Pollution clouds the mind: Evidence from real-time monitoring in Kenya

Article

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Exposure to fine particulate matter during cognitive assessments lowered adult cognitive performance in Kenya, and coarser pollution measures missed much of this short-run variation.

Editor's note: For a broader synthesis of themes covered in this article, check out our VoxDevLit on ***Air Pollution*** **(https://voxdev.org/voxdevlit/air-pollution)**.

Air pollution is usually discussed as a threat to physical health. Fine particulate matter, or PM2.5, is linked to mortality, respiratory disease, cardiovascular illness, and neurological disorders. These harms are especially salient in low- and middle-income countries, where urbanisation, traffic growth, industrial activity, waste burning, and biomass combustion often coincide with limited monitoring and regulatory capacity.

But air pollution may also impose a more immediate and less visible cost: it may make it harder for people to think clearly.

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This matters for development policy. Cognitive performance is central to learning, work, financial decisions, health decisions, and productivity. If pollution affects cognition not only over the life cycle but also in the moment – during a test, a work task, a business transaction, or a health decision – then the economic costs of pollution may be larger than standard health-focused estimates suggest.

In new research, we study this question using data from Kenya that links real-time air pollution exposure to adult cognitive performance (**Ma et al.** ***forthcoming*** **(https://www.sciencedirect.com/science/article/pii/S0167629626000640)**). We use the fifth round of the Kenya Life Panel Survey, a long-running study following adults originally enrolled in a school-based deworming programme in western Kenya. In the most recent survey round, more than 5,000 adults completed a detailed cognitive assessment while field officers carried portable air quality monitors. These monitors recorded PM2.5 during the assessment itself, allowing us to measure the pollution environment at the time and place where cognition was being tested.

Measuring pollution where people are actually thinking

A key challenge in studying pollution and cognition is exposure measurement. Many studies assign pollution exposure using satellites, reanalysis products, or fixed monitoring stations. These sources are valuable, especially where monitoring networks are sparse, but they can miss local and short-run variation. A person's actual exposure during a cognitive task can differ sharply from the average pollution level in a large grid cell or from readings at a monitor many kilometres away.

Our study instead measures PM2.5 close to the respondent during the cognitive assessment. Field officers were physically present with respondents, and the portable Atmotube monitors recorded minute-level PM2.5, temperature, and humidity. This allows us to align pollution exposure with the precise window during which cognitive performance is measured.

The Kenyan setting is useful because pollution varies meaningfully across places and seasons, while average exposure levels are not extreme by global standards. Mean PM2.5 exposure during testing was around 15 micrograms per cubic metre. This is above the World Health Organization guideline and above the current US annual standard, but far below levels observed in some of the world's most polluted cities. The setting therefore allows us to ask whether short-term pollution can affect cognition even at levels that may appear moderate relative to more heavily polluted urban environments.

Figure 1. Air pollution exposure varied substantially across locations and months in Kenya

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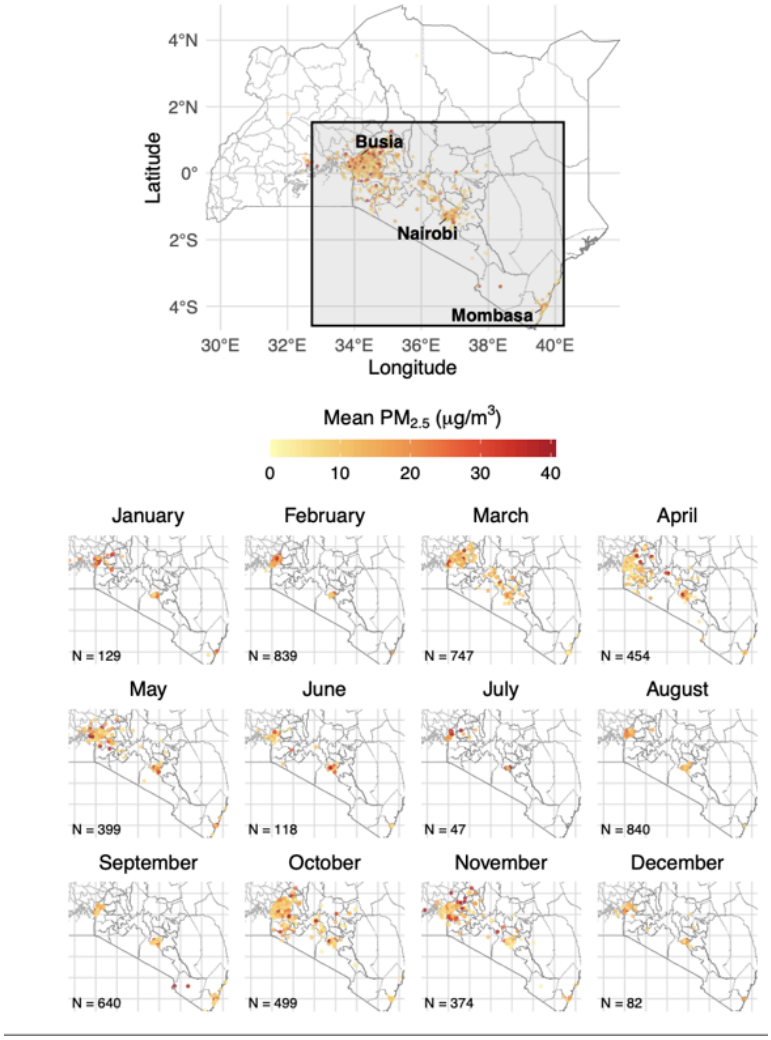

