Efforts to improve air quality in major regions - costs and benefits, successes and failures

Shizheng Lu *

Faculty of Natural, Mathematical & Engineering Sciences, King's college London, London, United Kingdom

* Corresponding Author Email: K22025262@kcl.ac.uk

Abstract. Today, pollution of the atmosphere presents serious dangers to human wellness and the environment in many major regions. The paper study the successes and failures of various pollution control methods by finding the root causes of air pollution in three major regions, Europe, Delhi in India, and California in USA, and the methods they implemented to reduce it. Targeted government policies and strict regulatory frameworks have brought improvements in Europe and California, on the other hand, hasty and coercive legislation has also led to some unforeseen challenges that were not anticipated. Delhi government also effort to implement pollution control policies, but in recent years, there has been a lack of further measures, mostly because of the fast industrialization and weak implementation of environmental and financial restrictions. The purpose of this paper is to provide assistance for the development of future global air quality control measures through the utilization of these cases.

Keywords: Air Quality guidelines, PM2.5, Environmental Policy.

1. Introduction

The Air Pollution Index simplifies the concentration of several commonly monitored air pollutants into a single conceptual index value form, and classifies them to characterize the degree of air pollution and air quality status. It focuses on the potential impact on human health in the hours or days following inhalation of polluted air, which normally update every 6 hours. On September 22th, 2021, the WHO updated its latest global air quality guidelines (AQGs) for particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) [1], provides detailed evidence of the negative impact of air pollution on human health, and stricter regulations have been established in various air quality indicators and concentrations, compared to the initial regulations in 2005 [2], the latest guidelines reduced the guidance values for particulate matter, updated the guidance values for ozone, and introduced new guidance values for other pollutants such as carbon monoxide (CO) and some volatile organic compounds (VOCs), which were not included in the 2005 version. Although AQGs are not legal binding, most major regions have formulated their own laws or policies based on it, such as the United States, Europe, and China.

The research done by Xie et al. indicate that when the annual average concentration of $PM_{2.5}$ has changed from $14.3\mu g/m^3$ to $52.5\mu g/m^3$, the average population attributable score for lung cancer has changed from 0.195 to 0.413, and that score for cardiovascular diseases has changed from 0.130 to 0.291 [3]. The substantial value of this proportion translates into a considerable number of deaths, with lung cancer deaths increase from 9.6 to 22.8 cases and cardiovascular disease deaths increase from 48.6 to 136.6 cases per 100000 residents. They found that for every $10\mu g/m^3$ increase in $PM_{2.5}$ in severe cases, the mortality and incidence rate of respiratory diseases increased by 4.6% and 4.48% respectively, which was much higher than the average level of 0.69% and 1.32%, and had obvious seasonal characteristics. The mortality and incidence rate of lung cancer increased most significantly in winter. In cold seasons, for every inter-quartile range increase in $PM_{2.5}$, the hospitalization frequency for pneumonia, asthma, and chronic obstructive pulmonary disease increases by 50%, 40%, and 46%, respectively [3].

Another research done by Tripathi A. D. (2021) used literature published in China from 1989 to 2014 to conduct a meta-analysis on the correlation between $PM_{2.5}$ and adverse health outcomes of respiratory diseases [4]. They found that for every 10μg/m^3 increase in $PM_{2.5}$, the mortality rate of respiratory diseases increased by 0.5%. These all results indicate a close relationship between adverse health outcomes of respiratory diseases in China and $PM_{2.5}$ pollution in the atmosphere [4].

However, dealing with air pollution still faces many challenges. In recent decades, the worldwide use of energy has risen exponentially, ranging from 8,588.9 million tonnes in 1995 to 13,147.3 million tonnes in 2015 [5]. The global demand for energy has also increased the demand for fossil fuels. Although efforts have been made to find alternatives to fossil fuels, due to various issues such as transportation, storage, and extraction, fossil fuels including oil, coal, and natural gas will account for a very high proportion of total human energy use in the foreseeable future [6]. Controlling these fossil energy power plants that cause significant air pollution requires a large amount of capital investment, including technology research and development, equipment procurement, operation and maintenance costs.

