5 to spike in Bangkok
Source: Bangkok Post (2024)

c) A firefighter tries to control a blaze on Doi Suthep mountain in Chiang Mai province
Source: Photo by Panumate Tanraksa (2024)

d) PM 2.5 dust affects the health of 10.5 million Thais.
Source: Than Settakij News (2024)

e) Siriraj Hospital reveals that Thais are getting more lung disease due to deteriorating air quality.
Source: Srirakul (2024)

Figure 5: Causes, effects, and ingestions of PM2.5 toxic dust from air pollution into the body

Step VI: Reviews of Previous Research Studies Indicate the Carcinogenicity in the Body from PM2.5 Dust (Cancer)

Medgyesi *et al.* (2021) explained that commercial databases can be used to identify participant addresses over time in their quality and impact on environmental exposure assessment are uncertain to evaluate the performance of a commercial database to find residences and estimate environmental exposure and match rates to survey addresses by participant characteristics were compared geographically-referenced predictors and estimates of ultrafine particulate matter (UFP) exposure from a land use regression model using LexisNexis and survey addresses at enrollment. The match rate at both survey periods was high (82-86%) and similar across characteristics.

Prakash Thangavel, Duckshin Park, and Young-Chul Lee (2022) detailed that several epidemiologic and toxicological studies have commonly viewed ambient fine particulate matter (PM2.5), defined as particles having an aerodynamic diameter of less than 2.5 μm, as a significant potential danger to human health. PM2.5 is mostly absorbed through the respiratory system, where it can infiltrate the lung alveoli and reach the bloodstream. In the respiratory system, reactive oxygen or nitrogen species (ROS, RNS) and oxidative stress stimulate the generation of mediators of pulmonary inflammation and begin or promote numerous illnesses. While PM2.5 is an established lung carcinogen, a growing body of research indicates it may also increase the risk of other cancers. To improve understanding of cancer risks associated with this common outdoor air

pollutant, OEEB investigators are studying the relationships between PM2.5 and other traffic-related pollutants at several other cancer sites, including breast, liver, and lymphohematopoietic malignancies (Division of Cancer Epidemiology & Genetics at the National Cancer Institute, 2022).

Jones *et al.*, (2024) described particulate matter ⩽2.5 μm in aerodynamic diameter (PM2.5) as an established cause of lung cancer, but the association with ultrafine particulate matter (UFP; aerodynamic diameter < 0.1 μm) is unclear. UFP was modestly associated with lung cancer risk overall (hazard ratio [HR], 1.03 [95% confidence interval (CI), 0.99-1.08]). Observation of a positive trend among men; risk was increased in the highest exposure quartile versus the lowest (HR, 1.39 [95% CI, 1.05-1.85]; P for trend = 0.01) and was also increased in continuous models but no increased risk was apparent among women (P for interaction = 0.03). Adenocarcinoma risk was elevated among men born between 1925 and 1930 (HR, 1.13 [95% CI, 1.02-1.26] per 10,000) but not for other birth cohorts, and was suggestive for men with ⩾10 years of residential duration (HR, 1.11 [95% CI, 0.98-1.26]). This study found no consistent associations for women or other histologic subtypes. UFP exposure was modestly associated with lung cancer overall, with stronger associations observed for adenocarcinoma of the lung.

Step VII: Thai Government Policy on Solving PM2.5 Dust Problems

Economic growth leads to environmental pollution, especially PM2.5 air pollution, which affects public health and the quality of human life throughout the world. This is a challenge for the governments of all countries facing this problem in issuing various policies and measures to correct, prevent, and reduce the impacts that will occur on the health of the population in their country. Thailand is an added country that is facing the problem of PM2.5 pollution. Guidelines and policies of the government sector to control and reduce the impact of the PM2.5 particulate pollution crisis in Thailand, to propose measures for prevent and correct PM2.5 particulate pollution, government measures in solving the problem of particulate matter consists of policy-level measures by classified into various aspects according to the National Agenda Action Plan Solving the problem of dust pollution in 2019 by focusing on 3 main measures, that including improving spatial management efficiency; reducing and preventing pollution at source; and improving efficiency. Pollution Management Policies: There are also key measures that government agencies have set up to control pollution from each designated source; to control transportation and transport; control the industrial sector, control burning in open areas and agricultural areas, dust control measures from construction, and cross-border smog control atmosphere. The last recommendation for the government's PM2.5 pollution control guidelines is to enhance the management of PM2.5 dust pollution in Thailand (Chanabawornsakul *et al.*, 2022).

A national committee to devise a policy on battling the PM2.5 problem and an agency to manage the smog are needed to address the nation's air pollution, according to the Thailand Development Research Institute (TDRI). The impact on human health is the

most serious concern. The State of Global Air report blamed toxic haze for 32,200 deaths in 2019. Greenpeace (Thailand) recently linked the ultra-fine dust to 29,000 premature deaths in 36 provinces — making it a much bigger threat than the death toll from traffic accidents, narcotics, and homicides. The government must solve these problems at its core by tackling inadequate state regulations, inert bureaucracy, and silo culture. The government cannot stick with its same old centrality; different departments must be given authority to have "Departmentocracy". The government must look at haze as a chronic health and environmental threat instead of "seasonal air pollution" that will be dissipated over time when the rain comes. The country's policy on PM2.5 is inconsistent and piecemeal because the problem is presented as being seasonal. The prime minister would also be able to steer all departments to work proactively and cooperatively, with appropriate goals and action plans based on the level of pollution in that airshed area. Cooperation should also be fostered with neighboring countries and Thai businesses that promote mono-crops like maize or sugarcane in Cambodia, Laos, and Myanmar (Poapongsakorn, Panthakuo, & Rasakom, 2023).

The Government is taking serious action against the PM 2.5 dust pollution and stresses the need to curb the sources of the problem. To deal with this issue effectively, the Thailand Board of Investment (BOI) has approved measures to promote investment in tackling the PM 2.5 issue. Under these measures, inventions have been offered to companies that help farmers groups and local organizations in environmental management to reduce and prevent the PM 2.5 problem in all parts of the country. The target areas include community forests, national reserves, and national forests. The provision of equipment to stop forest fires, and the organizing of training programs in forest fire prevention and control. Entrepreneurs participating in forest management and the reduction of PM 2.5 dust pollution will be offered a corporate income tax exemption for three years. The Government is also committed to implementing short- medium-, and long-term measures to promote clean air for people's health and safety (The Government Public Relations Department, 2024).

Step IX: Populaces' Perceptions of Their Health from the Thai Government Will Be Supported

Because air pollution from PM 2.5 dust has been a major problem for more than 15 years, it is an environmental threat that affects the health of people around the world. In October 2021, the World Health Organization (WHO) issued new 15-year air quality guidelines to be lower than the 2005 criteria. This situation revealed that 38 million Thais live in areas with excessive dust pollution, which is the cause of increased illnesses! Heart disease, stroke, chronic obstructive pulmonary disease, lung cancer WHO points out that air pollution is a health threat, proposes new air quality criteria, protects the lives of 170,000 Thais/year, Thai Health Promotion Foundation supports academic work, aims to adjust air quality standards at the right point. Air quality levels for PM 2.5 dust have an annual average of 5 micrograms per cubic meter, up from 10 micrograms per cubic meter,

and a 24-hour average of 15 micrograms per cubic meter, up from 25 micrograms per cubic meter, set as a standard value as an alternative for setting policy goals, as well as a tool for designing effective measures to reduce air pollution and protect public health (Rajarathnam, 2021).

Air pollution is a major cause of the risk of developing non-communicable diseases, accounting for 3 out of 4 of all deaths in the country. This is consistent with the 73rd United Nations General Assembly in 2018, which announced that air pollution is one of the 5 risk factors, along with unhealthy eating habits, smoking, drinking alcoholic beverages, and physical inactivity. The Thai Health Promotion Foundation is aware of the impact of PM 2.5 dust. Expanding from the individual or local level, led to the promoted Thai government policies to solve the PM 2.5 dust problem. In the past, the Thai Health Promotion Foundation, together with the Breath Council of 8 Northern Provinces, drove the resolution of the PM 2.5 dust crisis in the northern region, resulting in a change in regional values, such as reducing agricultural burning, creating community firebreaks, and establishing an academic center for air pollution prevention and resolution to develop academic that responds to the context of society, to apply the knowledge gained to work guidelines in each area, aiming to promote public participation in reducing air pollution problems that affect the health of people in the country (Adulyanon, 2023).

38 million Thais live in areas with PM2.5 levels exceeding 50 micrograms per cubic meter. Of these, 15 million are at-risk populations, including children, pregnant women, the elderly, and people with respiratory diseases. In 2017-2020, Thais were found to be suffering from four diseases caused by air pollution: cardiovascular disease, cerebrovascular disease, chronic obstructive pulmonary disease, and lung cancer. When calculated, the cost of treating lung cancer patients is nearly 200,000 baht per person per month. If air quality improves, healthcare costs will likely decrease accordingly. When comparing the WHO's recommended air quality standards between the old standards in 2005 and the new standards in 2021, it was found that if Thailand used the old recommended criteria at an annual average of 10 micrograms per cubic meter, it would reduce premature deaths by 110,000 people per year, equivalent to a health benefit value of 3.75 trillion baht. In 2021, recommended criteria at an annual average of 5 micrograms per cubic meter were used, it would reduce premature deaths by up to 170,000 people per year, equivalent to a health benefit value of 5.82 trillion baht (Thiwantha, 2023).

Approximately 1 million (95% CI 690 000–1·3 million) premature deaths per year from 2000 to 2019 were attributable to short-term PM2·5 exposure, representing 2·08% (1·41–2·75) of total global deaths or 17 (11–22) premature deaths per 100 000 population (Yu et al., 2024). In social psychology, the term person perception refers to the different mental ideal processes that are used to form impressions of other people or organizations. This includes not just how the response forms these impressions, but the different conclusions we make about other people based upon our impressions. This research focused on creating questionnaires that assessed populaces' perceptions of their thinking

about clearing the air to address pollution's cardiovascular health crisis of the particulate matter (PM2.5) concentration levels, the key pollutant for human health toward their spiration system effects declined globally by just annually between 2021 and 2024 in Thailand. Populaces' attitudes to the problems and supported by the government were assessed. The independent and dependent variables of their responses were associated.