Notes: Each point shows mean PM2.5 exposure during an individual's cognitive assessment, measured using portable Atmotube monitors.

Higher pollution during testing is associated with lower cognitive performance

We find that higher PM2.5 exposure during the cognitive assessment is associated with lower cognitive performance. In our preferred specification, a 10 microgram per cubic metre increase in contemporaneous PM2.5 is associated with a 0.03 standard deviation decline in general cognitive ability.

To interpret the magnitude, this effect is comparable to the cognitive decline associated with roughly one year of age in the same sample. Larger short-run pollution increases imply larger losses: a 30–40 microgram per cubic metre increase corresponds to an estimated 0.09–0.12 standard deviation decline in cognitive performance.

The empirical strategy compares respondents tested under different pollution conditions while accounting for geography, time of day, day of week, month, temperature, humidity, interview setting, and respondent characteristics. The intuition is simple: we ask whether people perform worse when pollution is higher than usual for the place and time in which they are tested.

Figure 2. Cognitive performance falls when pollution is higher than usual for a given place and time

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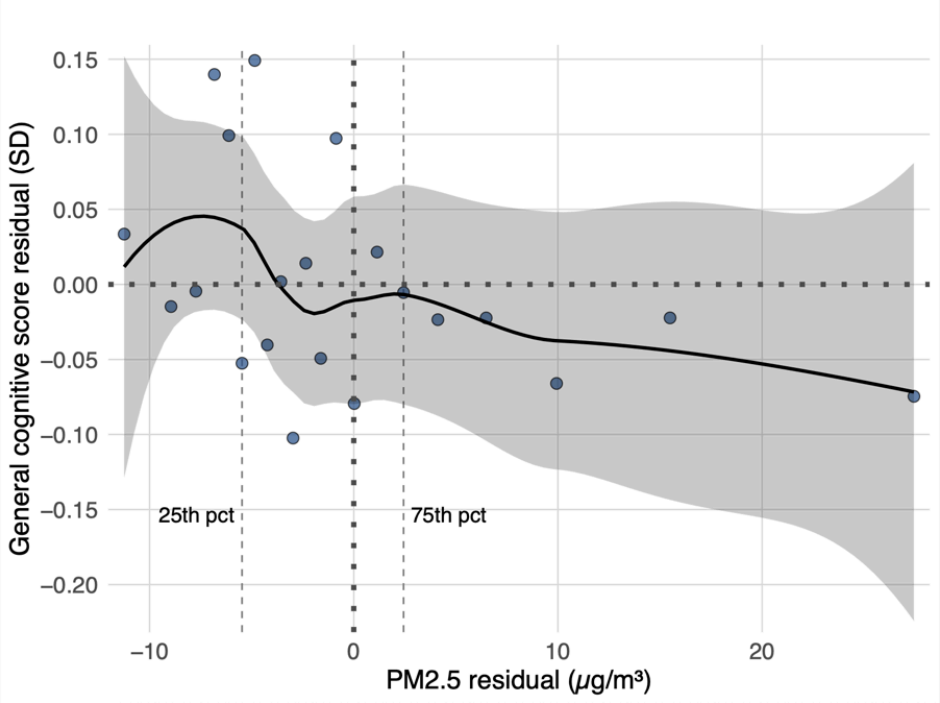

Notes: The figure plots residualised cognitive performance against residualised PM2.5 exposure, after accounting for geographic and temporal fixed effects.