Air quality is now one of the biggest environmental factors affecting human health. Many countries have formulated and implemented policies to optimize air quality. This paper aims to discuss the difficulties they face and the solutions they adopt, in order to obtain a more universal solution.

2. Air quality and measures for improvement in Europe

2.1. Sources of Pollution

In the past few decades, although European cities have made significant progress in clean air, some cities still face serious air pollution incidents, and the air quality in various urban areas often exceeds the levels allowed by European legal standards and World Health Organization guidelines [7]. The research done by Daellenbach K. R. et al. used on-site observations and air quality modeling to quantify the main primary and secondary sources of particulate matter and oxidation potential in Europe, and the results showed that secondary inorganic components, crustal materials, and secondary biogenic organic aerosols controlled the mass concentration of particulate matter, in contrast, the oxidation potential concentration was mainly related to artificial sources, particularly fine mode secondary organic aerosols from residential biomass combustion and coarse mode metals from non-exhaust emissions from vehicles [8]. And the results of the research done by Viana M. et al. suggested some emerging sources such as inland shipping, construction/demolition and recreational wood burning [9].

2.2. Control Policy

The emission control policy is implemented by setting limits and target values to protect human health and ensuring that member states fully monitor air quality in a coordinated manner, thereby controlling the emission of harmful substances into the atmosphere and regulating the concentration of air pollutants such as $PM_{2.5}$, PM_{10}, NO_2, and O_3 [10]. Therefore, the number of air quality monitoring stations in Europe has grown rapidly, with the number of monitoring stations in European cities and suburbs increasing from 1300 in 1990 to 3600 in 2000, and to approximately 5000 in 2020 [10]. The European Commission published The Clean Air Pro-gramme for Europe (CAPE) in 2013, aims to improve air quality in Europe by 2030 and to reduce the number of premature deaths by half compared with 2005 [11].

During the first wave of COVID-19 pandemic, the air pollution level declined after the implementation of blockade measures [12]. The study by Schneider R. et al. quantified the association between specific lockdown measures and the decrease in NO_2, O_3, $PM_{2.5}$, and PM_{10} levels in 47 European cities, evaluated the effects of different policy interventions and the number of deaths avoided during this period [13]. The results showed that under very strict policy levels, the decrease in NO_2 concentration was greater compared to $PM_{2.5}$ and PM_{10} concentrations, and found a strong impact of differences between intervention measures [13].

In January 2017, the Polish government led by Beata Szydło identified 15 action areas to develop a national clean air plan, with a core focus on prioritizing funding for the National Environmental

Protection and Water Management Fund (NFEP&WM) to rapidly improve air quality and bring maximum benefits to people's health and ecology [14], However, the research of Sakson-Boulet A. shows three types of obstacles which implement this programme, the distribution of funds, potential beneficiaries of the programme and its construction, and those resulting from potential limitation of access to grants from EU funding [14].

2.3. Gap

The paper by Čavoški A. makes the case that over the previous 10 years, the EU's regulatory framework in the field of air pollution regulation led to a number of unforeseen effects, the increasing influence of environmental aims upon the air quality agenda led to a shift in the regulatory strategy with regard to automobile pollutants; this shift was centered on the general purpose of reducing greenhouse gas emissions and led to the development of specific laws that had an effect [15]. This led to a discrepancy between vehicle emissions standards and regulatory approaches to urban air quality, which had the unintended consequence of causing illegal air pollution levels, particularly for particulate matter and nitrogen oxides, and their unforeseen effects on customers and the automotive sector [15].