3.3 Research Methods

Designing the *Document Research Methodology* method is used to investigate, categorize, and analyze physical sources, most commonly written documents, in the social, public, or digital world. This research method is just as good as and sometimes even more cost-effective than surveys, in-depth interviews, or other observation-based methods such as ethnography. Quantitative data research was associated with and examined. Qualitative data research was reviewed.

3.4 Research Participants

Pollution Control Department and Department of Health, Ministry of Public Health reported that PM2.5 dust tends to increase to the level that starts to affect health (orange), spreading in various regions, which will affect health, causing diseases of the respiratory system, cardiovascular system, and lung cancer if ingested in large quantities and for a long time. In addition, some chemical components cause cancer, such as polycyclic aromatic hydrocarbons or volatile organic compounds, which can also cause lung cancer. The World Health Organization's 2019 Burden of Disease Study found that a total of 31,081 Thais died from atmospheric particulate matter, with 11,408 deaths from ischemic heart disease, 7,274 from stroke, 3,043 from chronic obstructive pulmonary disease (COPD), and 2,464 from lung cancer. Air pollution disease from the Ministry of Public Health's health database found that air pollution disease tends to increase every year, including lung cancer. In 2022, there were 189,713 reports of lung cancer patients, which is 291.18 per 100,000 population.

Air pollution-related disease surveillance between January 1 - March 5, 2023, a total of 1,325,838 patients with air pollution-related diseases. This week (March 2nd-8th, 2023), 196,311 patients were found, an increase from the previous week, when 161,839 patients were also found. The sickest groups were respiratory diseases, 583,238 patients, an increase from the previous week by 85,910 patients; dermatitis, 267,161 patients, an increase of 35,878 patients; eye inflammation, 242,805 patients, an increase of 36,537 patients; and cardiovascular and cerebrovascular diseases, 208,880 patients, an increase of 33,413 patients. Summarized, PM2.5 dust: More than 10 million Thais will be sick from "air pollution" in 2023 in 38 provinces in Bangkok and surrounding area provinces, Central regions, Northern region, and Northeast region.

This research study will select the participants consisting of populaces who have been sick with PM2.5 dust in each region, including Bangkok and surrounding provinces, totaling 400 people, aged 18 years and above, who can read, write, or communicate in

Thai version in 2023 from the based on of the Ministry of Public Health website data based.

3.5 Research Instruments

3.5.1 The Questionnaire on Populaces and PM2.5 Affected Interaction (QPPAI)

Creative the 36-item *Questionnaire on Populaces and PM2.5 Affected Interaction* (QPPAI) consists of six scales namely: Awareness of the Causes of PM2.5 Toxic dust Pollution (ACTP); Understanding of Effects of PM2.5 Toxic Dust (UETD); can be inhaled deep into the respiratory tract and lungs. Understanding the Health Effects of PM2.5 dust on the Respiratory system and lungs (UHER), Awareness of news from the media or Government organizations for groups at risk of danger from PM2.5 dust, and receiving Advice on the care and Treatment (AGAT); Knowing how to Protect yourself from PM2.5 dust and getting Support from the Government (KPSG), and Receiving Care from the Government for being a Patient with PM2.5 dust pollution (RCGP) scales. Each scale consists of 6 items in five options (Never (0), Seldom (1), Sometimes (2), Often (3), and Always (4).

3.5.2 The Attitudes on Solving-Problem PM2.5 Toxic Dust (ASPTD)

Air pollution has emerged as a global public health concern. According to the World Bank, PM2.5 dust caused damages of 210 billion baht in 1990. This jumped to 870 billion baht in 2023. Meanwhile, the financial burden from PM2.5 on households in Bangkok and 38 Provinces and its satellite provinces amounted to 436 billion baht a year in PM2.5 knowledge, PM2.5 preventive attitude, or PM2.5 preventive behavioral intention among the Thai populaces with chronic diseases. The medical populace's knowledge of air pollution is paramount for implementing future interventions directed toward patients about a person who used to be sick with PM2.5 dust or thing; tendency or orientation, especially of the mind and health. Their perceptions of their thinking may be a positive or negative attitude to their posture position of the body appropriate to or expressive of an action, and emotion that was assessed using the 10-item *Attitudes on Solving-Problem PM2.5 Toxic Dust* (ASPTD) in five options, strongly agree (4), agree (3), neither disagree nor agree (2), disagree (1), and strongly disagree (1) of their responses' threatening attitudes to be solved problems of the PM2.5 Toxic Dust, sustainability.

3.6 Research Collections

The sample group who participated in this research project were people with respiratory tract disease from PM2.5 dust pollution, aged 18 years and over, with a telephone, Facebook, Twitter, Line, or other media that could be contacted and coordinated. The researcher would send the research instruments to them and can reply with the complete information that they commented on. The research team will randomly collect data from the Ministry of Public Health website. The names or other patient data will not be disclosed. The populace's perceptions assessment form will be randomly sent to 500

relevant persons between December 2022 and March 2023 and will be selected as the complete version of the sample group of 400 sets.

3.7 Data Analysis

Designing the Document Research Methodology was administered and reviewed on the documents, essay publications, media communications, research studies, organization reports, etc., that involved more than 10 million patients suffering from air pollution-related diseases from November 2022 to April 2023, especially from the first five days of January 2023 due to PM2. 5 toxic dust pollution, a total of 1,325,838 patients. Creative the qualitative data research methodology including interviews, focus groups, and observation, that every participant is asked via mobile, Facebook, Online, e-mail, and other media communication. The quantitative data research method was analyzed using item means, item standard deviation, scale means, variance, internal consistency (Cronbach alpha reliability) coefficient, and F-test statistics. The independent variable with scale grand means of the QPPAI and dependent variable (the gran means of the ASPTD) were associated using simple and multiple correlations, standardized regression coefficient, and the determination coefficient (R^2) predictive value analysis.

4. Results

4.1 The Document Research Methodology Data

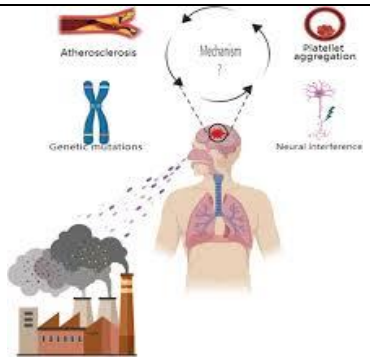
The results of this section using the Document Research Methodology Data analysis, the steps of the impact of the perception of PM2.5 dust pollution into the body, both short-term, medium-term, and long-term, until the body changes into a sick person, the symptoms are indicated of people's sickness, and the physical therapy will show symptoms in various forms periodically until it may die. The research results will sequence the steps to indicate each step as follows:

Step 1: Symptoms Indicating That PM2.5 is Affecting Health

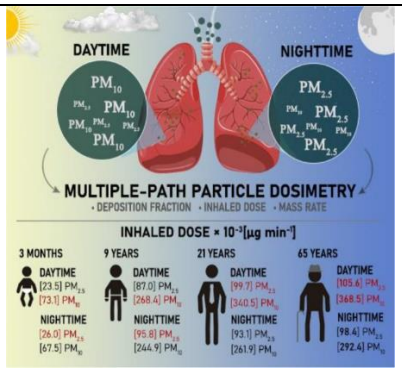
Short-term effects: Eyes, nose, throat, and respiratory irritation: Eye pain, cough, sneeze, runny nose, breathing difficulty, and exhaustion. Deteriorates lung function: It might cause the recurrence of congenital diseases such as asthma or heart diseases. *Long-Term Effects:* Chronic bronchitis: Deteriorates lung function: Increases the risk of lung cancer because PM 2.5 dust is one of the carcinogens. Especially, in patients who have respiratory problems, and heart diseases as well as children and elderly people, are more sensitive to dust, and they might be more susceptible than others. *How to protect themself from PM 2.5 dust:* Avoid outdoor activities such as exercise or running in unsafe PM2.5 level areas. Wear a mask that can protect you from PM 2.5. Drink water to increase oxygen to the blood. Avoid volatile organic compounds such as combustible waste, painting materials, and pollution from transportation and industrial wastes. If humans have any abnormal symptoms such as respiratory distress, cough, breathing difficulty,

or exhaustion, they should appoint a doctor immediately (Vej Thani Hospital, 2020) (Figure 5).

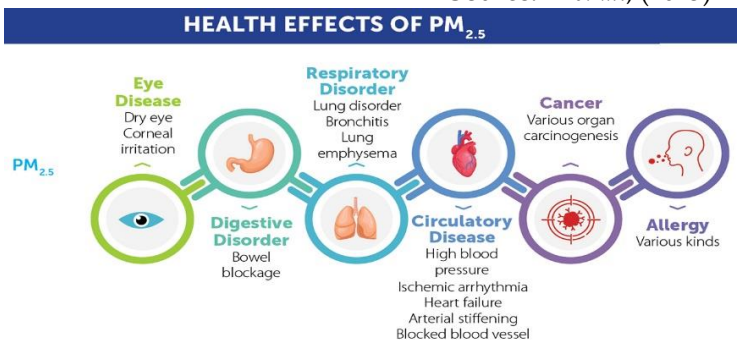
Step 1: Symptoms indicating that PM2.5 is affecting health
Source: Vej Thani Hospital, 2020



Step 2: PM2.5 progress of toxic dust from the air pollution into the body and ischemic stroke
Source: Li *et al.*, (2023)



Step 3: Respiratory deposition dose of PM2.5 and PM10 at the toxic dust source environment
Source: Cipoli *et al.*, (2023)



Step 4: Health effect of PM2.5
Source: Sehgal (2021)

Step 5: Death of patients with respiratory illness from PM 2.5
Source: WHO (2023)

Figure 6: Health effect of PM2.5 on human death of patients with respiratory illness

Step 2: PM2.5 Progress of Toxic Dust from the Air Pollution into the Body and Ischemic Stroke

Previous studies on PM2.5 and ischemic stroke indicate that the progress of toxic dust has reached different or even opposing conclusions, and considering the heterogeneity of PM2.5 has led researchers to focus on the health effects of specific PM2.5 components. However, due to the complexity of PM2.5 constituents, assessing the association between exposure to specific PM2.5 constituents and ischemic stroke presents significant challenges. Li *et al.* (2023) review and analyze studies related to PM2.5 and its different components and ischemic stroke, aiming to understand the composition of PM2.5 and identify its harmful components, elucidate their relationship with ischemic stroke, and thus provide some insights and considerations for studying the biological mechanisms by which they affect ischemic stroke and for the prevention and treatment of ischemic stroke associated with different components of PM2.5 (Figure 5).

