STUDIA UNIVERSITATIS BABEŞ-BOLYAI BIOLOGIA, 67, 1, 2022 (p. 177-198)
doi:10.24193/subbbiol.2022.1.10

Breathing chemicals: a review of air pollution over the years

Alex-Ionuț Totolici[1], Silvia Mitrea[1✉], Anghel Tudor Cioloca[1], Andrei Lupu[1], Patricia Mercedes Móricz[1], Daria Muntean[1], Raluca Negre[1], Andra Topîrceanu[1], Mara Țoc[1] and Dumitrana Iordache[1,2]

[1]Department of Molecular Biology, Faculty of Biology and Geology, Babeș-Bolyai University, Cluj-Napoca, Romania; [2]Doctoral School of Integrative Biology, Babeș-Bolyai University, Cluj-Napoca, Romania. ✉***Corresponding author, E-mail: silviamitrea14@gmail.com.***

Article history: Received: 1 April 2022; Revised: 21 April 2022; Accepted: 27 May 2022; Available online: 30 June 2022.

Abstract: Air is necessary for human survival and the preservation of the environment. The scientific community is concerned about the ongoing rapid expansion of the population, which uses resources faster, and thus the accumulation of an enormous amount of waste will gradually worsen the air quality. The change in the pollutants released in the atmosphere became more complex throughout human history, and they were released in huge quantities. The sources of air pollution vary greatly – from burning fuel, the household, agricultural or mining activities to natural disasters or significant industrial accidents. New techniques that monitor the air composition are being developed to ensure air quality control. The population exposed to these harmful compounds is predisposed to various health concerns, including skin, cardiovascular, brain, blood, and lung illnesses. The substances also contribute to global warming, acid rains and ozone depletion. During the COVID-19 pandemic, it was noticed that reducing human activities causing pollution leads to improved air quality, which shows that long-term solutions can also be found. This paper aims to offer an overview of the air pollution problems persisting around the globe and present the current state, causes and evolution of air pollution. Some of the solutions we propose in this article include energy-saving, public transportation and material recycling. We also emphasize the need to develop new technologies to control the air quality and implement a sustainable approach.

Keywords: air pollution, biosensors, greenhouse gases, human health.

Introduction

The air quality and the view of the scientific community

In recent years the topic of air pollution has been brought more into discussion by scientific community. It becomes evident that the ability of the environment to purify itself does not cope with the amount of pollution caused by human activity (Tan *et al.,* 2021). The poor quality of air is felt in most cities, where there are multiple sources of pollution (Fig. 1), and the Global Burden of Death claimed in 2017 that air pollution caused 4.9 million deaths (Tan *et al.*, 2021).

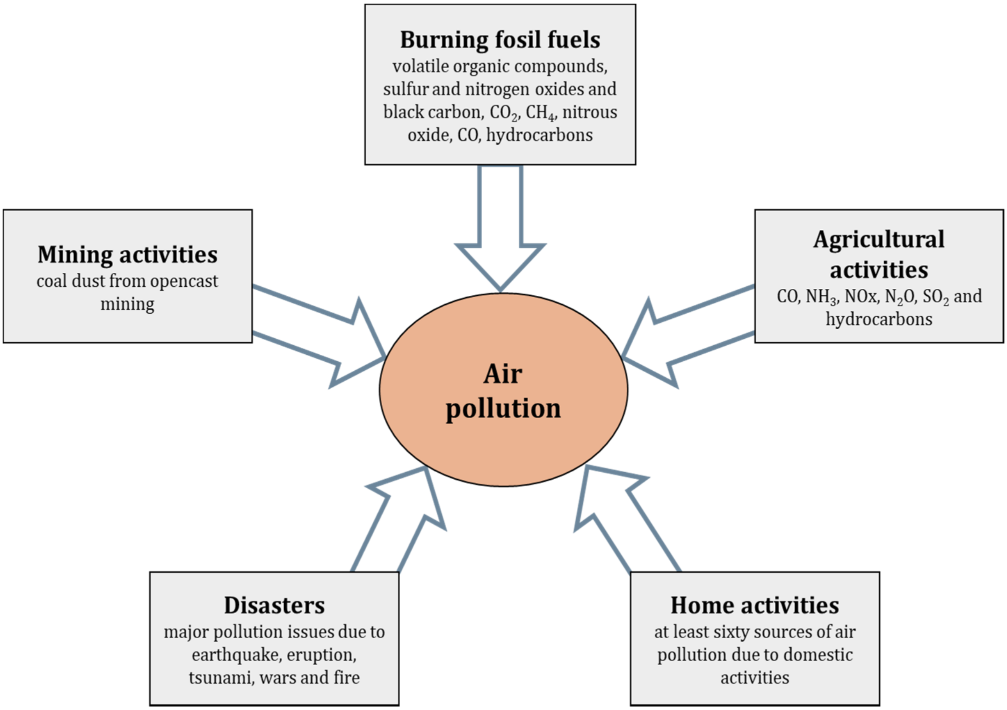

Figure 1. Sources of air pollution

Energy consumption has grown significantly due to urbanization and intense human activity in cities (Lin and Zhu, 2018). Overpopulation has led to a high concentration of pollutants (Hood *et al.,* 2018). Rapid population expansion, car ownership, solid fuels, and inadequate waste management practices have contributed to the degradation of air quality in cities, especially in developing countries (Amegah and Agyei-Mensah, 2016). In addition to the increase in global temperature, there are other existing problems due to air pollution, such as changes in precipitation (Stohl *et al.,* 2015), increased rate of acid rains (Grennfelt *et al.,* 2020), and ozone depletion (Barnes *et al.,* 2019). Because of the energy structure stored in coal and fossil fuels, pollutants such as carbon dioxide, sulfur dioxide, particulate matter, nitrogen oxide, and dioxide are produced (Stohl *et al.,* 2015; Lin and Zhu, 2018). Air quality monitoring can help provide the data to develop a response to the problem of air pollution and reduce the disease rate attributable to air pollution (Amegah and Agyei-Mensah, 2016). Society has begun to be aware of the risks of air pollution, and research is promoted to develop methods of quantifying different pollutants (Bai *et al.*, 2018). To reduce and fight global air pollution in recent years several measures have been initiated, such as accelerating the deployment of low-carbon, climate-resilient infrastructure that is critical not only for achieving climate targets but also for guaranteeing long-term development and equitable economic growth (Afrifa *et al.,* 2020). Studies to estimate the level of pollution and examine its impacts on the humans would help scientists to develop techniques for improving and maintaining air quality (Bai *et al.*, 2018).

