Air pollution linked to the raised COVID-19 death risk

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Introduction

1. The dramatic impact of Coronavirus outbreak on air quality: Has it saved as much as it has killed so far?

In December 2019, several cases of "unknown viral pneumonia" have been reported which were initially linked to the exposure at the Huanan Seafood Market, Wuhan, China [(1)]. In January 2020, a novel coronavirus was detected (Fig. 1), capable of infecting humans and termed COVID-19[(2)]. By the 11th of March 2020, therewere 80,955 confirmed cases inside China and 37,367 with COVID-19 globally [(3)]. Common symptoms of COVID-19 include dry cough, fever and fatigue. The current official incubation period of COVID-19 is between 2 and 14 days.

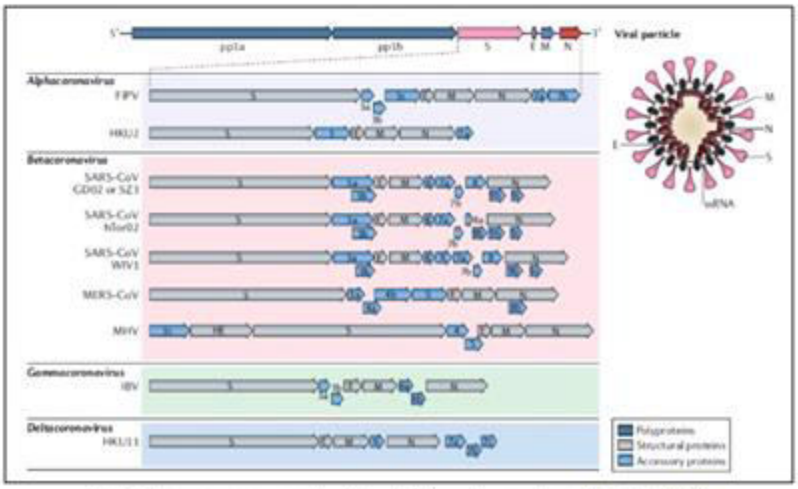


Fig. 1: The genomes, genes and proteins of different coronaviruses (Cui *et al.*, 2019)

A study has been carried out in March, 2020 to highlight the possible impacts of the dramatic reduction of air pollution due to the lockdown of major activities in China in order to control the spread of the virus. It reports on the first case study that compares the air quality status before and after the crisis. This study sheds light as well on the facts related to the demographics of deaths by gender, age and health status before infection. To this end, the evaluation of deaths due to poor air quality vs. COVID-19 leaves the answer to the main question open; whether this infection has saved more people than it has killed so far. On the 4th February 2020, The National Health Commission (NHC) of China stated that national mortality rate due to COVID-19 was about 2.1%. The formula that was used using the figures on the 3rd of February is given by Eq. 1.

Mortality rate = cumulative current total deaths / current confirmed cases (1).

To apply the above formula using the status as of 24:00 on the 3rd of February 2020, the mortality rate was 2.1 % of confirmed cases. Hence, the aboveformula was used to calculate specific mortality rates in different provinces which resulted in the figures shown in (Table 1).

The results show that although the number of deaths increases on daily basis, the rate of change in daily mortality decreases with time. This might indicate that the rate of infection is not changing from day to day; rather, the numbers of new infections/ mortalities are getting closer in value.

Another method to evaluate the mortality rate was proposed by Ghani et al., (2005). The study was published in the American Journal of Epidemiology and was considered simple due to the advantage of not having to estimate a variable, yet the results were reasonable if the hazards of death and recovery are proportional at any time "t" measured from admission to the hospital. The cited formula was as given by Eq. 2.

Mortality rate = deaths / (deaths + recovered) (2).

Table 1: Mortality rates due to COVID-19 as per the 3rd February, 2020 (Worldometer, 2020)

Province	Mortality rate (%)
Wuhan	4.9
Hubei Province	3.1
Nationwide	2.1
other provinces	0.16