Step 3: Respiratory Deposition Dose of Pm2.5 and Pm10 at the Toxic Dust Source Environment

Inhalation of particulate matter (PM) has been extensively associated with the worsening and onset of cardiorespiratory diseases, being responsible for millions of deaths annually. Assessment of PM deposition in the human respiratory tract is critical to understanding the health risks from environmental exposure of vulnerable age groups. Cipoli *et al.*, (2023) reported that the concentrations for PM fractions were higher at night time and is a period marked by the burning biomass for residential heating. Regional deposition fractions (DF) for PM2.5 were in the ranges 17–38% (head), 4–14% (tracheobronchial) and 20–28% (pulmonary), while for PM10 were 24–67% (head), 4–27% (tracheobronchial) and 12–22% (pulmonary). Children and the elderly were found to be the most vulnerable groups to PM deposition, especially for the TB and H regions, respectively.

Step 4: Health effects of PM2.5

Generally, people know that air pollution is one of the top health risks in humans and severely affects children. To understand a health assessment of children across six ecologically different districts to help formulate better policies prioritizing action on air pollution and formulate a new Heavy Metal Exposure Index. Children are more sensitive to changes in air pollution. Thus, health effects are more evident. Sehgal (2021) reported from a research survey in India that damage to the respiratory system in children can be devastating and permanent. The adverse effects of air pollution may be obvious in the adult population owing to the long exposure period resulting in several chronic diseases. As a result, it is essential to monitor the levels of air pollutants that affect air quality and human health daily. The following infographics on step 5, Figure 6, depict the Ambient PM2.5 in six cities and their health effects.

Step 5: Death of Patients with Respiratory Illness from PM 2.5

The World Health Organization states that if the air contains PM 2.5 dust exceeding 10-25 micrograms per cubic meter and the body receives it continuously for a long period, it will cause inflammation, adversely affect blood clotting, the function of blood vessel lining cells, and cause chronic diseases such as heart disease, lung disease, and cancer. Small dust particles of no more than 2.5 microns or PM 2.5 dust not only spread into the respiratory system, and bloodstream and hurt the functioning of various organs in the body, but also seriously damage the heart to the point of heart failure (Heart Failure) and heart attack (Heart Attack). Therefore, avoiding PM 2.5 dust is something that must be aware of and careful to keep the heart strong for a long time. The Ministry of Public Health monitors the PM 2.5 dust in the North, finding that 2 million Thais were sick at the beginning of the year 2023. The Department of Health of Thailand (2023) revealed that more than 31,081 Thais have died from dust, which is also a cause of cancer. Statistical data reviewed by the World Health Organization (WHO) has suggested that approximately 20% of cardiovascular deaths are caused by excessive exposure to air

pollution including PM2. 5 and more than 3 million people die from this cardiovascular cause every year (The World Health Organization: WHO, (2023).

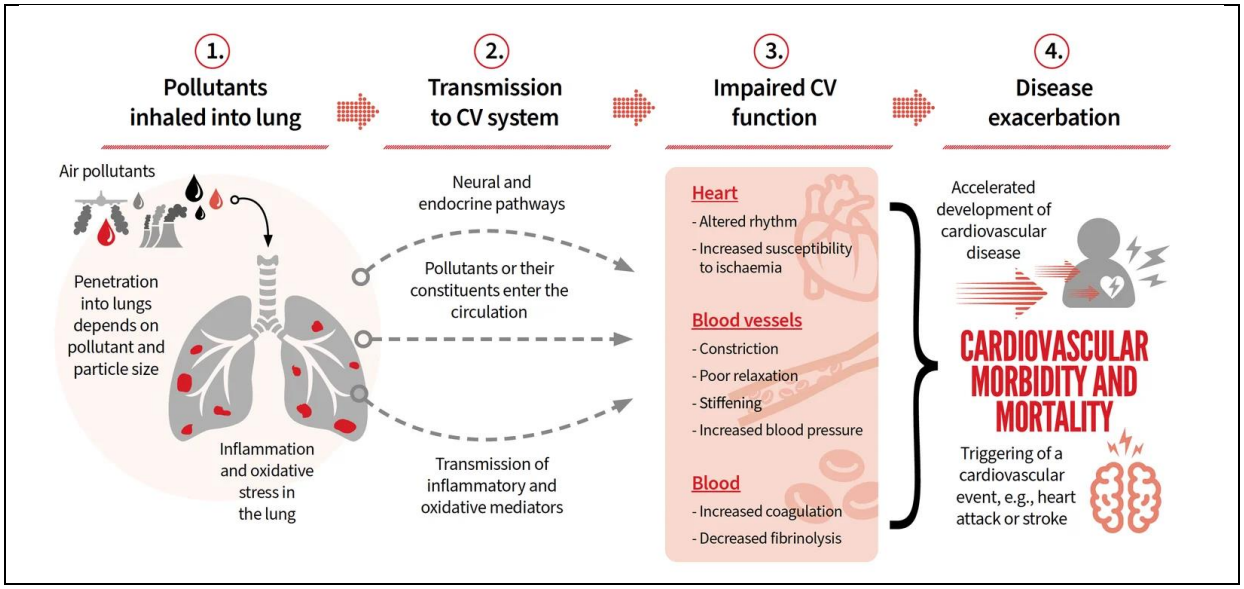
Step 6: Effect of Patients with Respiratory Illness from Pm 2.5 on Heart Failure to Die

Dr. Chatthanong Yodwutthi, a Cardiologist at Bangkok Heart Hospital (2023) explains that the impact of PM 2.5 dust on the heart, if it occurs acutely, will cause blood vessels to become brittle and blood vessels to burst, and in patients with heart disease, it will stimulate the existing disease to become more severe. In the long term, the impact will cause changes at the cellular level, stimulate inflammation throughout the body, and cause blood vessels to thicken, causing the muscles in the blood vessel walls to grow, which is as harmful to the body as people who smoke. In the future, it is expected to increase to be one of the main risk factors for heart disease. Air pollution is linked to cardiovascular and respiratory diseases because it causes damage to blood vessels and increases stress, leading to higher rates of high blood pressure, diabetes, stroke, heart attacks, and heart failure, which are the biggest risk factors for death.

Step 7: The Impacts of Air Pollution on Cardiovascular Health Risk Factors for Ill Health and Death

World Heart Federation (2024) has reported that everyone is exposed to air pollution throughout their lives, no matter where they live in the World. its impacts are far-reaching – from causing and exacerbating ill health to loss of life. Air pollution—which has been shown to have damaging effects on most organs of the body—is the sixth biggest risk factor for mortality globally, the seventh for disability-adjusted life years (DALYs)*, and the number one environmental risk factor for ill health and death. The impacts of air pollution on cardiovascular health are profound, with exposure linked to the exacerbation of all major CVDs, including IHD and stroke. The World Bank estimates that the global cost of health damages associated with exposure to air pollution is US$8.1 trillion, equivalent to 6.1% of the global GDP, with 1.2 billion annual workdays lost. Predictions indicate that global air pollution-related healthcare costs will surge from US$21 billion in 2015 to US$176 billion in 2060. There are no countries in Africa, the Eastern Mediterranean, or Southeast Asia regions recorded an average annual PM2.5 concentration below 10 μg/m^3. *Long-term Health Effects*: Long-term exposure to PM 2.5 can impair lung function, particularly in children and adolescents whose lungs are still developing. *Cancer:* There is a growing body of evidence linking long-term PM 2.5 exposure to an increased risk of lung cancer. *Mortality*: Studies have shown a strong correlation between increased PM 2.5 levels and premature mortality. The risk is particularly high for the elderly and those with pre-existing health conditions (Figure 7).

Figure 7: The impacts of air pollution on cardiovascular health risk factors for ill health and death



Source: World Heart Federation (2024)

Figure 7 confirms that most large-scale meta-analyses show clear associations between exposure to both short-term and long-term air pollutants and the increased risk of CVDs. In many cases, various CVDs are associated with more than one pollutant. While there will be some overlap in risk estimates from closely related pollutants, combined air pollutant mixtures will compound risks.

4.2 Qualitative Data Analysis

Certain groups are more vulnerable to the effects of PM 2.5, including children, the elderly, and individuals with heart and lung diseases. The effects: Expecting women exposed to high levels of PM 2.5 risk a low birth weight and preterm birth of their babies. The effects are mitigating the PM 2.5 for monitoring the air quality indexes, reducing exposure during days with high pollution, using air purifiers indoors, wearing masks designed to filter out fine particles (N95), and avoiding outdoor activities.

4.2.1 Serious Threat: The Dangers of PM2.5 Fine Dust

Due to PM2.5's very small size, PM2.5 toxic dust particles can be inhaled deep into the respiratory tract and lungs. Some particles may even enter the bloodstream and circulate throughout the body, causing a variety of health problems. Air pollution certainly has a direct impact on the respiratory system and lungs. Especially, small dust particles that cannot be seen with the naked eye can easily and quickly pass into the respiratory tract, causing asthma patients to flare up or causing normal people to develop asthma as well. If it is not resolved quickly, or if you are not aware that you have inhaled small pollutants into the respiratory system and lungs and accumulated for a long time, it may eventually be a factor in causing lung cancer.

