Air (ine)quality in the European Union

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Abstract

Purpose of Review This paper presents an analytical review of recent research on social inequality caused or compounded by ambient air pollution in the European Union.

Recent Findings While empirical studies have developed significantly both in the academic and institutional arena, they have largely focused on only one aspect: the exposure and sensitivity of individuals and groups to air pollution according to various criteria, documenting substantial and overlapping inequality.

Summary While EU policy should better address this proven impact inequality, research is also needed on new fronts of air (ine)quality (namely mental health impact and indoor air quality) as well as other types of ambient air inequality (such as inequality in responsibility and impact of air pollution mitigation policy).

Keywords Ambient air pollution · Inequality · European Union · Health impact

Introduction: Air Quality and Human Health in the EU

Air quality has been a health concern in Europe as far back as the development of the Hippocratic approach to environmental health in ancient Greece [1] while European governments have tried to regulate human-induced air pollution at least since the early stages of industrialization in England in the beginning of fourteenth century.1

But in Europe as elsewhere, the massive detrimental health effect of ambient air pollution is a fairly recent evidence-based policy concern. While the World Health Organization (WHO) has been informing policymakers on air pollution’s impact on human health as early as 1958 and setting guidelines for Europe since 1987, the first ever WHO international conference on Air Pollution and Health has been organized in the Fall of 2018 [2]. The purpose of this convening was indeed to take stock of the robust and growing body of contemporary research documenting the adverse effect of air pollution on human health—from in utero exposure to affections of the respiratory and cardiovascular systems and neurologic damages (due to finer particles)—and to offer policy solutions to this increasingly costly public health crisis. In the European Union (EU) as well, while air pollution has been a policy concern for half a century, efforts to converge toward a harmonized methodology for monitoring air pollution across the EU, mandated by the 2008 EU Ambient Air Quality Directive, really took off in the last decade (as an illustration, the European Environmental Agency or EEA “Air quality in Europe” report series, which for the first time presented systematic data on air quality, was launched in 2010 while the agency’s “Air Quality Index” was launched in 2020 [3]).

In spite of past efforts, air pollution remains a major health challenge: in the most recent study to date by the Europe’s bureau of the WHO, experts note that “air pollution is the largest environmental health risk in Europe” [4•], an assertion confirmed by the European environmental agency which latest assessment similarly states that “air pollution is the biggest environmental health risk in Europe” [3], with “almost all Europeans still suffering from air pollution, leading to about 400,000 premature deaths across the continent”.2 The OECD similarly stresses the magnitude of the health challenge of air pollution in Europe [8]: “depending on the methods of estimation, between 168 000 and 346 000 premature deaths across all EU member states in 2018 can...

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1 In 1306, then King Edward passed legislation banning the burning of sea-coal enacting severe physical punishments and death sentences to those who would sell and burn coal.

2 According to the EEA, exposure to fine particulate matter caused 379,000 premature deaths in EU-28 where 54,000 and 19,000 premature deaths were attributed to nitrogen dioxide (NO2) and ground-level ozone (O3), respectively.
be attributed to exposure to outdoor air pollution in the form of fine particles (PM$_{2.5}$) alone. This represented 4% to 7% of all deaths in 2018. In addition, hundreds of thousands of people develop various illnesses associated with air pollution, leading to a loss of about 3.9 million disability-adjusted life years (DALYs) annually in the European Union. In fact, exposure of Europeans to ambient air pollution appears to be a key element of the perception of the quality of life within the European population [5].

While indoor air pollution is a serious concern in some European states, the European air quality literature and policy is largely focused on ambient air quality, and so will this article. In the EU as elsewhere, ambient air pollution with serious health impacts (namely cardiovascular and respiratory diseases but also, although less explored, mental illness) is caused mostly by particulate matter (PM), nitrogen dioxide (NO$_2$), ozone at ground level (O$_3$), and to a lesser extent sulfur dioxide (SO$_2$).

Two stylized facts are highly consensual when it comes to ambient air pollution in the European Union in recent years: While air quality has improved in the EU in recent decades [6] and [3], EEA most recent available data indicate that significant shares of EU member states and the EU population are still exposed to high levels of ambient air pollution according both to EU and WHO air quality guidelines levels (see Table 1).