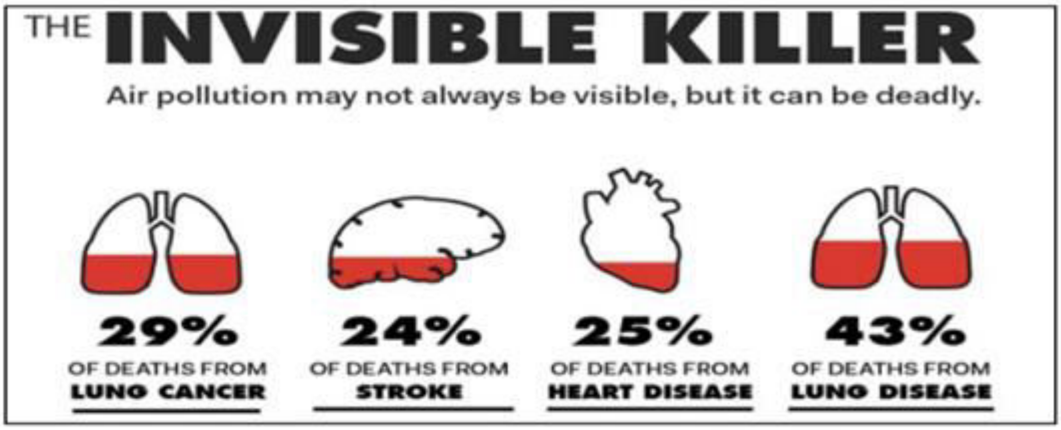
Further analysis of COVID-19 death cases related to the demographic profile showed that males have accounted for 2/3 of the reported deaths with females accounting for 1/3.

In addition, the mortality rate is given by Eq. 3.

Mortality rate = (number of deaths/ number of cases) = probability of dying ifinfected by the virus (%) (3).

The percentages should not necessarily add up to 100%, as they do not represent the share of deaths by sex.

In terms of age groups, mainly elderly people aged 80+ years are more susceptible. It is worth noting though, that more than 75% of deaths were related to cases that had underlying present diseases such as heart and cardiovascular diseases, diabetes and, in some cases, different types of tumours[5, 6]. It is worth noting that the mortality rate of COVID-19 was significantly higher when the patient had pre-existing health condition before being diagnosed with coronavirus. Nevertheless, The WHO has reported in 2016 that 4.2 million deaths have been caused by ambient air pollution worldwide. Ambient air pollution is estimated to cause about 29% of lung cancer deaths, 24% of stroke deaths, 25% of heart disease deaths and 43% of other lung diseases as shown in figure below. Moreover, air pollution has attributed to 26% of respiratory



infection deaths, 25% of chronic obstructive pulmonary disease (COPD) deaths and about 17% of ischemic heart disease and stroke [7]. It is worth noting at this stage that the death rate by COVID-19 is significantly higher for those with chronic respiratory and cardiovascular diseases. These diseases are well linked with air pollution as well which would imply that air pollution might be considered as a secondary factor for these mortalities. The impact of air pollution on developing these health conditions has been confirmed by previous studies. Further detailed studies on the mortalities by COVID-19 taking into consideration the pre-existing health conditions of the patients shall contribute to a clear conclusion about the link between COVID-19 and air pollution mortalities. The negative health impacts of air pollution have generated considerable interest in the previous decades where several studies have confirmed that exposure to air pollution has increases health risks related to respiratory, cardiovascular, pulmonary, and other health-related outcomes [8,9]. The economic and social impacts of air pollution arising from itsnegative effects on public health have been reported extensively, especially in China and other countries around the world [10, 11]. The situation in China has gained attention due to the unprecedented growth and development that led to a substantial cost on the environment and posed a threat to public health and human welfare[12] in 2016, Fang et al., has conducted research on the health impact of air pollution on the inhabitants of 74 leading cities of China [13]. The results showed that air pollution in 2013 was responsible for about 32% of the reported deaths, with a mortality rate of 1.9% that were associated with PM2.5. The reported deaths were linked to cardiovascular, respiratory and lung-cancer diseases [13]. In 2003, an unpublished internal report by the Chinese Academy of Environmental Planning estimated that about 300,000 people die annually from ambient air pollution, mostly due to lung cancer and heart diseases [14]. Those figures have dramatically increased to 1.2 million annually due to poor air quality in China [15]. Globally, the WHO estimates that 92% of the world's population lives in places where air quality is below guideline levels, and that outdoor air pollution causes about 3 million premature deaths every year (Fig. 8).

In addition to the impact of air pollution on human health, it has significant negative effects on materials, structures and welfare that account for huge economic burden annually [16, 17, 18, 19, and 20]. One of the most significant impacts on building structures as well as surfaces of solar panels is due to soiling. Soiling refers to the accumulation of dust or particulate matter on the surfaces which causes significant drop in the energy output of solar power if it was not cleaned regularly [20].

