BURNING UP

HEALTH IMPACT OF INDONESIA'S FOREST FIRES AND IMPLICATIONS FOR THE COVID-19 PANDEMIC

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Table of contents

Summary

As Indonesia braces for the 2020 forest fire season, a timely review of data of the effect on smoke-affected communities shows consecutive governments have been consistently and massively underestimating the impact on human health. The review also presents compelling evidence from research, indicating that the risk and severity of infection from Covid-19 may significantly increase amongst already vulnerable communities exposed to high levels of air pollution.

For almost four decades the toxic smoke and air pollution from yearly forest and peatland fires have exacted a huge toll on the communities, biodiversity, environment and economy of Indonesia and its neighbouring countries.

Successive governments have considerably downplayed the scale of the impact on human health. After the devastating 2015 fire season, the official death toll was put at just 24 lives lost. In contrast, epidemiologists estimate tens of thousands of people died; monitoring reports note the fires had created "perhaps the worst sustained air quality ever recorded worldwide"; and other researchers calculated tens of millions of people had been exposed to levels of air pollution ranging from 'unhealthy' to 'hazardous'.

The health of people across the ASEAN region has been damaged and many thousands have died prematurely, because of exposure that could have been avoided. Commercial activity, particularly forest clearing and peatland draining by the palm oil, pulp and paper industries has dried out huge swathes of the Indonesian landscape, creating the perfect conditions for fires to take hold. Despite having the authority to prevent this devastating process, the Indonesian government has consistently enabled the industry to continue down this destructive path.

Studies have found that fires in Indonesia's peatlands, which account for nearly half the burnt land in commercial concessions, produce pollution which is particularly damaging to health. The peatland blazes create a larger proportion of fine particles ($PM_{2.5}$) than other forest fires. These particles, 30 times smaller than a human hair, are more easily absorbed and damaging to human health.

The damage to health from forest fire air pollution has been long documented. However, official monitoring of air quality remains entirely inadequate in Indonesia. Pollution monitoring in neighbouring countries is considerably more widespread and reliable. A combination of data from other countries, as well as accurate modelling studies has provided compelling evidence of large-scale health impacts across the region.

By examining the available data and literature, clear commonalities have also emerged between the health impacts of exposure to air pollution and vulnerabilities related to the Covid-19 pandemic.

In addition to causing serious health conditions such as chronic lung conditions, increased respiratory infections and cardiovascular disease, there is now a growing body of evidence that suggests air pollution could increase the chance of Covid-19 infection and exacerbate the severity of the infection for those already Covid-19 positive.

Research carried out earlier this year in China found exposure to air pollution was significantly higher in Covid-19 positive patients. It has been established that Covid-19 positive patients with certain 'preexisting' or underlying conditions, such as diabetes, hypertension, cardiovascular disease, and chronic lung conditions including asthma and chronic obstructive pulmonary disease, are at greater risk of being hospitalised and even dying. Many of the same conditions are caused by or worsened by forest fires – including pollution from the blazes occurring repeatedly in Indonesia.

While earlier studies highlighted the elderly as at particular risk from both forest fire pollution and Covid-19 infection, one new study has also highlighted the risks posed to the next generation from recurring forest fires. Children exposed at a young age to smoke through living in Sumatra or Kalimantan during the 1997 fires were examined over subsequent years and showed lower grades of completed schooling, lower scores in cognitive tests, and slower physical growth than children who were not smoke-exposed. The children's lower height and weight for age is an indicator of poor health. This study data is particularly concerning given the findings of the Indonesian Paediatrician Association, which has blamed poor health among impoverished children for Indonesia recording among the world's highest child Covid-19 death rates – 51 fatalities reported in July and double the figure by the following month.

The case for immediate and decisive action to end Indonesia's fires crisis cannot be disputed. Successive studies, over decades, have uncovered the impact on the biodiversity of the region. Carbon emissions are altering the climatic patterns which affect Indonesia's dry season, worsening fires and making them more frequent, which in turn releases more emissions and accelerates climate change. The massive economic cost of continuing to create the conditions for these fires runs into billions of dollars.

However, this distillation of evidence clearly points to forest fires also being a major public health crisis, one that risks being compounded by the global Covid-19 pandemic.

A range of industry commitments and government regulations are already in place, which need to be strengthened further, but even in their current form would already reduce the incidence of fires. It is vital that the Indonesian government enforce those regulatory controls, prevent clearing and draining of forest and peatlands; hold accountable the industries continuing to act with impunity; and ensure that public health is prioritised over corporate profit.

Introduction

For nearly forty years, since the 'Great Fire of Borneo' in 1982-83, recurring forest fires[1] in Sumatra and Indonesian Borneo have caused significant, yet preventable harm to local communities and neighbouring countries (Aiken 2004). Tens of millions of people have been exposed to air pollution, and many have needlessly died as a result of the fires (Barber and Schweithelm 2000; Crippa et al. 2016). Those communities are now potentially facing an additional threat, with research indicating smoke from the blazes may increase both the occurrence and severity of the novel coronavirus (Covid-19) on human health.

Forest Fires in a plantation area near Palangkaraya, Central Kalimantan. | 23 Sep, 2019

The decades of damage and these newer risks could have and could still be avoided with meaningful political action but, despite evidence of the deadly harm of forest fires, the burning continues, with experts recently documenting "perhaps the worst sustained air quality ever recorded worldwide" (Wooster et al. 2018).

This briefer has reviewed and distilled dozens of studies, research papers, and scholarly reports on the historical health impacts of Indonesia's forest fires, as well as collated some of the growing evidence of correlations between increased impacts and risks of Covid-19 infection by communities impacted by forest fires.

The data presents a clear and immediate rationale for government intervention to stop the destruction of peatlands and implement measures to protect Indonesia's forests and the health of tens of millions of people across the region.

Cause and impact of forest fires in Indonesia

The rapid clearing and draining of Indonesia's forests and peatlands has created the conditions for massive forest fires (Page et al. 2009). Much of this land use change has been undertaken at industrial scale for oil palm and pulpwood plantations covering thousands of hectares.

Fires and smoke occur to some extent during Indonesia's dry season every year (Dawud 1999). Longer and more severe fire seasons are recorded in years where positive phases of the El Niño – Southern Oscillation (ENSO) and positive Indian Ocean Dipole climate phenomena occur, usually between August - October (Frankenberg, McKee, and Thomas 2005; Crippa et al. 2016). During ENSO episodes, smoke from Indonesia's forest fires is often carried across to neighbouring countries, but this can also occur in non-ENSO years, as it did for example during 2005, 2010 and 2013 (Koplitz et al. 2018).

Fire emissions from Indonesia contribute to human-induced climate change; climate change will in turn affect the ENSO system and result in changed weather patterns in Indonesia. It is possible this will involve increased ENSO variability (Chen et al. 2017) or more frequent extreme El Niño events (Cai et al. 2015; Bin Wang et al. 2019). Coral records from the Mentawai Islands show that positive Indian Ocean Dipole events have become more intense in recent decades, and that extreme positive Indian Ocean Dipole events were rare before the 1960s (Abram et al. 2020). The frequency of extreme positive Indian Ocean Dipole events is predicted to rise linearly along with increased global temperatures, the expected rate doubling at 1.5 °C warming from pre-industrial times (Cai et al. 2018).

In addition to the impact on climate systems, Indonesia's fires also cause huge spikes in pollution levels. A team led by Martin Wooster (2018) took readings in Palangkaraya, Central Kalimantan during the 2015 forest fire crisis, and noted the figures were "perhaps the worst sustained air quality ever recorded worldwide".

World Health Organisation (WHO) guidelines for PM_{10} particulate matter pollution (PM_{10} – particles smaller than 10 microns) state concentrations over a 24-hour average should not exceed 50$\mu g/m^3$. According to Wooster's data Palangkaraya residents were exposed to levels above 1000$\mu g/m^3$ for weeks, with readings reaching as high as 3500$\mu g/m^3$ (Burki 2017; Wooster et al. 2018). In severe fire seasons, people seeking treatment for respiratory ailments have overwhelmed Indonesian medical clinics (Aditama 2000) and smoke haze has seriously impacted nearby countries.