Air pollution over time

Air pollution is closely tied to citizens' daily lives, habits, and behaviours. History has demonstrated that the public's ability to tolerate air pollution in urban environments results from a complex and changing inter-relationship between political, financial and social decisions (Charlesworth, 2019). Air pollution occurred long before the industrial revolution, approximately 1760, but it started having a significant impact on the atmosphere, population and environment once the industrial revolution began in the 19th century (Meetham *et al.,* 2016). Some claim that the process of air pollution started once humans started burning fuels. This single act alone would lead to emissions of different chemical gases in the atmosphere that would alter its composition (Daly and Zannetti, 2007). The evolution of pollution over time can be separated into three periods: The Pre Industrial Era, The Age of Smoke, and The Era of Invisible Threats. In the Pre Industrial Era, smoke generated in households and small manufacturing works (potteries, smelting furnaces, wood and charcoal burning) and the use of coal had a considerable impact on the air quality in the cities (Mosley, 2014). The Age of Smoke represented the period between the years 1780-1950. The rapid increase of coal usage has generated an increase in air pollutants that considerably damaged the air quality in urban areas in different parts of the world (Germany, The United Kingdom, and The United States). Smokestacks generated by the furnaces of the factories in important industrial cities substantially helped the spread of pollutants in the air in the 19th and early 20th centuries (Mosley, 2014). The Era of Invisible Threats started in the 1950s and is ongoing. While the coal-based pollution decreased, new concerns arose from the Alkali industry and the accelerating use of cars which generated emissions of SO_2, NO, CO_2 (Mosley, 2014). These gases are responsible for acid rains that negatively impact agriculture, interact with the sunlight, and form a photochemical ozone smog that can seriously affect the inhabitants (Rawate, 1980; Dickerson *et al.,* 1997; Tiwary *et al.,* 2018).

Sources of air pollution

Burning fossil fuels

Globally, the primary source of air pollution is burning fossil fuels such as coal, oil, gasoline, diesel fuel, and natural gas, which has major importance in several industries, such as transportation, heating, and electricity production (Perera, 2018). Around 80% of the energy generated by humans stems from fossil fuels, which shows that humankind highly depends on them. The combustion of non-renewable fossil fuels generates air pollutants such as volatile organic compounds, sulfur and nitrogen oxides and black carbon, CO_2, CH_4, nitrous oxide, CO and hydrocarbons. These gases and compounds alone can cause severe air pollution, but they can also transform into secondary air pollutants such as ozone and airborne particulate matter that form the photochemical smog (Armaroli and Balzani, 2011). Global warming and the greenhouse effect are the most critical consequences caused by these compounds in the atmosphere. Ever since humans started burning fossil fuels, the concentration of CO_2 in the atmosphere has increased by 25%, leading to the combustion of fossil fuels and being responsible for almost 65% of the global greenhouse gas emissions, which has become a severe and alarming issue that our planet is dealing with (Casper, 2010; Covert *et al.*, 2016).

Agricultural activities

Agriculture is a substantial source of greenhouse gases (GHG), contributing to poor air quality and causing climate change (Wollenberg *et al.,* 2016). Agriculture is estimated to be responsible for 30% of anthropogenic GHG emissions (Tubiello *et al.*, 2013). Agriculture-related emissions are expected to rise in the coming years as the world's population grows, posing a threat to the environment (Wollenberg *et al.*, 2016). Ruminant animals are the largest source of agricultural emissions, producing CO_2, methane, N_20 through enteric fermentation (Nayak *et al.*, 2015). Cattle, in particular, are responsible for more than 60% of farm animal emissions (McAllister *et al.*, 2011; Tubiello *et al.*, 2013). Manure from farm animals is a significant contributor to GHG emissions (McAllister *et al.*, 2011; Tubiello *et al.,* 2013). Another significant source of agricultural air pollution is synthetic fertilizer, which emits harmful substances into the atmosphere, and rice cultivation, which produces a significant amount of CO_2 during the growth process (Tubiello *et al.*, 2013). Farmers have a limited time between harvests to remove straws and agricultural waste. Burning is a popular method for crop residue removal because it cleans the field faster and is less expensive than other methods. These practices are responsible for emitting up to 50% of total PM10 (the amount of particles that are smaller than 10 µm in diameter) concentrations in China's agricultural regions (Shi *et al.,* 2014). Agricultural fires emit various hazardous gases, including CO, NH_3, NOx, N_2O, SO_2, and hydrocarbons (Bray *et al.*, 2019). Only in Romania this year, in March 2022, it was estimated that 20.000 hectares of land were set on fire (Fig. 2), of which 1.000 were forested, where the fire got out of control (Europa Liberă România, 2022).

Mining activities

Opencast mining is the most common type of mining operation, and it is known to contribute to air pollution due to dust from haul and transport routes, which are regarded as an essential source of air pollution (Ghose and Majee, 2000; Mandal *et al.,* 2012). Furthermore, because they rely on fossil fuels and coal to generate electricity, several countries use opencast surface mining,

Figure 2. Agricultural fires out of control, Romania, 2022

which adds the benefit of increasing coal output (Ghose and Majee, 2001). As a result of these circumstances, opencast mining is being used more frequently, resulting in the release of a significant amount of dust (suspended and respirable particles) as well as other gaseous pollutants into the atmosphere (emissions from vehicles) (Mandal *et al.,* 2012). As a result, the collected coal dust from opencast mining would pollute the air, affecting the flora and wildlife in and around the mining sites and posing serious health risks (Pandey *et al.*, 2014; Nayak and Chowdhury, 2018). For example, several studies have shown that mining activities (particularly those involving the extraction of minerals such as coal) negatively influence people in southern Brazil (Honscha *et al.,* 2022). Another example is copper mining in Iran (specifically, the Arasbaran forest region), which was discovered to negatively influence the region's wildlife after extensive research (Khazini *et al.,* 2022).

Home activities

Domestic activities are responsible for at least sixty sources of air pollution worldwide (Pluschke and Schleibinger, 2018). Among them, indoor tobacco smoking counts along with construction materials and the fuel used for cooking, heating, and lighting (Hu *et al.*, 2014). Different methods of cooking: stir-frying, deep or shallow frying and grilling have different emission levels of particulate matter (Pluschke and Schleibinger, 2018). The control of the temperature may require heating and cooling of the house. Poor ventilation caused by preventing the air that is temperature-controlled from escaping the closed environment inside the house is the main cause that leads to the accumulation of pollutants inside it (Hu *et al.,* 2014). Chemical repellents are used for mosquito control, which has become a burning need because of the high mortality rates caused by mosquito-borne illnesses (Hu *et al.,* 2014). The most commonly used repellent is the mosquito coil. Other examples include vaporizers, sprays and ointments that can irritate the airway mucosa due to the production of gaseous air pollutants. A study identified the volatile organic compounds from air fresheners, laundry and personal care products, and cleaning agents, and it identified 156 volatile organic compounds, of which at least 42 are toxic or hazardous to human health (Apte and Salvia, 2016). The main volatile organic compounds found indoors are benzene, formaldehyde, dichloromethane, styrene, acrolein, naphthalene and d-limonene. It has been found that some of them (benzene, formaldehyde, dichloromethane) may represent a real threat to human health due to their carcinogenicity, as they can contribute to several types of cancer, such as leukaemia, lymphoma, kidney and liver cancer (Dimitroulopoulou *et al.,* 2015; Tsai, 2018). Also, paints and varnishes used in household activities spread considerable amounts of volatile organic compounds (Apte and Salvia, 2016). Carcinogens such as benzopyrene and particulate matter, carbon monoxide, nitrogen dioxide, sulfur oxides are emanated by biomass and coal smoke, which constitute hazards for human health (Ezzati and Kammen, 2002). Among some human activities that cause air pollution, burning wood also counts because people in semi-rural and urban areas burn wood during winters to keep their households warm. The gas kitchen stoves release nitrogen dioxide, a highly reactive gas. A potent oxidizing agent by nature, nitrogen dioxide reacts with the oxygen and moisture in the air to form toxic nitrates and nitric acid. The refrigerators use ozone-depleting aerosol sprays to condition and modulate room temperature (Apte and Salvia, 2016).