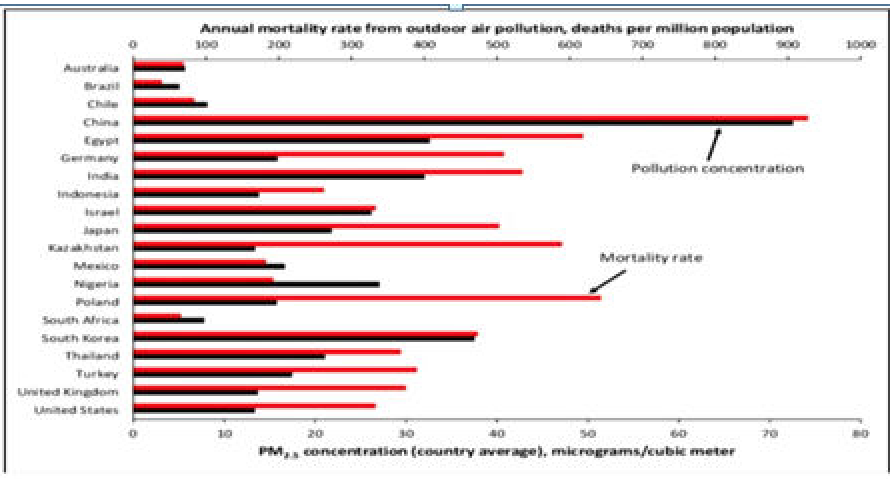


Fig. 8: Annual mortality rate from ambient air pollution (deaths per million populations) (Parry *et al.*, 2017

Although China has taken several measures to reduce its ambient air pollution, thecontinuous industrial and urbanization activities have contributed to elevated levels of air emissions in the past decades (Fig. 10). The emissions of air pollutants including fine particulate matter from vehicles, industrial manufacturing, power plants, industrial manufacturing, burning coal and wood have caused severe adverse health impacts. Recent research has found that despite the continuous efforts to limit future emissions, the number of premature deaths linked to air pollution will continue to increase in the next two decades unless more stringent targets are set. The results of several analysis show that China and India account for 55% of the global deaths caused by air pollution which represent 1.6 and 1.4 million deaths in China and India, respectively [(21)]. The figures continue to rise if indoor air pollution is accounted for as per a recent study reported by Jyoti et al. who indicated that more than 5.5 million people die prematurely every year due to indoor air pollution combined together where more than half of deaths taking place in India and China, both representing the world's fastest growing economies [(22)].

The main driving activity of air pollution in China is attributed to coal burning. It was reported recently that outdoor air pollution from coal alone caused an estimated 366,000 deaths in China in 2013. The researchers have also expected that by 2030, approximately 990,000-1.3 million premature deaths will be caused in case China did not implement efficient energy policies and pollution controls to strict coal combustion [(23).] The outbreak of COVID-19 was an alarming incident that resulted in major lockdown of most industrial and commercial activities in China. This has tremendously impacted the air quality reducing its emission levels to what have not been witnessed in years since the last mega event of the Olympic Games. In 2008 Olympic Games, China has responded to the global concerns to host the games and had enforced clean-up controls on air quality in Beijing over the period of the Games [(24, 25)]. During that summer, government officials in Beijing shut down factories and imposed limited vehicle movement before and during the games in order to improve air quality. This action has caused the level of some air pollutants to drop by half. Another control measure that was taken during 2008 Olympic Games was the

Odd-even car ban which implied that, based on the license plate number; vehicles should be kept off the road on alternative days. Moreover, the government has banned about 2 million motor vehicles during that period. The evaluation of the impact of these actions on air quality was linked with course and fine particulates since they are mainly linked with health impact [24, 25]. Another period that witnesses an occasional reduction in air pollution is the weeks that follow the Chinese New Year. Nevertheless, there was no systematic evaluation on the reduction of other air pollutants such as nitrogen oxides, sulphur gases or ammonia. Right after that period, a study of a group of young men and women reported an improved lung and cardiovascular functionality during that time period in Beijing The study has also included pregnant women and reported higher weight of new born babies whose mothers had a third trimester pregnancy during the Olympics games duration when the air quality was better compared with those who were born a year before and a year later.