Forest fire air pollution contains many contaminants, but fine particles, especially those smaller than 2.5 microns ($PM_{2.5}$) are thought to have the greatest health impact. Burning peatlands are estimated to have contributed 95% of the $PM_{2.5}$ pollution during Indonesia's 2015 fires crisis (Wooster et al. 2018). Historically, intact forested tropical peatlands rarely burned, but the clearing and draining of peatlands for plantations has resulted in a significant increase in fires in Indonesia's peatlands during recent decades (Page et al. 2009).

It is against this backdrop of established and recurring health risks to the people of Indonesia and neighbouring countries that 2020 has brought a new and potentially compounding threat.

During forest fire crises, patients overwhelm medical services in smoke-struck areas of Indonesia. Here patients are seen wearing masks because of haze in Doris Sylvanus public hospital, Palangkaraya city, Central Kalimantan. | 24 Sep, 2019

Early studies have noted that the SARS-CoV-2 virus, which causes Covid-19, can be especially dangerous for the elderly. It has also been discovered that a large proportion of people hospitalised for Covid-19 – 89% of US patients in data reviewed by Garg (2020) – have 'preexisting' or underlying conditions. Garg documented the proportion of Covid-19 hospitalised patients with underlying conditions, and found that conditions which are also linked to air pollution exposure occurred at the following rates:

- Hypertension (50%)
- Chronic lung conditions (34%) – including asthma (17%) and chronic obstructive pulmonary disease (11%)
- Cardiovascular disease (28%)
- Diabetes mellitus (28%)

Furthermore, as Wu et al. (2020) noted, the pre-existing conditions listed above that increase the risk of hospitalisation or death from COVID-19 are the same diseases which can be caused or exacerbated by long-term exposure to common forms of air pollution. To make things worse, elderly people are especially vulnerable to forest fire smoke (Liu et al. 2015) as well as to Covid-19.

While there are numerous studies on air pollution from around the world, the majority focus on continuous industrial and transport-related emissions and far fewer examine intermittent but high

intensity forest fire pollution. A number of studies have confirmed however that forest fire pollution is associated with respiratory (lung) disease, cerebrovascular disease (stroke), and cardiovascular (heart) disease (Reid et al. 2016; Cheong et al. 2019; Liu et al. 2015). Forest fire smoke is also associated with increased deaths; global annual mortality from fires[2] has been estimated at 262,000 during La Niña climate years and 532,000 during El Niño (Johnston et al. 2012).

Surprisingly few studies have investigated the specifics of Indonesia's situation. Key findings from those studies are highlighted in the following pages.

Forest fires damaging health in Indonesia

In their review of scientific papers on the health impacts of wildfire smoke, Reid et al (2016) noted "it is possible that smoke originating from peat fires, forest fires, grassland fires, and agricultural burning could lead to differential health effects due to different constituents in the smoke." This is because pollutants generated by fires vary by location due to differences in fuel composition and fire behaviour (Ward 1990). There are differences between tropical versus temperate forest fires, and also by soil type, for example between mineral and peat soils. Fire behaviour also varies – peat fires are notable for extended low-temperature (< 400 Celsius) smouldering (Jayarathne et al. 2018), which increases output of particulate pollution but also toxic carbon monoxide, ammonia, hydrogen cyanide and formaldehyde (Wooster et al. 2018).

Forest fire smoke at Jekan Raya, Palangkaraya, Central Kalimantan, during a state of emergency called in August 2019. | 9 Aug, 2019

U.S. Environmental Protection Agency (US EPA) analysis in Palembang during the 1999 fires determined that approximately 85% of the mass of PM_{10} pollution was actually composed of fine particles in the $PM_{2.5}$ size category (Pinto and Grant 1999). Measurements made under real-world conditions in Kalimantan during 2015 have further revealed that $PM_{2.5}$ pollution is emitted from peat burning underground at levels 'far higher than past laboratory burning of tropical peat has suggested' (Wooster et al. 2018).

Frankenberg, McKee, and Thomas (2005) used self-reported health data collected as part of the Indonesia Family Life Survey, to examine health impacts of Indonesia's 1997 forest fires. A longitudinal approach enabled them to look at data from the same households both before (1993) and during the 1997 fires, and also to compare households living in areas exposed to forest fire smoke (in Kalimantan and Sumatra) with those from unaffected areas elsewhere in Indonesia. The study participants reported that their exposure to forest fire smoke reduced their ability to carry out strenuous activity and increased coughing episodes. They also reported that coughs cleared up within a month after the smoke exposure had ended, leading the study authors to conclude 'the haze has a substantial negative effect on respiratory health' (Frankenberg, McKee, and Thomas 2005).

In an overview of the health impacts of Indonesia's 1997 fires crisis, Aditama (2000) cited Ministry of Health data on 12.36 million people affected by smoke haze in eight provinces: in Sumatran provinces Riau, Jambi, West and South Sumatra; and in every province of Indonesian Borneo – South, East, West and Central Kalimantan.[3] The official figures, recorded from September to November 1997, showed 298,125 cases of asthma, 58,095 cases of bronchitis and 1,446,120 cases of acute respiratory infection – 1.8 million in total.[4] Compared with data from the years 1995 and 1996, cases of acute respiratory infection during the 1997-1998 fires were reportedly up by 1.8 times in South Kalimantan and by 3.8 times in South Sumatra. Across all eight provinces, official government figures attributed 527 deaths to the 1997 forest fires (Aditama 2000).[5]

Aditama also reported that the Jambi Provincial Health Office experienced a 51% increase in respiratory diseases during the 1997 smoke crisis, and 'an increased mortality rate two to four times that of previous months' in the pulmonary (respiratory) ward of the Jambi public hospital.

In a separate study, researchers from Japan questioned over 500 people in Jambi about health problems before and during the 1997 smoke crisis, and carried out medical examination of one quarter of the cases, chosen at random. As many as 91% had respiratory problems, and half (49%) reported that these health problems were disturbing their ordinary lives. Among those with respiratory symptoms, 31% were fevered, 46% were short of breath when they walked, and 34% experienced chest discomfort (Kunii et al. 2002).[6]

A team of pulmonary specialist doctors from Jakarta examined 158 patients in Palembang in October 1997. None of the patients had symptoms prior to the fires, but at the time of treatment 81% were experiencing coughing, 24% had breathing difficulties and 9% were suffering chest pain (Faisal, Yunus, and Harahap 2012).

An IPB University dissertation (Novita 2008)[7] examined data on numbers of people suffering acute respiratory tract infection, taken from four community health clinics (puskesmas), in sub districts of Indragiri Hulu, Riau over seven months during the 2007 fire season. The study design was unable to reach a conclusion on causality, and local air pollution data was unavailable. However, by using remotely observed fire hotspots as a proxy it found a strong positive correlation between subdistricts experiencing fire hotspots and acute respiratory infections.

Two separate studies conducted in Pekanbaru city in Riau province, one from 2011-2015 and the second from 2015, both found correlations between forest fire smoke and respiratory illness. Irawan et al. (2017) studied monthly health data[8] during 2011-2015 along with air quality data from the city, recording a number of months when smoke from forest fires drove pollution levels to dangerous levels.[9]

They found that the rate of acute respiratory tract infection had a moderate correlation with the level of PM_{10} particulate air pollution[10] one month previous. The 2015 study of data on patients presenting to public health facilities, concluded that high air pollution index readings had a significant effect: a strong correlation with upper respiratory tract infections and a moderate correlation with pneumonia (Hermawan, Hananto, and Lasut 2016). In both of the studies above, it was not possible to control for confounding factors, so only correlation rather than causality could be established.