4.2.2 The Lessons Learned from PM2.5 and Right to Clean Air in Thailand's Situation in 2023

According to the Pollution Control Department (PCD), during the beginning of the season, between Jan 1 to Feb 15, nearly 19,000 (18,988) hotspots had occurred in the region, or a 118% increase compared to last year's record of 8,698 already. The PM2.5 air pollution reached to show off a peak in March when its 24-hour concentration level rose over 500 μg/m³. The country's safety limit stands at 50 μg/m³, and the WHO's is recommended at 15 μg/m³. Over two million people since January 1, 2024, have had their health affected by the haze, with symptoms ranging from mild to severe effects, according to the ministry. The most notable symptoms were involved with respiratory systems, but long-term exposure could also cause chronic health problems, including lung cancer. At the end of the fire season, the PCD noted that the average 24-hour concentration level of PM2.5 in the North was at 63 μg/m³ or a 110% increase from last year's 30 μg/m³. The number of days with PM2.5 beyond the safe limit stood at 112 days, or a 60% increase from last year's 70 days, and the hotspots recorded for the whole season stood at 108,984, or a 356% increase from last year's 23,877.

4.2.2.1 Heart Hazards

Continuously breathing in fine dust particles can cause deposits in blood vessels, leading to heart attacks or strokes. Exposure to air pollution also affects heart muscle cells, causing irregular heartbeats and, in severe cases, sudden heart attacks.

4.2.2.2 Brain Threats

When fine dust particles enter the bloodstream and accumulate, it results in high blood pressure and thick blood, which increases the risk of blood clots in the brain, including hardening of the cerebral arteries, causing the blood vessels in the brain to narrow or rupture, which is the cause of stroke and death.

4.2.2.3 Carcinogenicity in the Body from PM2.5 Dust (Cancer)

Long-term (months to years) exposure to PM2.5 has been linked to premature death, particularly in people who have chronic heart or lung diseases, and reduced lung function growth in children. It can also cause chronic heart and blood vessel diseases, particularly coronary heart disease. For the long-term effects, it can lead to lung function decline, emphysema, and increased risk of lung cancer, even for non-smokers. The International Agency for Research on Cancer has classified ambient outdoor pollution, including fine particulate matter (PM2.5, aerodynamic diameter <2.5μm) as a Group 1 human carcinogen. Division of Cancer Epidemiology & Genetics at the National Cancer Institute (2022) confirms that most of the epidemiologic evidence supporting this classification was from studies showing an association between PM2.5 and lung cancer. Associations for other traffic-related pollutants, such as nitrogen dioxide (NO_2) are more mixed. There are few studies of ultrafine particulate matter (UFP, <100nm) and cancer.

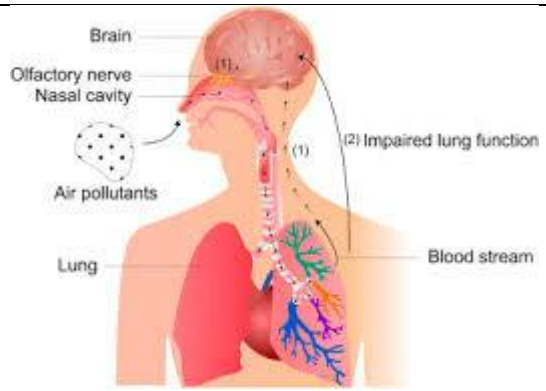
UFP is an unregulated pollutant with unique physiochemical properties that suggest it may be more toxic than larger particles.

4.2.3 PM2.5 Dust Pollution into Human Lung Function Processes

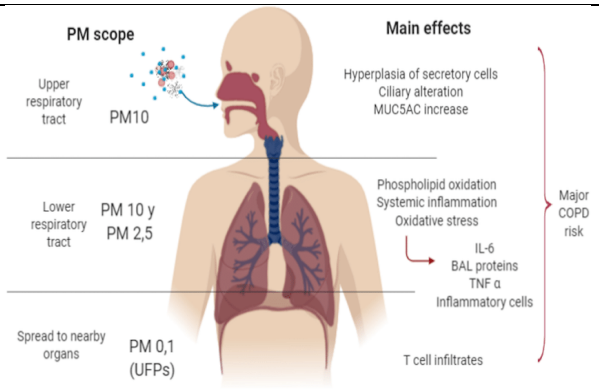
Although the negative effects of particulate matter (PM2.5) dust pollution on cognitive performance, the exact routes by which air pollutants may unfold their neurotoxic effects have barely been tested empirically, and there are substantial gaps in the knowledge of the underlying causal mechanisms (Griffiths & Mudway, 2018).

First, air pollutants may damage the brain directly by entering through the olfactory nerve or the lung, with subsequent entry into the bloodstream providing access to the brain. It is mainly very fine particles that are assumed to follow this route (Block & Calderón-Garcidueñas, 2009; González-Maciel *et al.*, 2017). (Figure 8a).

Mainly, smaller air pollutants (fine particles) may damage the brain directly by entering through the olfactory nerve or the lung, with subsequent entry into the bloodstream providing access to the brain (path 1). Air pollutants may also enter the lung by inhalation, thus impairing lung function or causing pulmonary inflammation (path 2). Impaired lung function may cause lower (abnormal) blood oxygen levels (hypoxemia), leading to systemic inflammation, oxidative stress, cerebral arterial stiffness, and small-vessel damage. Air pollutants also cause inflammatory responses of immune cells residing in the lung, e.g. pulmonary macrophages, thereby adding to or causing a substantial systemic presence of inflammatory mediators.



a) Lung function: Routes taken by inhaled fine particles to cause subsequent cognitive impairments
Source: Arete *et al.*, (2021).



b) Main effects and anatomical reach of particulate matter (PM10, PM2.5 and PM0.1)
Source: Loaiza-Ceballos *et al.*, (2022)

Figure 8: PM2.5 dust pollution into human's lung function process

Second, air pollutants may enter the lung by inhalation, thus impairing lung function or causing pulmonary inflammation (Figure 1a, path 2). After inhalation, fine particles can penetrate the deepest parts of the lung, e.g. the alveoli, due to their small size (Xing *et al.*, 2016). Impaired lung function may cause lower (abnormal) blood oxygen levels (hypoxemia), leading to systemic inflammation, oxidative stress, cerebral arterial

stiffness, and small-vessel damage (Lutsey *et al.*, 2018). Air pollutants also cause inflammatory responses of immune cells residing in the lung, e.g. pulmonary macrophages, thereby adding to or causing a substantial systemic presence of inflammatory mediators (Guarnieri & Balmes, 2014). Main effects and anatomical reach of particulate matter. Depending on the aerodynamic diameter (< 0.1 μm, 2.5 μm, or 10 μm), PM can enter different anatomical sites of the respiratory tract, where it can remain or spread to other organs and tissues, causing diverse effects on them and increase susceptibility to human pathologies, including COPD (Loaiza-Ceballos *et al.*, 2022) (Figure 8b).

4.2.4 Long-term Exposure to Pm 2.5 Can Impair Lung Function

For PM2.5, short-term exposures (up to 24 hours duration) have been associated with premature mortality, increased hospital admissions for heart or lung causes, acute and chronic bronchitis, asthma attacks, emergency room visits, respiratory symptoms, and restricted activity days. These adverse health effects have been reported primarily in infants, children, and older adults with preexisting heart or lung diseases. In addition, of all the common air pollutants, PM2.5 is associated with the greatest proportion of adverse health effects related to air pollution, both in the United States and worldwide, based on the World Health Organization's Global Burden of Disease Project.

Exposure to fine particulate matter and black carbon is related to cognitive impairment and poor lung function but is less known about the routes taken by different types of air pollutants affect cognition. Aretz *et al.* (2021) reported the longitudinal observational data for 49,705 people aged 18+ from 2006 to 2015 from the Dutch Lifelines cohort study. By linking current home addresses to air pollution exposure data from ELAPSE in 2010, long-term average exposure to PM2.5 and BC was assessed. Lung function was measured by spirometry, and Global Initiative (GLI) z-scores of forced expiratory volume in 1s (FEV1) and forced vital capacity (FVC) were calculated. Cognitive performance was measured by cognitive processing time (CPT) assessed by the Costate Brief Battery. Linear structural equation modeling was performed to test direct/indirect associations. Higher exposure to PM2.5 but not BC was related to higher CPT and slower cognitive processing speed [Total Effect PM2.5: FEV1 model = 8.31 × 10−3 (95% CI: 5.71 × 10−3, 10.91 × 10−3), FVC model = 8.30 × 10−3 (95% CI: 5.69 × 10−3, 10.90 × 10−3)]. The direct association of PM2.5 constituted more than 97% of the total effect. Mediation by lung function was low for PM2.5 with a mediated proportion of 1.32% (FEV1) and 2.05% (FVC), but higher for BC (7.01% and 13.82% respectively).

Long-term (months to years) exposure to PM2.5 has been linked to premature death, particularly in people who have chronic heart or lung diseases, and reduced lung function growth in children and general populations. The effects of long-term exposure to PM10 are less clear. Although, several studies suggest a link between long-term PM10 exposure and respiratory mortality. The International Agency for Research on Cancer (IARC) published that concluded that particulate matter in outdoor air pollution causes

lung cancer. Even though Lung cancer is not a genetic inheritance like other kinds of cancer, if there is someone in the family who has lung cancer starting from a young age, the family members also have a high risk of having lung cancer.