Disasters

A disaster may be a hazard leading to a significant impact on the environment as well as physical damage and loss of life. Many disasters can cause air pollution and the other way around. Here it is elaborated on major pollution caused by earthquakes, eruptions, tsunamis, wars and fire accidents that occur worldwide at different magnitudes (Chandrappa and Kulshrestha, 2015; Knap and Rusyn, 2016). Disasters like earthquakes, wars and volcanic eruptions disturb the air quality within airsheds for a long or short period. Therefore, releasing a large concentration of pollutants may result in an unpredicted impact, as witnessed in the release of toxic gases in industrial accidents (Chandrappa and Kulshrestha, 2015). The most noteworthy air pollution episodes are: in the Meuse Valley, Belgium episode in 1930, where, due to temperature inversion in the valley, the concentration of pollutants emitted from industries along the narrow valley increased considerable and led to the death of about 60 and sickness of 6.000 people in valley (Nemery *et al.,* 2001). Another episode occurred in London, UK in 1952, where the widespread burning of high-sulfur coal caused a dense smog. This event is known in history as The Great Smog of London (Polivka, 2018). Extreme air pollution occurred in 1997 in Sumatra and Indonesian Borneo due to the massive burning of vegetation and peat for soil cleaning, and it was intensified by an El Nino climate event (McDonald and Horwell, 2020). Bhopal, India in 1984, Chernobyl, Ukraine in 1986 and the Fukushima Daiichi, Japan nuclear disaster in 2011 are other significative events witch led to air pollution. (McDonald and Horwell, 2020). Wildfires can affect the air quality for thousands of kilometres. Aside from the smoke, which contains unburned charcoal particles, the emission of carbon monoxide, ash participles, methyl chloride, methyl bromide, polynuclear aromatic hydrocarbons, aldehydes, and volatile organic compounds (VOCs) also affect the air quality (Sapkota *et al.,* 2005). Tsunamis are a sequence of water waves caused by the movement of a significant amount of water in a body of water, and the effect on air pollution depends on the activities in the tsunami-affected area. In 2011, the nuclear accident at the Fukushima Nuclear Power Plant resulted in the collapse of three of the plant's nuclear reactors after the plant was struck by a tsunami triggered by the Tohoku earthquake. The disaster resulted in the release of large amounts of radioactive materials, making it the second-largest nuclear disaster after Chernobyl (Chino *et al.,* 2011). Human errors, negligence and even intentions could cause hazards named anthropogenic disasters, such as the industrial disaster at Bhopal in 1984 at the Union Carbide India Limited, where more than 500.000 people were exposed to methyl isocyanate (MIC). Many major wars in history had severe effects on air quality (Chandrappa and Kulshrestha, 2015). The largest contemporary military attack on a European state, Russia's invasion of Ukraine, is having a major impact on local air quality due to massive troop movements and the destruction of over 1800 buildings (according to Reuters – as of March 2022) in many large Ukrainian cities such as Odessa, Kiev, and Mariupol. A major threat is the possible attacks on existing nuclear power plants in Ukraine, along with the threat posed by nuclear bombs from Russia's arsenal (The Guardian, 2022).

Monitoring of air pollution

Methods for measuring air pollutants

Over the past half-century, developed countries monitored concentrations of the primary pollutants known to damage health and destroy the environment. They focused on the most populated areas to assess daily, monthly or annual concentrations. Although greater spatial and temporal assessment of the pollution was desired, the costs of acquiring and operating sufficiently robust and accurate instruments are not feasible from an economic point of view. The motivation to develop cheap, responsive air quality monitoring devices that can be deployed in large numbers in specific areas can provide enough data to obtain the expected air quality resolution. Indeed, over the last decade, many researchers, entrepreneurs and manufacturers have been pursuing the development, implementation and evaluation of lower-cost devices measuring air pollution (Cross *et al.,* 2017). Two main methods are used in assessing the degree of air pollution: an analytical method based on using sensors for measuring the chemical and physical properties of the air (Michulec *et al.,* 2005), and a relatively new technology that uses living systems such as microorganisms to measure the concentration of contaminants in the atmosphere (Gavrilescu *et al.,* 2015). The analytical methods resort to techniques that can measure more precise concentrations of pollutants. The applied analytic approaches can be chosen regarding the volatility of the air contaminant (Michulec *et al.,* 2005). These techniques are sensor-based systems that monitor the pollutants such as NO_x, O_3, SO_2, CO (Lewis *et al.,* 2016). These consist of a sensor element that can detect, interact and measure the pollutants, a transducer that transforms the sensor's response into an electrical signal, and a device that stores and displays the data (Snyder *et al.,* 2013). The primary type of sensors that are used for measuring the air quality is those that detect and measure the interaction between the sensor material and compound of interest, or the photometrical method that can display the absorption or emission of light (Michulec *et al.,* 2005; Snyder *et al.,* 2013). The analytic method implies using an electrochemical cell and metal oxide semiconductors, and the photometrical method resorts to instruments that measure the non-dispersive infrared absorption and ultraviolet absorption (Snyder *et al.,* 2013). The sensors are desired to become more accessible and easier to use for most people because, in this case, every person can monitor the quality of air around the location they live in and contribute to a more extensive database regarding the situation of pollution (Sun *et al.*, 2016).

Biosensors represent one specific sensor that gained attention over the past years. Biosensors are instruments capable of detecting analytes by using a biological pathway or system (Nigam and Shukla, 2015). These consist of the following components: a recognition element of biological nature (genetically modified microorganisms, antibodies, proteins, DNA fragments, enzymes), a transducer or detector (optical, electrochemical, piezoelectrical, thermal or calorimetric) and a signal processing system (Fig. 3) (Salgado *et al.,* 2011).

This method is accessible and low cost, given that microorganisms have a rapid growth rate and can quickly adapt to any living conditions. The bacterial systems can also be engineered to detect a specific kind of air pollutant, making this method highly efficient in monitoring the air quality. Enzymes isolated from microorganisms can also be incorporated into the sensors for more precise assessment. Furthermore, these devices are quite small and can be easily installed in different areas to monitor air pollution. They can detect air contaminants instantly, without preparing a sample or separating the analyte from its matrix. One major disadvantage would be that biosensors are usually designed only to recognize one pollutant per biosensor (Nigam and Shukla, 2015).

