Current status of air quality research

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Abstract

This paper aimed to review the current status of air quality research. Papers from 2014 to 2021 were selected from Google Scholar and have been reviewed in different sections. The basic cause for research in air quality is its effect on human health and the environment. Mainly six variables are measured to evaluate whether the air quality at a particular site is good or bad according to the standards set by any reference agencies. For measurement, stationary air quality monitoring stations are used. However, mobile or low-cost sensor platforms are becoming popular now. A network of sensors in an area can provide sufficiently reliable measurements. Economic development variables of a country may be related to the air quality there. More research seems to have been done in the case of particulate matter, as its effect on health is direct. The effect of vegetation in stopping particulate matter from spreading leads to considering integrated crop-livestock systems to reduce pollution. On the other hand, the adverse effects of biomass burning on air quality are well-researched. The review also found that a lot of research has been done on the impact of the Covid-19 pandemic on air pollution. The pandemic has helped to reduce air pollution significantly.

Keywords: Air quality, pollution, covid-19, indoor, review

Introduction

The quality of air that we breathe needs to be good. Poor air quality can lead to serious health problems for humans and the environment. Air quality is affected by human activities, wind, and temperature.

UNEP points out that in 2019, 99% of the world population was living in places where the WHO's strictest 2021 air quality guideline levels were not met. In 219, about four million people died due to exposure to fine particulate outdoor air pollution. The highest death rates were in East Asia and Central Europe. The adverse effects of poor air quality on health include stroke, heart disease, lung disease, lower respiratory diseases (for example pneumonia), and cancer. High levels of fine particles can also contribute to other illnesses, like diabetes. They can hinder cognitive development in children and mental health problems (UNEP, 2021). Creating community awareness and prompting them to engage in participative actions on air quality were recommended by Chandler (2023).

Considering the harmful aspects of poor air quality, much research has been done on determining the variables for air quality monitoring, monitoring of air quality, and improving air quality. This paper aims to review the current status of research on these and other aspects.

Method and Results

A qualitative search of Google Scholar was done to select relevant research papers on air quality. As only the current status of research is reviewed, papers published since 2014 only (last 10 years) were selected for this review. The search yielded 17 papers. These are discussed in the following sections.

General

Fuzzi, et al. (2015) attributed the recent increase in published research papers on air quality to the rapid advances in measurement technologies leading to a more precise understanding of the physical properties, chemical composition, and processes of atmospheric particles. A synthesis of research by the authors showed a new understanding of many processes and developments in the climate–aerosol interactions and effects of particulate matter (PM) on human health and the environment. However, the relative importance of the different chemical components and the overall effects of PM on climate change remain less understood. This lack of understanding has not stopped finding solutions to poor air quality problems.

Air quality monitoring

For the evaluation of the relationship between financial development, CO2 emissions, trade and economic growth, Omri, Daly, Rault, and Chaibi (2015) used simultaneous-equation panel data models for a panel of 12 MENA countries over the period 1990-2011. There was evidence of bidirectional causality between CO2 emissions and economic growth and between economic growth and trade openness. The feedback hypothesis is validated between trade openness and financial development. A neutrality hypothesis was noted between CO2 emissions and financial development. There was unidirectional causality from financial development to economic growth and from trade openness to CO2 emissions. The existence of the environmental Kuznets curve was also noted. However, there were differences between the 12 MENA countries concerning these relationships.

