POLICY FORUM

ENVIRONMENTAL JUSTICE

Air quality policy should quantify effects on disparities

New tools can guide US policies to better target and reduce racial and socioeconomic disparities in air pollution exposure

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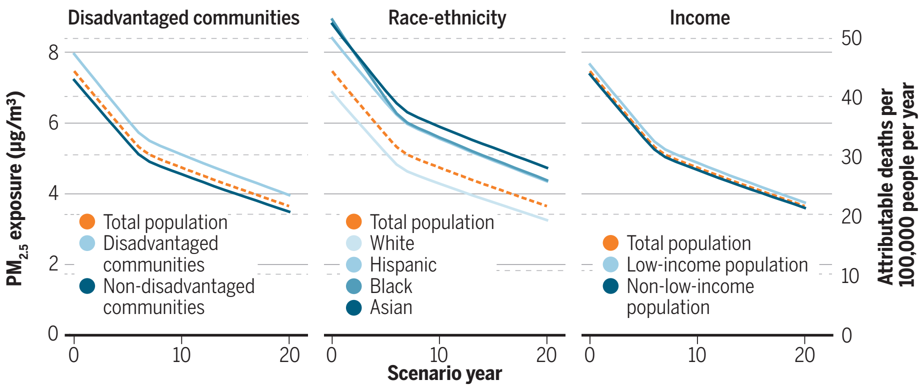
In countries around the world, exposure to environmental pollutants commonly is unequal across communities, leading to disparities in harm to human health. Often those facing the highest burdens have lower socioeconomic status and are from historically marginalized groups. Although these inequities are being increasingly recognized, eliminating them has proven difficult. In the United States, the Biden Administration's Justice40 Initiative uses the Climate and Economic Justice Screening Tool (CEJST) to identify disadvantaged communities and prioritize them for government programs and funding based on climate and environmental burdens and socioeconomic indicators. We found that although application of CEJST to guide ambient air pollution emission reductions may eliminate the modest exposure disparities by income and for disadvantaged communities, it may not ameliorate the frequently larger disparities by race-ethnicity. Effectively reducing or eliminating exposure disparities will require regulatory decision-makers to measure and report exposure disparities and assess how proposed policies may affect those disparities.

Ambient air pollution is one of the largest environmental risk factors in the United States, causing an estimated 100,000 premature deaths each year, which corresponds to billions of dollars of health damage each day. Although there have been substantial improvements in ambient air quality in recent decades, disparities in exposure have been remarkably persistent (*1*–*4*), suggesting that new approaches beyond the Clean Air Act and other current regulatory mechanisms are needed to reduce these disparities.

In most cases, the largest exposure disparities are by race-ethnicity, which represent a major environmental injustice. Disparities by other attributes (such as income, age, or education) are relevant but are generally much smaller than and statistically distinct from disparities by race-ethnicity (*3*, *4*). Disparities by race-ethnicity exist in every US state, are seen for nearly all air pollutants and categories of emission sources, and have continued across multiple decades (*3*, *5*, *6*). An important underlying cause is racist policy, land-use planning, and regulatory actions (for example, refusal to offer loans and insurance, "redlining," exclusionary zoning, racial covenants, and decades of disparities in regulatory oversight and enforcement) (*7*–*11*).

Predicted $PM_{2.5}$ exposure and attributable deaths

Average $PM_{2.5}$ exposure (left *y* axis) and attributable deaths (right *y* axis) for "business as usual" scenario, disaggregated by disadvantaged community status, race-ethnicity, and income.



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The Justice40 Initiative is a cornerstone of the Biden Administration's effort to address environmental injustice. Its stated goal is that disadvantaged communities that are marginalized, underserved, and overburdened by pollution receive at least 40% of the overall benefits of certain federal investments. Justice40 is using CEJST to inform allocation of tens of billions of dollars, across hundreds of government programs (such as in clean energy and transportation, workforce development, and remediation of legacy pollution) [see supplementary materials (SM)]. However, the extent to which this strategy addresses environmental disparities remains unstudied.