Researchers in West Sumatra reported that public health facilities recorded 287,145 cases of acute respiratory tract infection during 2015, of which health authorities attributed[11] 167,893 cases to forest fire smoke exposure (Handayuni, Amran, and Razak 2018).

Impacts of forest fires on child health and mortality

Two studies have examined the impact of Indonesia's forest fires and subsequent smoke hazes on fetal, infant and child mortality and wellbeing.

Abi Huroiro sits beside his daughter's grave at the public cemetery in Pemulutan Ilir village, Ogan Ilir district, South Sumatra. Abi lost Annisa (2 months old) who passed away due to breathing difficulties caused by haze from plantation and forest fires. | 30 Oct, 2019

Jayachandran (2008) examined effects of particulate pollution on under-3-year-old children in Indonesia during the 1997 fires crisis. Calculations to estimate the number of "missing" children in census data found that "air pollution from land fires that engulfed Indonesia in late 1997 led to over 15,600 child, infant and fetal deaths".

Rafa, 50 days old, is held by his mother while he receives oxygen to treat breathing difficulties from thick forest fire air pollution, in the ICU of Doris Sylvanus public hospital, in Palangkaraya city, Central Kalimantan. | 24 Sep, 2019

Similarly, data from a multi-year Indonesian government survey was examined to look for differences among children who were aged 12-36 months during the 1997 haze crisis. When followed up in 2000 and 2007, on average, those children exposed to smoke through living in Sumatra or Kalimantan during the 1997 fires had lower grades of completed schooling, lower scores in cognitive tests, and slower physical growth than children who were not smoke-exposed (Lo Bue 2019).[12]

Transboundary impacts

High quality monitoring data both of air pollution and public health metrics in Singapore, Malaysia and Brunei have enabled studies to examine the health impacts of Indonesia's transboundary forest fire pollution. Seven of the ten ASEAN countries – Brunei, Indonesia, Malaysia, Philippines,[13] Singapore, Thailand and Vietnam[14] – with Cambodia a suspected eighth[15] – have been affected by Indonesia's smoke haze.

One of the worst transboundary smoke events occurred in June 2013, during neutral ENSO conditions, when Riau experienced a extremely high number of fire hotspots thought to be due to an early tropical cyclone season and a strong Madden–Julian Oscillation event (Oozeer et al. 2020).

Studies have found that the more dangerous, finer particles, which remain airborne for longer and travel further than larger particles, are impacting neighbouring populations. Such pollution is considered more dangerous because finer particles are carried deeper into the lungs and are more readily absorbed into the bloodstream (Frankenberg, McKee, and Thomas 2005).

Electron microscope analysis of the transboundary air pollution arriving in Singapore during the 1997 fires showed 94% of smoke particles were $PM_{2.5}$, ie below 2.5 micrometers in diameter (Emmanuel 2000). A more recent study of transboundary pollution created by Indonesia's 2013 fires showed over 90% of the $PM_{2.5}$ pollution was composed of submicrometer size particles: PM_{1}, $PM_{0.5}$ and $PM_{0.2}$ (Betha, Behera, and Balasubramanian 2014).

Left image: Thick transboundary air pollution originating from forest fires in Indonesia hits Robinson Road, Singapore. | 21 Jun, 2013

Singapore

Even before the 1997 fires crisis, medical journal The Lancet published data showing that smoke from Sumatran fires was leading to more than double the usual number of children needing treatment in Singapore's hospitals (Chew et al. 1995). More studies followed: particulate pollution from Indonesia's 1997 fires was observed by Emmanuel (2000) to result in a 30% increase in smoke-related cases recorded at Singapore's public health facilities during that year's haze crisis. This included a 12% increase in cases of upper respiratory tract illness and a 19% increase in cases of asthma due to an increase in PM_{10} from 50 $\mu g/m^3$ to 150 $\mu g/m^3$. Further data gathered from Singapore's air quality monitoring stations, its health system and from fire-monitoring satellites during 2010-2016 found increasing air pollution from Indonesian fires lead directly to increased visits to public polyclinics[16] for acute upper respiratory tract infections in the city-state (Sheldon and Sankaran 2017).

85-year-old Chaw Sen Siong (left, pictured in her wedding decoration store), had to stay indoors after suffering acute breathing problems during the 2013 air pollution crisis. A Singapore study found over-65s were especially at increased risk of cardiovascular mortality after exposure to transboundary pollution from Indonesia's forest fires in 2013. | 23 Jun, 2014

Also in Singapore, Ho et al (2018) examined data on almost 30 thousand cases in the country's comprehensive Stroke Registry dating from 2010 to 2015. They found that ischemic stroke incidence rose significantly when transboundary smoke from Indonesia carried the air pollution index up to 'moderate' or 'unhealthy' levels. Subsequently researchers examined Singapore's Myocardial Infarction Registry for the same six year period (Ho et al. 2019). They found the risk of heart attacks also rose

significantly along with bouts of transboundary haze: an 8% increase after smoke exposure at 'moderate' air pollution index levels, and a 9% increase after the index was at 'unhealthy' levels.

Separately, researchers conducted a study which did not set out to examine transboundary smoke per se, but nevertheless found a very high linear correlation between increased particulate air pollution[17] and both overall mortality and cardiovascular mortality, especially in over-65s (Yap et al. 2019). The study, which covered Singapore's population from 2001 to 2013, was the first such contemporary study in an equatorial country. The results showed that each 10μg/m^3 increase in $PM_{2.5}$ pollution was matched with an 1.073% increased risk of cardiovascular mortality over the following 5 days. During the study period smoke from Indonesia's 2013 fire season pushed Singapore's levels of PM_{10} and $PM_{2.5}$ as high as 336μg/m^3 and 275μg/m^3 respectively.

Malaysia

Researchers examined data on 190,000 hospitalisations over a four year period in the Kuching area of Malaysian Borneo (Sarawak). From 1995-1998 there was no significant industrial pollution and air quality data was continuously monitored (Mott et al. 2005). Their time-series analysis showed that people exposed to smoke from the 1997 fires experienced a significant increase in hospitalisation for cardiorespiratory (heart and lung) conditions. It evidenced a significant increase in hospitalisation for coronary heart disease (up 54%), for chronic obstructive pulmonary disease (up 50%) and asthma (up 83%) among middle-aged people (40-64 years).[18]

Kuala Lumpur's Petronas Tower barely visible through transboundary haze from forest and peatland fires in Indonesia, | 15 Sep, 2019

Mott et al also showed that over-65s with a prior history of hospital admission were more likely to end up back in hospital after being exposed to the 1997 forest fire smoke than those who had not been exposed. Of those over-65s, people with cardiorespiratory problems were the worst affected by forest fire smoke exposure. Examining death rates in Kuching and Kuala Lumpur over a similar period (1994-1997), Sastry (2002) found elderly people were two to three times more likely to die of respiratory or cardiovascular causes[19] following a high air pollution day.

As discussed below, evidence has emerged during the worldwide experience of the Covid-19 pandemic that people in this age and pre-existing condition category are also at increased risk from hospitalisation from the virus.

Thailand

In southern Thailand, analysis of Ministry of Public Health data was able to show the number of additional respiratory cases estimated to have been caused by exposure to the 1997 fires by comparing with data from the previous year and from a control area in far northern Thailand (Phonboon et al. 1999). It was calculated that approximately 45,000 additional outpatient (clinic) visits for respiratory illness were made across southern Thailand and 1,500 additional hospital admissions. Consistent with other studies, illnesses attributed to exposure to the 1997 fires included upper respiratory symptoms, pneumonia, bronchitis, COPD, asthma, conjunctivitis and eczema[20] (Phonboon et al. 1999).

