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Dynamics of Air Pollution and Eco-Friendly Methods for its Control

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ABSTRACT: There is a cross-disciplinary link between air pollution, climate crisis, and sustainable lifestyle as they are the most complex struggles of the present century. This review takes an in-depth look at this relationship, considering carbon dioxide emissions primarily from the burning of fossil fuels as the main contributor to global warming and focusing on primary SLCPs such as methane and ground-level ozone. Such pollutants severely alter the climate through the generation of greenhouse gases. The discussion is extensive and includes best practices from conventional pollution control technologies to hi-tech alternatives, including electric vehicles, the use of renewables, and green decentralized solutions. It also addresses policy matters, such as imposing stricter emissions standards, setting stronger environmental regulations, and rethinking some economic measures. Besides that, new developments such as congestion charges, air ionization, solar-assisted cleaning systems, and photocatalytic materials are among the products discussed. These strategies differ in relation to the local conditions and therefore exhibit a varying effectiveness level, but they remain evident as a tool of pollution deterrence. This stresses the importance of holistic and inclusive approach in terms of engineering, policies, stakeholders, and ecological spheres to tackle.

KEYWORDS: air, pollution, climate, control, economic, eco-friendly, methods

I. INTRODUCTION

Air pollution is a global issue because it not only causes global warming but also affects human health. Human activities have exacerbated global warming through the production of excessive greenhouse gases, which induce harmful effects on human health. According to the World Bank and the Institute for Health Metrics and Evaluation [1], about 92% of people worldwide do not breathe clean air due to air pollution, and the resultant costs of air pollution stand at USD 5 trillion every year. Short-term exposure to air pollutants causes dizziness, nausea, asthma, pneumonia, and heart problems [2]. Specifically, exposure to air pollutants affects human skin, causing symptoms such as skin aging, eczema, acne, and urticaria, and affects the eyes, causing irritation or dry eye syndrome [3,4]. Long-term exposure can even induce cancer or death [5]. Particulate matter, benzene, ozone, and dust cause serious damage to the human respiratory system, and some of these substances can even accumulate in cells and blood, having been ingested through the airways [6,7]. Studies have shown that air pollution could be the main cause of cardiovascular disease and affect the immune system extensively [1,2,3].

As air pollution is known to vary with the rate of industrialization or structural change in economy, and many previous studies have explored how air pollution is related to the stages of economic growth. Grossman and Krueger [10] first found a nonlinear inverted U-shaped curve between per capita income and air pollution, showing that air quality tends to get worse as economies grew until the gross domestic product (GDP) per capita reaches a certain level, after which it gradually improves. They found a tendency for early economic development to neglect ecological protection, and for industrialization processes to cause serious environmental pollution. Many subsequent studies confirmed the inverted U-shaped curve [11,12,13,14,15,16], and subsequently the literature was extended to find an N-shaped curve representing the relationship between economic growth and air pollution [17,18,19,20,21,22]. Most past studies emphasized that sufficient economic growth is required before air pollution problems are addressed.

Moreover, energy consumption has been considered a key factor of driving air pollution. Past studies have focused on the effects of using fossil fuels on air pollution, but the use of renewable energy sources recently became of interest for policy makers because these are environmentally friendly energy sources with potential for sustainable development. Due to the interest in renewable energy, consumption increased dramatically from 520,370.4 ktoe (approximately 7.4% of total energy consumption) in 2000 to 902,546.4 ktoe (approximately 9.7% of total energy consumption) in 2014, according to the International Energy Agency (IEA). In addition, the 2015 Paris Agreement on climate change motivated many countries to develop renewable energy policies. Renewable energy consumption is beneficial for

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environment: many studies have confirmed that increasing renewable energy intensity improves environmental quality and leads to a decline in carbon dioxide emissions [23,24,25,26,27,28,29]. However, with regard to air pollution, only a few studies in the literature have found evidence that the use of renewable energy sources can ease air pollution problems [23,24,28,30].