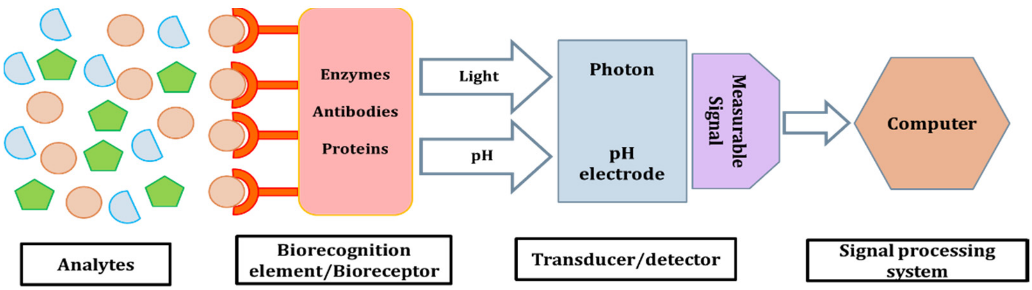

Figure 3. Elements of a biosensor

Health and environmental effects

Human health problems (direct and indirect)

The increasing concern about the consequences of air pollution led to more research on the subject. Epidemiological studies have shown a direct correlation between decreased lung function, cardiovascular disease, increased hospital admissions, mortality and concentrations of pollutants in the air (Kelly, 2003). One of the most disquieting outcomes of air pollution is the negative impact on pregnant women, newborns and children, considered more vulnerable (Vizcaíno *et al.*, 2016; Mannucci and Franchini, 2017). Numerous studies show that exposure to polluted air may cause miscarriages, reduce women's fertility, or trigger health problems in newborns due to mother transmission of pollutants (Vizcaíno *et al.,* 2016). The respiratory system is also heavily affected. Irritations of the respiratory tract and damaged alveoli are common health issues triggered by air pollution (Kampa and Castanas, 2008; Mannucci and Franchini, 2017). Cardiovascular disease is caused mainly by carbon monoxide that binds to haemoglobin, reducing the capacity to transfer oxygen and diminishing the transfer of oxygen in the organism (Kampa and Castanas, 2008). Dioxins and heavy metals are dangerous pollutants that can induce neuropathies and damage the kidney or liver cell affection (Kampa and Castanas, 2008). PAH (polycyclic aromatic hydrocarbons) are strongly genotoxic and carcinogenic and are found in high concentrations in the air of urban areas (Singh *et al.*, 2007). Air pollution also causes atherosclerosis in long exposure (Künzli *et al.,* 2011). More research is still in process to increase the knowledge regarding the interaction between air pollution and the human body. Effective methods to prevent such health problems are also being investigated (West *et al.,* 2016).

Global warming

Air quality has become a severe concern in many industrialized countries and a growing one for the rest of the globe due to the enormous increase in emissions pollutants due to economic and industrial expansion (D'Amato *et al.*, 2016). Owing to the growing relevance of air quality, many scientists have begun to link air pollution to global warming (Manisalidis *et al.,* 2020), as the climate is an important factor that may affect air quality (Orru *et al.*, 2017). High quantities of greenhouse gases, such as CO2, methane, tropospheric ozone, and aerosols, build up in the Earth's atmosphere and influence the amount of solar radiation received, which can contribute to climate change and global warming (D'Amato *et al.*, 2016; Orru *et al.*, 2017; Manisalidis *et al.,* 2020). As a result, climate change is predicted to worsen air quality, and because the quantity of solar energy we receive is reduced, the temperature of the Earth is rising, which may result in melting ice and an increase in the prevalence of diseases in many modern populations (Gibson, 2015; Orru *et al.*, 2017; Manisalidis *et al.,* 2020). Therefore, it seems to be likely that climate change may impact air pollution exposure through modifying weather patterns, human-caused air pollution levels, and biogenic emissions, as well as the type and distribution of allergens released into the air (Bernard *et al.,* 2001; Orru *et al.,* 2017).

Acid rains

Acid rain refers to the atmospheric deposition of acidic constituents that impact the Earth in the rain, snow, particulates, gases, and vapour (Burns *et al.*, 2016). That was one of the most critical environmental issues during the last decades of the twentieth century and the largest environmental threat (Grennfelt *et al.,* 2020).

Coal is a source that contains the substances necessary for the formation of acid rain. It is currently the largest energy source on Earth, used in electricity generation. The main components of coal are carbon, sulfur, oxygen, hydrogen, small compounds of nitrogen. After combustion, these react with oxygen and produce carbon dioxide and monoxide, sulfur dioxide and trioxide, nitrogen dioxide and nitric oxide, forming acid rains. The emission of the gases has been directly and indirectly correlated with skin, cardiovascular, brain, blood and lung diseases and different types of cancers (Munawer, 2018). Furthermore, acid rains negatively affect soil fertility and the normal functioning of plants at all stages of growth and development by acidifying the soil and surface water, depositing on leaves and changing the symbiotic microbial community (Xalxo and Sahu, 2017). Marine life is also affected by harming the food chain and interferential acid and oxygen circulation, damaging the gills and causing heart problems in fish (Shammas *et al.,* 2020).

Ozone depletion

Ozone depletion has a significant impact on environmental climate change. These changes harm the environment and the globe's population by affecting human health, fauna, and crops (Barnes *et al.,* 2019). It can lead to higher exposure to UV radiation since stratospheric ozone is known to absorb considerable amounts of UV radiation. This type of radiation triggers various problems, such as photo-ageing, skin cancer, cataracts and photosensitivity disorder (Lucas *et al.,* 2015; Barnes *et al.,* 2019). Despite past worries about the harmful effects of UV-B radiation on global plant production due to stratospheric ozone loss, this radiation is an energetic driver of a wide variety of plant responses. Rapid advancements across a variety of organizational scales indicate that essential plant responses to UV-B radiation, such as alterations in secondary metabolism, improved photoprotection, up-regulation of the antioxidative response, and changed pest and disease attack resistance, could be exploitable in the sense of a sustainable contribution to the strengthening of global food supply (Wargent and Jordan, 2013). In low concentrations, it favours vitamin D synthesis, which is beneficial for human health (Lucas *et al.,* 2015; Barnes *et al.,* 2019).

The effects of the COVID-19 pandemic on air quality

The COVID-19 pandemic that has led to nationwide lockdowns has had a massive impact on everyday life by challenging the healthcare system, forcing businesses to close down, limiting transportation and halting international travel (Berman and Ebisu, 2020). As a result, lower air pollutants such as CO2, CO, SO2, NO2, particulate matter (PM), ozone and other volatile organic compounds (VOCs) have been registered. Daily human activities such as burning fossil fuels, car emissions, biomass burning, and other industrial processes are the main sources of these air pollutants in the atmosphere, thus the most logical assumption would be that halting activities would decrease these compounds in the atmosphere. This hypothesis has been confirmed by several studies which tracked the decline of most air pollutants in the atmosphere since the outbreak of the COVID-19 pandemic (Ghahremanloo *et al.,* 2021). In addition, countries like China, USA, and several European cities have registered a significant drop in nitrogen dioxide and other air pollutants compared to data collected in early 2020 and previous years (Berman and Ebisu, 2020). Moreover, research data provided by Le Quéré *et al.* (2020) suggests that the daily global emissions of CO2 have decreased by -17% since the beginning of the lockdowns in march 2020 compared to CO2 emissions registered in 2019. Interesting but not surprising is that the emissions of air pollutants have drastically decreased in the regions that were epicentres of the COVID-19 pandemic, such as China, Italy, Spain, and USA, where down to 30% were registered (Barua and Nath, 2021).

