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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 (NO_2) and ground-level ozone (O_3), respectively.

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

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,[3] the European air quality literature and policy is largely focused on ambient air quality, and so will this article.[4] 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 (O3), 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],[5] 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].[6]

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[7] attested by the release of the first report by EU institutions on the matter [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].

[3] New Eastern member states which still rely on solid fuels such as Bulgaria, Hungary, and Romania experience health concerns from indoor air pollution, but a recent estimate by the European Commission indicates that household solid fuel combustion represents around 2.5% of the total energy consumption within the EU [4].

[4] In addition, it will focus on the European Union (the 28 now 27 member states, after Brexit, forming the regional block) because of data and policy integration on air pollution.

[5] Compared to 2009, the number of premature deaths linked to air pollution in 2018 decreased by 13% for $PM_{2.5}$ and by 54% by NO_2,

Footnote 5 (continued)

but increased by 24% for ozone (for EU27 and the UK), according to EEA.

[6] According to WHO data, 17 of the 20 largest French cities exceed the standards for particulate matter $PM_{2.5}$ for the year 2016.

[7] This is also true for indoor air pollution [15]

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 (ine)quality 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

Table 2 A typology of air inequality

	Philosophical approach	Generative fact	Inequality vectors	Inequality criteria	Air inequality examples
Types of air inequality					
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.), ethnic characteristics, etc	Non-participation in the decision to install a toxic site (e.g., a chemical plant) in the city of residence
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]

*This is a process model of social justice that includes a positive regard for social difference and the centrality of socially democratic processes

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.".[8] 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

[8] 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 PM2.5 and PM10 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/m3 for PM2.5 and 8–9 μg/m3 for PM10 (see Fig. 3.1 for the percentage of people without higher education). In contrast, PM2.5 exposure tended to be lower in NUTS 2 regions with a higher proportion of children".

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.

[9] See [20] for an explanation of the difference between the Europe and the USA in this respect.

[10] In total, over 450,000 more deaths occurred in the EU between March and November 2020 compared with the same period in 2016–2019. https://ec.europa.eu/eurostat/fr/web/products-eurostat-news/-/ddn-20210216-2

[11] For instance, data collected by the European Environmental Bureau (EEB) https://eeb.org/library/industrial-emissions-database-and-viewer-methodology-note/ and http://eipie.eu/projects/ipdv