We investigated how using CEJST to target emission reductions might affect ambient air pollution exposures and exposure disparities. We found that application of CEJST may not ameliorate (and in some cases may increase) exposure disparities by race-ethnicity. This outcome likely reflects that CEJST does not explicitly use race-ethnicity as a factor to define disadvantaged communities. This finding also highlights the broader problem of insufficient investigation of how existing or proposed policies will affect disparities in environmental outcomes.

Our calculations predict annual-average particulate matter ($PM_{2.5}$; particles in the air with diameter 2.5 μm or smaller) concentrations throughout the contiguous United States according to the emissions of each chemical component of $PM_{2.5}$ [primary (directly emitted) and secondary (formed in the atmosphere from precursors, such as ammonia or nitrogen dioxide)] and from each sector of the economy. We focused on $PM_{2.5}$ because of the large monetized health damages (the largest of any ambient air pollutant); because it has an intermediate level of disparities among air pollutants (*3*); because it is one of the measures used in CEJST to identify disadvantaged communities; and because of the availability of data and models (see SM). We considered three future 20-year emission scenarios. In the "business as usual" (BAU) scenario, historical rates of emissions and emission changes (by $PM_{2.5}$ component and sector of economy) are continued into the future (by using linear extrapolation) as though the Justice40 initiative had not been implemented. This BAU is a plausible estimate for the isolated effects of future air pollution regulatory approaches. For the second and third scenarios, we modeled that in disadvantaged communities, the Justice40 initiative leads to a doubling or quadrupling, respectively, of historical rates of emission reduction. (Herein, the term "disadvantaged communities" refers to Census Tracts identified by CEJST.) In all scenarios, non-Justice40 communities experience historical BAU reduction rates. The doubling and quadrupling scenarios represent aggressive or very aggressive emission reductions in disadvantaged communities (see SM). Those additional emission reductions in disadvantaged communities could reflect, for example, upgrading, modernizing, or retrofitting older equipment; more stringent monitoring and enforcement of existing requirements; efficiency improvements; pollution-control devices; and granting of fewer permits for new sources. If in reality Justice40 turns out to be less spatially targeted than the doubling or quadrupling scenarios, then the true outcome from Justice40 may be between the BAU and the doubling or quadrupling scenarios; in that case, core conclusions of this article would still hold.

We analyzed the effect of these scenarios on human exposure using a reduced-complexity chemical transport model [Intervention Model for Air Pollution (InMAP)] to predict how changes in emissions would alter $PM_{2.5}$ concentrations and concentration disparities. InMAP simulates the fate and transport of anthropogenic emissions leading to primary and secondary $PM_{2.5}$ and provides national coverage at high spatial resolution, as small as 1 km in urban centers. Future emissions were estimated on the basis of the historical National Emission Inventories from the US Environmental Protection Agency (EPA). The population and demographic composition in the baseline year were applied into the future. Exposure to $PM_{2.5}$ contributes to morbidity and premature mortality by increasing rates of heart attack, stroke, lung cancer, respiratory infections, and more. In this work, we only considered increases in mortality, which contributes most of the monetized health impacts of ambient air pollution. We do not expect the core conclusions to change if we were to consider additional health endpoints. We assessed disparities (absolute and relative differences in population-average exposures between a demographic group and the overall population) (see SM) (*1–4*, *12*) for four groups: (i) people living in disadvantaged communities; (ii) people with low income (people in households with incomes at or below two times the poverty level); (iii) people of color [all people except non-Hispanic (NH) whites]; and (iv) the most exposed racial-ethnic group of the four groups considered (NH white, NH Black, NH Asian, and Hispanic).