3. Air quality and measures for improvement in California (U.S.A.)

3.1. Sources of Pollution

Jerrett M.'s research compares the features of the national CPS-II cohort to a large portion of the population of California, data from the American Cancer Society Cancer Prevention II Study cohort were abstracted for 73,711 Californian subjects; baseline individual characteristics were determined in 1982, and vital status was monitored until 2000 [16]. Among the research, the participants died from CPD, CVD, IHD, Respiratory diseases, and Lung cancer was 13.6%, 10.9%, 6.2%, 2.7%, and 2.0%, respectively, it can be concluded that deaths caused by air pollution account for a significant proportion of all causes of death (26.8% of all subject) in California [16]. According to California Air Resources Board, 90% of diesel particulate matter, 50% of CO_2 equivalent GHG emissions, and 90% of smog-forming oxides of nitrogen were caused by emissions from mobile sources [17]. Due to a variety of variables, the San Joaquin Valley and the greater Los Angeles region of California-both of which are included in the South Coast Air Quality Management District territory-will have the greatest challenges in reaching attainment [18].

3.2. Control Policy

Adoption of low-carbon energy sources in 2050 can lower the racial/ethnic inequality in air pollution exposure in California by up to 40% for $PM_{0.1}$ mass and up to 20% for $PM_{2.5}$ mass, according to an environmental justice (EJ) analysis [19]. Furthermore, as per the research conducted by Li Y. et al., the mean exposure to PM2.5 calculated by the population varied between 8.2μg/m3 and 12.5μg/m3 depending on where it occurred. On the other hand, the average exposure to PM0.1 calculated by the population varied between 1.3μg/m3 and 2.2μg/m3. In the identical region, the implementation of renewable energy sources led to a reduction in PM0.1 concentrations that was as much as fourfold that observed in PM2.5 levels (10% to 12% for PM0.1 compared to 2.5% to 2.7% for PM2.5) [19]. VSL was used to calculate the benefits to public health, which are expected to amount to $7.6 million around 2050 [19].

In the study conducted by Lurmann F. et al., a number of southern California locations involved in an ongoing investigation evaluating the wellness of kids from 1994 to 2011 saw changes in outdoors nitrogen dioxide and PM2.5 pollution levels [20]. yearly standard nitrogen dioxide drops vary between 53 percent (roughly 41 to 19 parts per billion) in Upland, the top NO_2-informing society, to 28 percent (10 to 7 parts per billion) in Santa Maria, which is California's least NO_2-informing societies [20]. shifts in yearly mean $PM_{2.5}$ had been barely larger, varying between 54 percent (33 to 15 $\mu g/m^3$) within Mira Loma towards 13 percent (9 to 8 $\mu g/m^3$) within Santa Maria [20].

3.3. Gap

Paper by James K. and Edmund U. critically questioned California's air pollution legislation, it believed that environmental regulators had not given enough thought to the causes of air pollution and how it affected public health, as a result, air control policies were developed too quickly, failing to adequately address the issue and leading to the contentious mandatory solution, and suggested that the government should exercise more caution when drafting environmental regulation [21].

4. Air quality and measures for improvement in Delhi (India)

4.1. Sources of Pollution

Delhi is the main administrative and political centre of India. From 2001 to 2017, PM_{10} concentrations in Delhi grew from 150μg/m^3 to 263μg/m^3, while NO_2 concentrations increased from 41.8μg/m^3 to 73.55μg/m^3 (The yearly limit is 60μg/m^3 and 40μg/m^3 respectively), and in 2017, PM2.5 levels also above the yearly average of 40μg/m3, reaching 130μg/m3 [22]. From the data, it can be concluded that air pollutants in Delhi are persistently over the standard limit. Using a receptor modeling approach, the CPCB (2010) calculated the sector's contributions to particulate matter pollution in Delhi. The mean predicts for filtering specimens coming from chosen tracking locations through 2006 were as follows: 9% to 21% for automobile emission; 15% to 29% for roadway debris resuspension; 3% to 10% for home sources; 11% to 25% for trash combustion; 7% to 10% for manufacturing gases; and 7% to 13% for diesel-powered enigine sets [23]. Another research found that for the contribution of the factors of volatile organic compounds (VOCS), traffic accounts for 56.6%, solid fuel accounts for 27.5%, and secondary pollutants accounts for 15.9%, and for the contribution of the factors of ambient organic aerosols (OAS), traffic accounts for about 20%, solid fuel accounts for about 30%, and secondary pollutants accounts for about 50% [24]. Roughly 74% of the electricity produced in India is produced by thermal power plants. According to The Energy and Resources Institute (TERI) reports, between 1947 and 1997, there was a 50-fold rise in SO_2, NO_X, and PM emissions. Between 1990 and 2000, power stations in Delhi were responsible for 68% of the city's SO_2 emissions and 80% of its PM10 concentrations [25].

