REVIEW ARTICLE

A review on smoke haze in Southeast Asia: Deadly impact on health and economy

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ABSTRACT

Haze is a phenomenon of the lower atmosphere where dust, smoke and other dry particulate matter (PM) decreases visibility. Particles with different bioaerosol and chemical compositions form haze. Gases, volatile organic compounds, metals, acids, sulphates are key constituents for the formation of haze. The seasonal haze that afflicts large parts of Southeast Asia is mainly observed during the dry periods. The transboundary smoke haze has drawn international attention as it has become a major concern due to its deadly impact on human health and economy. According to the Global Burden of Disease Study 2015, approximately 4.2 million deaths were associated with fine particle air pollution (PM2.5) and 59% of those are from South Asia. Physiological complications of haze include dry mouth, eye and nose discomfort, headache, shortness of breath, cough, sore throat, rhinitis, sudden worsening of chronic obstructive airway disease (COPD) symptoms, acute childhood asthma, decreased pulmonary function among children and skin irritation. Haze has a major impact on the economy due to the increasing number of hospitalizations, loss of biodiversity and disruption of transportation which has caused a marked decline in the number of tourists. Farmers should also be encouraged to practice sustainable agriculture methods other than the slash and burn method.

Keywords

Economy, forest fire, haze, particulate matter, respiratory illness

Introduction

Over the last half-century, the increase in globalization and economic interests have led to a rural-urban transformation. Industrialization and other human activities created harmful particulates and gases (e.g. ozone, nitrogen dioxide) which pollute the air. [1]

About Haze

Haze is a phenomenon which causes a lack of transparency of the atmosphere. Haze constitutes of dust, smoke and other dry particulate matter (PM). Particulates in haze are produced from primary or secondary pollution. The basic constituents of particulates include ozone, sulfur dioxide, nitric oxide, nitrogen dioxide, carbon monoxide, carbon dioxide, volatile organic compounds, metals, nitric acid, nitrates, sulfuric acid, sulfates, organic carbon, etc. [2]

The main sources of haze particles are from agriculture (cultivating in dry weather conditions), traffic pollution, industrial emissions, and forest fires. Meteorologically haze denotes wet haze, in which, particulate matters serve as condensation nuclei, form mist droplets and reduces the visibility of the atmosphere.

Coarse particles (PM10), also known as inhalable particles, with a diameter of 2.5–10µm can penetrate the thoracic airways. [3] These particles are derived from soil and other crustal materials and have the ability to suspend and float in the environment for a long time.

Fine particles (PM2.5) are mainly generated by primary pollution and has an aerodynamic diameter of 0.1–2.5µm. Pollutants from the transport system, manufacturing, power generation which are originated due to combustion constitute nitrogen oxides, sulfur dioxide and carbon monoxide, etc. generates these fine particles. [4]

Secondary pollution occurs when atmospheric components react with primary pollutes or from the reactions between the primary pollutes. Secondary pollutants like soil dust, sea salts, pollen, spore, smoke, etc. contribute significantly in most urban areas.

Ultrafine particles (UFPs) are nanoscale particles, aerodynamically < 0.1µm in diameter. They are divided into two types, carbon-based type or metallic type. A condensation particle counter is used for measuring airborne UFPs. [5] UFPs can be either naturally occurring (e.g. Ocean spray, hot volcanic lava, and smoke) or derived from emissions from manufacturing processes, combustion reactions and exhaust fumes. [6, 7]

Pollutant Standard Index (PSI)

Air quality is determined by the PSI, which was developed by the United States Environmental Protection Agency. PSI is measured based on the five pollutants including carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), Sulphur dioxide (SO_2) and fine particle <10 micrometers (PM10). [8, 9]

For each type of pollutant, a sub-index is calculated from a segmented linear function that transforms ambient concentrations onto a scale extending from 0 through 500. PSI range and quality of air is depicted in table 1. [10]

Table 1: PSI range and quality of air

Index Category	PSI range
Good	0-50
Moderate	51-100
unhealthy	101-200
Very unhealthy	201-300
Hazardous	>300

