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Thoughts on How Air Quality Affects Premature Death

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Abstract: According to the World Health Organisation (WHO), air pollution is a cause of premature death. It is clear a priori that a cleaner environment, in particular atmospheric air, will be a more favourable environment for life. However, to what extent can we objectively link them? Can a definitive link be established between air pollution and "premature" death? To do this, we need to look at how premature death is defined, track changes in air quality and life expectancy over the most extended possible period for which we have reliable data. On this basis, we must try to formulate certain conclusions. It may turn out that the cleaner the environment, the longer we live. And the longer we live, the higher the age at which we consider death to be premature. But as this age increases, we can expect the number of "premature" deaths to increase as well. In the end, we may find that with a cleaner environment, or cleaner air, the rate of premature death increases!

Keywords: air pollution, quality of life, premature mortality, fine particulate matter, air pollution standards

Introduction

According to the World Health Organization (WHO), the American Lung Association, the European Environment Agency (EEA), and other authoritative institutions, air pollution has serious consequences for human health. Short-term or long-term exposure to pollution can affect most organs in the body. The main causes of health problems are fine dust particles (PM2.5 and PM10), ozone, nitrogen dioxide, sulphur dioxide, and carbon monoxide.

Again, according to the WHO, 99% of the world's population in 2019 lived in places that did not meet the recommended air quality standards, resulting in the premature death of 4. 2 million people in 2019, of which nearly 89% occurred in low- and middle-income countries [1]. Despite the higher standards of EU countries, according to the EEA, poor air quality in 2020 caused at least 238,000 premature deaths due to fine particulate matter pollution, 49,000 due to exposure to nitrogen dioxide pollution, and 24,000 due to ozone [2]. Specifically, for R. Bulgaria, which is often cited as the EU country with the highest rate of premature deaths due to air pollution, the agency's data show that there were 382 cases in 2005 and 180 in 2021 [3].

The issue of premature mortality requires serious analysis for a number of reasons. The most important is that the individual loses potential years of life, and for their family, in addition to emotional trauma, it can lead to financial instability. From a social perspective, premature loss of a person leads to a reduction in the workforce and, in many cases, to increased healthcare costs [4]. Last but not least are issues of a more general nature such as poverty, low education, poor housing conditions, and lack of access to healthcare.

Methods

In order to analyse the relationship between air pollution and premature mortality as objectively as possible, we need to consider the following questions: which deaths are defined as premature and according to what criteria, and what is the recommended air quality?

The ways of determining the age at which death is considered premature are examined.

The health effects of air pollution according to different pollutants are summarized.

Both the currently applicable permissible standards and their development over the years are examined.

The average life expectancy for the last 120 years in several countries (England, France, Greece, and Bulgaria) is presented and compared with the age of premature mortality. Several cities in Bulgaria are examined in more detail, analysing the presence or absence of a clear link between air pollution and premature mortality.

Results and Discussion

Premature death

Defining a death as premature leads us to believe that there is also such a thing as a timely death! However, the length of each person's life depends on many factors, and their death cannot be defined as timely or untimely. On the other hand, global, regional, and national studies and measurements require comparable criteria, and the concept of premature death provides us with just that. As such, we define death as the loss of part of a person's life span due to an event that shortened it and that would not have occurred if death had occurred naturally.

There are several approaches to determining the age at which death is considered premature. It is important to note at the outset that these may vary depending on the context, population, and purpose, i.e., premature death cannot be objectively defined. The approaches are [5] [6]:

- Age-based thresholds - a fixed age is determined based on statistical data, such as global average life expectancy. This is the clearest and most commonly used method, which involves setting a specific age as a threshold, and any death before that age is considered premature (according to the UN, this is 70 years).
- Years of potential life lost - this approach quantifies premature death by calculating the number of years lost before a certain age (e.g., 70 or 75 years).
- Longevity norms by age group - premature death is determined relative to the expected remaining life span for a person of a given age in the reference population.
- Life expectancy inequality points - considers death premature if it increases life expectancy inequality in a given population, focusing on inequality in age at death.