Solutions for remediation of air quality

Energy saving

Energy saving is viewed as a favourable solution to reduce air pollution by developing new technologies that can operate with a smaller quantity of energy and resources. One aspect of lifestyle that can reduce the amount of energy is to create buildings design that can optimize the use of sunlight. For example, using atrium is shown to save energy and decrease carbon footprint

(Sher *et al.,* 2019). Furthermore, natural ventilation can save energy as well. A better natural ventilation strategy in buildings can reduce energy consumption (Tong *et al.*, 2016). The development of automated vehicles could also contribute to energy saving by using advanced sensors that analyse and interact with other automated vehicles offering the most economical driving (Vahidi and Sciarretta, 2018). However, the best method to reduce air pollution by energy-saving is implementing new technology in a big factory that optimizes energy use and introduces a law regulating emission (Zhang *et al.,* 2018).

Material recycling

Recycling is the process of converting waste into new products. This process reduces fresh raw materials consumption, the use of energy, air and water pollution and the emission of greenhouse gases (Banerjee, 2015). Particles, sulfur dioxide, nitrogen oxides, ozone, carbon monoxide, volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) are among the most important pollutants of outdoor air results from zootechnical farms, burning fossil fuels, wood, factories, and others. (Saxena and Naik, 2018; Domingo and Rovira, 2020). Reducing the amount of waste sent to sites and burners would significantly improve the air quality. Some researchers found that methods such as collection types, curbing, dropping, a single strike, or pay-as-you-throw (PAYT) impact the success of a recycling program. Increased service departure from the PAYT system in municipalities could improve air quality (Giovanis, 2014).

Use of public transport

In populated urban areas, the main contributor to air pollution is heavy traffic, leading to vehicular emissions (Sun *et al.,* 2019). Several studies outline that pollution stemming from motor vehicles in urban areas increases rapidly and represents a considerable percentage of the total pollution in cities (Pan *et al.,* 2016). Different solutions are being implemented to decrease the high level of pollution caused by the car traffic. One effective method is the investment and promotion of public transport infrastructures. A plethora of studies and evidence prove that establishing and expanding a public transport system significantly reduces CO_2 and NOx (nitrogen oxides) emissions generated by cars (Sun *et al.,* 2019). In cities such as Taipei, Mexico City and urban areas in China, the implementation of a public transport system has shown to actively contribute to the decrease of the pollution generated by car emissions (Chen and Whalley, 2012; Bel and Holst, 2018, Sun *et al.*, 2019). Further research conducted in London suggests that the active use of public transport is responsible for a noticeable decrease in gases such as CO_2 and NOx concentration in the air of urban areas (Ma *et al.,* 2021). Moreover, according to Rojas-Rueda *et al.* (2012) replacing cars with public transport in the city of Barcelona, Spain could help reduce the level of mortality linked to the inhalation of fine particulate matter, which is released into the atmosphere. CO2 emissions are also estimated to drop significantly by using means of public transportation, which could lead to an even lower death rate caused by air pollution (Rojas-Rueda *et al.,* 2012).

Air pollution control technologies

Biofiltration is a technology that allows the control of air pollution. It implies transforming gases and vapours that can oxidize into mostly innocuous end products with the help of microorganisms. It was used successfully in many industries, such as the chemical and food sectors, but further research is needed to implement this method in other fields to stop air pollution (Janni *et al.,* 2001). Another effective method for controlling air pollution would be cloth filtering, which uses baghouses to filter dust particles. These baghouses can filter large amounts of different dust particles and have a modular design that requires large floors. Another disadvantage is that it cannot operate in moist environments or under fire hazards (Cooper and Alely, 2010).

Sustainable approaches

Air pollution is a significant concern in both developed and developing countries. It is critical to minimize air pollution and raise public consciousness to create sustainable cities for the future; however, this remains an open challenge (Kumar *et al.,* 2014). Citizens' science initiatives have been introduced over the years to track the environment and raise public awareness, but most of these works are of a contribution type, in which trained researchers design, prepare, and analyse tasks while citizens participate (Silva and Medes, 2012). By engaging local communities and stakeholders, citizen science can be used as a "tool" to increase public awareness of air pollution (Mahajan *et al.,* 2020). Every citizen can mitigate air pollution through behavioural changes in their lifestyles, such as reducing energy consumption in transport, households and supplies (Rickenbacker *et al.*, 2019).

Furthermore, it is well recognized that motor vehicle transportation is responsible for approximately 70% of all environmental emissions since exhaust gases are known for being the source of various pollutants (Sofia *et al.,* 2020). As a result, initiatives aimed at improving travel behaviour are critical. Every resident should take advantage of public transportation such as buses, trams, metros, and trains as much as possible and travel actively using alternatives like walking and cycling (Xia *et al.,* 2015). On a global scale, the joint effort to minimise carbon dioxide emissions will improve air quality. When fossil fuels are burned, oxygen combines with hydrogen to produce water or with carbon to produce carbon dioxide. These reactions release heat, which is used as energy. Therefore, a significant reduction in carbon dioxide emissions, together with increased energy efficiency, will contribute to achieving the energy security goals of countries and regions by encouraging a more efficient, versatile and diversified energy mix (Ibáñez-Forés *et al.,* 2013). Society and its decision-makers, who prioritize various valuable energy goals such as climate change mitigation, environmental pollution, and energy security, may shape the future energy system in various directions (Harlan and Ruddell, 2011; Sofia *et al.,* 2020).

Conclusions

Scientists have addressed the poor air quality topic more frequently in recent years, especially since the environmental capacity of self-purification does not cope with the number of pollutants that humans produce. Sources such as burning fossil fuels, agriculture, mining, household activities, natural disasters are just a few of the main causes that affect human health and cause global warming and acid rains. More people are aware that air pollution is a big problem, and they try to remediate this by energy saving, recycling, using public transport and finding technologies that control air pollution. Air pollution monitoring is necessary for environment and population as well. Scientific research is vital to help the public understand the effects of air pollution and spread awareness about this topic and its consequences.

Acknowledgements. This work was supported by Entrepreneurship Project POCU 123886.

References

Afrifa, G. A., Tingbani, I., Yamoah, F. & Appiah, G. (2020). Innovation input, governance and climate change: Evidence from emerging countries. *Technol. Forecast. Soc. Change*, 161, 1-13.

Amegah, A. K. & Agyei-Mensah, S. (2016). Urban air pollution in Sub-Saharan Africa: Time for action. *Environ. Pollut.*, 220, 738-743.

Apte, K. & Salvia, S. (2016). Household air pollution and its effects on health, *F1000Research*, 5.

Armaroli, N. & Balzani, V. (2011). The legacy of fossil fuels. Chem. Asian J., 6(3), 768-784.

Bai, L., Wang, J., Ma, X. & Lu, H. (2018). Air pollution forecasts: An overview. *Int. J. Environ. Res. Public Health*, 15, 780.

Banerjee, R. (2015). Importance of waste to energy conversion. *Int. J. Innov. Res. Adv. Eng.*, 2, 45-52.