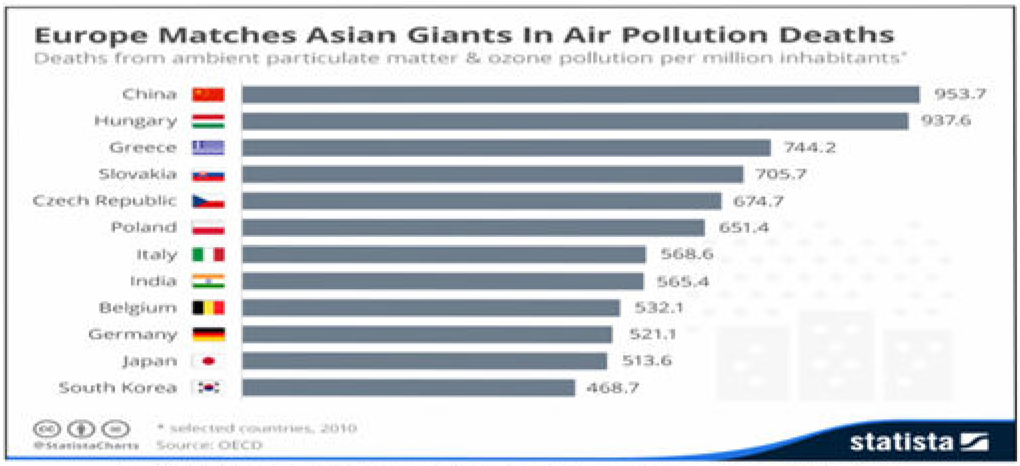


Fig. 10: Death per million inhabitants due to particulate matter and ozone (Statistica, 2016)

COVID-19 data were obtained from Situation Report 51 as published by the World Health Organization [3] while Air pollution data were obtained from WHO and other published works as cited throughout the manuscript. The average daily mortality due to air pollution was evaluated based on the annual reported figures (1.2 million deaths) [26]. The daily average deaths due to air pollution were obtained by dividing this value over 365 days which yield 3287 deaths every day.

In a recent press by researchers in the University of British Columbia, it was stated that Beijing and New Delhi will continue to report on high daily levels of particulate matter if they resumed theiractivities. This anthropogenic level of PM is 1,200per cent higher than the WHO guidelines (set at 25µ/m3) [27]. The closure ofcoal-fired power plants and otherindustrial facilities over the last months have causedair pollution levels to drop by 25%. In addition, thelimitation overvehicle driving to control the spread ofcoronavirus has reduced NO2 pollutant concentrationtremendously. Further detailed maps of NO2 levelsin Wuhan,China from the 1st of January throughthe 25th of February 2019 show the region coveredin fiery colours, with deeper darker shades indicatingmuch higher concentrations of NO. This drop in air pollution was also extended for longer period compared with the situation reported in Beijing during the Olympics in 2008 [24, 28]. This shocking decline in air pollution over China was caused by official decision to quarantine major cities which included halting subway traffic as well as planes and most private vehicles. As the virus spread outside the Province of Wuhan, further quarantine measures were taken to shut down businesses and hold on travel movement which curbed emissions immensely. The cleaner air is believed to provide some relief and positive health impacts as China copes with a novel coronavirus that affects the lungs. On its own, nitrogen dioxide can inflame airways and make it harder for people to breathe and it has proven to be linked with lung cancer [29]. It has been associated with high correlation factors in the development of lung and breast cancer incidences, followed by prostate, bladder, cervical and ovarian cancers. It also reacts with other chemicals to create soot, smog, and acid rain [28]. The lockdown that took place in China in reaction to COVID-19 has not only impacted NO_2 emissions but it has also reduced carbon emissions by 25% by February 2020 [30]. Several dramatic changes have taken place which included 36% less coal consumption at power plants, 15% less rates on main steel production, 23% less utilization rate of coking plants, 34% less utilization of oil refinery capacity, 10% less global passenger aviation volume and an overall of 15-40% less output across key industrial sectors[30]. Those dramatic impacts of COVID-19 had resulted in lower demand for electricity and

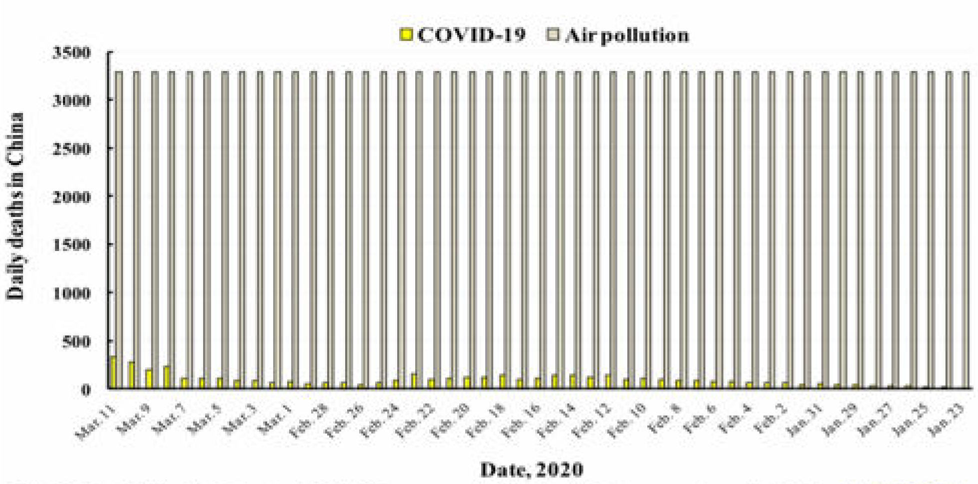


Fig. 13: Actual daily deaths due to CORVID-19 vs. averaged daily deaths due to poor air quality in China (WHO, 2020b)