As an illustration, the health impact of particulate matter pollution in France, one of the most developed EU countries and one of the earliest adopters of air quality regulation policies back in 1932, is currently very significant. In mainland France, the health burden for PM$_{2.5}$ pollution alone was recently estimated to 48,000 early deaths a year, i.e., about 9% of all deaths, as much as alcohol-related mortality [9].

As substantial as they are, these impacts could be underestimated [10••], the annual excess mortality rate from ambient air pollution in Europe could be as high as 659,000 in the EU-28 (air pollution reducing life expectancy in Europe by about 2.2 years), or twice the estimate by the EEA.

In this context, a new concern for environmental justice in the face of air quality has emerged in the European Union attested by the release of the first report by EU institutions [11•] and a report on environmental health inequalities in Europe by the WHO Regional Office for Europe [4•]. These institutional reports build on academic publications that have documented environmental injustice in Western Europe [12] and Eastern Europe [13] in the last two decades, and social inequality in the face of ambient air pollution [14].

### Table 1 % of EU member states and EU population above hazardous levels of air pollution in 2018

|                      | EU standards | WHO standards (2005) |
|----------------------|--------------|----------------------|
|                      | % of member states with concentration above threshold | % of urban population exposed to concentration above threshold | % of member states with concentration above threshold | % of urban population exposed to concentration above threshold |
| Particulate matter (PM$_{10}$) | 57% | 15% | 100% | 48% |
| Fine particulate matter (PM$_{2.5}$) | 14% | 4% | 100% | 74% |
| Ground-level ozone (O$_3$) | 67% | 34% | 100% | 99% |
| Nitrogen dioxide (NO$_2$) | 64% | 4% | 64% | 4% |

Source: authors’ calculations based on EEA data [7]

Note: EU standards are legally binding while WHO standards serve as guidelines. WHO 2005 air pollution standards have been revised in September 2021 to become even more stringent but official EEA calculations of exposed populations (consistent with previous calculations) under these new WHO guidelines are not available at the time of writing. A reasonable guess may be that close to 100% of urban EU population is now exposed to PM$_{2.5}$ concentration exceeding the new threshold.
Two facts thus appear salient: while air quality is a major determinant of human health and has improved significantly on average over the last decades in the EU, it still affects millions of Europeans in a disproportionate and unequal way. Before turning to empirical evidence provided in recent studies, a theoretical framework for understanding and measuring air (in)equality in the EU is needed.

**Mapping Air (ine)quality**

To understand why environmental inequalities may be unjust, one must adopt an explicit theory of justice. Many conceptions of justice co-exist and determine different streams of environmental justice. One of them consists in embracing the capability-building and human development framework developed by Amartya Sen. In essence, the capability approach recommends that well-being be assessed beyond material conditions and also reflect the quality of life of a given person. Among the determinants of quality of life, environmental conditions appear to be of great and growing importance [16].

Based on Sen’s analytical framework, one can define an environmental inequality as a situation that results in an injustice or is unjust if the well-being and capabilities of a particular population are disproportionately affected by its environmental conditions of existence [17].

The environmental conditions of existence consist of, negatively, exposure to pollution and risks, and, positively, access to amenities and natural resources (water, air, food). The particular character of the population in question can be defined according to different criteria: social, demographic, territorial, and so on.

Different categories of environmental inequality exist and must be broken down to be properly identified and possibly addressed and mitigated [20]. A first typology of environmental inequalities regarding their generative factor (the event generating the inequality) consists in dividing them into two categories: the inequality impact of individuals and groups on environmental damage and definition of environmental policies and the inequality impact on individuals and groups by policies and environmental damage. A second typology of environmental inequalities consists in considering their inequality vector: what form of environmental degradation is responsible for the observed injustice. A third typology looks at criteria of inequality: what dimension of human beings is at play in the observed injustice. Table 2 summarizes this framework and applies it to the issue of air quality. Four types of air (in)equality thus appear (Table 2):

- Type 1 is concerned with procedural justice and stems from the potential exclusion of individuals and groups from public policy procedures, for instance the inability

| Types of air inequality | Air inequality examples | Inequality vectors | Generative fact | Inequality criteria |
|-------------------------|-------------------------|--------------------|-----------------|--------------------|
| Type 1 Procedural justice | Impact of individuals and groups on air quality policies | Exclusion from public decision-making procedures | Nationality, spatial location, age, gender, socio-economic level, income, health, education, etc. | Vertical and horizontal income inequalities caused by banning polluting vehicles |
| Type 2 Recognitive justice* | Impact of air quality policies on individuals and groups | Taxation, regulatory policies, information/awareness | Vertical and horizontal income inequalities caused by banning polluting vehicles |
| Type 3 Distributive justice Exposure/sensitivity (vulnerability) to air pollution | PM$_{2.5}$; PM$_{10}$; NO$_2$; NOX; SO$_2$; O$_3$ Unequal exposure and sensitivity to air pollution in urban areas |
| Type 4 Distributive justice Impact of individuals and groups on air pollution Air pollution by the top income deciles |