Barnes, P. W., Williamson, C. E., Lucas, R. M., Robinson, S. A., Madronich, S., Paul, N. D., Bornman, J. F., Bais, A. F., Sulzberger, B., Wilson, S. R., Andrady, A. L., McKenzie, R. L., Neale, P. J., Austin, A. T., Bernhard, G. H., Solomon, K. R., Neale, R. E., Young, P. J., Norval, M. & Zepp, R. G. (2019). Ozone depletion, ultraviolet radiation, climate change and prospects for a sustainable future. *Nat. Sustain.*, 2(7), 569–579.

Barua, S. & Nath, S.D. (2021). The impact of COVID-19 on air pollution: evidence from global data. *J. Clean. Prod.*, 126755.

Bel, G. & Holst, M., 2018. Evaluation of the impact of bus rapid transit on air pollution in Mexico City. *Transp. Policy*, 63, 209-220.

Berman, J.D. & Ebisu, K. (2020). Changes in US air pollution during the COVID-19 pandemic. *Sci. Total Environ.*, 739, 139864.

Bernard, S. M., Samet, J. M., Grambsch, A., Ebi, K. L. & Romieu, I. (2001). The potential impacts of climate variability and change on air pollution-related health effects in the United States. *Environ. Health Perspect.*, 109(suppl 2), 199-209.

Bray, C.D., Battye, W. H. & Aneja, V. P. (2019). The role of biomass burning agricultural emissions in the Indo-Gangetic Plains on the air quality in New Delhi, India. *Atmos. Environ.*, 218, 116983.

Burns, D. A., Aherne, J., Gay, D. A. & Lehmann, C. M. B. (2016). Acid rain and its environmental effects: Recent scientific advances. *Atmos. Environ.*, 146, 1–4.

Casper, J. K. (2010). Fossil fuels and pollution: the future of air quality. Ed. Facts on File Infobase Publishing, 12-14.

Chandrappa, R. & Kulshrestha, U. C. (2015). Sustainable air pollution management: Theory and practice. *Sustainable Air Pollution Management: Theory and Practice*, 1–379.

Charlesworth, S. M. & Booth, C. A. (Eds.). (2019). Urban Pollution: Science and Management. *John Wiley & Sons*.

Chen, Y. & Whalley, A. (2012). Green infrastructure: The effects of urban rail transit on air quality. *Econ. J.: Econ. Policy.*, 4(1), 58-97.

Chino, M., Nakayama, H., Nagai, H., Terada, H., Katata, G. & Yamazawa, H. (2011). Preliminary estimation of release amounts of 131i and 137cs accidentally discharged from the fukushima daiichi nuclear power plant into the atmosphere. *J. Nucl. Sci. Technol.*, 48(7), 1129–1134.

Cooper, C. D. & Alley, F. C. (2010). Air pollution control: A design approach. Waveland press.

Covert, T., Greenstone, M., & Knittel, C. R. (2016). Will we ever stop using fossil fuels?. *J Econ Perspect.*, 30(1), 117-38.

Cross, E. S., Williams., L. R., Lewis, D. K., Magoon, G. R., Onasch, T. B., Kaminsky, M. L. & Jayne J.T. (2017). Use of electrochemical sensors for measurement of air pollution: correcting interference response and validating measurements. *Atmos. Meas. Tech.*, 10(9), 3575-3588.

Daly, A. & Zannetti, P. (2007). An introduction to air pollution–definitions, classifications and history. *The Arab School for Science and Technology & The EnviroComp Institute*, 1-14.
D'amato, G., Pawankar, R., Vitale, C., Lanza, M., Molino, A., Stanziola, A. & D'amato, M. (2016). Climate change and air pollution: effects on respiratory allergy. *Allergy Asthma Immunol. Res.*, 8(5), 391.
Dickerson, R.R., Kondragunta, S., Stenchikov, G., Civerolo, K.L., Doddridge, B.G. & Holben, B.N. (1997). The impact of aerosols on solar ultraviolet radiation and photochemical smog. *Science*, 827-830.
Dimitroulopoulou, C., Trantallidi, M., Carrer, P., Efthimiou, G. C. & Bartzis, J. G. (2015). EPHECT II: Exposure assessment to household consumer products. *Sci. Total Environ.*, 536, 890–902.
Domingo, J. L. & Rovira, J. (2020). Effects of air pollutants on the transmission and severity of respiratory viral infections. *Environ. Res.*, 1-7.
Europa Liberă România. 2022. România fumegă. De ce nu reușesc autoritățile să oprească incendierile intenționate. [online] Available at: <https://romania.europalibera.org/a/incendii-de-vegetatie-intentionate-/31774702.html?fbclid=IwAR3RY0AZVbSZ4PAYjoIXJHQse_-S9-lDmhr8mt6QQrYinNwXy8ZDnuArbro> [Accessed 31 March 2022].
Ezzati M. & Kammen, D. M. (2002). Household energy, indoor air pollution, and health in developing countries: Knowledge base for effective interventions, *Annu. Rev. Energy Environ.*, 27(1), 233-270.
Gavrilescu, M., Demnerová, K., Aamand, J., Agathos, S. & Fava, F. (2015). Emerging pollutants in the environment: present and future challenges in biomonitoring, ecological risks and bioremediation. *New Biotechnol.*, 32(1), 147-156.
Ghahremanloo, M., Lops, Y., Choi, Y. & Mousavinezhad, S. (2021). Impact of the COVID-19 outbreak on air pollution levels in East Asia. *Sci. Total Environ.*, 754, 142226.
Ghose, M. K. & Majee, S. R. (2000). Sources of air pollution due to coal mining and their impacts in Jharia coalfield. *Environ. Int.*, 26(1-2), 81-85.
Ghose, M. K. & Majee, S. R. (2001). Air pollution caused by opencast mining and its abatement measures in India. *J. Environ. Manage.*, 63(2), 193-202.
Gibson, J. (2015). Air pollution, climate change, and health. *Lancet Oncol.*, 16(6), 269.
Giovanis, E. (2014). Relationship between Recycling Rate and Air Pollution in the State of Massachusetts, *Munich Personal RePEc Archive*, 1-25.
Grennfelt, P., Engleryd, A., Forsius, M., Hov, Rodhe, H. & Cowling, E. (2020). Acid rain and air pollution: 50 years of progress in environmental science and policy. *Ambio*, 49(4), 849–864.
Harlan, S. L. & Ruddell, D. M. (2011). Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. *Curr. Opin. Environ. Sustain*, 3(3), 126-134.
Honscha, L. C., Penteado, J. O., de Sá Gama, V., da Silva Bonifácio, A., Aikawa, P., Dos Santos, M. & da Silva Júnior, F. M. R. (2022). Health impact assessment of air pollution in an area of the largest coal mine in Brazil. *Environ. Sci. Pollut. Res.*, 29(10), 14176-14184.

Hood, C., MacKenzie, I., Stocker, J., Johnson, K., Carruthers, D., Vieno, M. & Doherty, R. (2018). Air quality simulations for London using a coupled regional-to-local modelling system. *Atmos. Chem. Phys.*, 18, 11221–11245.