industrial output compared to the time before the infection outbreaks. Consequently, 25% less on CO_2 emissions was recorded. Over the same period in 2019, China released around 800 million tones of CO_2 (Mt CO_2), meaning that thevirus could have cut global emissions by 200 Mt CO_2 to date [30]. If considered combined, the reductions in coal and crude oil use indicated a reduction in CO_2 emissions by quarter or more, compared with the same two-week period following the Chinese new year holiday in 2019. This reduction in CO_2 amounts to approximately 100 Mt which is equivalent to 6% of the global emissions over the same period. To properly evaluate the impact of COVID-19 on air pollution and consequently on daily deaths, the average daily mortality due to air pollution was evaluated based on the annual reported figures (1.2 million deaths) [26]. The daily average deaths due to air pollution were obtained by dividing this value over 365 days which yield 3287 deaths every day. This average fixed value was plotted against the actual deaths due to COVID-19 reported on daily basis in China (Fig. 13).

The results show tremendous difference in deaths caused by CORVID-19 considering that the majority of deaths are related to cases with pre-existing health conditions .Several factors play a key role to determine the extent of impact of COVID-19 on China as well as the global economy. In China, the construction sector depends mainly on migrant workers who should as well comply with the restrictions on movement and can be enforced to stay at home for days or weeks; hence the resumption of operations is not straightforward. Another factor to evaluate the size of economic impact would be related to decision makers on how fast operations would return to normal. Nevertheless, the local governments continue to hold on and even take morestringent action to control traffic movement and keep businesses shut. This implies that the governments are more considerate towards the implementation of safer procedures that keep the economy stagnant than contributing to new viral outbreak (26). The potential for wider financial disruption might be related to high level debts by households as well as local government which pose extra stress as lack of cash adds to the complexity of the situation. In response, the leadership in Beijing is apparently aware of the consequent financial risks of this lockdown. Hence, the government has called on banks to roll over loans among other procedures to reduce rents and other costs (26). Nevertheless, the economic burden of air pollution has always cost China billions of dollars annually. A report published by group of researchers at MIT Joint Program on the Science and Policy of Global Change has elaborated on the economic impacts of air pollution in China.

2. How is Air Pollution Impacting COVID-19 Fatalities?

Elevated levels of nitrogen dioxide in the air may be associated with a high number of deaths from COVID-19. A new study by Martin Luther University Halle-Wittenberg (MLU) provides concrete data that back this assumption for the first time. The study combines satellite data on air pollution and air currents with confirmed deaths related to COVID-19 and reveals that regions with permanently high levels of pollution have significantly more deaths than other regions. Nitrogen dioxide is an air pollutant that damages the human respiratory tract. For many years it has been known to cause many types of respiratory and cardiovascular diseases in humans. "Since the novel coronavirus also affects the respiratory tract, it is reasonable to assume that there might be a correlation between air pollution and the number of deaths from COVID-19," says Dr Yaron Ogen from the Institute of Geosciences and Geography at MLU. Until now, however, there has been an absence of reliable data to further investigate this. Inlatest study, the geoscientist combined three sets of data. This included the levels of regional nitrogen dioxide pollution measured by the European Space Agency's (ESA) Sentinel 5P satellite, which continuously monitors air pollution on earth. Based on this data, he produced a global overview for regions with high and prolonged amounts of nitrogen dioxide pollution. "I looked at the values for January and February of this year, before the corona outbreaks in Europe began," explains Ogen. He combined this data with data from the US weather agency NOAA on vertical air flows. His premise: If air is in motion, the pollutants near the ground are also more disseminated. However, if the air tends to stay near the ground, this will also apply to the pollutants in the air, which are then more likely be inhaled by humans in greater amounts and thus lead to health problems. Using this data, the researcher was able to identify hotspots around the world with high levels of air pollution and simultaneously low levels of air movement.

He then compared these with the data on deaths related to COVID-19, specifically analysing the data from Italy, France, Spain and Germany. It turned out that the regions with a high number of deaths also had particularly high levels of nitrogen dioxide and a particularly low amount of vertical air exchange. "When we look at Northern Italy, the area around Madrid, and Hubei Provence in China, for example, they all have something in common: they are surrounded by mountains. This makes it even more likely that the air in these regions is stable and pollution levels are higher," Ogen continues. The advantage of his analysis is that it is based on individual regions and does not only compare countries. "Even though we can obtain a country's average value for air pollution, this figure could vary greatly from region to region and therefore not be a reliable indicator", says Ogen.