*Source: adapted from [17]
to participate in polluting site installation in their residential area;

- Type 2 is concerned with recognitive justice and stems from potentially adverse social effect of air quality policy on individuals and groups, for instance the regressive impact of energy taxation on poorer households;

- Type 3 is concerned with distributive justice and stems from the unequal exposure and sensitivity of individuals and groups to air pollution, for instance the heavier pollution burden placed on disadvantaged neighborhoods in metropolitan areas;

- Type 4 is also concerned with distributional justice but stems from the unequal responsibility of individuals and groups in air pollution, for instance the greater pollution footprint of richer households.

By combining these elements, it can be analytically assessed that the environmental inequality experienced by a Parisian child living near dense traffic during a spike of pollution due to PM$_{2.5}$ is an inequality of exposure whose vector is air pollution and the criteria are age, neighborhood, and locality (at play with possible others such as ethnicity and income level). In the next section, this framework is being used to shed light on existing empirical evidence using type 1, type 2, type 3, and type 4 air (ine)quality in reference to Table 2.

### Reviewing Air (ine)quality in the EU

A lot of recent studies on air (ine)quality in the EU are about type 3 air inequality, with various inequality vectors and criteria being tested.

#### Type 3 Studies

##### Place-Based Inequality

First, inequality in exposure and/or sensitivity exists between EU countries but they differ according to air pollutant: the EEA [12] has assessed that when YLL per 100,000 inhabitants are considered PM$_{2.5}$ higher impacts are observed in central and eastern European countries, but that for NO$_2$, Italy, Greece, Spain, France, and Germany are affected the most while for ozone (O$_3$), Hungary, Greece, and Croatia have the highest rates of YLL per 100,000 inhabitants.

Inequality is also strong within countries, the OECD [8] noting that while for instance in Denmark, less than 1% of the overall population was exposed to dangerous levels of PM$_{2.5}$; in the most polluted regions, this percentage was close to 100%. In the same vein, the EEA data show that “PM2.5 pollution levels are much greater in the north Italy than in the south” while in Poland, “PM2.5 levels are particularly high in the central and southern parts of the country” [3].

Substantial spatial inequality also exists at an even finer scale: in the UK, PM concentrations are higher on average in the most socially deprived areas, both in rural and urban neighborhoods [18]. The EEA [3] confirms that “generally, areas characterised by lower socio-economic status (e.g. higher unemployment rate, lower proportion of population with higher education, lower average household income) tend to have higher levels of PM2.5, PM10 and O$_3$ pollution”. Yet, the agency notes, “with regard to NO$_2$, the opposite was found — areas with higher economic status generally experienced higher levels of NO$_2$ pollution.”

This latter statement holds at the macroscale perspective but calls for microscale views, where social deprivation and pollution are indeed correlated, hence the necessity to cross spatial data with social data at a fine scale, which a number of studies have done [19, 21, and 22] in order to fully explore pollution-deprivation relations.

#### Socio-economic Status Inequality

In a recent review of 31 articles published between 2010 and 2017, compelling evidence has found [23•] a strong link between ambient air pollution (PM$_{2.5}$, PM$_{10}$, NO$_2$, and NO$_x$) and social deprivation in Europe.

In the capabilities perspective adopted in Table 2 typology, exposure metrics must be crossed with sensitivity data to have a sense of vulnerability inequality. In fact, “Disadvantaged groups are recognized as being more often exposed to air pollution (differential exposure) and may also be more susceptible to the resultant health effects (differential susceptibility).”[14]. Long-term effects can thus be documented: a French study has shown that even if in Paris rich and poor districts are exposed to air pollution, poorer residents are three times more likely to die in a severe pollution episode than richer residents because of poorer health status due to social and environmental determinants [26].

In a recent study of 380,000 Europeans, there was a tendency for stronger pollution impacts among the less educated [28].