The decline is not concentrated equally across all domains. We find clearer negative associations for memory, executive function, and visuospatial skills, while effects on orientation and language are smaller and not statistically significant. This pattern is consistent with the idea that pollution may be especially disruptive for tasks requiring attention, working memory, and flexible reasoning.

Pollution spikes may matter, not only average exposure

The relationship between pollution and cognition appears stronger at higher exposure levels. In binned models, cognitive performance declines more at higher PM2.5 ranges relative to exposure below 10 micrograms per cubic metre. For example, relative to the lowest exposure category, estimated declines reach 0.086 standard deviations at 30–40 micrograms per cubic metre and 0.14 standard deviations above 40 micrograms per cubic metre, though some bin-specific estimates are imprecise because fewer observations fall in the highest exposure ranges.

This point matters for policy. Air quality regulation often focuses on annual averages or daily thresholds. But if cognition is affected by short-run spikes, then policies that reduce temporary high-exposure episodes may have benefits even when average pollution levels appear moderate.

Coarser pollution measures can miss short-run cognitive effects

The most distinctive contribution of the study is that we compare several ways of measuring PM2.5 in the same sample and specification. In addition to portable Atmotube monitors, we construct exposure measures from CAMS EAC4 reanalysis, MERRA-2 reanalysis, and PurpleAir fixed-site monitors.

The different measures do not line up perfectly. PurpleAir has the strongest correlation with Atmotube exposure, while CAMS EAC4 is more weakly correlated and MERRA-2 aligns least well. In the paper, the correlation with Atmotube is 0.396 for PurpleAir, 0.284

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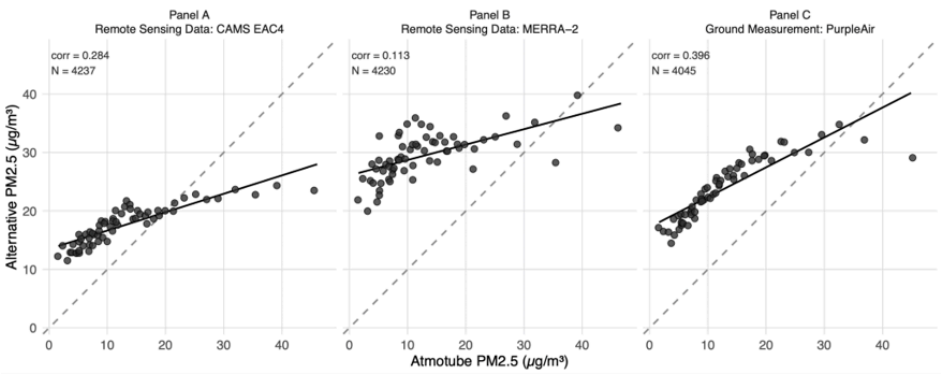
for CAMS EAC4, and 0.113 for MERRA-2.

Figure 3. Pollution measures differ substantially depending on the data source



Note: This figure compares portable Atmotube readings during cognitive assessments with CAMS EAC4, MERRA-2, and PurpleAir measures matched to the same respondents.

These measurement differences affect the estimated pollution-cognition relationship. Estimates using Atmotube exposure are consistently negative and statistically significant. PurpleAir also produces negative estimates when respondents are matched to nearby monitors. By contrast, reanalysis-based measures produce much weaker or differently signed estimates.

This does not mean one pollution measure is always best. Reanalysis products are useful for broad coverage and may be appropriate for studying long-run ambient exposure. Fixed monitors can capture local ambient conditions when networks are dense. But for short-run cognitive effects, exposure measured at the time and place of the task appears to be especially important.