4.2.5 Effects of PM2.5 Dust Pollution on Health and the Impact Contamination on the Respiratory System

PM2.5 has significant health impacts, particularly on the respiratory and cardiovascular systems. Short-term exposure to PM2.5 can irritate the eyes, nose, and throat. These fine particles can get deep into the lungs and alveoli some may even get into the bloodstream. Exposure to these particles can affect a person's lungs and heart and cause chronic respiratory diseases such as asthma chronic obstructive pulmonary disease (COPD) and lung cancer. Additionally, PM2.5 has been linked to cardiovascular diseases such as myocardial infarction, hypertension, and strokes. Bangkok, the bustling capital of Thailand, is currently facing a severe air pollution problem due to high levels of PM2.5. PM2.5 refers to fine particulate matter, is smaller than 2.5 micrometers in diameter, and can penetrate deep into the alveoli and bloodstream, causing respiratory and cardiovascular problems. In this article, learn more about what PM2.5 is, the sources of PM2.5 in Bangkok, and the impacts of PM2.5 on public health. The main sources of PM2.5 in Bangkok are vehicle emissions, construction sites, and open burning of agricultural waste. Bangkok is known for its heavy traffic congestion, which leads to high fine dust levels from vehicle emissions. Furthermore, there are many construction sites in the city (Winny, 2023)

4.2.6 Seek Medical Advice Humans' Experience

- **Persistent Respiratory Symptoms:** This includes ongoing coughing, wheezing, shortness of breath, or chest tightness. These symptoms may indicate a reaction to PM 2.5, especially if they persist or worsen over time.
- **Worsening of Pre-existing Conditions:** If populaces have asthma, COPD, or other respiratory conditions and notice a deterioration in populace symptoms coinciding with high PM 2.5 levels, it is important to consult a doctor.
- **Cardiovascular Symptoms:** PM 2.5 can affect heart health. Symptoms like unusual chest pain, palpitations, or shortness of breath should prompt immediate medical attention.
- **Severe Allergic Reactions or Asthma Attacks:** If the populace experiences a significant increase in allergic reactions or asthma attacks during high PM 2.5 periods, medical guidance is crucial.
- **Symptoms in Vulnerable Populations:** Children, the elderly, and pregnant women should seek medical advice if they experience respiratory or cardiovascular symptoms in areas with high PM 2.5 levels.

Early medical intervention can help manage symptoms effectively and prevent potential long-term health impacts of PM 2.5 exposure. PM 2.5 poses a significant health

risk, particularly due to its small size and ability to penetrate deep into the body. Understanding the sources and effects of PM 2.5 is crucial in developing effective strategies to avoid adverse effects. As awareness grows, it becomes increasingly important for individuals, communities, and policymakers to work together to reduce exposure to this insidious pollutant.

4.3 Quantitative Data Research Analysis

4.3.1 Validity and Reliability of the Research Instruments

Reliability and validity are important aspects of selecting a survey instrument. Reliability refers to the extent that the instrument yields the same results over multiple trials. Validity refers to the extent to the instrument measures what it was designed to measure.

4.3.1.1 Validity and Reliability of the QPPAI

The 400 populaces' responses of their perceptions were assessed using the 36-item Questionnaire on Populaces and PM2.5 Affected Interaction (QPPAI) consists of six scales namely: Awareness of the Causes of PM2.5 Toxic dust Pollution (ACTP); Understanding of Effects of PM2.5 Toxic Dust (UETD); can be inhaled deep into the respiratory tract and lungs. Understanding the Health Effects of PM2.5 dust on the Respiratory system and lungs (UHER), Awareness of news from the media or Government organizations for groups at risk of danger from PM2.5 dust, and receiving Advice on the care and Treatment (AGAT); Knowing how to Protect yourself from PM2.5 dust and getting Support from the Government (KPSG), and Receiving Care from the Government for being a Patient with PM2.5 dust pollution (RCGP) scales. Each scale consists of 6 items in five options (Never (0), Seldom (1), Sometimes (2), Often (3), and Always (4). The results as reported in Table 2.

Table 2: Item means, standard deviation, variance, internal consistency (Cronbach alpha reliability) coefficient, grand mean scales, and F-test for the QPPAI

Scale	Item mean	S.D.	Variance	α-reliability	Grand mean	F-test
ACTP	13.847	3.208	10.295	0.791	2.308	1.535
UETD	13.877	3.131	9.804	0.785	2.315	7.807***
UHER	13.660	3.367	11.340	0.837	2.260	8.807***
AGAT	13.635	3.233	10.453	0.815	2.273	2.430*
KPSG	13.960	3.202	10.254	0.785	2.327	10.949***
RCGP	13.880	3.136	9.835	0.778	2.313	7.243***
Total	**82.770**	**16.495**	**272.112**	**0.950**	**2.299**	**5.531*** **

N=400, *p<.05, **p<.01, ***p<.001

4.3.1.2 Validity and Reliability of the ASPTD

Analysis of the 10-item *Attitudes on Solving-Problem PM2.5 Toxic Dust* (ASPTD) in five options, strongly agree (4), agree (3), neither disagree nor agree (2), disagree (1), and strongly disagree (1) of their responses' threatening attitudes to be solved problems of the PM2.5 Toxic Dust, sustainability.

Table 3: Item means, standard deviation, variance, internal consistency (Cronbach alpha reliability) coefficient, grand mean scales, and F-test for the ASPTD

Scale	Item mean	S.D.	Variance	α-reliability	Grand mean	F-test
ASPTD	23.690	4.374	23.670	0.812	2.367	7.926***

N=400, *p<.05, **p<.01, ***p<.001

The internal consistency (Cronbach alpha reliability) coefficients are criteria by which researchers assess the measurement quality of the research instrument's reliability and validity. That is, how closely related a set of 6 items is suitability. It is considered to be a measure of scale reliability (Taber, 2018). The accepted value of Cronbach's alpha; however, values of 0.6-0.7 (acceptable), and 0.7-0.8 values are also accepted (good, and acceptance), 0.8 and above is better, and 0.9 and above is best (Frost, 2022). The results as reported in Tables 2-3, the values of Cronbach alpha reliability ranged from 0.778 (in the RCGP scale) to 0.837 (in the UHEP scale) for the QPPAI. The α-reliability value of the ASPTD indicates that of 0.812. On the whole, these results are acceptable for the QPPAI and the ASPTD questionnaires' producing guidelines, respectively. These are the two research instruments that are valid and reliable.

In Table 2, the grand means show that populaces' perceptions of their knowing how to protect themselves from PM2.5 dust and getting support from the government (KPSG) (mean = 2.327), they understand of effects of PM2.5 toxic dust and can be inhaled deep into the respiratory tract and lungs (UETD) (mean = 2.315), their receiving care from the government for being a patient with PM2.5 dust pollution (RCGP) (mean = 2.313), most of participants are understanding of effects of PM2.5 toxic dust (UETD) (mean = 2.305), however, their awareness of news from the media or government organizations for groups at risk of danger from PM2.5 dust, and receiving Advice on care and Treatment (AGAT) (mean = 2.273), and this situation has in shock because they do not yet understand the health effects of PM2.5 dust on the respiratory system and lungs (UHER) (mean = 2.260), respectively.

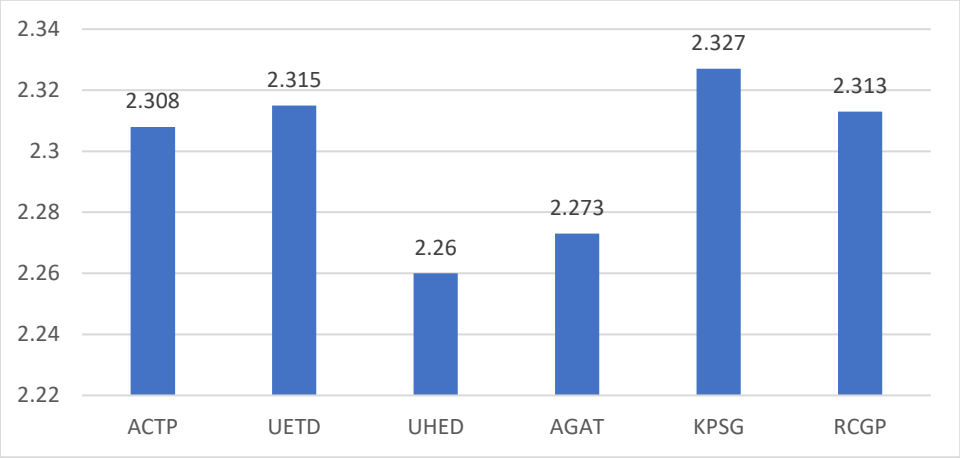


Figure 9: A pictorial comparison of the populaces' perceptions of the effects of the PM2.5 toxic dust to their aspiration system and health diseases

3.3.3 Associations between Populaces' Perceptions of Their Health Effects of the PM2.5 toxic dust pollution in the air environment and their attitudes on solving PM2.5 toxic dust In most cases, independent variables (six scales of the QPPAI) are what we expect will influence dependent variables (grand mean of the ASPTD). A dependent variable is what happens as a result of the independent variable. Generally, the dependent variable is the disease or outcome of interest for the study, and the independent variables are the factors that may influence the outcome. Using simple and multiple correlations, standardized regression coefficients and the determination predictive (R^2) value coefficient statistics with Grand means of variables were associated. The results are reported in Table 4.

Table 4: Simple correlation coefficient (r), standardized regression weight coefficient (β), multiple correlations (R), and Determinant of predictive (R^2) value coefficient for independent variables (QPPAI) and dependent variable (ASPTD)

Independent variable scale	Simple correlation coefficient (r)	Standardized regression weight coefficient (β)
ACTP	0.640***	0.293***
UETD	0.497***	0.240**
UHER	0.467***	0.138*
AGAT	0.503***	0.260**
KPSG	0.477***	0.150*
RCGP	0.681***	0.495***
Dependent variable (ASPTD) (mean = 2.367		
Multiple correlation (R)	0.784***	
Determinant of predictive (R^2) value coefficient	0.614**	

N=400, *p<.05, **p<.01, ***p<.001

As reported in Table 4, designing on all six grand mean scales of the independent variables to correlate with the grand mean of the dependent variable using simple correlation (r) are correlated significantly (p<.001) on all six scales of the A to the ASPTD scale. The second type of analysis consisted of the more standardized regression coefficient (β), which measured the association between populaces' perceptions of the health effects of the PM2.5 toxic dust pollution in the air environment and their attitudes towards the policy of the government for solving the problem PM2.5 toxic dust, and show that the associations are correlated significant (p<.05), relatively. In statistics, the coefficient of multiple correlation (R) is measured by how well a given variable can be predicted using a linear function of a set of other variables. It is the correlation between the variable's values, and the best predictions can be computed linearly from the predictive variables. The coefficient of multiple correlations shows the value predictability of the dependent variable from the independent variables for the QPPAI to the dependent variable ASPTD, indicating that of 0.784 (p<.001), significantly.