There are two purposes of air quality monitoring: legislation surveillance and scientific research. Hence, air pollution concentrations are monitored by professional persons including government authorities, scientists, and health experts using static monitoring stations. These monitoring stations are equipped with certified reference instruments for measuring regulatory pollutants, like carbon monoxide (CO), nitrogen oxides (NOx, NO, NO2), ozone (O3) and particulate matter (PM10, PM2.5). Due to the high cost of installation, operation and maintenance of these fixed stations, mobile monitoring stations are used for stationary measurements for a fixed duration as in the case of a measurement campaign. These are largely used in locations not covered by the fixed monitoring network. A more practical approach is to use low-cost sensor platforms like OpenSense and Citi-Sense-MOB. Commercially available gas sensors operate by measuring the electrochemical interaction between the sensing material and the pollutant (electrochemical or metal oxide technologies) or the absorption of light at the visible range. Particulate matter is measured by light scattering or absorption, using algorithms to relate the attenuated signal to the particle size and/or composition. However, the preciseness, reproducibility and reliability of these low-cost sensors may be suspect, especially as they suffer from chemical interference and environmental conditions. An extensive performance evaluation of the commercial AQMesh platform was done by Castell, et al. (2017) by monitoring NO, NO2, O3, CO, PM10 and PM2.5 in both laboratory and field conditions. All tested sensors performed with relatively good precision during the tests under stable laboratory conditions. In field tests, sensitivity to the varying ambient temperature and relative humidity affected the precision and reproducibility of the sensors. Even for identical sensors and platforms, there were variations in the performance of sensors. There were changes in the behaviour of sensors over two months. The performance for CO, NO and NO2 declined during July due to less traffic and improved again in August and September. The O3 concentrations did not show many variations. The performance of PM10 was lower during May and July. The performance of PM2.5 was lower during June and July coinciding with the months OF lower PM2.5 ambient concentrations. The effects of the detection limit of the sensors and varying air composition and meteorological conditions were seen in these results. Effects of meteorological and location were noted in these differential performances. The large variations in sensor outputs affected data quality. However, even if their data uncertainty was too high to use for legislative purposes, some sensors were capable of offering interesting information to citizens.

The air quality (AQ) of a large UK city was studied by Johnston, et al. (2019) using low-cost Particulate Matter (PM) sensors. The results obtained by these sensors were compared with government-operated AQ stations. In the first pilot deployment, six AQ Internet of Things (IoT) devices were developed each with four different low-cost PM sensors. They were deployed at two locations within the city. These devices were equipped with LoRaWAN wireless network transceivers to test city-scale Low-Power Wide Area Network (LPWAN) coverage. The study showed that the physical device can operate at a city scale. Some low-cost PM sensors were found to be viable for monitoring AQ and detecting PM trends. LoRaWAN was found to be suitable for city-scale sensor coverage where connectivity is an issue. Based on the findings from this pilot project, a larger LoRaWAN-enabled AQ sensor network was deployed across Southampton, UK.

The effects of different physical and chemical components of particulate matter in the air were discussed by Kelly and Fussell (2015). Apart from policies to reduce air pollution, the creation of public awareness and motivating them to adopt clean practices were suggested by the authors.

In China, the high frequency of haze pollution in 2013 led to the promulgation of the toughest-ever clean air policy in the country. During the implementation of this policy from 2013 to 2017, there was a significant decline in fine particle (PM2.5) concentrations in the whole country. As a part of the policy, industrial emission standards (power plants and emission-intensive industrial sectors) were strengthened, industrial boilers were upgraded, outdated industrial capacities were phased out, and clean fuels were promoted in the residential areas. These strategies were the major drivers of the observed reduction in PM2.5 pollution and health burden. the improvement in PM2.5 air quality was more due to the abatements in anthropogenic emissions rather than interannual variation in meteorological conditions (Zhang, et al., 2019).

Vegetation effects on air quality improvement

Trees remove air pollution by the interception of particulate matter on plant surfaces and the absorption of gaseous pollutants through the leaf stomata. The magnitude and impact of these effects were estimated by Nowak, Hirabayashi, Bodine, and Greenfield (2014). Computer simulations using local environmental data showed that trees and forests in the contiguous United States removed 17.4 million tonnes of air pollution in 2010 with effects on human health valued at 6.8 billion U.S. dollars. However, this effect accounted only for less than one per cent of an average air quality improvement. Rural areas accounted for most of the pollution removal. On the other hand, most of the health impacts and values were in urban areas. Health impacts included the avoidance of more than 850 likely incidences of human mortality and 670,000 incidences of acute respiratory symptoms.