Due to the importance of economic growth and renewable energy consumption in addressing the problem of air pollution, this paper pursues a deeper understanding of the nexus between air quality, economic growth, and renewable energy consumption. Since the literature has paid little attention to the dynamics of air pollution at a global level, this paper contributes to understanding how air pollution varies dynamically with both economic growth and renewable energy consumption. The specific objective of this paper is as follows. First, it evaluates the dynamic adjustment of air pollution, which shows how fast air pollution changes over time. Second, it examines how economic growth is associated with air pollution. With regard to major air pollutants such as particulate matter, sulfur dioxide, nitrogen oxide, and carbon monoxide, this paper tests the environmental Kuznets hypothesis that economic growth initially increases the levels of these pollutants and then reduces them. Third, this study examines the effects of renewable energy consumption on air pollution. Since the existing literature focuses mainly on analyzing the relationship between carbon dioxide emissions and renewable energy consumption at the single-country or regional levels, this paper contributes to determining whether the use of renewable energy sources can contribute to reducing air pollution at a global level. Fourth, it examines how air pollution is associated with urbanization and trade openness. Since the literature points out that urbanization and trade openness occur in economic development stages, this paper contributes to understanding how they affect air pollution levels.[4,5,6]

Air pollution is directly linked to the climate change and global warming. Some of the effects include rising sea levels, heatwaves that happen more often, droughts, and extreme weather events such as hurricanes, floods, and wildfires. The loss of biodiversity and changes in agricultural production are also the negative outcomes of the climate change. Almost all kinds of air pollutants are directly or indirectly involved in global warming resulting in uncertain climatic conditions. For instance, emissions from vehicles, industries, and domestic activities including combustion by-products comprising of carbon mono oxide, carbon dioxide, nitrogen oxides as well as char particles (in the form of particulate matter). Such particulate matters absorb or scatter radiation with greater capacity as compared to air and hence impart a direct impact on climate change, which may harm human, animal as well as plant health. Similarly, methane is another pollutant that contributes to climate change as its global warming potential is much higher than carbon dioxide. Possible options to cope with climatic issues and ambient air quality include an improvement in the environmentally efficient energy generation systems, less thermal losses, and use of clean energy resources to reduce emission levels around the globe]. Controlling air pollutant can have a direct and positive impact on the climate change and improves quality of environment. For this, it is very important to revise the policies for energy generation, which can minimize the consumption of fossil fuels.

II. DISCUSSION

A very high energy potential is possessed by winds blowing at high velocities. This is because of the natural convective loops caused by the temperature difference in different regions. Due to this factor, this is considered as a by-product of solar energy. The high speed and impact of wind is converted into mechanical energy and then to electricity by using wind turbines. Various designs of wind turbines and mills are used for this purpose, depending on the available potential of winds in a particular region. Primarily, wind turbines are classified into 1—Horizontal Axis Wind Turbines and 2—Vertical Axis Wind Turbines. In the first category, the wind turbine rotates in the horizontal plane and it is governed by lift force of the winds. On the other hand, Vertical Axis Wind Turbines rotate in the vertical plane by drag force of winds. There are certain drawbacks and benefits for both the categories. However, it is important to check the feasibility of both designs for the desired location. The speed of the wind can change a lot over time, which can make it hard to rely on wind energy alone to meet energy needs. Therefore, a stable and reliable energy supply requires energy storage systems or backup power sources [54, 55]. The feasibility of optimum design of wind turbine can be achieved by using different simulation tools such as CFD, which can provide a true insight of thrust and impact of winds on solid body of the turbines. Based on such simulation results, the turbine height can also be adjusted for maximum output. Many countries have set high goals for generating renewable energy. Wind energy is expected to continue to play a big role in reducing air pollution and slowing climate change in the future. Modern energy generation systems particularly at seashore are equipped with such technologies for harvesting of maximum energy from winds. As per an estimate, this technology is expected to meet around 18% of the world's electricity demand by future.[7,8,9]

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III. RESULTS

Nitrogen is present in the air in the form of several key pollutants, including nitrogen monoxide (NO), nitrogen dioxide (NO2) and ammonia (NH3). The atmospheric deposition of nitrogen in terrestrial ecosystems can cause harmful eutrophication when critical loads are exceeded. The critical load refers to a threshold below which the ecosystem is able to absorb pollutants deposited from the atmosphere without disruption, while deposition above this threshold is likely to disrupt terrestrial and aquatic ecosystems and lead to changes in species diversity. Critical loads vary by ecosystem type, and overall exceedances are estimated using modelling methods.