It thus appears that spatial inequality is compounded by inequality in exposure and sensitivity [26] (this spatial

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* The agency notes further: “The most vulnerable 20% of the NUTS 2 regions (in relation to unemployment, household income and level of education) was exposed to PM$_{2.5}$ and PM$_{10}$ pollution levels that, on average, were 1.3–1.5 times higher than the levels experienced by the least vulnerable 20% of regions. This means that the absolute difference in pollution between the most and the least vulnerable regions was around 3–5 μg/m$^3$ for PM$_{2.5}$ and 8–9 μg/m$^3$ for PM$_{10}$ (see Fig. 3.1 for the percentage of people without higher education). In contrast, PM$_{2.5}$ exposure tended to be lower in NUTS 2 regions with a higher proportion of children”.

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focus has recently been extended to travel environments [29], which opens new avenues for air inequality explorations. In this broader perspective, gender inequality has also been highlighted, one recent study showing that: “In French urban areas, pregnant women from the most deprived neighborhoods were those most exposed to health-threatening atmospheric pollutants” [30]. Finally, the interaction of various forms of socio-economic status inequality should be considered at fine spatial scales to reveal experienced inequality [24, 25].

Ethnicity

Environmental justice issues are not likely to be perceived, analyzed, and framed in ethnic terms in Europe but rather in terms of social categories,9 but it should not be understood as meaning that environmental inequalities do not have an ethnic dimension in Europe. They do, with regard to air (ine)quality as with other forms of environmental injustice [12, 13].

While mixed evidence was found in the aforementioned survey regarding ethnic status [23•], it has been shown that in Germany “clusters of high minority neighbourhoods are affected by high levels of environmental pollution” [32], similar patterns being observed in London [33] while ambient air pollution exposure in nine European metropolitan areas has been found to be more important in areas with a higher share of people born outside the EU [19].

COVID-19 Vulnerability

The latest Eurostat and EEA official estimates indicate that about the same number of people currently die from air pollution each year than have died from the first two waves of COVID-19 in 2020.10 But air pollution could have played a significant role in the risk of dying from COVID-19, so that unequal exposure to air pollution might appear to be an indirect air inequality in the face of COVID-19 [34, 35].

Type 4 Studies

Much fewer studies have focused on type 4 air inequality (cf. Table 2), highlighting the responsibility of groups (i.e., economic sectors, individual facilities, or social groups) in the pollution of contaminated sites resulting in ambient air pollution. Over the period 2010–2017, 14 articles were reviewed to show that in industrially contaminated sites in the WHO European Region, “an overburden of socioeconomic deprivation or vulnerability, with very few exemptions, was observed” [36]. Partial evidence is being collected by NGOs to track industrial pollution back to individual firms,11 but a comprehensive and systematic effort as the one observed in the USA [37] is lacking in the European Union. Yet data and methodology exist to explore inequality in responsibility: an innovative study has applied distance-based methods to highlight patterns of environmental inequality around industrial sites analogous in Austria [31•].

Type 1 and Type 2 Studies

Even fewer studies have focused on type 1 and type 2 inequality, namely the impact of individuals and groups on air quality policies and, conversely, the impact of air quality policies on individuals and groups. While there is a large and expanding literature on the political economy of environmental policy [38 and 40] and more specifically climate mitigation policy in Europe [40], papers analyzing and quantifying the distinct distributional effects of air quality policy at the European and national scale are still lacking, even though these policies are developing at the local level and recent papers attempt to empirically quantify their cost and benefits [41].

Conclusion: Toward an “Air (ine)quality Agenda”

Drawing on recent institutional and academic studies, this article has shown that not only is air quality a major health issue in the European Union, but so is inequality in exposure and sensitivity of individuals and groups according to a variety of criteria. Policy at the EU and national level should thus develop a new “air (ine)quality agenda” (see [11•] and [39] for policy options).

While research has developed significantly in recent years, it is still too focused on what has been referred to in this article as type 3 air (ine)quality (see Table 2).

Yet, important new fronts have opened up as the evidence of the health burden from air pollution accumulates. First, new health impact fields such as mental illness should be investigated using the lens of inequality. Other forms of pollution such as indoor pollution should as well, as it is estimated that Europeans spend 90% of their time indoors. Finally, other types of ambient air inequality (namely types 1, 2, and 4) should be given more space in the literature so that “air (ine)quality agenda” can take front and center in EU public policies.
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