An integrated crop-livestock system of agriculture was suggested by Lemaire, Franzluebbers, de Faccio Carvalho, and Dedieu (2014) to reduce the negative environmental impact of agriculture in the context of the need to increase food production. This will lead to better regulation of biogeochemical cycles and a decrease in environmental fluctuations to the atmosphere and hydrosphere through spatial and temporal interactions among different land-use systems; a more diversified and structured landscape mosaic favouring diverse habitats and trophic networks; and greater flexibility of the whole system to cope with the hazards of potential socio-economic and climate change. Grasslands are suitable for reducing environmental fluctuations in the atmosphere and hydrosphere due to the coupling of C and N cycles within vegetation, soil organic matter and soil microbial biomass. Therefore, cropland and grassland systems should co-exist in the new agricultural ecosystems.

Biomass burning

Biomass burning (BB) is a significant air pollution source, with global, regional and local impacts on air quality, public health and climate. China is one of the countries where the significance of BB has been recognized. Chen, et al. (2017) reviewed the research on different components of pollution particles from biomass burning with quantification as available. Some suggestions for future research were given based on the findings. Ballesteros-González, Sullivan, and Morales-Betancourt (2020) used the atmospheric regional chemical transport model WRF-Chem to assess the contribution of open BB events to pollutant concentration and to estimate potential health impacts associated with wildfire events in Northern South America. Dry season burning contributed to the dominance of aerosols in the region. Smoke from biomass burning contributed to secondary organic aerosols in the region. Biomass burning season influenced the regional ozone background levels. Biomass burning PM2.5 and O3 increases during February, often the most affected by fires, might have contributed to an additional 170 deaths.

Covid-19 effects

Nakada and Urban (2020) analysed the data from four air quality stations in São Paulo, Brazil during the late March 2020 partial lockdown due to the covid-19 pandemic. These data were compared to the five-year monthly mean and the four-week before the partial lockdown. There were drastic reductions in NO (up to 77.3%), NO2 (up to 54.3%), and CO (up to 64.8%) concentrations in the urban area during partial lockdown compared to the five-year monthly mean. On the other hand, there was an increase of approximately 30% in ozone concentrations in urban areas due to high vehicle traffic, which might be related to nitrogen monoxide decreases. The authors admit that the deaths due to covid are far more serious than the improvement seen in the air quality. The results obtained by Dantas, Siciliano, França, da Silva, and Arbilla (2020) revealed that during the partial lockdown due to covid, there were significant improvements in the air quality of Rio de Janeiro, Brazil, compared to 2019. CO levels decreased by 30.3–48.5% since they were related to light-duty vehicular emissions. NO2 also decreased. PM10 levels were only reduced in the first lockdown week. In April, there was an increase in vehicular flux and movement of people due to the lack of consensus about the importance and need for social distancing and lockdown. Ozone concentrations increased probably due to the decrease in NO levels. Compared to the values in the same period of 2019, NO2 and CO median values were 24.1–32.9 and 37.0–43.6% lower. Meteorological interferences, mainly the transport of pollutants from the industrial areas, might have impacted the results. In another paper, the results of a similar study in Barcelona, Spain, were reported by Tobías, et al. (2020) Lockdown measures were enforced in Spain from March 14th, two weeks after the start of the pandemic. The time course of atmospheric pollutants recorded at the urban background and traffic air quality monitoring stations were studied. After two weeks of lockdown, urban air pollution markedly decreased. But there were substantial differences among pollutants. The highest reduction of 45 to 51% was seen in the case of black carbon (BC) and NO2, possibly related to traffic emissions. PM10 decreased by 28 to 31%. On the other hand, O3 levels increased by 33 to 57% of the 8-hour maxima. This might be due to the lower titration of O3 by NO and the decrease of NOx in a VOC-limited environment. Regional contributions and the secondary origin of fine aerosols were attributed to the increase in PM10 levels. No definite trend was seen in the case of SO2. In an Indian study, Sharma, Zhang, Gao, Zhang, and Kota (2020) analysed the concentrations of six pollutants, PM10, PM2.5, CO, NO2, ozone and SO2 from March 16th to April 14th from 2017 to 2020 in 22 cities covering different regions of India. Overall, decreases of around 43, 31, 10, and 18% in PM2.5, PM10, CO, and NO2 were observed across all cities during the lockdown period compared to previous years. The O3 level increased by 17% and the SO2 level did not change. The air quality index (AQI) decreased by 44, 33, 29, 15 and 32% in north, south, east, central and western India, respectively. There was about a 52% reduction in the mean excessive risks of PM for the whole country as a result of the restricted activities during the lockdown period. Even during unfavourable meteorology, a significant improvement in air quality is due to the strict implementation of air quality control plans. In the case of Delhi (India), Mahato, Pal, and Ghosh (2020) found that during lockdown air quality is significantly improved. The concentrations of PM10 and PM2.5 were reduced by more than 50% compared to the pre-lockdown phase. Compared to 2019, during the same period, the reductions in PM10 and PM2.5 were 60% and 39% respectively. The reduction level of NO2 was 52.68% and that of CO was 30.35% during-lockdown phase. There was about a 40% to 50% improvement in air quality just four days after the start of the lockdown. About 54%, 49%, 43%, 37% and 31% reductions in NAQI were noted in the Central, Eastern, Southern, Western and Northern parts of the megacity. The authors used the air quality data of PM10, PM2.5, SO2, NO2, CO, O3 and NH3 for 34 monitoring stations spread over the megacity and used the National Air Quality Index (NAQI) to show the spatial pattern of air quality in pre-and during-lockdown phases. Studies on the effect of covid lockdown on air quality in Milan (Italy) by Collivignarelli, et al. (2020) showed a significant reduction of pollutants concentrations of PM10, PM2.5, BC, benzene, CO, and NOx, mainly due to a reduction in vehicular traffic. The lockdown led to a substantial drop in SO2 only in Milan and remained unchanged in the adjacent areas. Despite the significant decrease in NO2 in the TL, O3 exhibited a significant increase, probably, due to the minor NO concentration. High concentrations of benzene contributed to a higher increase in O3 concentration in some areas of the city.

