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Viewpoint

Tracing Environmental Equity and Air Pollution Research at *ES&T*

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Decades of academic and community-based research around environmental justice have highlighted that communities marginalized by intersecting dimensions of race, ethnicity, class, income, and other forms of structural inequity often experience higher air pollution exposure burdens. These disparities in exposure to health-harming air pollutants reflect both structural drivers that shape where emissions and people are located, and physical processes that determine how these pollutants move and transform in the atmosphere. Across these topics, one theme is that air quality improvements do not necessarily reduce relative disparities.

In recognition of 60 years of *ES&T* publications, this viewpoint highlights *Environmental Science & Technology* (*ES&T*) articles about air pollution exposure and environmental equity and then closes by identifying paths forward for research that supports equity outcomes. Our look back at *ES&T* articles on this topic had two starting points. First, *ES&T* editors provided us a list, generated October 22, 2025, of 1269 *ES&T* articles with "air quality" in the title or abstract. Second, our search (UC Berkeley library website; December 29, 2025) for articles in *ES&T* with keywords "equity justice", "equity air pollution"; "air quality justice", or "inequality air pollution" identified 55 unique articles. Most (84%; 46 out of 55 articles) were published in 2020 or later, reflecting that this topic has gained momentum in *ES&T* since 2020, when addressing social justice challenges was more widely prioritized. The first *ES&T* publications on this topic[1−5] were calls-to-action and reported methodological inadequacies within existing literature on science and engineering aspects of

air pollution injustice. For broader literature reviews on this topic, see, e.g., a review of articles from the past decade (ref. 6 covers the period from 2015 to 2025; it also points to publications from 1960s - 1980s), a 2013 review (Table S2 of ref. 3), or a (year-2026) methodological review.[7]

Among the articles we reviewed, three broad topics emerge. First, multiple articles quantify air quality disparities across various subpopulations. For example, the earliest *ES&T* publication on environmental justice (EJ)[1] analyzed county-level emissions of industrial chemicals in the U.S. and examined differences by race/ethnicity and household income. Subsequent *ES&T* studies quantified ambient spatial disparities across spatial scales, pollutants, and contexts, including neighborhood-scale gradients revealed through mobile and airborne monitoring, national-scale analyses using satellite and modeled data, and regional and international assessments of socioeconomic inequities in exposure to ambient air pollution (e.g., refs 2 and 8−11). U.S. regulatory monitoring station locations tend to miss hot spots. This spatial bias is greater for nonwhite, low-income, and disadvantaged communities; thus, disparity estimates based on monitoring station data may be underestimated.[12] In the U.S., "redlining", a racially discriminatory mortgage appraisal practice from the 1930s by the U.S. Federal Government, continues to impact modern exposure disparities: investigating contemporary NO_2 and $PM_{2.5}$ air pollution, Lane et al. (2022)[13] observed a concentration gradient, from "redlined" (i.e., HOLC category D; on average, most polluted) to "greenlined" (i.e., HOLC category A; on average, least polluted) locations.

The main geographic focus of relevant *ES&T* papers is the U.S. There also have been scholarly investigations in *ES&T* for geographies outside the U.S. For example, *ES&T* studies in China have focused on socioeconomic inequalities related to air pollution emissions and associated gains in gross domestic product (GDP), health effects, and mitigation benefits, as well as equity implications of electric vehicles.[4,14] Regional and socioeconomic disparities were mixed, where high- and low-income populations experienced disproportionate impacts based on season and urbanicity (e.g., high-income, urban wintertime disparities vs high-income summertime disparities across both urban and rural areas).[15] EJ patterns in China may differ from those in the U.S.[16,17] Additional studies in *ES&T* have identified air pollution inequities related to immigrant and low-income status (Greater Toronto, Canada),[18] rural deprivation (British Columbia, Canada),[19] urbanicity (Europe),[20] income (India),[5] and region (India).[21]

Second, researchers conducted source-specific equity analyses. These papers investigate, for example, whether reducing emissions from a specific source will reduce inequities. Patterns of disproportionate exposure have been linked to multiple source sectors, such as heavy and extractive industries,[19,22] toxics-emitting industries;[1] agriculture,[23] transportation[3,24,25] and electricity generation.[26]