Thai activists carry an hourglass filled with dust, calling on the government in Bangkok to urgently tackle air pollution caused by fine particulates (PM2.5). | 22 Feb, 2018

Brunei

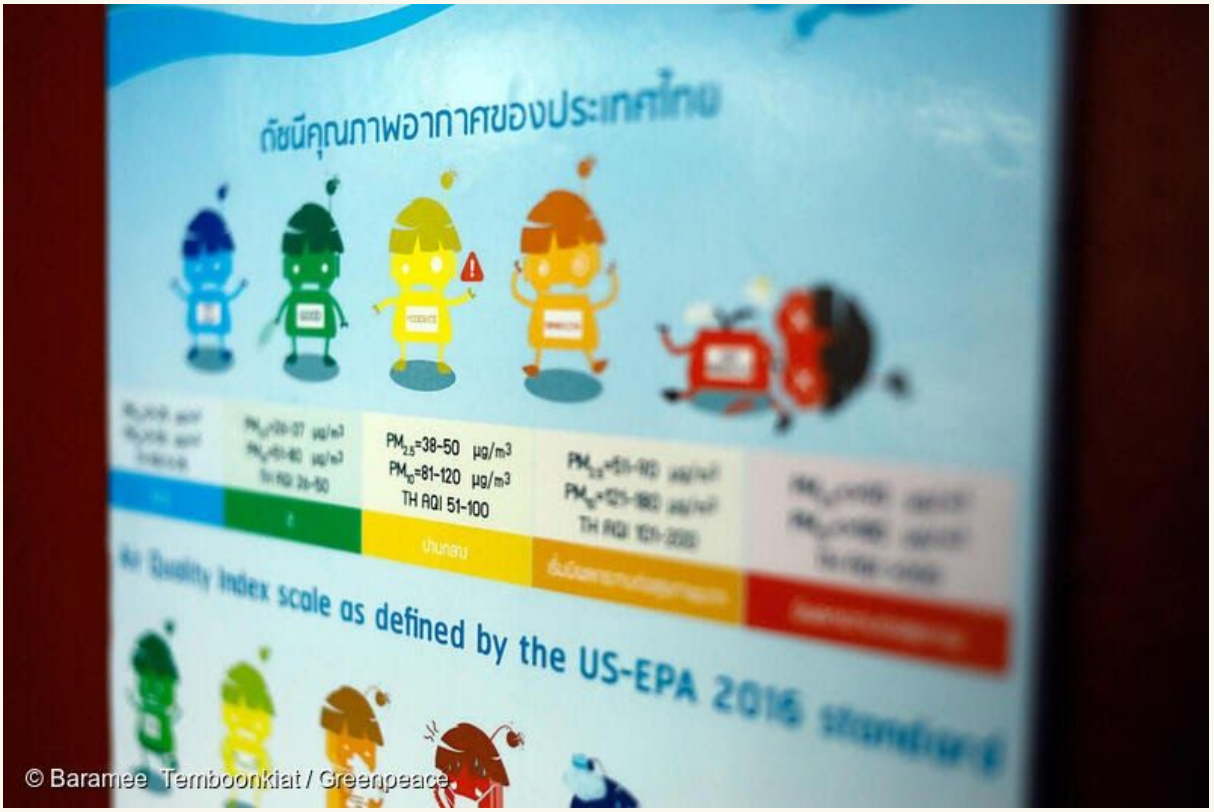
University of Brunei Darussalam researchers examined data from health facilities servicing two-thirds of Brunei's population, following exposure to air pollution from Indonesian forest fires in 1998 (Anaman and Ibrahim 2003). They found the daily case numbers of asthma, bronchitis, emphysema, influenza, pneumonia, and acute upper respiratory infections were significantly related to the previous day's air pollution level.[21]

Modelling studies

It is unfortunate and concerning that Indonesia still has only a limited network of air quality monitoring stations. Many fire-prone and well-populated rural areas are without government monitoring services, stations are often inactive, and $PM_{2.5}$ data, the most important metric for human health, is rarely available (Erou and Fadhillah 2019).

A comprehensive monitoring network is important to identify background pollution levels and smoke from forest fires as opposed to industrial and transportation sources (Grant 1999). When the US EPA reported on a mission to monitor Indonesia's 1997 fires, it noted the 'lack of any well-established routinely operating air monitoring network' (Pinto and Grant 1999).

By comparison, as early as 1997 Singapore had established 15 ambient air quality monitoring stations directly measuring particulate pollution (Emmanuel 2000), and southern Thailand had four stations[22] (Phonboon et al. 1999).



An air-quality monitoring device installed at Nak Prok Temple School in Bangkok to measure air quality and educate students, part of a network overseen by the Climate Change Data Center of Chiang Mai University. | 11 Mar, 2020

Barely any data was available in 1999 on the island of Papua (then Irian Jaya) despite widespread fires there (Dawud 1999); and by 2020 in Papua province government data is still available only for Jayapura, omitting areas in the southern half of the island most frequently exposed to forest fire smoke.

Because of this scarcity of pollution data in Indonesia, studies mentioned in this section rely partly on remote sensing to estimate concentrations of pollutants at ground level. In addition, health data is difficult to obtain and usually limited to particular cities or districts. Modelling studies have therefore been conducted to estimate national and regional health impacts.

Modelling studies estimate broad area health impacts of Indonesia's recurring smoke hazes by first estimating air pollution over Indonesia's inhabited areas and then, once the simulated surface-level air pollution levels have been calculated, corresponding expected health impacts are modelled based on a concentration-response relation (Crippa et al. 2016).

It should be noted that while modelling is a well-established approach in studying health impacts of air pollution (World Health Organization 2016), it is inevitably subject to a degree of uncertainty. This is because Indonesia's situation is unique in terms of forest and peatland fuel and fire behaviour as discussed above, but also because Equatorial Asia-specific epidemiological studies required to calculate exposure responses have not been available (Crippa et al. 2016). Instead they are based on epidemiology carried out in wealthy countries in Europe and North America where population structure, underlying health and health care infrastructure are quite different (Marlier et al. 2019).

Nevertheless, careful work has been done by scientists who are experts in this field to estimate Indonesia's situation. Koplitz et al. (2016) conducted modelling estimating that smoke, largely generated during just two months from September-October 2015, resulted in 100,300 excess deaths across Indonesia, Malaysia and Singapore. A recent application of this approach using a different concentration-response relation between $PM_{2.5}$ pollution and excess mortality revised this estimate downwards to 44,000 premature deaths due to the 2015 fires – still a catastrophic impact for a largely preventable human-made crisis (Kiely et al. 2020).

Another paper based on modelling health impacts from Indonesia's 2015 fires calculated the number of ASEAN citizens exposed to various Pollutant Standards Index levels of pollution during September to October 2015, based on their place of residence and the simulated transport of air pollution from Indonesian forest fire sources observed by satellite. The model showed 69 million people subjected to air pollution at 'unhealthy' levels; 6 million at 'very unhealthy' and 2 million at 'hazardous' levels (Crippa et al. 2016). On the basis of this estimated short-term exposure to air pollution during 1995, Crippa et al calculated between 6,153 - 17,270 excess deaths may have occurred.

Uda et al. (2019) used fire hotspot data, peat maps, village boundary maps and exposure-response modelling to estimate the long term impact of peatland fires on residents of Central Kalimantan's villages and towns during 2011-2015. They estimated that exposure to peat fire smoke caused 648 premature deaths per year in the province, due to chronic cardiovascular and respiratory diseases and lung cancer. They estimated that this rate may increase in future as peatland conversion is still ongoing in Central Kalimantan.

Accurately measuring health impacts

The health impacts and mortality as a result of Indonesia's fires are consistently downplayed. Official government figures for the death toll during the 2015 fires was just 24 lives lost (Nugroho 2016) – compared to tens of thousands of deaths estimated by epidemiological modelling (Kiely et al. 2020; Crippa et al. 2016; Koplitz et al. 2016). Given the 1997 fires were worse than 2015, then the 1997

official death toll of 527 (Aditama 2000) is likely an underestimate too, especially when taking into account government census records which suggest mortality among under-3-year-olds alone (child, infant and fetal) may have been 15,600 (Jayachandran 2008).