In 2016, under the baseline scenario of the European Commissions' Third Clean Air Outlook, critical loads for nitrogen deposition were exceeded in 75% of the total ecosystem area of the 27 Member States (EU-27), constituting 1,082,200km2 (Figure 5). This represents a fall of 12% since 2005. The zero pollution action plan has set a 2030 target of a 25% reduction from 2005 levels. Significant exceedances of critical loads for nitrogen were seen in the Po Valley (Italy), in the Dutch-German-Danish border areas and in north-eastern Spain.
The deposition of sulphur dioxide (SO2), nitrogen oxides (NOX) and ammonia (NH3) leads to changes in the chemical composition of soils, lakes, rivers and marine waters, resulting in acidification. The impacts of low pH values on freshwater and forest soils include the release of toxic metals and the loss of nutrients, resulting in fish mortality and forest decline, respectively.[10,11,12]

Significant decreases in emissions of SO2 over recent decades have successfully addressed the problem of acidification. The European Monitoring and Evaluation Programme (EMEP), which models deposition data, estimates that exceedances of critical loads for acidification were seen in 4% of the European ecosystem in 2016 (EMEP, 2015). Hotspots occurred in the Netherlands and its borders with Germany and Belgium and in small parts of southern Germany and Czechia. In these remaining hotspots, nitrogen deposition is usually the main driver of acidification.

Vegetation exposure to NOX and SO2 can also be assessed on the basis of monitoring data reported to the EEA in accordance with the ambient air quality directive (EU, 2008).

Regarding NOX, the annual critical level for the protection of vegetation from exposure (an annual mean of 30µg/m3) was exceeded in 2016 at only 4 out of 360 reporting rural background stations: two in Italy and two in Türkiye (see EEA annual air quality statistics). In most of Europe, NOX levels are estimated to be below the critical level for the protection of vegetation. In 2016, however, annual mean NOX concentrations were estimated to be above the critical level for the protection of vegetation in the Po Valley in Italy, the southern part of the Netherlands, northern Belgium, the German Ruhr region and a few rural areas close to major cities (ETC/EH Eionet report 2015/12).

Regarding SO2, the critical level of an annual mean of 20µg/m3 was not exceeded at any of the 254 rural background stations that reported data for 2016. The critical level for winter was also not exceeded at any of the 248 rural background stations that reported these data (see EEA annual air quality statistics).

Heavy metals emitted to air are transported long distances in the atmosphere and deposited into ecosystems. Heavy metals are toxic and their persistence in ecosystems leads to their bioaccumulation in the food chain. In addition, the deposition of heavy metals in marine waters contributes to the presence of metals in marine organisms (EEA, 2017b).

The deposition flux (meaning both wet and dry deposition) of lead, cadmium and mercury in high-vegetation areas, such as forests, is several times higher than that in low-vegetation areas, such as croplands (EMEP, 2015). In addition, the contribution of dry deposition to total deposition is higher for forested areas than for other ecosystems.

In 2016, the highest fluxes of lead deposition were estimated in the southern part of Poland, the north-western part of Germany and northern Italy, while the lowest were seen over the Scandinavian peninsula and Finland (EMEP, 2015).

Being eco friendly means living in a way that is not harmful to the environment. This way of life is becoming increasingly important, as we must protect our planet from man-made damage. There are various ways an individual can make sustainable changes to lessen the negative effects our daily lives usually contribute to.[13,14,15]

It is possible to be eco friendly in different areas of our lives.

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The Intergovernmental Panel on Climate Change continues to issue severe warnings of the failure of governments and systems to suitably react to the rapidly changing climate, which continues to rip through the poorest areas of the world, displacing more than 20 million people each year and intensifying global supply-demand dynamics.

The seismic shift required to circumvent further worsening of the effects of climate change will require action from individuals on a community level. This could include energy-based home improvements or reducing over-consumption. Currently, emissions from consumption in high-income cities are set to double by 2050. This must be urgently reduced by two-thirds by 2030 to ensure the health and happiness of future generations.

This extensive list spans 7 areas of your life where you can change your routines and reconsider your engagement with the systems around you. From small energy efficiency measures to energy system upgrades, from realising your purchasing power to adopting eco tourism habits. Making a start and having an awareness of personal changes that you can make can contribute towards system change and improve your local community.

Air Pollution Solutions
While air pollution is a serious problem, it is a problem that we can solve! In the United States and around the world, people are taking action to reduce emissions and improve air quality.