The first approach is the most commonly used, but the use of an "arbitrarily" selected threshold for different mortality models is a serious drawback. In the more complicated approach with the selection of different age groups, the main drawback is that the estimate depends to a large extent on how the distribution of deaths for a given age and/or reference population is determined. Combining the two approaches could probably reduce the impact of these drawbacks. This would mean that the distribution of deaths in old age would be kept constant for each country as a basic value, while the distribution of premature mortality could vary between countries. In this way, estimates of premature mortality become more comparable between countries with similar characteristics [5].

Notwithstanding the above, determining the age before which death is considered premature remains subjective, broadly speaking, depending on the purpose. Different studies will show different thresholds – from 65 years for some [7], to 70 years for others [8], and up to 75 years for others [9]. In studies relating to EU member states, the accepted threshold is 75 years.

Health effects of air pollution

- Fine particulate matter PM10 and PM2.5

Pollution with fine particulate matter increases the risk of cardiovascular and respiratory diseases [10]. Long-term exposure to PM2.5 and PM10 can cause cardiovascular and respiratory mortality. PM2.5 particles have a greater effect, especially on respiratory diseases [11], with death possibly caused by exposure to pollution in previous days. Conversely, in cardiovascular diseases, the cause of death may be momentary pollution. Studies on the impact of pollution at an early age show that in later years it can cause psychological and behavioural problems, including depression [12].

- Nitrogen dioxide – NO_2

Exposure to nitrogen dioxide can cause inflammation of the lungs and bronchi, including asthma and wheezing [13]. Acute exposure to NO_2 can increase airway sensitivity, while chronic exposure can lead to cellular and biochemical changes resulting in pulmonary dysfunction [14]. Long-term exposure to nitrogen dioxide is also associated with respiratory symptoms, cancer, myocardial infarction, and overall mortality.

- Sulphur dioxide – SO_2

Inhalation of SO_2 can cause bronchoconstriction, exacerbate asthma, and contribute to chronic obstructive pulmonary disease. Prolonged exposure to this gas can negatively affect the functioning of goblet cells, leading to epithelial hyperplasia and hypertrophy of the submucosal glands [13]. Exposure to sulphur poses a risk of changes in the physiology of the respiratory tract. It increases the risk of tuberculosis and chronic bronchitis and can also lead to adverse effects on the respiratory, cardiovascular, and nervous systems. In certain cases, it can contribute to type 2 diabetes [15].

- Ozone – O_3

Studies show that exposure to ozone has an adverse effect on the respiratory system, causing inflammation of the lungs. Ozone can exacerbate existing respiratory conditions, damage respiratory tract cells, cause allergic reactions, and even asthma [16]. A link has also been found between ozone concentrations and epidemiological data on respiratory mortality [17].

- Carbon monoxide – CO

Increased exposure to carbon monoxide can reduce the blood's ability to carry oxygen. In people with lung disease, this can cause acute symptoms such as shortness of breath, wheezing, and chest tightness [18]. In particularly severe cases, it can lead to reduced physical activity and weakened mucosal immunity, thereby increasing susceptibility to infections. Acute exposure to elevated CO levels is associated with increased cardiopulmonary mortality [19].

- Other health risks

Overall, air pollution increases the risk of heart attacks, strokes, high blood pressure, heart failure, and plaque build-up in the arteries. Prolonged exposure to polluted air is associated with an increased risk of developing lung cancer and other types of cancer. There is growing evidence linking air pollution to cognitive decline, dementia, and Alzheimer's disease [20].

Although there is still no conclusive evidence, some scientists claim that there is a link between air pollution and the risk of premature birth, low birth weight, stillbirths, and miscarriages in pregnant women [21].

Allowable and limit values for air pollution

From what we talked about earlier, it's clear that being around polluted air can cause serious illnesses and even death. Over the years, different standards for harmful pollutant concentrations have been set, which were thought to be safe and not cause any health risks. Globally, these standards are set by the WHO, following two guidelines: values that should not be exceeded within a 24-hour period (24-hour standards) and those that refer to average annual values. As of 2021, the 24-hour standards set by the WHO for pollutants are as follows: fine particulate matter (PM10) - 45 μg/m3, fine particulate matter (PM2.5) - 15 μg/m3, NO2 - 200 μg/m3, O3 – 120 μg/m3, and for SO2 – 40 μg/m3. The specified annual average standards are: fine particulate matter (PM10) - 15 μg/m3, fine particulate matter (PM2.5) - 5 μg/m3, NO2 - 40 μg/m3. SO2 - none [22].