The government of Indonesia is not alone in attempting to minimise the human cost of forest fires. In Malaysia and Singapore too, government officials have downplayed the health impact of transboundary smoke. Koplitz et al (2016) estimated 6,500 premature deaths in Malaysia were caused by the 2015 fires, however the country's deputy health director-general Datuk S. Jeyaindran was quoted as saying in response to the study "No such thing! We had no deaths last year directly related to the haze." (Straits Times 2016). Singapore Health Ministry's director-general of prevention for disease control, Mr Mohamad Subuh, was less adamant regarding the Koplitz et al estimate of 2,200 deaths in Singapore, saying "I'm not sure these figures describe the real situation. If it's only a statistical count, I don't think it is appropriate to conclude such a huge death toll" (Arshad 2016). Singapore, however, did not issue an official death toll of its own in response to the study.

Numerous reputable studies have consistently pointed to significant human health impacts and avoidable fatalities as a result of smoke from Indonesia's forest fires. Coupled with new evidence that air pollution worsens the risk posed by Covid-19, researchers are clear that governments need to act to prevent further fires. Scientists who examined the impact of air pollution on daily infections in China recommended reducing air pollution as "a useful way to control Covid-19 infection" (Zhu et al. 2020). For inhabitants of Indonesia and neighbouring countries, making every effort to tackle Covid-19 means making every effort to tackle Indonesia's forest fires crisis.

Air pollution likely increases Covid-19 infection rate

Studies have already established exposure to air pollution increases susceptibility to viral respiratory infection in general (Domingo and Rovira 2020). Occurrence of severe air pollution haze in China has been linked to increased transmission of respiratory syncytial virus (Ye et al. 2016), influenza (Pan et al. 2014) and influenza-like illness (Su et al. 2019).

In a study earlier this year "Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China" (Zhu et al. 2020) researchers looked at daily confirmed Covid-19 cases in 120 cities. They found short-term[23] exposure to higher air pollution ($PM_{2.5}$, PM_{10}, carbon monoxide, ozone and nitrogen dioxide) was associated with a statistically significant increase in numbers of people with confirmed Covid-19 infections. Zhu et al caution however that they did not attempt to identify the causal mechanism behind this association.

A similar study focussing just on particulate air pollution in 72 Chinese cities found that each $10\mu g/m^3$ increase in concentration of $PM_{2.5}$ air pollution increased relative risk of Covid-19 infection by 64% (Bo Wang et al. 2020).

Possible mechanisms which have been proposed to explain why air pollution worsens viral respiratory infections include: oxidative stress from pollutants, producing free radicals in the lungs which both increase susceptibility to viral infection and exacerbate infections through increased inflammatory response; depression of macrophages in the lungs, which perform the crucial roles of attacking viruses and disposing of virus-infected cells; and a reduction or alteration of protective surfactant proteins, leaving the body's innate immune system less able to prevent infection (Ciencewicki and Jaspers 2007). Another mechanism which has been recently identified is damage done by pollution to airway cilia – minute hairs which beat in concert to clear out mucus and contaminants (Cao et al. 2020).

A unique experiment to examine the impact of Indonesia's forest fire haze on human cells gives additional insight into potential risks posed by respiratory viruses. The study exposed human epithelial lung cells to smoke originating from Indonesia during a transboundary haze event in Singapore, 2010. Pavagadhi et al (2013) found that the lung cells, exposed in vitro for two days to captured $PM_{2.5}$ particles, suffered a 2.5-fold decrease in cell viability while cell death almost doubled compared to controls. Mechanisms proposed to explain the damage included evidence of a high degree of oxidative stress.

A brief description of the interactions between coronaviruses and human cells provides an additional theory on why air pollution may be a factor in Covid-19 infection.

Coronaviruses, including SARS-CoV-2, are named for the appearance of a 'corona' of spike glycoproteins which surround each virus particle. The spikes belonging to the original SARS-CoV-1 (which caused SARS) and SARS-CoV-2 (which causes Covid-19) enable the virus to infect human hosts by binding to a naturally-occurring receptor on the surface of cells, called angiotensin-converting enzyme 2 (ACE2). The Covid-19 (SARS-CoV-2) spikes have been shown to have 10 - 20 times greater binding affinity to ACE2 compared with SARS-CoV-1 (Ni et al. 2020).

So, ACE2 is crucial for the entry of SARS-CoV-2; cells without it have been shown to be immune from infection (Ni et al. 2020). It is found in differing amounts in different human tissues: it is strongly expressed in alveolar cells deep in the lungs, which is the primary point of infection. It is also found to different degrees among different people. Rates of expression of ACE2 are significantly lower in children, increasing with each age category into adulthood, which is thought to explain why children are at reduced risk from the virus (UNICEF 2020).

This brings us to a mechanism which is proposed to explain observed high infection rates in polluted areas. There is evidence that lung cells (from both humans and mice) exposed to particulate pollution express more ACE2 (Miyashita et al. 2020; Baoming Wang et al. 2020). Increased ACE2 expression is also found in the lungs of smokers. Ironically it is speculated to be a protective response (Miyashita et al. 2020), but one which appears to put people at greater risk of infection by Covid-19 – higher levels of ACE2 potentially offer increased opportunities for the virus spikes to bind. The diagram below illustrates this proposed mechanism:

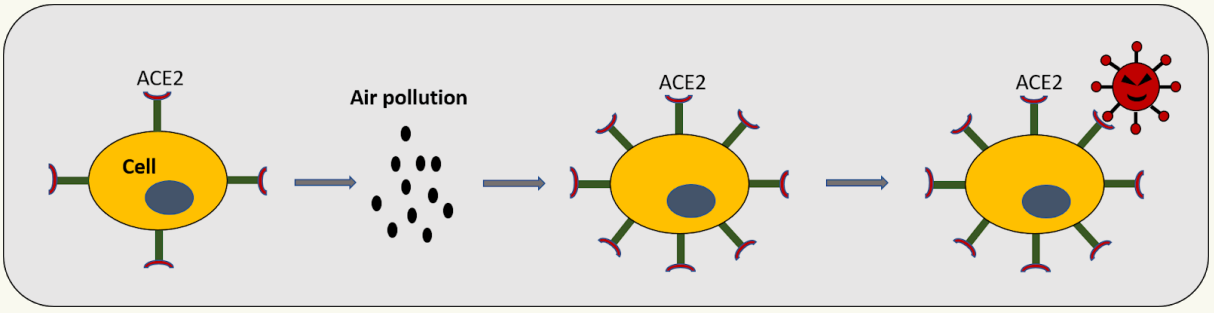


Illustration courtesy of Baoming Wang and Brian Oliver

Researchers in Italy have speculated that SARS-CoV-2, the Covid-19-causing virus, may attach to particulate matter, assisting it to persist for longer in highly polluted outdoors air (Setti et al. 2020). They based this on positive findings of SARS-CoV-2 viral genetic material (though not necessarily viable) when sampling outdoor airborne particulate matter. Individual SARS-CoV-2 particles are between 60 to 140 nm in diameter, approximately 20 times smaller than $PM_{2.5}$ category air pollution. Fine sooty particles of this size which result from burning hydrocarbons are often strongly adhesive and capable of aggregating with other particles (Shi et al. 2015). Researchers have speculated that particulate air pollution can provide condensation nuclei for influenza viruses (Wong et al. 2009). The proposal seems plausible, however there is no direct evidence yet that this particular mechanism is increasing Covid-19 infectiousness.

In addition to physical factors there are also environmental considerations that may have relevance. During previous fire crises, severe pollution has forced residents of Kalimantan and Sumatra to take cover in crowded shelters or to evacuate on crowded vessels – in 2015 as many as 424,000 were evacuated (Kantor Berita Radio 68H 2020). Evacuees forced to gather in close quarters will inevitably be at increased risk of Covid-19 transmission.

Air pollution worsens risks for some Covid-19 sufferers

As well as the potential for air pollution to increase the risk of being infected by the Covid-19 virus, new research also suggests those already infected could be at greater risk because of air pollution.