The Clean Air Act: How Laws Can Help Clean Up the Air
Creating policies and passing laws to restrict air pollution has been an important step toward improving air quality. In 1970, fueled by persistent visible smog in many U.S. cities and industrial areas and an increase in health problems caused by air pollution, the (link is external)Clean Air Act paved the way for numerous efforts to improve air quality in the United States. The Clean Air Act requires the Environmental Protection Agency (EPA) to set air quality standards for several hazardous air pollutants reported in the (link is external)Air Quality Index (AQI), requires states to have a plan to address air pollution and emissions reduction, and also addresses problems such as acid rain, ozone holes, and greenhouse gas pollution which is causing the climate to warm.[16,17,18]

Since the Clean Air Act was passed:
The amounts of the six common pollutants in the atmosphere measured by the EPA (particulates, ozone, lead, carbon monoxide, nitrogen dioxide, and sulfur dioxide) are declining.
The risks of premature death, low birth weight, and other health problems due to air pollution have decreased.
Vehicle emissions have decreased, despite increases in the number of miles driven each year, due to stricter emissions standards and increased efficiency in vehicle engines.
Emissions and toxic pollutants (such as mercury and benzenes) from factories and power plants have decreased, due to new technologies.
There is less acid rain, due to decreased power plant emissions.
The ozone hole continues to shrink as a result of banning the use of CFCs.
Pollution-caused haze in cities and wilderness areas has decreased.
Source: EPA

Most industrialized countries have laws and regulations about air quality. The United Kingdom first passed its Clean Air Act in 1956 following a deadly smog event that killed many London residents. In China, where rapid industrial and urban growth in recent decades resulted in a sharp decrease in air quality, numerous laws about air pollution have been passed, including a frequently updated five-year national plan to meet target reductions in air pollution.

It is important to note that while laws and regulations are helping, the effects of air pollution are still apparent. The decline of toxic air pollutants and health improvements are welcome changes, yet the growing threat of climate change due to fossil fuel emissions remains a problem that still needs to be solved.

There Are Many Solutions to Air Pollution
In order to improve air quality and slow climate warming, change needs to happen on a national and global scale. However, actions at the individual and community level are also important.

Burn less coal. Pollution from burning all fossil fuels is harmful to the atmosphere, but burning coal has a larger impact on air pollution than burning oil or gas because it releases more carbon dioxide, sulfur dioxide, and heavy metal pollutants per unit of energy. Also, over one-third of the electricity produced in the world comes from burning coal. As

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of 2014, the global demand for coal is beginning to decline. In North America, coal plants are being replaced by natural gas. Some countries, such as Japan and South Korea, rely more on nuclear energy, and there is a global increase in electricity supplied by clean, renewable sources like wind, solar, and water.

Lessen the impact of cars. Cars and vehicles create exhaust full of carbon dioxide, nitrogen dioxide, and other pollutants. Driving less, in favor of public transportation, biking, or walking, helps decrease air pollution. Also, using cars with increased fuel efficiency or electric cars that do not rely on fossil fuels can decrease the amount of pollution we are contributing to the atmosphere. When you use your car, keep the engine tuned and the tires properly inflated to decrease fuel consumption. Whenever possible, take fewer trips by combining errands. Many cities are helping by investing in better, affordable public transportation and developing city plans that include infrastructure for walking, biking, and public transit.

Conserve energy — at home, work, and everywhere! The demand for electricity, which is most often produced by burning fossil fuels, has grown exponentially over the past decades. Conserve energy by turning off lights, buy appliances rated for energy efficiency, and keep the thermostat set higher in the summer and lower in the winter. Whenever possible, invest in renewable energy sources to power your home. Several countries are using renewables, nuclear power, or lower-emission sources like natural gas to meet their increasing power demand. And many countries plan to significantly increase their use of renewable energy sources in the future.

Monitor air quality warnings and take action on poor air quality days. On days when pollution levels are high, taking action can help reduce the risk of harm to those who are most vulnerable. Reducing overall car usage and avoiding idling your car can help on days with high levels of ozone pollution. Save refueling and use of gas-powered yard equipment for the evening when it is cooler and ozone levels are lower. On days when particle pollutants are high, avoid burning yard waste and wood. Choosing to carpool or using a clean transportation method is always helpful, especially on days with high levels of air pollution. Check on the air quality in your area [19]

IV. CONCLUSION

Take action within your community to find solutions to air pollution. Around the world, many of the current solutions are the result of communities coming together to demand change. Citizens in Shenzhen, China, inspired a switch to electric buses in their city. In Brussels, Belgium, a movement started by parents concerned about poor air quality in schools led to a plan to invest in public transportation and bicycling, along with a ban on fueled cars by 2030. And in many countries, governments are closing coal plants and exploring new sources of energy because of citizens who are concerned about climate warming.[20]

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