REVIEW ARTICLE

The Impact of Air Pollution and Haze on Hospital Admissions for Cardiovascular and Respiratory Diseases

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ABSTRACT

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Air pollution has been widely known to have an influence on health of the general population. Air pollution can result from natural causes, human activities and transboundary air pollution. Weather and climate play crucial role in determining the pattern of air quality. In recent years, air pollution and recurrent episodes of haze has become a major concern in Malaysia. Surveillance data on concentrations of main air pollutants such as carbon dioxide, ($CO_{2)}$, Nitrogen Dioxide ($NO_{2)}$, Ozone ($O_{3)}$, sulphur dioxide (SO2) and particulate matter (PM10) were found to be higher during the haze days and this may have an impact on health of the community as reflected by an increase in hospital admissions particularly the respiratory and cardiovascular diseases.

Keywords Air pollution - Haze in Malaysia - Hospital admissions - Respiratory - Cardiovascular diseases.

INTRODUCTION

Air pollution is one of the major public health concerns among developing countries such as Malaysia. As the country strives towards development and industrialization, the control of the emission of major air pollutants such as nitrogen dioxide, carbon monoxide, ozone, sulphur dioxide and particulate matter (PM) is a great challenge. These air pollutants were notably increasing in urban and industrialized areas.[1] During certain months in a year, the concentration of PM10 increased due to haze episodes. Since 1980, there were six major haze episodes recorded in Malaysia, due to biomass burning. Exposure to haze has been shown to be significantly correlated with acute and chronic respiratory diseases such as asthma, upper respiratory tract infection and bronchitis.[2]

Source of air pollution

Air pollution can be due to natural sources such as wind-blown dust, wildfires and volcanoes.[3] These types of natural hazards may contribute significantly to the transboundary regional air pollution as we have experienced in the South-East Asia region, particularly involving Indonesia, Malaysia and Singapore. Air pollution may also result from human activities from mobile sources such as motorvehicle emission or stationary sources such as power plants, oil refineries, industrial facilities, and factories.[4]

During the last decade, the rising trend of transboundary air pollution and episodic haze incidences has become a major concern especially with regards to implications to health. The biomass burning in certain countries in South-East Asia region has caused major air pollution effects in the country as well as other neighbouring countries.[3,4,5]

Factors influencing the movement of air pollutants

Meteorological variables such wind velocity, wind directions, temperature, relative humidity, precipitation, solar radiation and atmospheric pressure play an important role in determining the movement and distributions of these air pollutants over multiple scales in time and space, owing to the fact that emissions, transport, dilution, chemical transformation, and eventual deposition of air pollutants can be influenced by these meteorological parameters.[6] Studies have shown that temperature in polluted region and high humidity will increase the ozone concentration.[7] The weather parameters which include temperature, humidity, wind speed, and wind direction not only influence the atmospheric chemical reactions; they can also affect atmospheric transport processes and the rate of pollutant export from urban and regional environments to the global-scale environments.[8]

Haze phenomenon

Since 1982, haze pollution has become almost an annual occurrence in Southeast Asia, with the worst episodes being in the period of 1997–1998 and in 2006-2007.[9] Since 1990, Malaysia has experienced the occurrences of haze during prolonged dry weather spells, usually attributed to forest fires.[10] The Klang Valley, a heavily industrialized urban area in Malaysia with a population of 7 million people, has experienced severe haze episodes since the early 1980s.[11]

During these haze episodes, the concentration of particulate matter with diameter smaller than 10 microns (PM_{10}), Carbon monoxide (CO), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Ozone (O_3), were found to be significantly higher when compared to non-haze days concentration.[12] The monthly concentrations of PM10 ranged from 35.90 to 104.46 μg/m^3 in Klang Valley for the period from July to September 2005. There were days that the level exceeded the permitted level of 50 μg/m^3 as stipulated by the Malaysia's Department of Environment (DOE).[13]

The Malaysian DOE monitors the air quality status based on the Air Pollution Index (API).[14] The API value is calculated based on average concentration of air pollutants namely SO_2, NO_2, CO, O_3 and PM_{10}. During the haze period, PM10 contributes significantly to the API calculations. The API is used as a guide to determine the air quality status or the severity of the air pollution with regards to impact on human health[15] (Table 1).

Table 1 API level and its implication to human health

API level	Descriptor
0-50	Good
51-100	Moderate
101-200	Unhealthy
201-300	Very unhealthy
>300	Hazardous

Source: DOE 2000

Air quality parameters

Haze is an atmospheric phenomenon where dust, smoke and other dry particles obscure the clarity of the sky. The main sources of haze are from biomass burning from the forest fire, the mobile sources and industrial emissions. This biomass burning not only produces smoke but also contains a large and diverse

number of chemicals, many of which are associated with adverse health risks.[16]

Respirable Particulate Matter (PM_{10})

Respirable particulate matter (PM_{10}) which is made up of particles with an aerodynamic diameter of less than 10 µm, represents a complex mixture of organic and inorganic substances. PM_{10} are particles of 10 µm and has a health significance because they can travel pass the nasopharyngeal region of the upper human respiratory tract to reach the lower respiratory tract, tracheobronchial region and the lungs.