Let's take a look at what they have been over the years. Until the end of World War II, no data on permissible pollution levels had been found. The first air quality standards were set in the Soviet Union. In 1956, they were as follows: SO2 0.15 mg/m3 for 24 hours and 0.5 mg/m3 for the average annual standard, for NOx (nitrogen oxides) – the 24-hour standard was 0.15 mg/m3, and the annual standard was 0.5 mg/m3.

In 1971, the first standards for particulate matter appeared in the US, without being divided by size, with a 24-hour standard of 260 μg/m^3 and an annual standard of 75 μg/m^3. This distinction was made in 1987, when different standards were introduced for PM10 and PM2.5, namely a 24-hour standard of 150 μg/m^3 and an annual standard of 50 μg/m^3. In 2006, the requirements for PM2.5 were tightened to a 24-hour standard of 35 μg/m^3 and an annual standard of 15 μg/m^3. A further tightening took place in 2012, when the health standard for PM 2.5 was lowered to 12.0 μg/m^3, while maintaining the 24-hour standard, and in 2024 the health standard was reduced to 9.0 μg/m^3.

For sulphur dioxide, changes in the US are significantly less frequent – from 1971 to 2010, the daily limit was 365 μg/m^3, and the annual average was 80 μg/m^3. After 2010, an hourly limit of 196 μg/m^3 was introduced. Within the EU, the dynamics are slightly greater: in 1980, the average hourly level was 400 μg/m^3, the average daily level was 250-350 μg/m^3, and the annual level was 140 μg/m^3. In 1999, the following reductions were introduced: hourly average – 350 μg/m^3, daily average – 125 μg/m^3, and annual average – 20 μg/m^3. In 2025, a new average daily value of 40 μg/m^3 will come into force.

Historically, nitrogen dioxide standards have also developed without significant changes – from 1971 to the present, the average annual standard in the US has been 100 μg/m^3, and since 2010, an hourly standard of 188 μg/m^3 has also been introduced. In the EU, the standards set in 2001 are still in force today, with an hourly average of 200 μg/m^3 and an annual average of 40 μg/m^3.

The US has a longer history of ozone standards. The first was set in 1997 for an 8-hour period at 157 µg/m³, followed by a reduction in 2008 to 147 µg/m³ and the current standard (since 2015) of 140 µg/m³. In 2002, the EU introduced a standard of 120 µg/m³, which has not been changed since.

It is striking that there has been a significant increase in the requirements for particulate matter, with the limit values for PM 10 being reduced by about 5 times and for PM 2.5 by more than 15 times. There has also been a significant increase in the requirements for sulphur dioxide standards – about sevenfold. In contrast, other standards remain significantly more constant.

Life expectancy and air pollution in Bulgaria

The average life expectancy in EU countries has doubled over the last 120 years, from around 40 in 1900, to 69 in 1960, and to 81.4 in 2023 [23]. The situation is similar in Bulgaria, where the average life expectancy at the beginning of the 20th century was only about 40 years, while in 2024 it will be almost 76 years.

The dynamics of average life expectancy in London and Paris show similar statistics – from an average of about 45 years in 1900 to 83 years in 2024. The situation is different in Sofia and Athens. In both capitals, life expectancy in 1900 was around 40 years, while today it is 78 years for Sofia and 82 years for Athens [24] [25]. The situation in other large cities in these countries is not very different. Statistics for rural areas also provide interesting information. The average life expectancy in the Western countries under review was around 50 years at the beginning of the 20th century and has reached around 78 today. For Bulgaria, it starts at 40 years and reaches 82-83 years in 2024. It is striking that the average life expectancy outside the big cities at the beginning of the 20th century is about 3-4 years longer. Bulgaria is an exception with almost equal values. The equalization occurred after 1950 and has remained so to this day. Bulgaria is again an exception, with the overall average life expectancy being about 3 years shorter than that in large cities.