In most cases, this research study was investigated and analyzed with an R-squared, a statistical measure that quantifies the proportion of the variance in the dependent (ASPTD) variable that is explained by the independent variables (QPPAI)

scales in a regression model. The R^2 was calculated as the square of the correlation coefficient (R) predicted values. Generally, a R-squared value between 0.50 to 0.99 is acceptable in social science or education research especially, when most of the explanatory variables are statistically significant. The results have found that the R^2 value indicates that 61% of the variance in populaces' perceptions of their attitudes to the government policies were attributable to their perceptions of the health effects of the PM2.5 toxic dust pollution in the air environment, they are supported by the government policies, significantly.

5. Discussions

This research study was designed and created to investigate and review the effects of particulate matter 2.5 (PM 2.5) dust pollution that caused the 4000 Thai populaces affected by the risk of stimulating the respiration system due to stroke, heart disease, lung cancer, and acute and chronic respiratory diseases to premature deaths using document research methodology, qualitative and quantitative research methods duration time in 2023. The results indicated 1,325,838 patients with air pollution-related diseases in the first week of January 2023 in 38 provinces in Bangkok and surrounding area provinces, Central regions, Northern region, and Northeast region. However, air pollution has built on one of the biggest environmental threats to the public's health. In 2005, the World Health Organization (WHO) released its first global air quality guidelines (AQGs) for particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide. In 2021, the WHO updated its AQGs, providing clear evidence of the adverse health effects of air pollution, at even lower concentrations than previously understood. For instance, the WHO AQGs 2021 recommend annual mean concentrations of PM2.5 not exceeding 5 μg/m^3 and NO_2 not exceeding 10 μg/m3 and the peak season mean 8-h O_3 concentration not exceeding 60 μg/m^3. As a comparison, the corresponding WHO AQGs 2005 values were 10 μg/m3 for PM2.5 and 40 μg/m^3 for NO_2, with no recommendation for long-term O_3 concentrations (World Health Organization, 2023).

Especially in Bangkok, the sickest groups were respiratory diseases, 583,238 patients, an increase from the last week by 85,910 patients; dermatitis, 267,161 patients, an increase of 35,878 patients; eye inflammation, 242,805 patients, an increase of 36,537 patients; and cardiovascular and cerebrovascular diseases, 208,880 patients, an increase of 33,413 patients on the first week of January 2023. Among its components, particulate matter 2.5 (PM 2.5) is particularly hazardous. PM 2.5 refers to fine particles that are 2.5 micrometers or smaller in diameter, making it about 30 times smaller than the width of a populace hair. This minuscule size allows these particles to pass the body's natural defense systems, and enter deep into the lungs and potentially the bloodstream (Bumrungrad International Hospital, Thailand, 2024). How to set standards and monitor outdoor air quality? Setting air quality goals is a foundational step for air quality management. This sets out the ambitious, health-based air quality targets that cities

should adopt, and how to develop high-density, targeted monitoring to inform action to reach those targets (The World Health Organization, 2022).

Moreover, the patient's effects throughout Thailand areas were more than 10 million were sick from "air pollution" in 2023 in 38 provinces in Bangkok and surrounding area provinces, Central regions, Northern region, and Northeast region at the spiration system diseases, following the Union of Concerned Scientists (2020) worked on global warming solutions for over 30 years. The effects of PM25 destroy lung function: the results emphasize the importance of the lung acting as a mediator in the relationship between exposure to PM2.5, and cognitive performance. However, higher exposure to PM2.5 was mainly directly associated with worse cognitive performance, which emphasizes the health-relevance of fine particles due to their ability to reach vital organs directly. The causes or motivations of these forest fires are varied, officials concerned have pointed out that almost all of them are human-driven, relating closely to the conventional utilization of forests and hilly farmland by the locals to sustain their farm-based livelihoods; ranging from farmland expansion, clearing of farm residues in the fields, grazing, wildlife hunting, and collecting of forest products. All are typical of seasonal fire burning elsewhere in Southeast Asia (Arporniem, 2023). The problem was not just about PM2.5 or forest fires here. It's actually about the unsustainable use of natural resources here and elsewhere. It's a social and economic problem that occurs almost everywhere now and will continue on and on if we cannot address its causes or drivers. The challenge now is whether Thailand has learned this hard lesson and managed to address the true causes and come up with new measures and policies to address them proportionately (Suraswadi, 2023).

This research found that the impact of toxic dust is that more than 1,000,000 Thai people have respiratory diseases, lung cancer, and heart failure due to lack of oxygen, and 70,000 people die from PM2.5 dust per year. World Heart Federation (2024) reported that the global number of stroke deaths attributable to air pollution increased by only 1% from 2010 to 2019, though with significant regional variation. Increases were observed in the Africa, South-East Asia, and Eastern Mediterranean regions in this period. Europe experienced a 25.3% decline, and the Americas and Western Pacific regions saw fewer reductions. The level of standardized age stroke mortality rates attributable to air pollution declined in all Regions from 2010 to 2019, with the Eastern Mediterranean, Africa, and Southeast Asia regions recording an average annual of around 1%. The remaining region experienced an annual reduction average of 2.6-3.3%. There is no significant difference between males and females in the regional distribution of IHD deaths attributable to air pollution, except in the European regions. Where the proportion of female IHD deaths was higher (22.5%) than male deaths (17%). Regarding deaths from stroke attributable to air pollution, almost 50% of total global male deaths occurred in the Western Pacific, compared to 40% of total global female deaths. As with IHD, the proportion of female stroke mortality attributable to air pollution in the Europe region was higher than males (13.4% compared to 8.8%) (World Heart Federation, 2024).

In terms of quantitative research, the study has found that populaces' perceptions of their knowing how to protect themselves from PM2.5 dust and getting support from the government, they understand the effects of PM2.5 toxic dust, which can be inhaled deep into the respiratory tract and lungs, their receiving care from the government for being a patient with PM2.5 dust pollution, most of the participants are understanding of effects of PM2.5 toxic dust. However, their awareness of news from the media or government organizations for groups at risk of danger from PM2.5 dust and receiving Advice on care and treatment, and this situation shock because they do not yet understand the health effects of PM2.5 dust on the respiratory system and lungs (UHER), respectively. Fine dust particles containing carcinogens can irritate many organs, such as the eyes, nose, and throat, which can cause eye irritation, red eyes, itchy nose, runny nose, coughing, sneezing, difficulty breathing, and rashes and dermatitis. Tyler Cowen (2024) believes that "Air Pollution Kills Far More People Than Covid Ever Will" is a "recent study" by researchers from three institutions: the University of Birmingham, Harvard University, and University College London. However, patients and deaths from the effects of PM.5 dust each year. The results of this research are reliable in that only 61% of patients receive care from the government and there are still almost 40% of Thai people who do not have knowledge and understanding of the dangers and health effects of PM 2.5 dust.

6. Conclusion

Creative the mixed research methodology: the document research method was reviewed, the qualitative research method was interviewed and observed, and the quantitative research method was assessed by the 4000-participants who used to be sick, which the dangers and health effects of PM 2.5 dust, which is a cloud of dangerous dust that can enter the body deep into the alveoli of the lungs, some of which can pass through the walls of the alveoli into the capillaries, float in the bloodstream, and spread and infiltrate throughout the body, causing people with chronic respiratory diseases to exacerbate symptoms, such as allergic rhinitis, asthma, and emphysema, chronic cardiovascular diseases, especially ischemic heart disease. In the long term, it will cause lung function to decline, and emphysema may occur even if you do not smoke, and increase the chances of getting lung cancer. Selected 4000 patients with respiratory tract disease from PM2.5 dust pollution, aged 18 years and over, with a telephone, Facebook, Twitter, Line, or other media that could be contacted and coordinated. The researcher would send the research instruments to them and can reply with the complete information that they commented on. The research team will randomly collect data from the Ministry of Public Health website. The names or other patient data will not be disclosed. The populace's perceptions assessment form will be randomly sent to 500 relevant persons between December 2022 and March 2023 and will be selected as the complete version of the sample group of 400 sets.

Creative the 36-item Questionnaire on Populaces and PM2.5 Affected Interaction (QPPAI) consists of six scales namely: Awareness of the Causes of PM2.5 Toxic dust Pollution (ACTP); Understanding of Effects of PM2.5 Toxic Dust (UETD); can be inhaled deep into the respiratory tract and lungs. Understanding the Health Effects of PM2.5 dust on the Respiratory system and lungs (UHER), Awareness of news from the media or Government organizations for groups at risk of danger from PM2.5 dust, and receiving Advice on the care and Treatment (AGAT); Knowing how to Protect yourself from PM2.5 dust and getting Support from the Government (KPSG), and Receiving Care from the Government for being a Patient with PM2.5 dust pollution (RCGP) scales. Each scale consists of 6 items in five options (Never (0), Seldom (1), Sometimes (2), Often (3), and Always (4). The Attitudes on Solving-Problem PM2.5 Toxic Dust (ASPTD). Their perceptions of their thinking may be a positive or negative attitude to their posture position of the body appropriate to or expressive of an action, and emotion that was assessed using the 10-item Attitudes on Solving-Problem PM2.5 Toxic Dust (ASPTD) in five options, strongly agree (4), agree (3), neither disagree nor agree (2), disagree (1), and strongly disagree (1) of their responses' threatening attitudes to be solved problems of the PM2.5 Toxic Dust, sustainability.

The conclusions of this research study have found that the research instruments are valid and reliable. The populaces' responses to their perceptions on six scales indicate that the grand means show that populaces' perceptions of their knowing how to protect themselves from PM2.5 dust and getting support from the government (KPSG) (mean = 2.327), their understanding of effects of PM2.5 toxic dust and can be inhaled deep into the respiratory tract and lungs (UETD) (mean = 2.315), their receiving care from the government for being a patient with PM2.5 dust pollution (RCGP) (mean = 2.313), most of participants are understanding of effects of PM2.5 toxic dust (UETD) (mean = 2.305), however, their awareness of news from the media or government organizations for groups at risk of danger from PM2.5 dust, and receiving Advice on care and Treatment (AGAT) (mean = 2.273). This situation is in shock because they do not yet understand the health effects of PM2.5 dust on the respiratory system and lungs (UHER) (mean = 2.260), respectively. In most cases, this research study was investigated and analyzed with an R-squared, a statistical measure that quantifies the proportion of the variance in the dependent (ASPTD) variable that is explained by the independent variables (QPPAI) scales in a regression model. Associations between populaces' perceptions of their health effects of the PM2.5 toxic dust pollution in the air environment (QPPAI) and their attitudes on solving PM2.5 toxic dust (ASPTD). The R^2 was calculated as the square of the correlation coefficient (R) predicted values. Generally, an R-squared value between 0.50 and 0.99 is acceptable in social science or education research, especially when most of the explanatory variables are statistically significant. The results have found that the R^2 value indicates that 61% of the variance in populaces' perceptions of their attitudes to the government policies were attributable to their perceptions of the health effects of the PM2.5 toxic dust pollution in the air environment. They are supported by government

policies, significantly with simple and multiple correlations and standardized regression weight coefficient statistics were analyzed.