Third, *ES&T* articles have investigated equity aspects of emission reduction strategies, including climate-mitigation strategies. Increasingly, there are calls for evidence that moves beyond characterization, that can support action and intervention to address disparities.[27] A key finding is that reducing exposure disparities is not a guaranteed cobenefit of either air quality or climate policy;[28−33] equity outcomes depend in part on which sources are controlled, and where, rather than only on the magnitude of emission-reductions. For example, retrospective studies in the U.S. have shown that air quality has improved substantially over the past 30 years, linked to environmental regulation, yet these benefits have not been shared equally, with relative exposure disparities often persisting for communities of color.[31,34,35] Similarly, prospective studies indicate that traditional regulatory approaches to air quality and climate policy that do not explicitly take into account equity (i.e., policies that do not target reductions in currently overburdened communities) can simultaneously reduce emissions and average exposures, yet not reduce relative disparities.[28,29,33,36] However, through targeted approaches to emissions reduction and more systemic transformations (e.g., large scale energy transition), there are opportunities to simultaneously advance air quality, equity, and climate goals.[30,31,37,38]

In summary, *ES&T* papers on this topic estimate levels of air pollution inequity and inform interventions to reduce exposure disparities. They incorporate various methodological innovations, including mobile measurements, satellite data, conventional air pollution models, and reduced complexity models.[39] The increasing spatial coverage of air quality data from low-cost sensors,[40] satellite remote sensing,[41,42] and mobile monitoring[8,15] have uncovered variations in air quality and exposure at finer scales and clarified the impact of specific source types on communities. *ES&T* has published many papers on satellite-based empirical models, which are useful for understanding disparities.[43−47] This research has demonstrated how diverse data (e.g., land-use information, satellite estimates of column-total pollution and remote sensing of land cover, regulatory monitoring, low-cost sensors, sensor networks, and mobile monitoring) can be combined using statistical approaches (regression, fusion, machine learning, etc.) to make concentration predictions with high spatial precision and coverage, often with strong temporal resolution. The ability to model air quality more rapidly and at higher resolution has enabled more systematic investigation of process drivers (both physical and social) of pollution distribution.[21,48]

While the studies featured in this viewpoint were largely data-driven equity analyses, community-engaged research (CER) and community-based participatory research (CBPR) methods have long been central to air quality environmental justice research,[49−51] underscoring the links between procedural (e.g., how decisions are made) and distributive (e.g., who experiences risks and benefits) justice. The wider availability of consumer-grade monitors has empowered many communities to undertake their own monitoring, documenting elevated air pollution levels or hot spots to advocate for substantive air pollution mitigation. One example of community-academic collaboration involves codesign of deployment strategies to better support community goals (e.g., data that could be used in legal advocacy) and address persistent data gaps.[52−54] Community-driven studies on air pollution equity and justice can be more prominently featured in *ES&T* given the importance of CER and CBPR within restorative justice movements.

Future research needs include the following: expanding the range of pollutants considered (including legacy and emerging contaminants that are not currently regulated), accounting for cumulative impacts, and focusing on a wider range of study sites, particularly in the Global South. Improved approaches to investigate combined climate and health equity impacts are required to help predict and shape such impacts in real time. Importantly, studies are needed that propose and test "solutions" (e.g., policy options; climate and air-quality

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Environ. Sci. Technol. XXXX, XXX, XXX−XXX

interventions), not just document "problems" (e.g., risk disparities). A new generation of geo-stationary satellites provides dramatic improvements in spatiotemporal variability of observations. Future research can use these satellite data and other novel methods (e.g., mobile monitoring) to connect policy actions (e.g., emission reduction strategies) with changes in greenhouse gas emissions, air pollution, and equity.

Lastly, studies commonly made direct recommendations for closing equity gaps, such as cogovernance of emission mitigation along international supply chains;[14,21,55] localized mitigation strategies for overburdened communities;[56,57] and greater reliance on equity-relevant, spatially resolved data (<100m resolution) to better inform source- and pollutant-specific policy interventions. Future studies could provide retrospective or counterfactual analyses of how equity-focused policy has or has not been effective in protecting the most vulnerable populations around the world. Studies highlight the diversity of vulnerabilities across countries and municipalities, reiterating the need for tailored and culturally relevant solution building to eliminate air pollution inequities.

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Notes

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Environ. Sci. Technol. XXXX, XXX, XXX−XXX