Figures 2 and 3 show the average life expectancy and the lines defining premature mortality at ages 65 and 75. It is very clear that the conclusions that can be drawn depending on the choice of years to be considered as a starting point for life expectancy can vary greatly. For example, if we choose 75 years, we can see that in Bulgaria this coincides with the average life expectancy. On this basis, it is difficult to make assumptions about individual causes, such as air pollution.

Let us look more specifically at the situation in Bulgaria. As shown above, the average life expectancy in large cities is about 3 years higher than that in villages (78 vs. 75 years). It is well known that the air in villages is cleaner than that in cities, according to the indicators that are monitored. In other words, air purity is not a significant factor in this case. Moreover, over the last decade, average life expectancy in cities has increased by 2.8 years, while in villages it has increased by 1.6 years. This is a period in which air pollution in cities has remained higher than in villages.

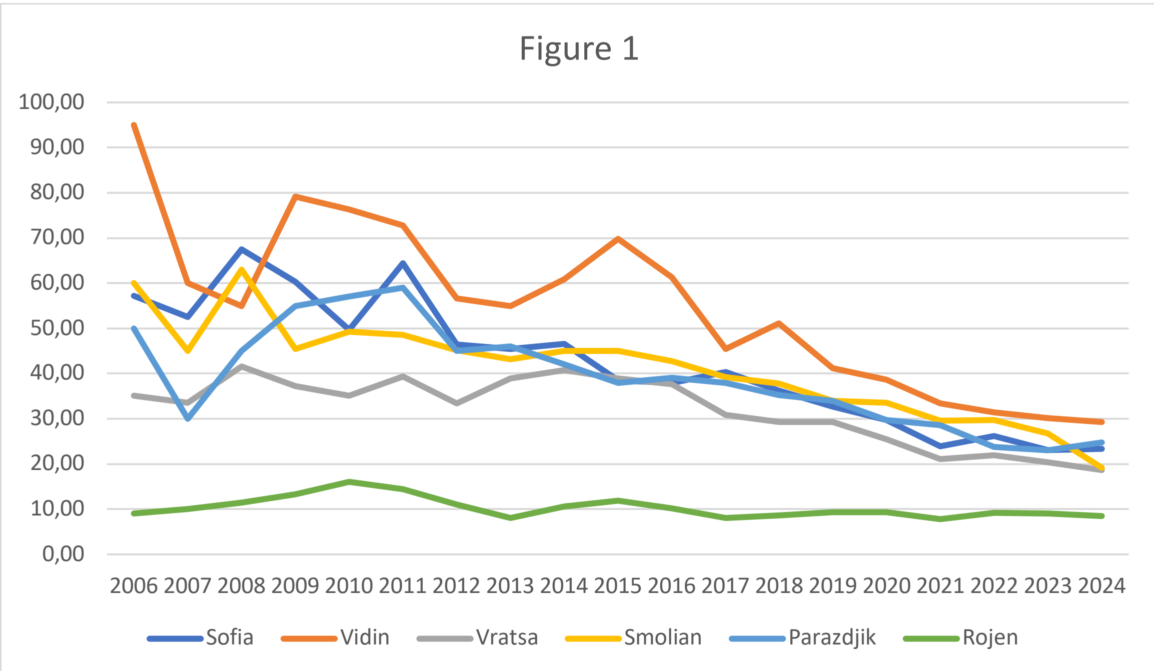
Statistics also show that Sofia has the highest life expectancy (close to 79 years) despite being designated as one of the cities with the most polluted air. Vidin, with an average life expectancy of