Before the emergence of Covid-19, exposure to air pollution was already known to worsen a number of respiratory viral infections (Ciencewicki and Jaspers 2007). Studies undertaken during the 2002-2004 SARS outbreak are especially relevant in this instance.

SARS was caused by the SARS-CoV-1 virus, closely related to the SARS-CoV-2 virus responsible for the current Covid-19 pandemic. During the SARS outbreak, researchers in China found that high air pollution doubled the risk of dying from SARS and hypothesized that the known adverse effects of exposure to inhaled particulate matter worsened the progression of SARS illness (Cui et al. 2003). There is therefore concern that exposure to haze from Indonesia's forest and peatland fires may worsen the risk faced by some people infected by Covid-19.

Research into quantifying observed correlations between chronic exposure to fine ($PM_{2.5}$) air pollution and the risk of death due to Covid-19 is underway in China, Europe and the US.

Initial results from a respected team of Harvard university researchers found that in the US a small increase in $PM_{2.5}$ pollution was associated with a measurable increase in the COVID-19 death rate (Wu et al. 2020). This study, published without time for peer review, along with others published so early in the Covid-19 pandemic, are necessarily subject to caveats, due to the difficulty of controlling for complex factors including the impacts of varying government policies, infection clusters, and difficulty with availability and accuracy of early tests (Villeneuve and Goldberg 2020). Nevertheless, while it is still early days in determining the degree to which air pollution worsens Covid-19 death rate, the link found by Wu et al appears robust according to other researchers (Cole, Ozgen, and Strobl 2020).

A study quantifying the relationship between Covid-19 cases and long-term air pollution exposure in the Netherlands has reinforced the role of $PM_{2.5}$ pollution identified by Harvard researchers. Cole et al (2020) analysed air pollution data averaged over 1995-2019 from 355 Dutch municipalities and confirmed covid-19 infections, hospital admissions and deaths up till 5 June 2020. At that time, the Netherlands was suffering among the top-ten highest per-capita covid-19 death rates, with its medical system providing a robust source of data. A striking and statistically significant relationship was found: a single unit increase in $PM_{2.5}$ pollution exposure ($1\,\mu g/m^3$) was associated with an increase of between 13% and 21.4% in the number of Covid-19 deaths averaged over the Dutch municipalities. This finding is comparable with that of the Harvard University researchers, above.

Chronic inflammation due to air pollution also causes what researchers in Italy describe as 'hyper-activation' of the innate immune system, which they hypothesise may contribute to deadly overactive immune response to Covid-19 infection (Conticini, Frediani, and Caro 2020). Although further research is required to confirm the hypothesis, high levels of industrial air pollution in Northern Italy may be blamed as an 'additional co-factor' for the high rate of Covid-19 mortality there.

As mentioned in the Introduction, Covid-19 positive people with certain 'comorbidities' or preexisting conditions are at greater risk of hospitalisation or death. Prominent among these conditions are diabetes, hypertension, cardiovascular disease, and chronic lung conditions including asthma and chronic obstructive pulmonary disease (Garg 2020). As we have seen in the earlier sections, a number of these comorbidities are caused or worsened by air pollution in general (Wu et al. 2020), and more specifically by forest fires (Reid et al. 2016; Liu et al. 2015) – including those occurring repeatedly in Indonesia (Cheong et al. 2019; Ramakreshnan et al. 2018).

As with its role in initial infection discussed earlier, increased ACE2 levels, possibly through exposure to air pollution, may play a role in these more severe Covid-19 cases (Naughton et al. 2020). The danger of increased ACE2 was also emphasised in a new paper looking at data on 700 lung samples 'ACE2 Expression Is Increased in the Lungs of Patients With Comorbidities Associated With Severe COVID-19' (Pinto et al. 2020).

Children engulfed in thick smoke from forest fires at Sei Ahass village, Kapuas district in Central Kalimantan. Research has shown children exposed to Indonesia's forest fire smoke suffered poor health; Indonesian doctors fear poor health increases the risk children face from Covid-19. | 24 Oct, 2015

As well as patients with preexisting conditions, anything which impacts children's health during the current pandemic is a concern (UNICEF 2020). Height and weight for age are often used as a proxy for children's general health; Lo Bue (2019) found that children exposed to Indonesia's forest fires smoke suffered a decline in both indicators. The Indonesian Paediatrician Association (IDAI) has blamed poor health among impoverished children for Indonesia recording among the world's highest child Covid-19 death rates (Yulisman 2020); in July, an IDAI spokesperson announced that 51 Indonesian children had died of Covid-19 (Wuragil 2020) and in August, the figure had reportedly reached around 100 (Arlinta 2020).

Any patient recovering from Covid-19 infection, and especially people who have experienced damage to their lungs or blood vessels, may be more susceptible to health impacts from forest fire smoke (CDC 2020). By preventing fires, we can help these people's recovery from Covid-19. And Indonesia's under-resourced health system,[24] already under unprecedented strain from an influx of Covid-19 patients, will be ill-prepared for any additional burden of patients with illness stemming from forest fire smoke exposure.

The case for immediate action

Government officials and politicians in Indonesia, have consistently failed to give sufficient priority and resources to addressing the environmental and human health impacts of the recurring fires. During the 2015 fire season alone 11.3 million tonnes of carbon dioxide per day were estimated to have been released into the atmosphere, higher than the fossil fuel emissions rate of the whole European Union[25] (Huijnen et al. 2016).

In addition to the human health impacts documented earlier in this brief, the biodiversity of Indonesia's vital forest regions has been massively impacted, especially peatland ecosystems, which have been ravaged by repeated fires, with little chance of rapid recovery (Harrison, Page, and Limin 2009; Page et al. 2009). Iconic species such as orangutans, birds including culturally significant species such as hornbills, and countless more insects, reptiles and amphibians die annually and needlessly, due to destruction of their habitat, as well as direct exposure to fire, smoke and ash. (Syaufina 2018; Husson, S.J. et al. 2018; Barber and Schweithelm 2000).

Otan, a 7-month-old orangutan rescued from forest fires in an oil palm plantation near the village of Linga, West Kalimantan. | 18 Sep, 2015

Besides direct environmental impact of fires within Indonesia, transboundary air pollution has been recorded impacting measures of biodiversity in Singapore (Lee, Davies, and Struebig 2017). The emergence of Nipah virus, a deadly new zoonotic disease has even been attributed in part to Indonesia's 1997-1998 fires crisis, when the impact of transboundary haze is thought to have lead virus-carrying Malaysian flying foxes out of forests and into farmland orchards (Looi and Chua 2007). Unless we

reverse our unsustainable consumption, destruction of natural environments and degradation of ecosystem services, we can expect many more serious zoonotic diseases, such as Covid-19, to emerge in future (Everard et al. 2020).

The social distancing measures required to slow the spread of Covid-19 are also expected to create difficulties for firefighters tackling blazes (Singapore Institute of International Affairs 2020). This may mean the 2020 fire season is worse than it would otherwise be, and this problem may extend into 2021 if the pandemic is still not under control.

The economic costs of Indonesia's recurring fires are substantial. The 2015 fires are estimated to have cost Indonesia US$16 billion in losses to forestry, agriculture, tourism and other industries (World Bank 2016), the 2019 fires are estimated to have cost a further US$5.2 billion (World Bank 2019).

Forest and peatland destruction is the main source of air pollution

While climatic conditions determine the difference in scale between 'bad' and 'worse' years, forest destruction and peatland drainage are recognised as the underlying cause of the Indonesian forest fires crisis (Huijnen et al. 2016; Page et al. 2009; Barber and Schweithelm 2000). Officials ranging from Indonesia's National Police spokesperson, the head of the National Disaster Mitigation Agency, through to President Joko Widodo have all stated that human actions were the cause of almost every blaze during the 2019 forest fire crisis (Regan 2019; Prabowo 2019; Detikcom 2020).