Conflict of Interest Statement

The authors declare no conflicts of interest.

About the Authors

Dr. Prachayakul Tulachom

Researcher & Academic;

B.A.: Business Administration, General Management from Valaya Alongkorn Rajabhat University under Royal Patronage, Thailand;

M.A.: Public Administration General Management, Burapha University, Thailand;

Ph.D.: Environmental Education from Valaya Alongkorn Rajabhat University under Royal Patronage;

Current Position: An Independent Academic in Environmental Education, Mueang Sa Kaeo District, Sa Kaeo 27000, Thailand; and Member of the Sa Kaeo Provincial Administrative Organization, Thailand. Advisor in Publish Health of Master's students at Pathumthani University, Thailand

Dr. Jumnean Wongsrikaeo

Medicine Doctor and Researcher;

B.D.: Public Health from Sukhothai Thammathirat Open University, Thailand;

M.D.: Health (M.P.H) from Burapha University, Chonburi, Thailand;

Ph.D.: Environmental Education, Pathumthani University, Pathum Thani Thailand;

Currently Position: Deputy Director of Administration, Phutthasothon Hospital, Mueang District, Chachoengsao Province, 24000, Thailand.

Prof. Dr. Toansakul Tony Santiboon

Supervisor in Research of Ph.D. students, Excellence Reviewing Awards, Editor, Research Post-Doctorate Administration;

B.S. (Physics) from Ohio State University, Ohio, USA;

M.S. (Geophysics) from the University of British Columbia, Vancouver, Canada;

Sc.Ed.D. (Physics Education) from Curtin University of Technology, Australia;

Ph.D. (Teaching Physics) from the University of Technology Sydney, Australia Post Doctorate Degree (Research Administration) from Oxford University, UK;

Excellence Reviewer Awards on SCOPUS Journal Indexing;

Retirement Job in Research & Post-Doctorate Administrator from Queen's University Belfast, University Rd, Belfast Northern Ireland, United Kingdom.

Prof. Dr. Gregory Alexander

Researcher, Reviewer, Instructor, Senior Educational Administrator;

B.Ed.: Psychology from Free State University, Free State, South Africa;

M.Ed.: Educational Administration from Free State University, Free State, South Africa;

Ph.D.: Graduate Education Administration from Oregon State University, the USA;

Currently Status: Researcher, Instructor & Reviewer at the Department of Post-Graduate Studies, Central University of Technology, Bloemfontein, Free State, South Africa, Bloemfontein, Free State, South Africa.

References

Adulyanon, S. (2023). *In-deep health system.* Manager of the Health Promotion Foundation (ThaiHealth). http://www.healthpromotionfoundation.org/

Air Quality Index (AQI). (2023). *Air quality in Thailand*. https://www.iqair.com/th-en/thailand?srsltid=AfmBOor9IQI-XsPGLlaVQjiEMnWlsIS-PQiTtb50QeY8rPDSzSxeuIkQ

Air Quality in Thailand. (2024). Air quality index (AQI) and PM2.5 air pollution in Thailand. *Overview: How polluted is Thailand?* April 26, 2024. https://www.iqair.com/th-en/thailand?srsltid=AfmBOoonR9EDyrHnTmx-nCdwZgCA2s-TEjZOGvHqMzf9mCGUYio_A6T2

Arporniem, P. (2023). The lessons learned from PM2.5 and the right to clean air. *Foundation Office Thailand*. https://www.kas.de/en/web/thailand/veranstaltungen/detail/-/content/the-lessons-learned-from-pm2-5-and-right-to-clean-air-1

Aretz, B., Janssen, F., Vonk, J. M., Heneka, M. T., Boezen, H. M., Doblhammer, G. (2021). Long-term exposure to fine particulate matter, lung function, and cognitive performance: A prospective Dutch cohort study on the underlying routes. *Environmental Research, 201*: 111533. https://doi.org/10.1016/j.envres.2021.111533

Bangkok Post. (2024). *PM2.5 to spike in Bangkok.* January 15, 2024. https://www.bangkokpost.com/learning/easy/2724382/pm2-5-to-spike-in-bangkok

Block, M. L., Calderón-Garcidueñas, L. (2009). Air pollution: mechanisms of neuroinflammation and CNS disease. *Trends in Neurosciences, 32*: 506-516.

Buakhamsri, T. (2023). *Why doesn't the Thailand Air Quality Index tell us the current air quality? Greenpeace Thailand*. October 1, 2019. https://www.greenpeace.org/thailand/story/9145/thai-aqi-accuracy/

Bumrungrad International Hospital, Thailand. (2024). *The health risks of PM 2.5*. A Joint Commission International (JCI) Accredited Hospital. January 03, 2024.

California Air Resource Board. (2022). Inhalable particulate matter and health (PM2.5 and PM10). *Offices under the Umbrella of the California Environmental Protection*. https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health

Chairakul, N. (2024). Siriraj Hospital reveals that Thais are getting more lung disease due to deteriorating air quality, Head of the Respiratory and Tuberculosis Division, Department of Internal Medicine, Faculty of Medicine, Siriraj Hospital.

Chanabawornsakul, W., Tuprakay, S., Premanoch, P., Ratcha, (2022). A Study of government measures and guidelines for managing the particulate matter PM2.5 pollution crisis in Thailand. *Journal of the Association of Researchers, 27*(3): July – September. https://so04.tci-thaijo.org/index.php/jar/article/view/259514

Chatpattarasill, P. (2024). Heavy fine dust covers the historic Rattanakosin Island district of Bangkok on March 9th, 2024. *Bangkok Post*. https://www.bangkokpost.com/thailand/general/2524040/dust-above-safe-limits-in-north-northeast-greater-bangkok

Cipoli, Y. A., Furst, L., Feliciano, M., Alves, C. (2023). Respiratory deposition dose of PM2.5 and PM10 during night and day periods in an urban environment. *Air Quality, Atmosphere & Health, 16*: 2269–2283. https://link.springer.com/article/10.1007/s11869-023-01405-1

Cleveland Clinic. (2024). *Respiratory system: Body systems & organs*. February 4, 2024. https://my.clevelandclinic.org/health/body/21205-respiratory-system

Cowen, T. (2024). Thai people have a continuously increasing cancer rate and 70,000 people die from PM2.5 dust per year. *Thai Health Promotion Foundation (ThaiHealth)***.** March 24, 2024. https://resourcecenter.thaihealth.or.th/

Department of Health, the World Health Organization. (2021). *Air: Environmental Quality*. https://www.tn.gov/health/cedep/environmental/healthy-places/healthy-places/environmental-quality/eq/air.html

Department of Health and Aged Care, Australian Government. (2022). Respiratory system. *Health Direct.* https://www.healthdirect.gov.au/respiratory-system

Dimitriou A., Christidou, V., Khallaf, M. (2021). Causes and consequences of air pollution, and environmental injustice as critical issues for science and environmental education. *The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources, InTech*, DOI:10.5772/17654

Dahms, H. U., Schizas, N. V., James, R. A., Wang, L., Hwang, J. S. (2018). Marine hydrothermal vents as templates for global change scenarios. *Hydrobiologia, 818*: 1–10. doi:10.1007/s10750-018-3598-8

Division of Cancer Epidemiology & Genetics at the National Cancer Institute. (2022). Traffic-related outdoor air pollution: Studies of fine particulate matter and lung cancer. https://dceg.cancer.gov/research/what-we-study/traffic-related-outdoor-air-pollution

Frost, J. (2022). Reliability vs validity: Differences & examples. *Statistics by Jim: Making Statistics Intuitive.* August 17, 2022. https://statisticsbyjim.com/basics/reliability-vs-validity/

Griffiths, C. J., Mudway, I. S. (2018). Air pollution and cognition. *British Medical Journal (BMJ: Clinical Research ed.), 363*: Article k4904.

González-Maciel, A., Reynoso-Robles, R., Torres-Jardón, R., Mukherjee, P. S., Calderón-Garcidueñas, L. (2017). Combustion-derived nanoparticles in key brain target cells

and organelles in young urbanites: Culprit hidden in plain sight in Alzheimer's disease development. *Journal of Alzheimer's Disease, 59*: 189-208.

Grossman, L. (2024). The air out there: Discover the health benefits of simply going outside. *St. Mary's Health System: Covenant Health*. https://stmarysmaine.com/the-air-out-there-discover-the-health-benefits-of-simply-going-outside/

Guarnieri, M., J.R. Balmes, J. R. (2014). Outdoor air pollution and asthma. *Lancet, 383*: 1581-1592

Jones, R. R., Fisher, J. A., Hasheminassab, S., Kaufman, J. D., Freedman, N. D., Mary H Ward, M. H., Sioutas, C., Vermeulen, R., Hoek, G., Silverman, D. T. (2024). Outdoor ultrafine particulate matter and risk of lung cancer in Southern California. *American Journal of Respiratory and Critical Care Medicine,1*(3): 307-315. DOI: 10.1164/rccm.202305-0902OC.