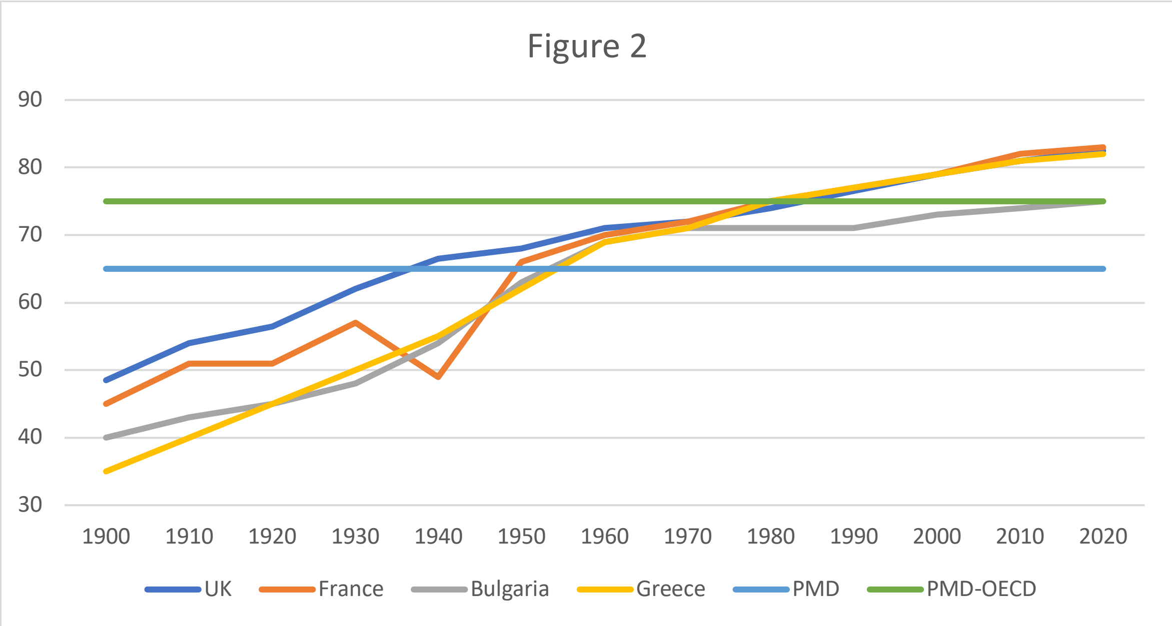
74.9 years, and Vratsa, with 75.5 years, are at the other end of the spectrum in terms of life expectancy, but they are also among the cities with significant air pollution [26].

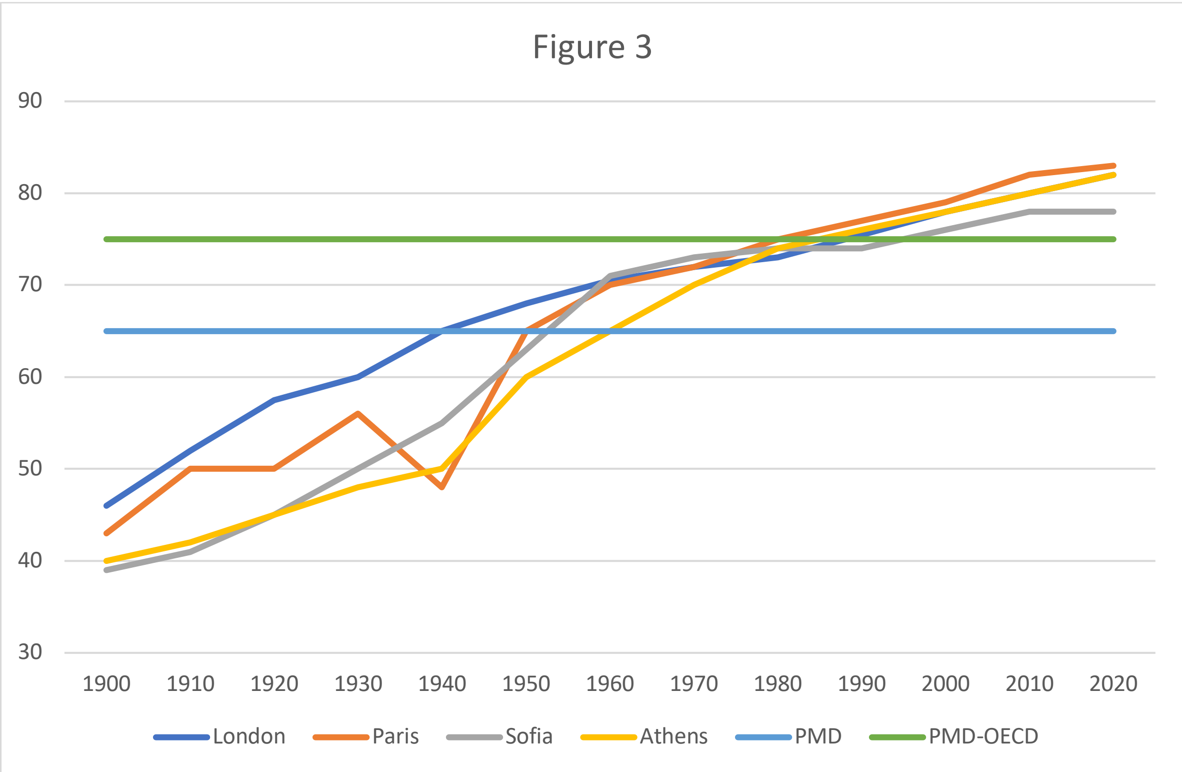
I will also add two cities with an intermediate life expectancy of around 77 years, which is lower than that in Sofia and higher than that in Vidin and Vratsa. Let us examine air pollution in these five cities in Bulgaria. Figure 1 shows the development of PM concentration over a period of nearly 20 years. The first thing that stands out is that pollution has decreased significantly in all the cities discussed here. Secondly, Sofia has consistently ranked between Vidin and Vratsa in terms of air pollution levels, but average life expectancy does not correlate with this in any way. Third, pollution in Smolyan and Pazardzhik is close to that in Sofia and falls between the levels in Vidin and Vratsa, but in these towns, average life expectancy is lower than in Sofia and higher than in the other two cities [27].