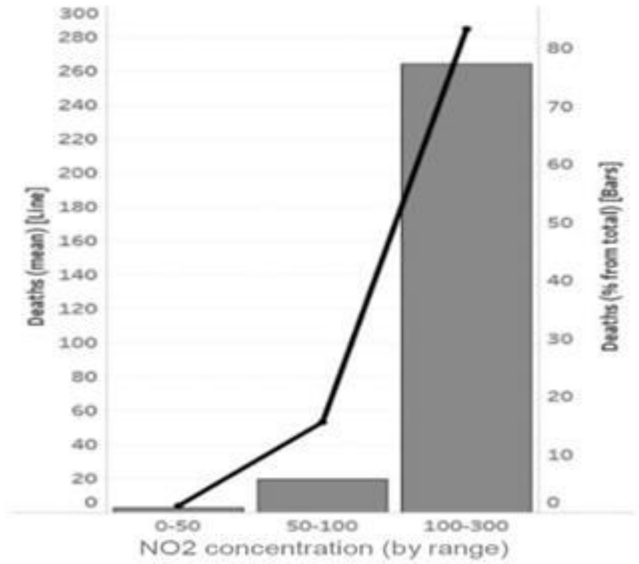


Fig. 4. The mean death cases and the percentage of deaths in each NO2 concentration range.

The geoscientist suspects that this persistent air pollution in the affected regions could have led to overall poorer health in the people living there, making them particularly susceptible to the virus. "However, my research on the topic is only an initial indication that there might be a correlation between the level of air pollution, air movement and the severity of the course of the corona outbreaks," says Ogen. This correlation should now be examined for other regions and put into a broader context [32].

3. Is there an association between exposure to air pollution and severity of COVID-19 infection?

Over the past few decades, considerable research has been undertaken into the adverse health effects of ambient (outdoor) air pollution and potential mitigation measures [33].However ambient air pollution remains a major environmental health hazard, responsible for an estimated 8.8 million premature deaths per year (95%CI 7.11 to 10.41) and loss of life expectancy of 2.9 years (95%CI 2.3 to 3.5 years) [34]. Air pollution, and particularly high nitrogen dioxide (NO2) concentration, may be of particular importance in the context of respiratory tract infections. Both household and ambient air pollution have been linked to an increased risk of hospitalisation and death due to pneumonia [35]. An observational analysis during the 2003 Severe Acute Respiratory Syndrome (SARS) epidemic in China found mortality rates were higher in urban regions with high-levels of ambient air pollution compared to low pollution areas, as measured by the Air Pollution Index (API), although these results were not adjusted for important confounders, such as age, sex and co-morbidities[36].

A number of risk factors have been identified for developing the COVID-19 infection associated with the SARS-CoV-2 virus, including population density [37]. This may be because the virus is transmitted more rapidly between people living in the close proximity of urban compared to rural areas. However, there may also be an effect from ambient air pollution, given this too is strongly associated with population density [38].

4. CURRENT EVIDENCE

Hoang Nicholas R. Jonessearched MEDLINE from 1946 to present, Embase from 2000 to 2020, and the Cochrane Library of systematic reviews up to 20th April 2020 for studies looking at the association between coronavirus infection and ambient air pollution. They screened 46 research articles at title and abstract, of which seven were relevant to infection with COVID-19. Of these seven, they included the three studies that reported the relationship between ambient atmospheric pollution and severity of COVID-19[39, 40, and 41]. Two were observational analyses and one a narrative review. The other four studies we excluded as not being relevant to exposure to air pollution (one described public health measures to prevent COVID-19, one described the airborne transmission of COVID-19([42] and a further two articles described the effects of public health measures on ambient air pollution levels [43, 44].All three studies included concluded that there was a likely association between regions with high ambient air pollution and case fatality from COVID-19. Wu et al compared historical levels of ambient air pollution with COVID-19 death rates (n=45,817) across 3,000 counties in the United States of America. Air pollution was calculated in terms of fine particulate matter (PM2.5), estimated using a combination of satellite imaging, monitored PM2.5 data and modelling. Results were adjusted for 20 potential confounders including age, ethnicity, household income, population density, smoking, weather and local health resources. In the adjusted analysis, an increase of 1μg/m3 in long-term exposure to PM2.5 was associated with an 8% increased risk of COVID-19 mortality (Estimated mortality rate ratio 1.08, 95%CI 1.02 to 1.15). It is important to note this is a pre-print publication that has not been peer-reviewed. The study by Ogen combined data on NO2 concentration from the Sentinel-5 Precursor space-borne satellite as part of the European 'Copernicus' programme with atmospheric conditions and COVID-19 fatality rates across 66 regions in France, Germany, Italy and Spain.8 Across these 66 regions there were 4,443 reported fatalities due to COVID-19 as of March 19, 2020. Of these fatalities, 83% (n=3,701) occurred in the regions with the highest NO2 concentration and just 1.5% (n=51) in the regions with the lowest NO2 concentration. Mortality rates are not reported with reference to population size. The review article reported data showing case fatality for COVID-19 was 12% in the dense urban areas of Lombardy and Emilia Romagna compared to the Italian national average of 4.5%. The authors postulate this may be because long-term exposure to ambient air pollution promotes a chronic inflammatory state and increased risk of chronic respiratory disease, both of which have been linked to an increased risk of death in COVID-19.