In Malaysia, the Air Pollution Index (API) is considered for the quality of air at a specific area. API which is similar with PSI based on the same pollutants (CO, NO_2, O_3, SO_2 and PM10) in the ambient air, hourly values for PM10 and the pollutants are taken into consideration. [11]

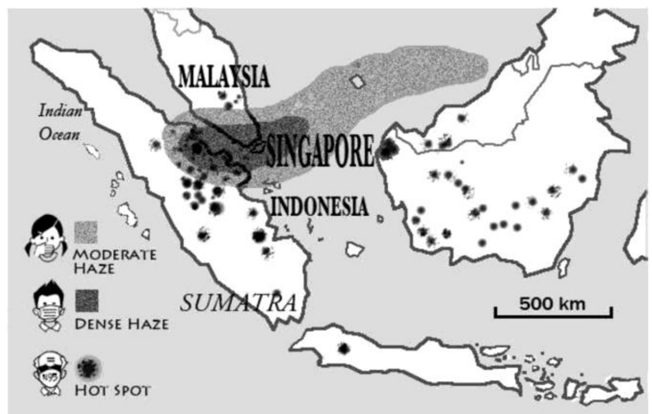

Figure 1: 2013 haze crisis: A geographical schematic map illustrating the haze density over Southeast Asia. [12]

Seasonal Haze

A large part of Southeast Asia is vulnerable to seasonal haze, which is mainly observed during dry periods. This phenomenon has attracted the Association of Southeast Asian Nations attention. A major cause of seasonal haze is due to the burning of forests. Forest fire is a serious concern because of its socio-economic and political impact. [13] In Malaysia, the prime time for the haze occurrence is the southwest monsoon season between June and September and it becomes deadly in dry weather. [14] The major cause of haze in Malaysia is due to forest fires in Indonesia. Indonesian farmers practice shifting agriculture, a traditional way of farming which includes clearing tracts of forests by the slash-and burn method.

The first serious episode occurred in 1997 when 1802 square kilometers (km^2) to 2840 km^2 of the forest was subjected to slash and burn for future agricultural usage. This process is intensified because of commercial production of oil palm, pulp and paper plantations. [15, 16]

Figure 2: An aerial view of a forest fire next to an oil palm plantation at Kumpeh Ulu district in Muarojambi, Indonesia. [17]

Recent data from Indonesia's National Disaster Agency, 328,724 hectares of land was burnt within the first eight months of 2019. The geographically affected regions were Central, West and South Kalimantan, Riau, Jambi and South Sumatra. In some cases, uncontrollable fire engulfed nearby protected areas. Due to these forest fires, the land becomes dry and this makes it more prone to catch fire in the future.

The haze spreads hundreds of kilometers as a result of transboundary winds, affecting the neighbouring countries of Indonesia namely Malaysia, Singapore, the south of Thailand, Brunei, and The Philippines. The quality of air in Indonesia and neighbouring countries significantly deteriorates. [18-20]

The irregularly of the periodic variation in winds and oscillation of sea-surface temperatures (El Nino-Southern Oscillation and positive Indian Ocean Dipole) makes weather drier which exacerbated the situation. [21]

Haze impacts on population and health

According to the Global Burden of Disease Study 2015, it is estimated that 4.2 million deaths occurred due to ambient fine particle air pollution (PM2.5) and 59% of these deaths were mostly from east and south Asia. [22]

During the haze crisis in 2015, 43 million Indonesians were exposed to poor air quality which was 3 times more than the “hazardous” limit of the International Pollutant Standard Index. Schools were forced to close down affecting approximately 5 million students in Indonesia. 2.6 million hectares of forest, peat, and other lands that were burned impacted the economy of the country. Approximately 500,000 people were affected by acute respiratory infections due to haze. An estimated 100,000 premature deaths occurred in Indonesia, Malaysia, and Singapore and a state of emergency had been declared during the haze outbreak. [23]