4.2. Control Policy

The central and state governments in India have implemented various measures to mitigate air pollution and enhance ambient air quality, including the adoption of the use of CNG as a substitute for petroleum, the enforcement of odd-even traffic regulations in Delhi, the introduction of Bharat Stage 6 automobile and energy regulations, the PMUY, and the NCAP. The initiative uses electric automobiles for public transportation and encourages the construction of bicycle facilities in the transportation sector. The application of zigzag technologies to monitor chimney emissions from brick-making facilities, online discharge monitoring using OCEMS, with the placement of online cams in extremely polluting enterprises are a few of the industrial sector's applied initiatives [25]. The Indian Ministry of Environment, Forest, and Climate Change (MoEFCC) issued updated criteria for coal-fired thermal power plants in December 2015, with the primary goal of reducing air pollution, according to the updated guidelines, coal thermal power plants in India would be required to reduce PM emissions by up to 40% and water use by nearly a third beginning in 2017 [26].

Research done by Menon J. et al. gave a Nature-based solution, which plants with an effective cover and laminar framework may get rid of particles, and kinds of plants which have elevated APTI values are capable of helping shorten particle pollutant, whereas kinds that have lower APTI values are able to be utilized for air quality detector due to their excellent sensitivity. Some of the often-researched tree types for their susceptibility to and endurance of pollutants in the atmosphere in cities and manufacturing regions were introduced in the publication [27]. And they proposed that besides restoring the original green spaces, integrating greening into the urban area (e.g. vertical greening system) is also feasible [27].

4.3. Gap

The implementation of various policies to reduce the vehicular and industrial emissions is hindered in rapidly urbanizing nations such as India by a lack of financial resources and space constraints. Delhi currently lacks adequate infrastructure and funding to deploy progressive infrastructure technologies, and it is also very difficult for it to relocate factories out of the city center area [25]. While some funds have been allocated for green initiatives (60.5 million INR has been allotted through NCAP for green projects in 28 designated cities as not meeting standards), there is a lack of strategic planning in the air pollution and climate change policies [27].

5. Conclusion

This paper analyzes the air pollution in three regions: Europe, California, and Delhi, and corresponding treatment measures. Overall, traffic pollution is a significant source of air quality degradation in almost all regions. In developing countries that have just experienced rapid urbanization, the pollution caused by various secondary industry factories cannot be ignored. Although there are many similarities in air pollution across regions, when considering actual implementation measures, local terrain, climate, and economic capacity must also be taken into account, that is, all air governance policies should be adapted to local conditions. For instance, renewable alternatives to public transit should be the main emphasis of city air pollution management strategies. such as subways, to improve the convenience of public transportation, thereby increasing the number of hospitals where residents can use public transportation and further reducing the use of private cars. The government can also establish stricter emission regulations, provide more welfare support for electric or hybrid transportation, and facilitate the promotion of the widespread application of alternative fuels. Replace thermal power plants with cleaner energy sources such as wind, hydro, and solar power. Residents in rural regions are often unaware of the dangers of air pollution and its severe impact on human health. The government must to put more effort into disseminating information on air pollution, stressing the value of tackling the issue at its source as well as the many mitigation strategies available to reduce emissions of pollutants. By spreading this knowledge, there's a chance to drastically cut down on things like burning crops, incinerating outdoor trash, using biomass for firewood, and burning rubber and plastic during the colder months.

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