They used the STROBE checklist to assess quality of reporting for the observational studies [45] with additional questions for ecological studies, as suggested by Dufault and Klar [46]. The study by Wu et al was well conducted, with a range of important confounders considered and adjusted for. Sensitivity analysis was conducted to check the influence of potential outliers, such as New York metropolitan area, where the death rate was considerably higher than the national average. Nonetheless, unmeasured confounding may have influenced these results and the analyses, which were done at county level, are not directly applicable to individuals. They found that the quality of evidence from the other two studies was weak and neither reported any quantifiable correlation or relative risks(47).The findings of these two studies are limited by the cross-sectional, ecological study designs and the lack of data to account for sources of potential bias or imprecision. Death rates were not adjusted for population density, nor for relevant population characteristics, such as age, sex or deprivation profiles, which are known to be linked to increased risk of COVID-19.Evidence of the effect of ambient air pollution from the previous coronavirus epidemic of SARS in 2003 is also limited. One cross-sectional, ecological study assessed the risk of death from SARS in relation to ambient air pollution, as measured by the API across different areas of China. The study reported a positive association between API and risk of mortality, with the relative risk of death for people living in the most polluted regions, compared to least polluted of 2.18 (95% CI: 1.31–3.65). However, the results were not adjusted for important confounders, such as age, sex and co-morbidities. Currently the only published cluster randomised controlled trial into the effects of air pollution and coronavirus studied the effect of indoor household pollution on acute lower respiratory tract infections caused by coronavirus and other pathogens (both bacterial and viral)(48). The study, conducted in Ghana, showed no link between levels of household air pollution and viral nasal carriage.16 Evidence for the effectiveness of interventions to limit indoor household air pollution on health is generally limited(49,50).

The global burden of disease study suggests that interventions to reduce household air pollution, ambient particulate matter pollution, and second hand smoking are important to reduce mortality from lower respiratory tract infection in both adults and children (51). These interventions to improve air quality may also have an effect in lowering the baseline of demand on health services during the COVID pandemic (52).

They have found emerging evidence to suggest increased levels of ambient air pollution or NO2 concentration may be linked to adverse outcomes in COVID-19. However, the nature and strength of any direct association remains uncertain. The current lockdown measures have led to dramatic reductions in levels of urban air pollution, with the most significant reductions in black carbon and NO2 (45 to -51% decrease). Further research is needed into changing levels of air pollution and the potential link with COVID-19, which can inform public health policy in the context of easing lockdown measures.

5. Research on Air Pollution and Coronavirus

As Don Kennedy, the former head of the FDA and Editor-in-Chief of Science magazine (one of the world's premier peer-reviewed scientific journals) once said, "Replication is the ultimate test of truth in science."The Harvard study is one of several that have now suggested that air pollution is affecting COVID-19 mortality. Researchers analyzing 120 cities in China found a significant relationship between air pollution and COVID-19 infection, and of the coronavirus deaths across 66 regions in Italy, Spain, France and Germany, 78% of them occurred in five of the most polluted regions. There's also evidence from previous outbreaks like SARS, which was also a coronavirus, as well as many other respiratory infections including influenza, that breathing more polluted air increased risks of death(53).

China

- Yang et al found that patients with severe Covid-19 infections requiring, for instance intensive care, were two times as likely to have had pre-existing diseases, especially heart disease, strokes, chronic lung diseases and diabetes—all of which are known to be caused by air pollution. (International Journal of Infectious Diseases, March 5, 2020).
- Zhu et al analyzed 120 cities in China and found a significant relationship between air pollution and COVID-19 infection after controlling for confounding factors. (Science of the Total Environment, July 20, 2020).
- Tian et al found that places with higher levels of nitrogen dioxide pollution (10 micrograms per cubic metre) in the five years before the pandemic had 22% more Covid-19 cases, while higher levels of small particle pollution saw a 15% rise in infection rates. (Beijing Normal University, PREPRINT posted April 24, 2020).
- Wang et al found that particulate matter pollution was positively associated with increased cases of COVID-19. (Lanzhou University, PREPRINT posted April 14, 2020).
- Yao et al found that air pollution was positively associated with higher fatality rates from COVID-19. (Fudan University, PREPRINT posted April 10, 2020).
- Yao et al found that air pollution may be associated with the transmission of COVID-19. (Fudan University, PREPRINT posted April 10, 2020).