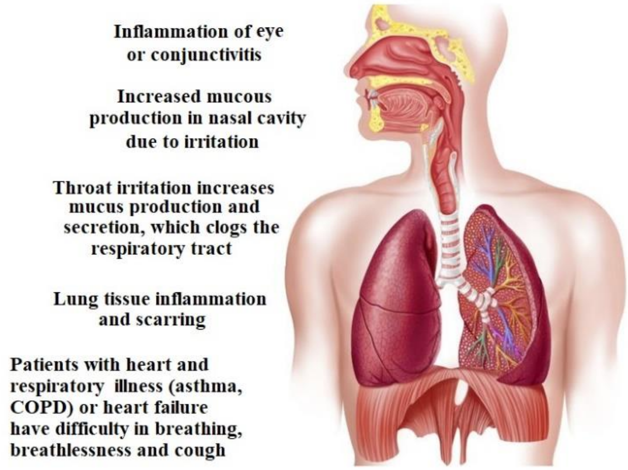

Figure 3: Short term complications associated with haze

Many small-scale retrospective studies have shown the rate of emergency attendances associated with symptoms of respiratory health increased dramatically during haze. Dry mouth, nose discomfort, dyspnea, cough, sore throat and acute exacerbations of COPD, eye discomfort, headaches and skin irritation were common amongst the haze exposed residents. [24-26] The severity of the symptoms depended on the extent of how air pollution affected the individuals. The adverse health symptoms may take up to three days to occur after haze exposure. Haze causes increased acute childhood asthma [27], decreased pulmonary function among children. [28] Haze increases the release of polymorphonuclear leukocytes (PMN), precursors from the marrow and increases the band cell count in circulation, which plays a vital role in cardiorespiratory morbidity. [26] Migraines and nonspecific headaches were a great concern as a result of particulate matters in the haze. [29] A study by Sastry N reported that total mortality was associated with a 100μg/m3 increase in PM10 concentrations in Kuala Lumpur, associated relative risk is 1.07. [30]

Tan BY et al. showed that the haze was probably associated with various psychosomatic symptoms because of altered cerebral hemodynamics. The greatest concern is that even with short-term exposure to moderate haze conditions, the susceptible individuals will be severely affected. [31] As a precautionary measure it is recommended to use the N-95 mask during haze as it can filter 95% of particles between 0.2μm and above. [9]

Economic impact

Haze strikes the economy by increasing the number of hospitalizations, loss of biodiversity, reduced tourism, airport closure and other fire impacts. Data from Unesco revealed that in 2015, there was an economic loss of USD$16.1 billion in Indonesia due to forest and plantation fires. Costs associated with loss of biodiversity of endangered species was USD$295 million. [23, 32]

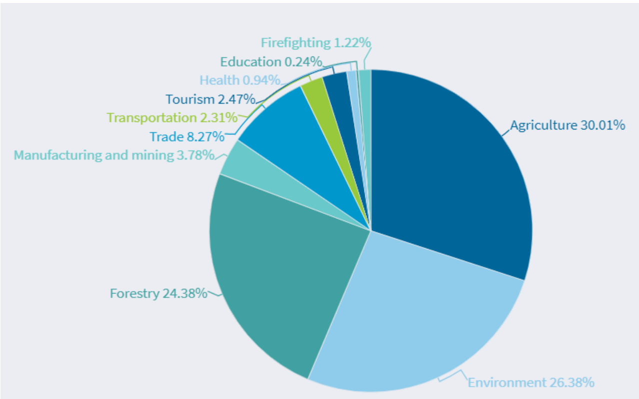

Figure 4: June to October 2015 haze losses by sector in Indonesia, the estimated total cost is USD$16.1 billion. [32, 33]

2015 haze and economic damage in Singapore:
In 2015 the PSI level in Singapore was 341, which is considered hazardous, this compelled the authorities to close all the schools. Suspension of food delivery services also slashed a big chunk of the revenue. Haze cost Singapore USD$1.83 billion in 2015. A study by Quah E estimated that an average Singapore resident is willing to pay up to $118.04 for haze-free air from their annual income to be safe, making the total willingness to pay $363.58 million, a hefty cost for haze. [34]

In 2019, due to low air quality the school authorities of several districts of Malaysia were forced to shut down when the API reached at the level of 208. On the 14th of September 2019, the PSI levels in Singapore exceeded the 100 mark, which was the highest in three consecutive years. [18]

Loss of productivity in Malaysia due to haze-associated illnesses in 1997 (August-October) compared with the same period in 1996 can be listed as:

- Increase in number of sick leave obtained by adult 20,743 out-patients
- Incremental total workdays missed 21,501
- Incremental productivity foregone from workdays lost USD$227,910
- Incrementally reduced activity days 141,068
- Loss of productivity arising from reduced activity days USD$1,495,324
- Loss of productivity due to illness USD$1,723,234

Economic damage to Indonesia due to forest fires and haze episodes during middle and late 1997 can be summarized as:

- 35.4 million inhabitants were residing in "above normal" levels of the haze zone
- There were 267,000 hospital admission cases, 623,000 un hospitalised treatments, and 9.78 million self-treatment cases occurred.
- 27.9 million workdays were lost, equivalent to 100,000 person-years of employment.
- estimated total medical costs were USD$295 million, with an additional USD$167 million, as a result of the loss of productivity. An "indirect cost" of USD$462 million due to lost consumer surplus (WTP factor of 2:1) was estimated.
- USD$924 million was associated with short-term health damages.

Tourism losses: Tourism is an important aspect of the Association of Southeast Asian Nations (ASEAN) economies. Haze affected the number of inbound tourists, which lead to a reduction in businesses and employment, job losses escalated considerably. Approximately, between 187,000 and 281,000 visitors were lost in 1997 which result in a mean loss of USD$58.63 million during three months of haze period. [35]

Airport closures: Data from major airlines in Indonesia shows that a total of 1,108 flights were cancelled in the period 1 August to 31 October 1997 with a total loss of USD$7.54 million.

Fire impacts: (USD$ millions)
• Losses of timber - 493.67
• Losses of Firming/plantation - 470.39
• Losses of direct forest ecosystem production - 704.97
• Function losses of Indirect forest ecosystem - 1,077.09
• Losses of domestic (capturable) biodiversity - 30.00

Firefighting cost USD$13.46 million, Carbon dioxide and methane emission cost USD$272 million. [35-37]
Reduced efficiency in the manufacturing and construction industry was also observed during the haze, as most of these industries involve mainly outdoor work. Human productivity decreased as the number on sick leave increased [38].

Economic loss of haze in June 2013, Malaysia
The June 2013 haze cost MYR 1.49 billion (0.48% of the GDP); MYR 78.03 was for each household expense due to haze (MYR 410.6 million for entire Malaysia); cost of hospital admission and treatment-related costs were MYR 22.59 per household (MYR 118.9 million); sick leave cost MYR 38.54 per household (MYR 202.8 million); reduced activity days, MYR 13.17 per household (MYR 69.3 million); protective measures to combat haze such as masks were MYR 3.73 per household (MYR 19.6 million); and loss of chances for income was MYR 182.05 per family (MYR 958 million), which was 64.11% of the total economic cost. [39]

Conclusion

The Southeast Asian haze crisis has become recurrent and it is significantly associated with increased health risks in all age groups. The existing studies of the affected countries demonstrated that haze causes irreversible damage to the health and economy of the country. Evidence showed that there are constant detrimental effects on cardiorespiratory, psychological, neurological morbidity, and mortality during the haze. More insights are required to understand the mechanism of the diseases, the toxicity of haze particles and its contribution to the underlying pathophysiology in mortality and morbidity. This may be useful to prepare the healthcare industry in anticipation for seasonal haze in the affected regions. In 2013, economic loss from haze in Malaysia was MYR 1.49 billion; in 2015, USD$1.83 billion was an estimated haze cost for Singapore, whereas for Indonesia it was USD$16.1 billion in the same year. In conclusion, this review encourages farmers to practice sustainable agriculture methods rather than the slash and burn method. Future studies are required to assess the economic damage in detail which would be beneficial for policymaking and taking strategic steps to minimize the damage caused by the haze episodes in Southeast Asia.

Abbreviations

Air pollution index (API), Association of Southeast Asian Nations (ASEAN), chronic obstructive airway disease (COPD), particulate matter (PM), pollutant standard index (PSI), polymorphonuclear leukocytes (PMN), Sulphur dioxide (SO_2), ultrafine particles (UFPs)

Author’s contribution

NG and BR designed and the project; BR conducted the bibliographic research and drafted the manuscript with NG. The final version of the manuscript was approved by both authors.

Competing interests

None declared.

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