Hu, K., Davison, T., Rahman, A., & Sivaraman, V. (2014). Air pollution exposure estimation and finding association with human activity using wearable sensor network in proceedings of the MLSDA 2014 2nd workshop on machine learning for sensory data analysis, *ACM*, pp. 48–55.

Ibáñez-Forés, V., Bovea, M. D. & Azapagic, A. (2013). Assessing the sustainability of Best Available Techniques (BAT): methodology and application in the ceramic tiles industry. *J. Clean. Prod.*, 51, 162-176.

Janni, K. A., Maier, W. J., Kuehn, T. H. & Ching-Hsu, Y. (2001). Evaluation of biofiltration of air-an innovative air pollution control technology. *ASHRAE Trans.*, 107, pp. 198.

Kampa, M. & Castanas, E. (2008). Human health effects of air pollution. *Environ. Pollut.*, 151(2), 362-367.

Kelly, F. J. (2003). Oxidative stress: its role in air pollution and adverse health effects. *Occup. Environ. Med.*, 60(8), 612-616.

Khazini, L., Dehkharghanian, M. E. & Vaezihir, A. (2022). Dispersion and modeling discussion of aerosol air pollution caused during mining and processing of open-cast mines. *Int. J. Environ. Sci. Technol.*, 19(2), 913-924.

Knap, A. H. & Rusyn, I. (2016). Environmental exposures due to natural disasters. *Rev. Environ. Health*, 31(1), 89-92

Kumar, P., Morawska, L., Birmili, W., Paasonen, P., Hu, M., Kulmala, M. & Britter, R. (2014). Ultrafine particles in cities. *Environ. Int.*, 66, 1-10.

Künzli, N., Perez, L., von Klot, S., Baldassarre, D., Bauer, M., Basagana, X. & Hoffmann, B. (2011). Investigating air pollution and atherosclerosis in humans: concepts and outlook. *Prog. Cardiovasc. Dis.*, 53(5), 334-343.

Le Quéré, C., Jackson, R.B., Jones, M.W., Smith, A.J., Abernethy, S., Andrew, R.M., De-Gol, A.J., Willis, D.R., Shan, Y., Canadell, J.G. & Friedlingstein, P. (2020). Temporary reduction in daily global CO 2 emissions during the COVID-19 forced confinement. *Nat. Clim. Change*, 10(7), 647-653.

Lewis, A. C., Lee, J. D., Edwards, P. M., Shaw, M. D., Evans, M. J., Moller, S. J. & White, A. (2016). Evaluating the performance of low cost chemical sensors for air pollution research. *Faraday Discuss.*, 189, 85-103.

Lin, B. & Zhu, J. (2018). Changes in urban air quality during urbanization in China. *J. Clean. Prod.*, 188, 312-321.

Lucas, R. M., Norval, M., Neale, R. E., Young, A. R., De Gruijl, F. R., Takizawa, Y. & Van Der Leun, J. C. (2015). The consequences for human health of stratospheric ozone depletion in association with other environmental factors. *Photochem. Photobiol. Sci.*, 14(1), 53–87.

Ma, L., Graham, D.J. & Stettler, M.E. (2021). Air quality impacts of new public transport provision: A causal analysis of the Jubilee Line Extension in London. *Atmos. Environ.*, 245, 118025.

Mahajan, S., Kumar, P., Pinto, J. A., Riccetti, A., Schaaf, K., Camprodon, G. & Forino, G. (2020). A citizen science approach for enhancing public understanding of air pollution. *Sustain. Cities Soc.*, 52, 101800.

Mandal, K., Kumar, A., Tripathi, N., Singh, R. S., Chaulya, S. K., Mishra, P. K. & Bandyopadhyay, L. K. (2012). Characterization of different road dusts in opencast coal mining areas of India. *Environ. Monit. Assess.*, 184(6), 3427-3441.

Manisalidis, I., Stavropoulou, E., Stavropoulos, A. & Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: a review. *Public Health Front.*, 8.

Mannucci, P.M. & Franchini, M. (2017). Health effects of ambient air pollution in developing countries. *Int. J. Environ. Res. Public Health*, 14(9), 1048.

McAllister, T. A., Beauchemin, K. A., McGinn, S. M., Hao, X. & Robinson, P. H. (2011). Greenhouse gases in animal agriculture-Finding a balance between food production and emissions. *Anim. Feed Sci. Technol.*, pp. 1-6.

McDonald, F. & Horwell, C. J. (2020). Air Pollution Disasters: Liability Issues in Negligence Associated with the Provision of Personal Protective Interventions (Facemasks). *Disaster Med. Public Health Prep.*, 1–7.

Meetham, A.R., Bottom, D.W. & Cayton, S. (2016). Atmospheric pollution: its history, origins and prevention. 4th Ed. *Pergamon Press*.

Michulec, M., Wardencki, W., Partyka, M. & Namieśnik J. (2005). Analytical techniques used in monitoring of atmospheric air pollutants. *Crit. Rev. Anal. Chem.*, 35(2), 117–133.

Mosley, S. (2014). Environmental history of air pollution and protection, In: *The basic environmental history Environ. Hist. Durh. N. C.*, 143-169.

Munawer, M. E. (2018). Human health and environmental impacts of coal combustion and post-combustion wastes. *J. Sustain. Min.*, 17(2), 87–96.

Nayak, D., Saetnan, E., Cheng, K., Wang, W., Koslowski, F., Cheng, Y. F. & Smith, P. (2015). Management opportunities to mitigate greenhouse gas emissions from Chinese agriculture. Agriculture, *Agric. Ecosyst. Environ.*, 209, 108-124.

Nayak, T. & Chowdhury, I. R. (2018). Health damages from air pollution: Evidence from opencast coal mining region of Odisha, India. *INSEE Journal*, 1(1), 43-65.

Nemery, B., Hoet, P. H. M. & Nemmar, A. (2001). Department of medical history The Meuse Valley fog of 1930: an air pollution disaster. *The Lancet*, 357, 704–708.

Nigam, V.K. & Shukla, P. (2015). Enzyme based biosensors for detection of environmental pollutants-a review. *J. Microbiol. Biotechnol.*, 25(11), 1773-1781.

Orru, H., Ebi, K. L. & Forsberg, B. (2017). The interplay of climate change and air pollution on health. *Curr. Environ. Health Rep.*, 4(4), 504-513.

Pan, L., Yao, E. & Yang, Y. (2016). Impact analysis of traffic-related air pollution based on real-time traffic and basic meteorological information. *J. Environ. Manage.*, 183, 510-520.

Pandey, B., Agrawal, M. & Singh, S. (2014). Assessment of air pollution around coal mining area: emphasizing on spatial distributions, seasonal variations and heavy metals, using cluster and principal component analysis. *Atmos. Pollut.*, Res, 5(1), 79-86.

Perera, F. (2018). Pollution from fossil-fuel combustion is the leading environmental threat to global pediatric health and equity: Solutions exist. *Int. J. Environ. Res. Public Health*, 15(1), 16.

Pluschke, P., & Schleibinger, H. (Eds.). (2018). Indoor air pollution. *Springer Berlin Heidelberg*. pp. 125-150.