PM 10 has also been shown to increase the incidence of cardiovascular diseases. Researchers suggest that the possible mechanism is that particulate matter alters the autonomic control of the heart.[17] Animal studies have shown that exposure to combustion particles can produce a reduction in heart rate variability, which reflects alterations in cardiac autonomic function is considered as a risk factor for sudden death and death from arrhythmia.[18,19,20]

Sulphur dioxide (SO_2)

SO_2 is highly water soluble and therefore, it is almost entirely removed in the nasal passages, throat and mouth. Only 1% reaches the alveoli and exposure increases during exercise. The physiological effects are changes in the mechanical function of the upper airways which are seen as an increase in nasal flow resistance and a decrease in nasal mucus flow rate.[20, 21]

Bronchoconstriction is characterised by increased airway resistance, decreased forced expiratory volume (FEV), and persistence of symptoms such as chest tightness, shortness of breath and wheezing. In some severe occasions, the bronchoconstriction required removal of exposure, medical intervention, or both.

Mild to moderate asthmatic children and adults are at greatest risk for short-term SO_2-induced respiratory effects.[23]

Nitrogen dioxide (NO_2)

Nitrogen dioxide is absorbed by mucous membrane and caused lipid peroxidation and oxidative stress that lead to irritation of bronchioles and alveoli. This may result in pneumonitis and pulmonary oedema. It also alters the macrophage function causing the individual to be more susceptible to infections.[24]

NO_2 reacts with water vapours in the atmosphere to form acid precipitations which fall to earth as rain, fog, snow or dry particles. Some may be carried by wind for hundreds of miles. The nitric acid and related particles formed when NO_2 reacts with ammonia, moisture, and other compounds, its human health implications include effects on the respiratory system, damage to lung tissue, and premature death. Fine particles penetrate deeply into the deeper reaches of the lungs. This can cause or worsen respiratory diseases such as chronic obstructive pulmonary diseases (COPD) which include emphysema and chronic bronchitis, as well as aggravate existing heart disease.

Carbon monoxide (CO)

Carbon monoxide diffuses quickly into the blood via the lungs and causes injury and an adaptive response that continue after carboxyhemoglobin levels have returned to normal. CO causes hypoxemia through the formation of carboxyhemoglobin and a leftward shift of the oxyhemoglobin dissociation curve.[25] CO binds to heme proteins such as cytochrome c oxidase (CCO), impairing mitochondrial function and thereby contributing to hypoxia.[26]

This will lead to oxidative stress and cellular necrosis which will cause neurologic and cardiac injury.[27] Individuals with cardiovascular disease will have reduced exercise tolerance, causing the appearance of typical angina pain after exercise, increase the frequency of arrhythmias.[28]

Ozone (O_3)

Stimulation of nociceptive interepithelial nerve fibers by ozone leads to reflex cough and a decrease in maximal inspiration that is relieved by opioid agonists, which block sensory pathways. Two possible mechanisms are involved: (1) stimulation of irritant receptors contributes to cough and induces a vagally mediated reflex that increases airway resistance, probably via airway smooth muscle contraction that is blocked by atropine; (2) C fiber stimulation releases neurokinins such as substance P that dilate nearby capillaries, activate mucous glands, and contract airway smooth muscle via neurokinin receptors. Prostaglandin E2 released by epithelial cells exposed to ozone or to ozone reaction products also sensitizes C fibers.[29] This will cause permanent lung damage,[30] lung airways irritation and inflammation.[31,32]

Respiratory and cardiovascular illness

Cardiovascular and respiratory diseases are among the top causes of hospitalisation and deaths in the Ministry of Health hospitals.[33] Studies have shown that air pollution was associated with respiratory and cardiovascular hospital admission. For example, asthma hospitalization has often been linked to a higher concentrations of PM_{10}[34], SO_2 [34,35,36] and NO_2.[36,37]

In Chronic Obstructive Pulmonary Disease (COPD) hospitalization, the admission rate was significantly related to a 10 $\mu g/m^3$ increase in PM_{10},[38] while other studies showed a significant increase of COPD admission rate by increased concentration of other pollutant gases such as SO_2, NO_2 and Ozone.[39,40] An increased concentration of PM_{10} and ozone were found to be significantly associated with an increase of hospital admission cases[41] due to pneumonia.

Exposure to NO_2 is significantly associated with stroke hospitalizations.[42,43] All pollutant gases and PM_{10} were found to be significantly association with arrhythmia hospitalization whereas CO, Ozone and SO_2 have significant association with embolism and thrombosis cases.[44]

Higher concentration of CO was found to be significantly associated with an increase in the ischaemic heart disease (IHD) admission rate.[45] A 10 $\mu g/m^3$ increase in PM_{10} was associated with a 0.72% (95% confidence interval 0.35% to 1.10%) increase in the rate of admission for congestive cardiac failure (CCF) on the same day[46] while other studies showed that all the pollutant gases has significant influence in the CCF admission rate.[45,46,47]

Positive association between individual air pollution and mortalities or morbidities have been found in American[48] and European studies[49] and some Asian countries such as China,[50] Korea[51] and Qatar[52] as well as in Malaysia. [53,54]

CONCLUSION

Air pollution has been found to be significantly associated with serious human health effects particularly an increase in the cardiorespiratory diseases as well as mortality. The effects of environmental risk factors such as chronic long term exposure to air pollutants need to be addressed by all stakeholders so that preventive and remedial actions can be implemented to protect the health of the population.

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