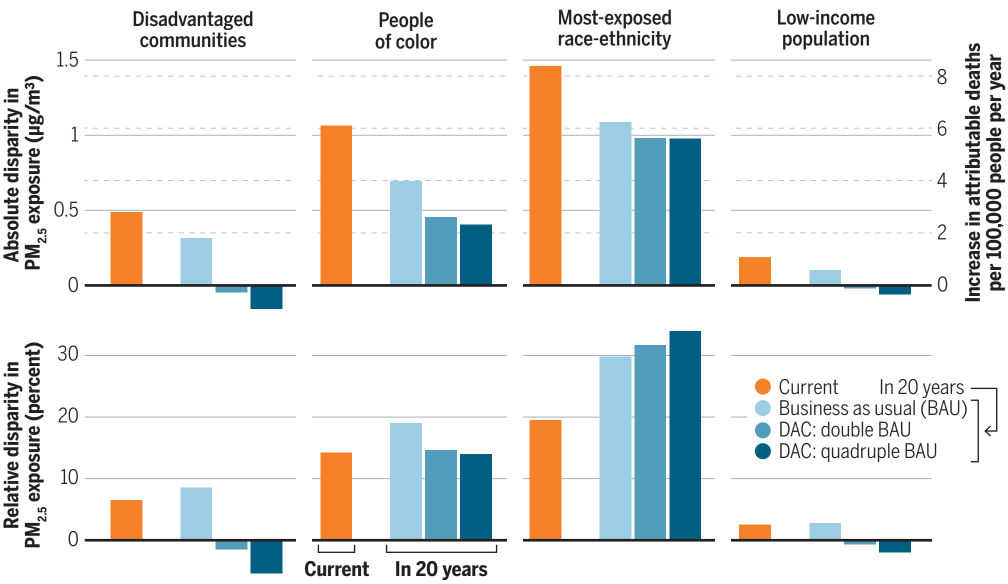
In the current state [baseline year (see the first figure, year "0"), before applying any new emission-reductions], InMAP results indicate that average exposure to $PM_{2.5}$ is ~14% higher for people of color than for the overall population. The Black population is currently the most exposed racial-ethnic group (disparity relative to population-average: Black, +20%; Asian, +14%; Hispanic, +10%; white, –7%). Disparities by race-ethnicity are larger than disparities for disadvantaged communities (~6% higher than population-average) or by low-income status (~3% higher than population-average). Those results from InMAP are consistent with findings from an empirical model (see SM) (*3*).

As expected, for all three emission reduction scenarios, all demographic groups experience cleaner air in the future. However, two key findings emerge with respect to exposure disparities. First, under BAU, exposure disparities by race-ethnicity persist. As emission reductions occur, $PM_{2.5}$ concentrations decrease at slightly different rates for different groups. For example, InMAP predicts that Asian people will soon become the most exposed group. However, concentrations remain higher than average for Black, Hispanic, and Asian populations (see the first figure). In addition, racial-ethnic disparities persist and remain much larger than disparities for disadvantaged communities and for low-income households (see the first figure). This finding underscores that new regulatory strategies for emission reduction (deviating from BAU) are needed to reduce emissions in ways that also address exposure disparities.

Second, the two scenarios with enhanced emission reductions in disadvantaged communities eliminate absolute and relative disparities for disadvantaged communities and for low-income populations. Yet these scenarios do not reduce the comparatively larger relative disparities by race-ethnicity (although they do decrease absolute disparities) (see the second figure). Scenarios two and three increase the relative exposure disparity for the most exposed racial-ethnic group (see the second figure), relative to present-day and the BAU future. The result suggests that the enhanced emission-reductions in disadvantaged communities has more exposure benefits for the overall population than for the most exposed racial-ethnic group. This outcome could be interpreted as

Disparities in $PM_{2.5}$ exposure and deaths for the three future scenarios

Disparities relative to the population-average, for "business as usual" (BAU) scenario and when emission-reductions in disadvantaged communities (DAC) are double or quadruple the BAU rate. Top row, absolute disparities; bottom row, relative disparities.



GRAPHIC: D. AN-PHAM/*SCIENCE*

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undermining a core environmental justice goal: eliminating exposure disparities by race-ethnicity.

Our findings are robust to several sensitivity analyses, including considering alternative methods and outcomes (see SM). Results from the sensitivity analyses indicate that only with enhanced emission reduction in or upwind of communities of color will both absolute and relative racial-ethnic disparities in exposure to $PM_{2.5}$ air pollution be reduced. Our findings regarding BAU are also supported by concentration forecasts by using a high-resolution empirical-model (see SM), suggesting that results here for BAU are not strongly dependent on the emission inventory nor on InMAP.