According to the National Centre for Public Health and Analysis at the Ministry of Health [28], average life expectancy for the same period did not increase significantly–from 73 years in 2006 to 73.5 in 2023. This is a period during which PM10 air pollution has decreased significantly – between 30% and 40% for the various cities considered here.

The lack of reliable data on air pollution over a longer period does not allow the analysis to be extended back in time. However, the 20-year period under consideration is sufficient to make certain assumptions, namely that there is no obvious link between life expectancy and air pollution. It is natural to expect longer life expectancy with cleaner air and a cleaner environment in general. However, the claim that there is a certain premature mortality rate in Bulgaria as a result of air pollution can be questioned, not least because the statistical data does not confirm it.







Conclusions

Average life expectancy depends on many factors. Some are purely genetic and hereditary, while others may be related to quality of life. Air purity falls into the latter category.

Let us consider an even longer period of time than the one mentioned above–the last 220 years, during which average life expectancy has doubled from 40 to 80 years [29]. The general perception is that nature was much cleaner back then and that industrialisation has polluted it to a significant extent. There is no doubt that industrialization has contributed to environmental pollution, but that does not mean that the air and water were clean before factories appeared.

Our ancestors lived in terrible environmental conditions. Individual heating with coal literally leads to deadly air pollution. These were times when there were no toilets or bathrooms, no running water or sewage systems, and waste, feces, and everything else, including carcasses, dead animals, and so on, were thrown out onto the streets. Latrines were dug near wells and contaminated drinking water. The dead are thrown into huge pits, which are covered with soil only after they are filled. Until then, the poison and stench of decomposing bodies spreads through the air. Food is scarce and rotten. Bacterial and viral infections are commonplace.

All this changed with the advent of industrialization. It created a problem with pollution, but it solved a much bigger problem with another type of pollution, as well as many other problems.

What's more, the change in the age of premature death from 70 to 75 shows that life continues to improve. But isn't air quality also improving? In fact, today we see that premature mortality due to air pollution has increased, but isn't it possible that this is a consequence of those added 5 years? And isn't it possible that we have higher mortality rates with cleaner air, simply because raising the threshold from 65 and 70 to 75 years naturally leads to increased mortality?

If we enter a spiral in which an increase in average life expectancy leads to an increase in the age of premature death, it may turn out that the better and longer we live, the more we die prematurely.

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