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References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. Hippocrates. On airs, waters, and places. Kessinger Publishing, 2004
2. WHO. First WHO global conference on air pollution and health, 30 October – 1 November 2018 [WWW Document]. World Health Organ. URL https://www.who.int/airpollution/events/conference/en/ (accessed 8.15.21).
3. European Environment Agency's (EEA). Air quality in Europe 2020 report, 2020
4.• WHO, Environmental health inequalities in Europe. Second assessment report. Copenhagen: WHO Regional Office for Europe; 2019.
5. Anon. Special Eurobarometer 468: Attitudes of European citizens towards the environment. 2017. Available at: http://data.europa.eu/88u/dataset/S2156_88_1_468_ENG. Accessed 21 March 2022.
6. Guerreiro C, González Ortiz A, de Leeuw F, Viana M, Colette A, European Environment Agency 2018. Air quality in Europe - 2018 report.
7. European Environment Agency's (EEA), Air quality briefing, September 2021.
8. OCDE/Union européenne, Health at a glance: Europe 2020: state of health in the EU cycle, Éditions OCDE, Paris, 2020. https://doi.org/10.1787/82129230-en
9. Medina S, Pascal M, Tillier C. Impacts de l'expositionchronique aux particules fines sur la mortalité en France continentale et analyse des gains en santé de plusieurs scénarios de réduction de la pollution atmosphérique. Saint-Maurice : Santé publique France ; 2016. 12 p. Disponible à partir de l'URL: www.santepubliquefrance.fr. Accessed 21 Nov 2021.
10.•• Lelieveld J, Klingmüller K, Pozzer A, Pöschl U, Fnais M, Daiber A, Münzel T. Cardiovascular disease burden from ambient air pollution in Europe reassessed using novel hazard ratio functions. Eur Heart J 40, 1590–1596. 2019. https://doi.org/10.1093/eurheartj/ehz135. **Provides new data suggesting that the health impact linked to ambient air pollution in the European Union is much higher than previously and officially assumed.**
11. •EEA. Unequal exposure and unequal impacts: social vulnerability to air pollution, noise and extreme temperatures in Europe (No. 22), European Environment Agency, 2018. EEA
12. Heike Köckler, Séverine Deguen, Andrea Ranzi, Anders Melin and Gordon Walker, Environmental justice in Western Europe in The Routledge handbook of environmental justice 1st edition, Edited by Ryan Holifield, Jayajit Chakraborty, Gordon Walker, 2018
13. Tamara Steger, Richard Filcák and Krista Harper, Environmental justice in Central and Eastern Europe: mobilization, stagnation and detraction in The Routledge handbook of environmental justice 1st edition, Edited by Ryan Holifield, Jayajit Chakraborty, Gordon Walker, 2018.
14. Deguen S, Zmirou-Navier D. Social inequalities resulting from health risks related to ambient air quality–a European review. Eur J Public Health. 2010;20(1):27–35. https://doi.org/10.1093/eurpub/ckp220.
15. Ferguson L, Taylor J, Zhou K, Shrubsole C, Symonds P, Davies M, Dimitroulopoulou S. Systemic inequalities in indoor air pollution exposure in London, UK. Build Cities. 2021;2(1):425–48. https://doi.org/10.5334/bc.100.
16. Laurent É (ed.). The well-being transition: analysis and policy. Palgrave-MacMillan. 2021
17. Laurent É. "The sustainability-justice nexus" in Laurent, É., & Zwickl, K. (Eds.). The Routledge handbook of the political economy of the environment (1st ed.). Routledge. 2021. https://doi.org/10.4324/9780367814533
18. Milojevic A, et al. "Socioeconomic and urban-rural differentials in exposure to air pollution and mortality burden in England", Environmental Health: A Global Access Science Source, Vol. 16/1, p. 104, 2017. https://doi.org/10.1186/s12940-017-0314-5
19. Samoli E, Stergiopoulou A, Santana P, Rodopoulou S, Mitsakou C, Dimitroulopoulou C, Bauwelinck M, de Hoogh K, Costa C, Mari-Dell'Olmo M, et al. Spatial variability in air pollution exposure in relation to socioeconomic indicators in nine European metropolitan areas: a study on environmental inequality. Environ Pollut. 2019;249:345–53. https://doi.org/10.1016/j.envpol.2019.03.050.
20. Laurent É. Issues in environmental justice within the European Union. Ecol Econ. 2011;70(11):1846–53.
21. Aether, Updated analysis of air pollution exposure in London. Report to Greater London Authority, Oxford Centre for Innovation, Oxford, United Kingdom, 2017 (https://www.london.gov.uk/sites/default/files/aether_updated_london_air_pollution_exposure_final_20-2-17.pdf). Accessed 4 Feb 2022.
22. Temam S, Burte E, Adam M, Anto JM, Basagana X, Bousquet J, Carsin AE, Galobardes B, Keidel D, Kunzli N, et al. Socioeconomic position and outdoor nitrogen dioxide (NO2) exposure in Western Europe: a multi-city analysis. Environ Int. 2017;101:117–24. https://doi.org/10.1016/j.envint.2016.12.026.
23.• Fairburn J, Schüle SA, Dreger S, Karla Hilz L, Bolte G. Social inequalities in exposure to ambient air pollution: a systematic review in the WHO European Region. Int J Environ Res Public Health. 2019;16(17):3127. https://doi.org/10.3390/ijerph16173127. **Reviews 31 articles published between 2010 and 2017 documenting the reality of socio-economic and ethnic inequality in exposure to ambient air pollution.**
24. Padilla CM, Kihal-Talantikit W, Perez S, Deguen S. Use of geographic indicators of healthcare, environment and socioeconomic factors to characterize environmental health disparities. Environ Health. 2016;15:11. https://doi.org/10.1186/s12940-016-0163-7.
25. Moreno-Jiménez A, Vidal-DomínguezMJ, Palacios-García Aand Martínez-Suárez P Assessing environmental justice through potential exposure to air pollution: a socio-spatial analysis in Madrid and Barcelona, Spain Geoforum, 2016; 69:117–31