Failure of CEJST-directed emission reductions to directly address the largest source of exposure disparities (those by race-ethnicity) would very likely undermine the Biden Administration's environmental justice goals. Compared with the national average, disadvantaged communities identified by the current CEJST are composed of only modestly higher proportions of people of color (especially Black, Hispanic, and Indigenous populations) and low-income populations (see SM). This decision to exclude race-ethnicity as an indicator in CEJST reflects in part concern about potential political and legal challenges if a federal policy or tool explicitly includes race as a factor for guiding Justice40 investments (for example, see the 29 June 2023 Supreme Court decision disallowing use of race as a factor in college admission decisions). Nevertheless, present-day racialized exposure disparities reflect in part decades of racist policy and practice (*8*, *10*, *11*). Because legacies of race-based actions helped create this problem, solving it is made more difficult if the government does not consider, or bars itself or is legally barred from considering, information about the racial makeup of communities as part of its decision-making and action. Tackling the challenges posed here will require systematic assessments of how proposed regulatory strategies and tools would affect exposure disparities and whether racial-ethnic exposure disparities can be eliminated within a reasonable time frame (for example, in less than a decade). Our analysis provides a proof of concept of this sort of regulatory scenario testing and evaluation and demonstrates that new tools such as InMAP enable such analyses (*6*, *13*, *14*).

Air quality regulation can be more effectively designed to improve overall air quality while also eliminating air pollution exposure disparities by race-ethnicity. This dual goal can be supported by regulatory impact analyses for air pollution that quantify whether and how relevant policies will not only affect air quality but also reduce absolute and relative exposure disparities. For example, the EPA's "Status and Trends" reports, other regulatory information, and accountability studies should quantify disparities or exposures for overburdened communities. Although politically challenging, emission reduction efforts must address disparities by race-ethnicity if we wish to uphold everyone's right to breathe clean air.

Overall, Justice40 aims to address multiple challenges, not just exposure to $PM_{2.5}$. Although we found that using the current CEJST to target emission-reductions will not eliminate racial-ethnic disparities in $PM_{2.5}$ exposure and attributable mortality, there likely will be other environmental and justice benefits from Justice40, including economic opportunities from investments and building resilience to climate change in disadvantaged communities. At the same time, disadvantaged communities, as defined by CEJST, comprise ~34% of the US population. The goal of delivering 40% of benefits to 34% of the population represents a modest deviation from an exactly proportional share of the Justice40 benefits. The finding that relative exposure disparities by race-ethnicity will not decrease (and may increase) with use of CEJST indicates that additional and more targeted actions will be needed to end racial-ethnic exposure disparities. For example, future iterations of CEJST could use a different set of locations or could aid in better targeting investments (that is, differentiating among CEJST locations). Other policies, including by states (such as in California, New Jersey, and Washington), also aim to address environmental disparities; the effectiveness of those policies at reducing disparities should also be evaluated as we have done here.

Our analysis has several implications. First, the EPA and other agencies should quantify how proposed programs, regulations, and decision-making tools would affect environmental justice outcomes, especially exposure disparities by race-ethnicity. If possible, this should be undertaken when such initiatives are being developed, not after. Previously, in the realm of air quality, this type of national analysis would have been difficult to do because of the computation costs and spatial-resolution limitations of many air quality models. However, recently developed air quality models such as InMAP make this type of analysis faster and easier to carry out and provide national coverage at much higher spatial resolution than many conventional models. One can do similar types of calculations with conventional models, but their higher computational cost hinders analysis, and their coarser resolution may mean that the results would underestimate total disparities. One can use reduced-complexity models to rapidly examine the impacts of multiple policy options on exposure disparities to help to design optimal control strategies.

Second, our prior research indicates that in theory, location-based approaches can efficiently eliminate exposure disparities by race-ethnicity within a reasonable time frame (*12*). We did not find a trade-off between reducing disparities and reducing overall air pollution averages. More work is needed to identify the most effective policies and strategies for achieving location-specific emission reductions. This could identify a new set of locations or a more targeted approach to emission reductions in those locations.

Last, current approaches in the Clean Air Act have been effective at reducing average concentrations and absolute exposure disparities (*15*), but relative disparities are generally ignored and have persisted (*1–4, 12*). If, as our results suggest, neither BAU nor the present CEJST can eliminate racial-ethnic exposure disparities, then new regulatory strategies are needed to advance environmental justice goals. ■

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SUPPLEMENTARY MATERIALS

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