Europe

- Ogen found that of the coronavirus deaths across 66 administrative regions in Italy, Spain, France and Germany, 78% of them occurred in just five regions, and these were the most polluted. (Science of the Total Environment, July 15, 2020).
- Conticini et al found high death rates seen in the north of Italy correlated with the highest levels of air pollution. (Environmental Pollution, June 2020)
- Travaglio et al found air pollution levels in England are associated with COVID-19 cases and deaths. (University of Cambridge, PREPRINT posted April 28, 2020).
- Setti et al detected Coronavirus on particles of air pollution while investigating whether this could enable it to be carried over longer distances and increase the number of people infected. (University of Bologna, PREPRINT posted April 24, 2020).
- Setti et al found that higher levels of particle pollution could explain higher rates of infection in parts of northern Italy before a lockdown was imposed. (University of Bologna, PREPRINT posted April 17, 2020).
- Coccia found that the rapid spread of COVID-19 in North Italy has been strongly associated with air pollution. (National Research Council of Italy, PREPRINT posted April 11, 2020).

Previous Outbreaks

- Cui et al found that someone living in a highly polluted area of China was more than twice as likely to die from SARS as someone living in an area with cleaner air. (Environmental Health, November 20, 2003).

- During the SARS epidemic in 2003, Kan et al found that increases in particulate matter air pollution increased risks of dying from the disease. (Biomedical and Environmental Sciences, November 2019).
- Researchers have found that several viruses, including adenovirus and influenza virus, can be carried on air particles. Zhao et al found that particulate matter likely contributed to the spread of the 2015 avian influenza. (Scientific Reports, August 13, 2019).
- Chen et al found that air pollution can accelerate the spread of respiratory infections. (Environment International, January 2017).

6. CONCLUSIONS

The outbreak of coronavirus disease (COVID-19) was first reported from Wuhan, China, on December 31st, 2019. As the number of coronavirus infections has exceeded 100,000 with toll deaths of about 5000 worldwide as of early March, 2020, scientists and researchers are racing to investigate the nature of this virus and evaluate the short and long term effects of this disease. Despite its negative impacts that obliged the World Health Organization to declare COVID-19 epidemic as a Public Health Emergency of International Concern, the rate of mortality of this infection has not exceeded 3.4% globally. On the other hand, the mortality rate caused by ambient air pollution has contributed to 7.6% of all deaths in 2016 worldwide. The outbreak of COVID-19 has forced China to lockdown its industrial activities and hence dropped its NO2 and carbon emissions by 30 and 25%, respectively. The historical data on air quality, estimates of annual deaths and its economic burden have been presented and analysed. The actual daily deaths due to COVID-19 have been obtained from the official records of the daily Situation Reports published by World Health Organization as of March 11th. The rate of mortality due to COVID-19 was impacted by two factors: age and health status. Results show that 75% of deaths were related to cases that had underlying present diseases with the majority aged of 80+ years. The reported figures were compared with the average daily mortality due to poor air quality which reached up to 3287 deaths due to high levels of NO2, O3 and PM. The air quality status before the crisis was compared with the current situation showing that COVID-19 forced-industrial and anthropogenic activities lockdown may have saved more lives by preventing ambient air pollution than by preventing infection.

Emerging evidence suggests there may be a positive association between long-term exposure to ambient air pollution and severity of COVID-19 infection.

Overall the current evidence is limited, and more research is required to categorise the importance of exposure timing and pollution level, especially from studies with robust designs and adjusted for important confounders.

However, the global burden of disease study suggests that interventions to reduce household air pollution, ambient particulate matter pollution, and passive smoking are still important public health measures and could prevent many avoidable deaths. Whilst it is not certain whether these interventions to improve air quality could reduce coronavirus disease severity, they will have an important impact in lowering the baseline demand on health services during the COVID pandemic.Chronic exposure could be an important contributor to the high COVID-19 fatality rates observed in these regions. As earlier studies have shown that exposure to NO2 causes inflammatory in the lungs, it is now necessary to examine whether the presence of aninitial inflammatory condition is related to the response of the immune system to the coronavirus. Hence, poisoning our environment means poisoning our own body and when it experiences a chronic respiratory stress, its ability to defend itself from infections is limited.

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