26. Deguen S, Petit C, Delbarre A, Kihal W, Padilla C, et al. Correction: Neighbourhood characteristics and long-term air pollution levels modify the association between the short-term nitrogen dioxide concentrations and all-cause mortality in Paris. PLOS ONE. 2016;11(3):e0150875.
27. Brunt H, et al. Air pollution, deprivation and health: Understanding relationships to add value to local air quality management policy and practice in Wales, UK. Journal of Public Health (United Kingdom). 2017;39(3):485–97. https://doi.org/10.1093/pubmed/fdw084.
28. Bert Brunekreef, Maciej StrakJie ChenZorana, J Andersen, Richard Atkinson, Mariska Bauwelincket al., Mortality and morbidity effects of long-term exposure to low-level PM2.5, BC, NO2, and O3: an analysis of European cohorts in the ELAPSE Project, Research Report 208, 2021, Health Effects Institute.
29. Age Poom, Elias Willberg, Tuuli Toivonen, Environmental exposure during travel: a research review and suggestions forward, Health & Place, Volume 70, 2021, 102584, ISSN 1353-8292, https://doi.org/10.1016/j.healthplace.2021.102584
30. Ouidir, Marion, et al. "Is atmospheric pollution exposure during pregnancy associated with individual and contextual characteristics? A nationwide study in France." Journal of Epidemiology and Community Health (1979-), vol. 71, no. 10, BMJ, 2017, pp. 1026–36. https://www.jstor.org/stable/26383982. Accessed 23 Nov 2021.
31. •Glatter-Götz H, Mohai P, Haas W, Plutzar C. Environmental inequality in Austria: do inhabitants' socioeconomic characteristics differ depending on their proximity to industrial polluters? Environ. Res. Lett. 14, 074007. 2019. https://doi.org/10.1088/1748-9326/ab1611
32. Rüttenauer T. Neighbours matter: a nation-wide small-area assessment of environmental inequality in Germany. Soc Sci Res. 2018;70:198–211.
33. Tonne C, Milà C, Fecht D, Alvarez M, Gulliver J, Smith J, Beevers S, Anderson HR, Kelly F. Socioeconomic and ethnic inequalities in exposure to air and noise pollution in London. Environ Int. 2018;115:170–9. https://doi.org/10.1016/j.envint.2018.03.023.
34. Pozzer A, Dominici F, Haines A, Witt C, Münzel T, Lelieveld J. Regional and global contributions of air pollution to risk of death from COVID-19. Cardiovasc Res. 2020;116(14):2247–53. https://doi.org/10.1093/cvr/cvaa288.
35. Pegoraro V, Heiman F, Levante A, et al. An Italian individual-level data study investigating on the association between air pollution exposure and Covid-19 severity in primary-care setting. BMC Public Health. 2021;21:902. https://doi.org/10.1186/s12889-021-10949-9.
36. Pasetto R, Mattioli B, Marsili D. Environmental justice in industrially contaminated sites. A review of scientific evidence in the WHO European Region. Int J Environ Res Public Health. 2019;16:998. https://doi.org/10.3390/ijerph16060998.
37. Michael Ash and James Boyce, Toxic 100 Air, Political Economy Research Institute (University of Massachusetts Amherst) https://peri.umass.edu/toxic-100-air-polluters-index-current. Accessed 22 Nov 2021.
38. Alexander Mackie & Ivan Haščič. "The distributional aspects of environmental quality and environmental policies: opportunities for individuals and households," OECD Green Growth Papers 2019/02, OECD Publishing. 2019.
39. Sofia D, Gioiella F, Lotrecchiano N, et al. Mitigation strategies for reducing air pollution. Environ Sci Pollut Res. 2020;27:19226–35. https://doi.org/10.1007/s11356-020-08647-x.
40. Laurent É, Zwickl K (Eds.). The Routledge handbook of the political economy of the environment (1st ed.). Routledge, 2021. https://doi.org/10.4324/9780367814533
41. Bouscasse H, Gabet S, Kerneis G, Provent A, Rieux C, Salem NB, Dupont H, Troude F, Mathy S, Slama R. Designing local air pollution policies focusing on mobility and heating to avoid a targeted number of pollution-related deaths: forward and backward approaches combining air pollution modeling, health impact assessment, and cost-benefit analysis, Environment International, Volume 159, 2022. https://doi.org/10.1016/j.envint.2021.107030