Commercial concessions issued to companies for logging and oil palm and timber/pulpwood plantations, each cover thousands of hectares. Marlier et al (2015) examined air pollution during Indonesia's 2006 fire season and calculated that smoke from these three types of company concessions accounted for 41% of Sumatra's total fire emissions, and 27% of Kalimantan's.

Peatlands cover less than 8% of Indonesia's total land area, yet they made up 40% of all burned land inside oil palm and timber/pulpwood company concessions during 2015-2019 (535,543 ha, according to Greenpeace analysis). Meanwhile, 71,248 hectares of peatland within concessions burned twice or more during those five years – some areas burned up to five times. That fires occur repeatedly on the same company-managed peatlands is proof that both industry and government are not doing enough to stop them.

Of the total acreage of Indonesian peatlands converted to industrial plantations by 2015, 73% was for palm oil (Miettinen, Shi, and Liew 2016). Despite commitments by the industry's 'sustainability leaders' over the past decade, key brands were still connected to thousands of fire hotspots during Indonesia's 2019 fires crisis (Greenpeace International 2019).

Residents evacuate by truck, passing through smoke rising from an oil palm plantation on recently cleared peatland in Rokan Hulu, Riau, Sumatra. | 23 Jun, 2013

Separate from the palm oil industry development, the disastrous Central Kalimantan Mega Rice Project peat drainage and conversion, begun in 1996 and officially abandoned in 1999, not only failed to produce food, but created an enduring fire risk (Barber and Schweithelm 2000; Page et al. 2009; Limin, Jentha, and Yunsiska 2007). President Widodo's new plan to convert more vulnerable peatlands in Central Kalimantan for a mega food estate risks repeating the same mistakes and leading to further peatland fires (Greenpeace Southeast Asia 2020).

If forests and peatlands continue to burn, and without significant improvement in industry and government commitment to zero deforestation, modelling studies predict forest fire smoke will cause an annual average of 36,000 premature deaths across Indonesia and neighbouring Singapore and Malaysia (Marlier et al. 2019).

Resources and tools to implement change

Preventing health impacts from fires is not a simple matter of directing more public and private resources into fire fighting. Root causes must be addressed: deforestation for industrial plantations should be ended, drained and degraded peatlands should be rewetted and restored with fire-resistant natural forest.

Company excavators digging a drainage canal on the border between remaining rainforest and the charred stumps from fires on recently cleared peatland in the PT Rokan Adiraya Plantation palm oil plantation near Sontang village in Rokan Hulu, Riau, Sumatra. | 24 Jun, 2013

Companies' legal responsibility for fires on their land is well-established. Peat protection regulations, while flawed, are in place. A government appointed agency has already been set up to oversee the process of peatland restoration. New studies and resources are being developed. President Widodo's urgings to prevent fires are oft-repeated. The means are available. But national, regional and local governments have consistently chosen not to enforce the laws or empower the Agency.

Indonesia's Peat Restoration Agency (BRG) was tasked with restoring 2 million hectares of peatland, but did not receive the estimated $4.6 billion required to reach its target of 2 million hectares of peatland restored (Hansson and Dargusch 2018). Furthermore, the BRG is due to wind up at the end of 2020, and with only a few months left in the year there is still no indication whether its mandate will be renewed by President Joko Widodo, or whether he will instead roll its function into existing ministries, as he did with the National Climate Change Council (DNPI) and the National Reducing Emissions from Deforestation and Forest Degradation Agency (BP REDD+) (Afiff 2020).

Strategies should be informed by research on the political economy aspects that drive the decisions that lead to fire, including regulatory capture and corruption by regional oligarchs (Purnomo et al. 2017; Hergoualc'h et al. 2018; Berenschot 2015). They should also take advantage of emerging approaches such as the Smoke Policy Tool[26] presented by Marlier et al (2019) to direct limited peat restoration resources and other efforts for maximum public health benefit. For plantations already existing on peatlands, where companies are not willing to rewet the peat entirely, water table levels should be monitored in real time to minimise peat subsidence, carbon emissions and fire risk, using the best available technologies (Vernimmen et al. 2020).

Legal obligations

Indonesia has a number of established regulations which, if implemented by government and companies and enforced through administrative and legal sanctions, would go a long way to reduce forest fires. They include the general environmental protection law, peatland protection regulations, prohibitions on the use of fire to clear land, and orders on fire prevention and control, including detailed rules specifying monitoring and fire fighting equipment which must be installed by plantation companies.[27]

A cornerstone of this legal regime is strict corporate liability in relation to forest fires, meaning that forestry, plantation or mining companies are legally responsible for any fires on their land, regardless of the ignition source (Saputra 2019).

In 2014, a unit established by (then) President Susilo Bambang Yudhoyono conducted a fire prevention compliance audit in collaboration with the Riau Provincial Government. None of the 17 forestry and plantation companies audited were found in compliance, despite previous history of fires on their land. The audit chief recommended that company permits should be immediately revoked if fires reoccurred on their concession lands (Mongabay 2014).

Once a peat forest, this area near the Nyaru Menteng Orangutan Sanctuary has been cleared, burned and planted with oil palm seedlings. Palangkaraya area, Central Kalimantan. | 27 Oct, 2015

The following year Indonesia experienced one of its worst forest fire seasons on record, with 2,600,000 ha of land burned during 2015. Despite the 2014 audit recommendations and fresh promises of stern action by current President Joko Widodo, analysis by Greenpeace Southeast Asia (2019a) found no oil palm plantation companies had their licences revoked for forest fires between 2015 and 2018. Of industrial timber/pulpwood plantation companies with fires in their concessions during the same period, just three had licences revoked.

Despite a number of Government-run court cases which successfully held plantation companies financially accountable for fires, analysis in 2019 showed hundreds of millions of dollars in fines and compensation orders remained unpaid (Wright 2019).

The lack of implementation of legal rulings on forests and fires risks being compounded by the Covid-19 crisis, with forest law enforcement resources being diverted to the crisis response. The 2020 budget for the Ministry of Environment and Forestry, which manages the Manggala Agni fire fighting force, has been reduced by IDR 1.5 trillion (USD 100 million) to provide for Covid-19 response.[28]

Citizen suit to prevent forest fires

Frustrated by years of government inaction over forest fires, in 2016 a number of Central Kalimantan residents filed a citizen suit against the provincial and national government, including President Joko Widodo. A citizen suit is a legal move to ensure existing laws are enforced – in this case, the national Environment Law.

The Supreme Court ruled in favour of the residents, holding the government responsible for failing to prevent the fires (Supreme Court of Indonesia 2019), and ordering the President to issue a decree creating a joint national and provincial government team to tackle the fires by:

- Reviewing and revising logging and plantation licences in accordance with ecological capacity and fire risk;
- Taking legal action – criminal, civil and administrative – against companies with fires on their land; and
- Drawing up a roadmap to ensure fire prevention and handling, and environmental restoration and victims' recovery.

Additional orders were made by the Supreme Court, including:

- Central Kalimantan public must have free hospital care for cases of smoke exposure;
- A specialist hospital be established to treat cases of respiratory and other illnesses due to forest fire air pollution;
- Fire fighting teams to be funded, equipped and provided with training at least three times a year;
- Air pollution evacuation plans and pollution-free shelters be prepared; and
- A system be built to ensure transparency on which Central Kalimantan companies have fires on their lands, and their allocations for environmental protection.

In addition to this citizen suit is a longstanding Supreme Court order that the national government must publish detailed maps showing what land has been handed to companies for palm oil concessions (Mongabay 2017).

Despite the ruling coming from Indonesia's highest court, and repeated calls for the orders to be enacted, President Widodo's administration continues to ignore that judgement, which dates from

March 2017. It remains to be seen whether the government will also choose to ignore the Supreme Court orders in this new citizen suit.

ASEAN transboundary responsibility

In addition to the concessions held by Indonesian-based companies, in 2019 Greenpeace documented fire-affected plantation concessions linked to corporate groups based in Malaysia and Singapore. Groups with links to Malaysia included IOI, Genting, and KLK, while those linked to Singapore included Bumitama and Musim Mas (Greenpeace Southeast Asia 2019b).