Indoor Air Hygiene Institute. (2023). *PM2.5 Explained*. https://www.indoorairhygiene.org/pm2-5-explained/

International Organization for Standardization Logo. (2020). *ISO cleanroom standard*. https://www.clean-rooms.org/iso-cleanroom-standards/

Li, B., Ma, Y., Zhou, Y., Chai, E. (2023). Research progress of different components of PM2.5 and ischemic stroke. *Scientific Reports, 13*: 15965 (2023). https://doi.org/10.1038/s41598-023-43119-5

Lindholm, P., Lundgren, C. E. G. (2009). The physiology and pathophysiology of human breath-hold diving. *Journal of Applied Physiology, 106* (1): 284–292. DOI:10.1152/japplphysiol.90991.2008

Loaiza-Ceballos, M. C., Marín-Palma, D., Zapata, W., Hernández, J. C. (2022). Viral respiratory infections and air pollutants. *Air Quality, Atmosphere & Health, 15*(1): 105–114. DOI: 10.1007/s11869-021-01088-6

Lutsey, P. L., Chen, N., M.C. Mirabelli, M. C., Lakshminarayan, K., D.S. Knopman, D. S., Vossel, K. A., Gottesman, R. F., Mosley, T. H., Alonso, A. (2018). Impaired lung function, lung disease, and risk of incident dementia. *American Journal of Respiratory and Critical Care Medicine*: DOI: 10.1164/rccm.201807-1220OC

Medgyesi, D. N., Fisher, J. A., Flory, A. R., Hayes, R. B., Thurston, G. D., Liao, L. M., Mary H Ward, M. H., Silverman, D. T., Rena R Jones, R. R. (2021). Evaluation of a commercial database to estimate residence histories in the Los Angeles ultra-fines study. *Environmental Research, 197*: 110986. DOI: 10.1016/j.envres.2021.110986.

NASA Earth Exchange (NEX). (2023). *Earth system modeling*. https://www.nasa.gov/nasa-earth-exchange-nex/

National Aeronautics and Space Administration (NASA). (2023). *Climate change*. https://science.nasa.gov/climate-change/

Online Reporter. (2024). World's worst smog chokes Northern Thailand. *Bangkok Post*. April 1, 2024. https://www.bangkokpost.com/thailand/general/2768803/worlds-worst-smog-chokes-northern-thailand

Poapongsakorn, N., Panthakuo, K., Rasakom, S. (2023). Challenges in tackling the PM2.5 crisis. *Thailand Development Research Institute (TDRI)*. April 11, 2023. https://translate.google.co.th/

Pollution Control Department. (2023). Regional weather reports. *Air 4 Thai*. September 24, 2023. http://air4thai.pcd.go.th/webV3/#/Home

Public Health Department of Thailand. (2023). *Shocking: More than 31,081 Thais die from dust, which is also a cause of cancer*. March 8, 2023. https://multimedia.anamai.moph.go.th/news/080366/

Public Relations Department. (2024). The government solves the PM2.5 dust problem by setting up legal punishment measures. *Government News*. February 2, 2024. https://www.prd.go.th/th/content/category/detail/id/39/iid/257365

Rajarathnam, U., A WHO Regional Representative for Southeast Asia. (2021). Where is Thailand going with the New WHO Air Quality Guidelines? An Online Conference, Bangkok, Thailand. October 22, 2021. https://www.hfocus.org/content/2021/10/23451

Rujirawat, M. (2024). PM2.5: The dust crisis in Thailand that affects health. *Chulabhorn Research Institute*. March 24, 2024. https://www.cri.or.th/th/articles-20240320/

Sehgal, M. (2021). *Assessing the health effects of exposure to air pollution through survey-based study.* The Energy and Resources Institute: Creative Innovative Solutions in a Sustainable Future. https://www.teriin.org/project/assessing-health-effects-exposure-air-pollution-through-survey-based-study

Srihawan, C. (2024). *PM 2.5 is a tiny particle that has a huge negative (health) impact*. Sub-Division of Infectious Diseases Medicine, Samitivej Hospital, Bangkok, Thailand. https://www.samitivejhospitals.com/th/article/detail/

Sripiachai, P., Sunthorn Kongvarakhom, S. (2024). Dust above safe limits in North, Northeast, Greater Bangkok. *Bangkok Post Online Reporters*. March 9, 2024. https://www.bangkokpost.com/thailand/general/2524040/dust-above-safe-limits-in-north-northeast-greater-bangkok

Suraswadi, P. (2023). While causes or motivations of these forest fires are varied. *Air Quality Noise Management Division*, *The Pollution Control Department (PCD)*. Media Dialogue Forum 4 of 2023.

Taber, K.S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education, 48*: 1273–1296.

Thailand Air Quality Data Attribution. (2023). Air quality in Thailand. *Air Quality Index (AQI) Thailand*. September 24, 2023. https://www.iqair.com/th-en/thailand

Thai PBS: Policy Watch. (2023*). Statistics for 2023 show that Thailand's air quality is worse, ranked 36th in the world.* March 19, 2023. https://policywatch.thaipbs.or.th/article/environment-21

Than Settakij News. (2024). *PM 2.5 dust affects the health of 10.5 million Thais*. March 4, 2024. https://www.thansettakij.com/health/health/590018

Thangavel, P., Park, D., Lee, Y, C. (2022). Recent insights into particulate matter (PM2.5)-mediated toxicity in humans: An Overview. *International Journal of Environmental Research and Public Health, 19*(12): 7511. https://doi.org/10.3390/ijerph19127511

The Government Public Relations Department. (2024). *Thailand gives a major boost to reducing PM2.5 dust and promoting clean air*. January 9, 2024. https://thailand.prd.go.th/en/content/category/detail/id/48/iid/248642

The National Air Quality Index (AQI) of the Purelogic Labs India Ltd. (2019). *Here are the 10 Main causes of air pollution.* https://www.aqi.in/blog/here-are-the-10-main-causes-of-air-pollution/

Thiwantha, D. (2023). *Health benefits from air pollution control in Thailand*. Deputy Director-General of the Department of Health, Ministry of Public Health. https://anamai.moph.go.th/en/executive-department-of-health

The Union of Concerned Scientists. (2020). Climate solutions: We need to act now. *The Science Emergency Fund of the United States.* https://www.ucsusa.org/climate/solutions

The United Nations Framework Convention on Climate Change (UNFCCC) (2023). What is the United Nations Framework Convention on Climate Change? *United Nations: Climate Change*. https://unfccc.int/process-and-meetings/what-is-the-united-nations-framework-convention-on-climate-change

The U.S. Air Quality Index (AQI). (2019). Air Quality Index (AQI) basics. *AirNow.gov - Home of the U.S. Air Quality Index.* https://www.airnow.gov/aqi/aqi-basics/

The University of California Museum of Paleontology. (2024). *Respiration: Understanding global change.* https://ugc.berkeley.edu/background-content/respiration/

The World Health Organization. (2021). Air Quality Guidelines: Global Update 2005: Particulate Matter, Ozone, Nitrogen Dioxide, and Sulfur Dioxide. Geneva: World Health Organization; 2006. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8920460/

The World Health Organization. (2022). WHO Global Air Quality Guidelines: Particulate Matter PM2.5 and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. Geneva: World Health Organization; 2021. https://www.who.int/publications/i/item/9789240034228

The World Health Organization. (2022). *WHO air quality guidelines: Air quality and health in cities: A State of Global Air report.* https://www.c40knowledgehub.org/s/article/WHO-Air-Quality-Guidelines?language=en_US

Nagarani, N., Kuppusamy, A., Velmurugan, K., Devi, J., Devi, C. A., Tiyapairat, Y. (2021). Public sector responses to sustainable haze management in Upper Northern Thailand. *Environment Asia 5*(2): 1-10.

Tanraksa, P. (2024). World's worst smog chokes Northern Thailand. *Bangkok Post*. April 1, 2024. https://www.bangkokpost.com/thailand/general/2768803/worlds-worst-smog-chokes-northern-thailand

Turner, C. (2006). A longitudinal study of methanol in the exhaled breath of 30 healthy volunteers using selected ion flow tube mass spectrometry, SIFT-MS. *Physiological Measurement*, *27*(7): 637–48. DOI:10.1088/0967-3334/27/7/007

United States Environmental Protection Agency. (2018). Climate change impact: Climate impacts on human health. *City of Chicago*. https://climatechange.chicago.gov/climate-impacts/climate-impacts-human-health

United Nations. (2019). *Causes and effects of climate change*. https://www.un.org/en/climatechange/science/causes-effects-climate-change

United Nations. (2019). What Is Climate Change? *United Nations: Climate Action.* https://www.un.org/en/climatechange/what-is-climate-change

Weibel, E. R., Burri, P. H. (2018). The design of the respiratory system. *The Encyclopaedia Britannica*. https://www.britannica.com/science/human-respiratory-system

Winny, B. (2023). Understanding PM 2.5 air pollution and its impacts. *Primo Care Medical*. March 22, 2023. https://primocare.com/en/tag/air-pollution/

World Health Organization. (2024). *Air pollution*. https://www.who.int/health-topics/air-pollution#tab=tab_1

World Heart Federation. (2024). Everyone is exposed to air pollution throughout their lives, no matter where they live in the world. its impacts are far-reaching – from causing and exacerbating ill health to loss of life. *World Heart Report 2024*. https://world-heart-federation.org/report2024/

World News. (2024). Thai government approves 225-million-USD scheme to tackle PM2.5 pollution. *Vietnam Investment Review under the Ministry of Planning and Investment*. September 26, 2024. https://vir.com.vn/thai-government-approves-225-million-usd-scheme-to-tackle-pm25-pollution-107421.html

World Wildlife Fund. (2020). *Effect of climate change.* https://www.worldwildlife.org/threats/effects-of-climate-change

Xing, Y. F., Y.-H. Xu, Y. H., Shi, M. H., Lian, Y. X. (2016). The impact of PM2.5 on the human respiratory system. *Journal of Alzheimer's Disease*, *8*: E69-E74

Yodwutthi, C, A Cardiologist at Bangkok Heart Hospital. (2023). *How does PM2.5 air pollution potentially induce cardiovascular disease?* https://www.bangkokhearthospital.com/content/how-pm2-5-air-pollution-potentially-induces-cardiovascular-disease

Yu, W., Xu, R., Ye, T., Abramson, M. J., Morawska, L. M., alaludin, B. (2024). Estimates of global mortality burden associated with short-term exposure to fine particulate matter (PM2·5). *Planetary Health*, *8*(3): e146-e155. March 2024. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(24)00003-2/