In integrated air quality climate change mitigation efforts, ozone plays an important role as a short-lived climatic pollutant. Concerning the role of ozone in this, there are the challenges of explaining surface trends, incorporating new chemical understanding, ozone–climate coupling, and a better assessment of impacts. Knowledge across different scales (up to the global level) is essential to deal with air quality and climate change. For the measurement of O3, there is a need to combine the methods of satellites, ground-based remote sensing and ground-based observations with geostationary observations. The development of small sensors for many air pollutants, including ozone, can help in understanding spatial and temporal time scales. It may be possible to use a network of these sensors over an area in an integrated manner. One example of the beneficial effects of O3 is the effect of elevated O3 and whitefly herbivory significantly increasing tomato volatiles, attracting Encarsia formosa wasps to reduce the whitefly feeding on tomatoes. But such beneficial effects are rare (Monks, et al., 2015).

Conclusion

Air quality monitoring is done either for legislative compliance or research. Standards of WHO, EPA, EU or the respective countries are followed to evaluate whether the measured variables are within or outside the prescribed limits of good air quality.

The basic cause for research in air quality is its effect on human health and the environment. Mainly six variables are measured to evaluate whether the air quality at a particular site is good or bad according to the standards set by any reference agencies. For measurement, stationary air quality monitoring stations are used. However, mobile or low-cost sensor platforms are becoming popular now. A network of sensors in an area can provide sufficiently reliable measurements. Economic development variables of a country may be related to the air quality there.

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There is some evidence for the relationship between air quality and economic development variables of the country.

Crop cultivation is known to increase certain pollutants. But crop-livestock integrated systems may reduce air pollution through interactive effects between crops and livestock.

Although covid pandemic reduced most air pollutants due to lockdown restrictions, this effect needs to be weighed against the large number of deaths caused by the pandemic.

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