More educated respondents appear more affected

We also examine whether pollution effects differ across groups. The strongest pattern is by education. Respondents with at least some secondary schooling show larger cognitive declines when PM2.5 rises, while the estimated effect among less educated respondents is close to zero. In our estimates, individuals with at least some secondary schooling experience an additional 0.059–0.062 standard deviation decline in general cognition per 10 microgram per cubic metre increase in PM2.5, relative to those with less schooling.

This result should be interpreted carefully. It does not mean less educated individuals are not harmed by pollution. They may face greater lifetime exposure and fewer resources to avoid pollution. Instead, one interpretation is that more educated respondents may be more engaged in cognitively demanding tasks and therefore have more performance to lose during acute pollution shocks. Another possibility is differential adaptation: people who are less chronically exposed to high pollution may be more vulnerable to short-run spikes. These mechanisms remain speculative and deserve future study.

Figure 4. The pollution-cognition relationship is steeper among more educated respondents

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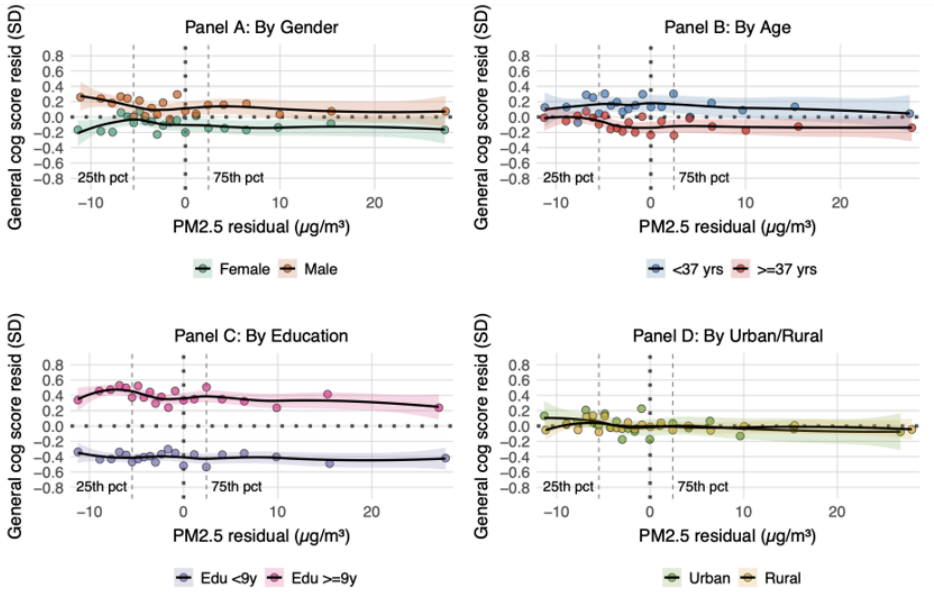

Notes: This figure plots residualised cognitive performance against residualised PM2.5 exposure separately by gender, age group, any secondary schooling, and urban/rural status.

Clean air is human-capital policy

These findings suggest that clean air should be viewed not only as health policy, but also as human-capital policy.

First, governments and donors should invest in better pollution monitoring, especially in low-resource settings where fixed monitoring networks remain sparse. Without sufficiently local and time-specific measurement, important exposure variation may go undetected, and the economic burden of pollution may be underestimated.

Second, policy should pay attention to short-run exposure spikes, not only long-run averages. Temporary increases in pollution may matter for school performance, workplace productivity, health decisions, and other cognitively demanding activities.

Third, targeted mitigation may be valuable in settings where cognition matters most. Mobile air quality alerts, better ventilation, portable filtration in schools and workplaces, reduced waste burning, dust control, and traffic management could all help reduce exposure during high-stakes periods. In some settings, scheduling cognitively demanding tasks away from predictable high-pollution windows may also be a low-cost adaptation strategy.

Air pollution is often framed as a trade-off between environmental quality and economic growth. But if pollution directly reduces people's ability to think, learn, work, and make decisions, that trade-off is incomplete. Cleaner air may support not only better health, but also better human capital.

References

Ma, X, M Layvant, E Miguel, E Ochieng, A Pillarisetti, and M Walker (forthcoming), "**Impacts of contemporaneous air pollution exposure on cognitive performance in Kenya (https://www.sciencedirect.com/science/article/pii/S0167629626000640)**," *Journal of Health Economics*.

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