Greenpeace Southeast Asia activists climb a billboard to unfurl a banner on the first day of the 35th ASEAN Summit in Bangkok, calling for urgent action to end transboundary haze. | 2 Nov, 2019

Despite Singapore's Transboundary Haze Pollution Act, its government has taken no serious action to ensure that producers, traders or consumer brands based in Singapore or their Singapore-based owners are properly sanctioned for their contribution to the fires.

Malaysia has likewise taken no legal action despite the health impacts on its own citizenry, and the existence of legal mechanisms which experts say could be pursued.[29] The current Malaysian government has unfortunately decided to drop the previous administration's plans for a haze-specific bill along the lines of Singapore's.[30]

Solutions to Indonesia's forest fire health crisis

A review of historic data outlining the massive impact of forest fires on human health across the ASEAN region, combined with the growing body of new evidence suggesting air pollution increases the risk and impact of infection from the Covid-19 virus, makes an undeniable case for urgent action to stop forest fires in Indonesia.

Protect, rewet and restore peatlands

- Drained peatlands should be rewetted by blocking drainage canals. Groundwater levels should be continuously monitored.
- Shelve plans to convert Central Kalimantan peatlands into a food estate.
- Companies should ensure they do not develop peatland or deforest to establish plantations. They should do this by adopting the High Carbon Stock Approach and committing to NDPE (No Deforestation, No Peat, No Exploitation).

Transparency

- Upgrade Indonesia's air quality monitoring system with more stations providing public access to data including $PM_{2.5}$ levels, in areas prone to forest fire air pollution.
- Publish detailed maps of company plantation boundaries in shapefile format.
- Publish regular government audits of plantation companies' compliance with regulations designed to prevent forest fires. This should not be a mere exercise in ticking boxes – staff training and preparedness should be assessed, and equipment must be tested as fit for purpose.

Cancel permits and enforce judgements in fires cases

- Government officials must assist court officers to ensure judgements are carried out; a financial deterrent will only succeed if companies have to pay fines and compensation.
- The government should apply strong administrative sanctions by cancelling permits of companies which fail to prevent serious fires.

Implement Environment Law and Supreme Court citizen suit orders

- National and provincial governments must implement their obligations to prevent forest fires under the Environment Law and related regulations. This includes carrying out actions ordered by the Supreme Court, not only in Central Kalimantan but in every province where forest fires happen regularly.

Protect existing environment laws from weakening via Omnibus Bill

- Government must stop pushing for environmental deregulation via the widely-criticised Omnibus Bill. The bill would drop strict corporate liability for fires, remove requirements for environmental impact studies, limit public participation and other retrograde moves. Weakening safeguards will increase forest fire risk.

Dozens of mannequins installed to represent activists unable to hold a mass protest against the Omnibus Bill during the Covid-19 pandemic. The protest, in front of the Parliament building in Jakarta, opposes weakening of environmental protections. | 29 Jun, 2020

ASEAN governments must act

- Governments such as Malaysia and Singapore must take action against companies within their own jurisdictions responsible for fires in Indonesia.

Endnotes

1. Known in Indonesian as karhutla – short for 'kebakaran hutan dan lahan' or 'forest and landscape fires'.

2. 'Landscape fires' – which this briefer refers to as 'forest fires' but encompasses wild and prescribed forest fires, tropical deforestation fires, peat fires, agricultural burning, and grass fires.

3. The province of North Kalimantan was created later in 2012 by splitting East Kalimantan.

4. Although these totals were not compared against totals from previous years, for example.

5. Actual comparative data was not presented however, and it is not entirely clear whether these figures relate to the same period during 1995-1996 and 1997-1998.

6. The authors noted that they did not make comparisons with conditions prior to the forest fire crisis, nor with unaffected areas. Their study is therefore not conclusive evidence of causality.

7. Supervised by noted Institut Pertanian Bogor (IPB) academic expert on forest fires, Bambang Hero Saharjo.

8. During Jan 2014 there were 22,000 cases of acute respiratory tract infection recorded in Pekanbaru, and during three and a half months from 29 June 2015 there were 14,208 cases recorded. The data was apparently obtained from the city's health department, although this was not explicitly stated.

9. Over 150μg/m^3.

10. Data for $PM_{2.5}$ was not available; Indonesian air quality standards at the time referred only to particulate pollution in the PM_{10} size category.

11. The public health agency methodology for attributing cause was not described and may not be reliable.

12. Exposure to forest fire smoke correlated with a drop of 90% of a standard deviation in height for age and 70% of a standard deviation in weight for age.

13. https://rappler.com/nation/philippines-suspects-haze-indonesia-fires and https://cnnphilippines.com/news/2019/9/18/Cebu-Indonesia-haze.html

14. https://tuoitrenews.vn/society/30851/indonesia-forest-fires-to-blame-for-foggy-ho-chi-minh-city-expert

15. https://thediplomat.com/2019/09/southeast-asias-deadly-annual-haze-is-back/ and https://webcache.googleusercontent.com/search?q=cache:vbsHs-0GjToJ:https://www.khmertimeskh.com/32140/indonesian-haze-may-be-choking-cambodia/+&cd=1&hl=en&ct=clnk&gl=au

16. A one standard deviation increase in air pollution index caused a 0.35 standard deviation increase in weekly polyclinic attendances for acute upper respiratory tract infections, statistically significant at the one percent level.

17. $PM_{2.5}$ and PM_{10}.

18. The study used cohorts of ages 0-18, 19-39, 40-64, and 65+.

19. Among over 75s in Kuching, relative risk of cardiovascular mortality was 3.121, and 2.363 for respiratory mortality, following a high air pollution day. In Kuala Lumpur, among over 65s relative risk of cardiovascular mortality was 2.020, and 1.946 for respiratory mortality after a high pollution day.

20. Eczema has been significantly associated with air pollution in studies elsewhere; see for example (Li et al. 2016).

21. PSI levels measured in the capital by Brunei's Ministry of Health.

22. In the cities of Phuket and Surat Thani, plus two in Hatyai, servicing a southern Thailand population of 8.6 million in 1999.

23. The correlation was strongest after a short lag (0-14 days). Symptoms from SARS-CoV-2 take a number of days to emerge after infection.

24. With 3.7 doctors per 1000 population https://www.who.int/gho/health_workforce/physicians_density/en/

25. The mean CO_2 emission rate of 11.3 Tg per day for Indonesia's 2015 fires exceeded the fossil fuel CO_2 release rate of the European Union (8.9 Tg CO_2 per day).

26. See https://smokepolicytool.users.earthengine.app/view/smoke-policy-tool

27. UU 32 Tahun 2009 Tentang Perlindungan dan Pengelolaan Lingkungan Hidup (Pasal 88); UU 39 tahun 2014 Tentang Perkebunan (Pasal 56); UU 41 Tahun 1999 tentang Kehutanan (Pasal 49); Permentan No 5 tahun 2018 tentang Pembukaan dan/atau Pengolahan Lahan Perkebunan tanpa membakar; Permen LH No. 10 Tahun Tahun 2010 Tentang Mekanisme Pencegahan Pencemaran dan/atau kerusakan Lingkungan Hidup yang berkaitan dengan Kebakaran hutan dan/atau lahan; Inpres No 3 tahun 2020 tentang Penanggulangan Kebakaran Hutan dan Lahan; Permen LHK No. 32 tahun 2016 Tentang Pengendalian Kebakaran Hutan dan Lahan.

28. https://www.merdeka.com/uang/antisipasi-dampak-corona-klhk-sunat-anggaran-hingga-rp-15-triliun.html

29. https://www.malaymail.com/news/malaysia/2019/09/17/can-and-should-malaysia-sue-indonesia-over-transboundary-haze/1791227

30. https://www.malaysiakini.com/news/537188

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