Polivka, B. J. (2018). The Great London Smog of 1952. *Am. J. Nurs.*, 118(4), 57–61.

Rawate, P.D. (1980). Acid Rains: Implications for agriculture. *J. Minnesota Academy of Science*, pp. 9.

Reuters. [online] Available at: <https://www.reuters.com/> [Accessed 31 Mar 2022].

Rickenbacker, H., Brown, F. & Bilec, M. (2019). Creating environmental consciousness in underserved communities: implementation and outcomes of community-based environmental justice and air pollution research. *Sustain. Cities Soc.*, 47, 101473.

Rojas-Rueda, D., de Nazelle, A., Teixidó, O. & Nieuwenhuijsen, M. J. (2012). Replacing car trips by increasing bike and public transport in the greater Barcelona metropolitan area: a health impact assessment study. *Environ. Int.*, 49, 100-109.

The Guardian (2022). Russia reasserts right to use nuclear weapons in Ukraine. [online] Available at: <https://www.theguardian.com/world/2022/mar/26/russia-reasserts-right-to-use-nuclear-weapons-in-ukraine-putin> [Accessed 31 Mar 2022].

Salgado A.M., Silva L.M. & Melo A.F. (2011). Biosensor for environmental applications. In: Environmental Biosensors. Ed. *Intech Open*, 1-12;

Saxena, P. & Naik, V. (2018). Air pollution: sources, impacts and controls. Ed. *Cabi*, pp. 1-224.

Shammas, N. K., Wang, L. K. & Wang, M. H. S. (2020). Sources, chemistry and control of acid rain in the environment. In: *Handbook of Environment and Waste Management: Acid Rain and Greenhouse Gas Pollution Control*, 1-26.

Sapkota, A., Symons, J. M., Kleissl, J., Wang, L., Parlange, M. B., Ondov, J., … Buckley, T. J. (2005). Impact of the 2002 Canadian forest fires on particulate matter air quality in Baltimore City. *Environ. Sci. Technol.*, 39(1), 24–32.

Sher, F., Kawai, A., Güleç, F. & Sadiq, H. (2019). Sustainable energy saving alternatives in small buildings. Sustain. *Energy Technol. Assess.*, 32, 92-99.

Shi, T., Liu, Y., Zhang, L., Hao, L. & Gao, Z. (2014). Burning in agricultural landscapes: an emerging natural and human issue in China. *Landsc. Ecol.*, 29(10), 1785-1798.

Silva, L. T. & Mendes, J. F. (2012). City Noise-Air: An environmental quality index for cities. *Sustain. Cities Soc.*, 4, 1-11.

Singh, R., Sram, R. J., Binkova, B., Kalina, I., Popov, T. A., Georgieva, T. & Farmer, P. B. (2007). The relationship between biomarkers of oxidative DNA damage, polycyclic aromatic hydrocarbon DNA adducts, antioxidant status and genetic susceptibility following exposure to environmental air pollution in humans. *MUTAT RES-FUND MOL M*, 620(1-2), 83-92.

Snyder, E. G., Watkins, T. H., Solomon, P. A., Thoma, E. D., Williams, R. W., Hagler, G. S. & Preuss, P.W. (2013). The changing paradigm of air pollution monitoring. *Environ. Sci. Technol.*, 47(20), 11369-11377.

Sofia, D., Gioiella, F., Lotrecchiano, N. & Giuliano, A. (2020). Mitigation strategies for reducing air pollution. *Environ. Sci. Pollut. Res.*, 27(16), 19226-19235.

Stohl, A., Aamaas, B., Amann, M., Baker, L. H., Bellouin, N., Berntsen, T. K. & Zhu, T. (2015). Evaluating the climate and air quality impacts of short-lived pollutants. *Atmospheric Chem. Phys.*, 15(18), 10529-10566.

Sun, C., Zhang, W., Fang, X., Gao, X. & Xu, M. (2019). Urban public transport and air quality: Empirical study of China cities. *Energy Policy*, 135, 110998.

Sun, L., Wong, K. C., Wei, P., Ye, S., Huang, H., Yang, F. & Ning, Z. (2016). Development and application of a next generation air sensor network for the Hong Kong marathon 2015 air quality monitoring. *Sensors*, 16(2), 211.

Tan, X., Han, L., Zhang, X., Zhou, W., Li, W. & Qian, Y. (2021). A review of current air quality indexes and improvements under the multi-contaminant air pollution exposure. *J. Environ. Manage.*, 279, 111681.

Tiwary, A., Williams, I. & Colls, J. (2018) Air pollution: Measurement, modelling and mitigation, 4th Edition, *CRC Press*, 7-9.

Tong, Z., Chen, Y., Malkawi, A., Liu, Z. & Freeman, R. B. (2016). Energy saving potential of natural ventilation in China: The impact of ambient air pollution. *Appl. Energy*, 179, 660-668.

Tsai, W.T. (2018). An overview of health hazards of volatile organic compounds regulated as indoor air pollutants. *Rev. Environ. Health*, 0(0)

Tubiello, F. N., Salvatore, M., Rossi, S., Ferrara, A., Fitton, N. & Smith, P. (2013). The FAOSTAT database of greenhouse gas emissions from agriculture. *Environ. Res. Lett.*, 8(1), 015009.

Vahidi, A. & Sciarretta, A. (2018). Energy saving potentials of connected and automated vehicles. Transp. *Res. Part C Emerg. Technol.*, 95, 822-843.

Vizcaíno, M.A.C., González-Comadran, M. & Jacquemin, B. (2016). Outdoor air pollution and human infertility: a systematic review. *Fertil. Steril.*, 106(4), 897-904.

Wargent, J. J. & Jordan, B. R. (2013). From ozone depletion to agriculture: Understanding the role of UV radiation in sustainable crop production. *New Phytol.*, 197(4), 1058–1076.

West, J. J., Cohen, A., Dentener, F., Brunekreef, B., Zhu, T., Armstrong, B., ... & Wiedinmyer, C. (2016). What we breathe impacts our health: improving understanding of the link between air pollution and health. *J. Am. Chem. Soc.*, 4895-4904.

Wollenberg, E., Richards, M., Smith, P., Havlík, P., Obersteiner, M., Tubiello, F. N. & Campbell, B. M., (2016). Reducing emissions from agriculture to meet the 2 C target. *Glob. Change Biol. Bioenergy*, 22(12), 3859-3864.

Xalxo, R. & Sahu, K. (2017). Acid rain-induced oxidative stress regulated metabolic interventions and their amelioration mechanisms in plants. *Biologia (Poland)*, 72(12), 1387–1393.

Xia, T., Nitschke, M., Zhang, Y., Shah, P., Crabb, S. & Hansen, A. (2015). Traffic-related air pollution and health co-benefits of alternative transport in Adelaide, South Australia. *Environ. Int.*, 74, 281-290.

Zhang, S., Ren, H., Zhou, W., Yu, Y. & Chen, C. (2018). Assessing air pollution abatement co-benefits of energy efficiency improvement in cement industry: A city level analysis. *J. Clean. Prod.*, 185, 761-771.