

This is a repository copy of *Transdisciplinary Research as a Means of Protecting Human Health, Ecosystems and Climate by Engaging People to Act on Air Pollution*.

White Rose Research Online URL for this paper:

<https://eprints.whiterose.ac.uk/id/eprint/209693/>

Version: Accepted Version

Article:

Medcalf, Alexander James orcid.org/0000-0002-8498-5075, West, Sarah Elizabeth orcid.org/0000-0002-2484-8124, Buker, Patrick et al. (17 more authors) (2024)

Transdisciplinary Research as a Means of Protecting Human Health, Ecosystems and Climate by Engaging People to Act on Air Pollution. CABI One Health. ISSN: 2791-223X

<https://doi.org/10.1079/onehealthcases.2024.0002>

Reuse

This article is distributed under the terms of the Creative Commons Attribution (CC BY) licence. This licence allows you to distribute, remix, tweak, and build upon the work, even commercially, as long as you credit the authors for the original work. More information and the full terms of the licence here:

<https://creativecommons.org/licenses/>

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.



ONE HEALTH CASES

February 2024

Transdisciplinary Research as a Means of Protecting Human Health, Ecosystems and Climate by Engaging People to Act on Air Pollution

Air pollution harms the health of humans, nature and wildlife, agricultural crops and livestock and the climate, while One Health approaches must account for local knowledge, cultural practices and priorities. This case trialled a co-created transdisciplinary approach in Kenya that used techniques such as interviews, storytelling and music to ascertain community perceptions of air pollution, boost understanding and empower people to demand policy makers act to clean up their air.

Authors: Patrick Büker¹, Sarah E. West², Cressida J. Bowyer³, William Apondo⁴, Steve Cinderby², Cindy M. Gray⁵, Matthew Hahn⁶, Fiona Lambe⁷, Miranda Loh⁸, Alexander Medcalf⁹, Cassilde Muhoza⁴, Kanyiva Muindi¹⁰, Timothy Kamau Njoora¹¹, Marsailidh M. Twigg¹², Charlotte Waelde¹³, Anna Walnycki¹⁴, Megan Wainwright¹⁵, Jana Wendler¹⁶, Mike Wilson¹⁷ and Heather D. Price¹⁸

Affiliations: ¹Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn, Germany

²Stockholm Environment Institute, University of York, UK

³University of Portsmouth, UK

⁴Stockholm Environment Institute, Nairobi, Kenya

⁵University of Glasgow, Glasgow, UK

- ⁶Independent theatre for development practitioner, London, UK
⁷Stockholm Environment Institute, Stockholm, Sweden
⁸Institute of Occupational Medicine, Edinburgh, UK
⁹University of York, York, UK
¹⁰African Population and Health Research Center, Nairobi, Kenya
¹¹Kenyatta University, Nairobi, Kenya
¹²UK Centre for Ecology and Hydrology, Lancaster, UK
¹³Coventry University, Coventry, UK
¹⁴International Institute for Environment and Development, London, UK
¹⁵Durham University, Durham, UK
¹⁶Playfuel Games CIC, Manchester, UK
¹⁷Loughborough University, Loughborough, UK
¹⁸University of Stirling, Stirling, UK

© The Authors 2024

Table of Contents

| | |
|---|----|
| Abstract | 2 |
| What is the Incremental Value that Makes this a One Health Case?..... | 3 |
| Learning Outcomes..... | 3 |
| Background and Context | 3 |
| Transdisciplinary Process..... | 4 |
| Project Impact | 6 |
| Project Outlook and Recommendations..... | 10 |
| Conclusions | 12 |
| Group Discussion Questions | 12 |
| Further Reading | 12 |
| References | 13 |

Abstract

Air pollution harms the health of humans, nature and wildlife, agricultural crops and livestock and climate. As a result, it hinders the attainment of Sustainable Development Goals 3 (Good Health and Wellbeing), 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities) and 13 (Climate Change). In order to improve human and (agro-)ecosystem health, One Health approaches for better air quality must account for local knowledge, cultural practices and priorities. People with lower socio-economic status often have limited awareness of air pollution yet are affected most through personal exposure and increased food prices. This case trialled a new, co-created transdisciplinary approach to air pollution awareness raising in the Mukuru community in Nairobi, Kenya. The pilot study used interviews, storytelling, participatory mapping, theatre, playful activities and music with the aim of discovering affected communities' perceptions of air pollution, increasing understanding and empowering people to demand that policy makers develop and implement effective, inclusive air pollution abatement policies.

What is the Incremental Value that Makes this a One Health Case?

This case employed a co-created transdisciplinary approach to air pollution awareness that provided an understanding of people's perceptions of air pollution and ideas for solutions in the informal settlement of Mukuru in the Kenyan capital Nairobi. By boosting awareness and understanding of air pollution and engaging people to demand action from policy makers that leads to cleaner air, it was hoped that the transdisciplinary process would ultimately help improve the health of the local community, agricultural systems and wildlife nearby and the climate.

Learning Outcomes

1. Understand the health risks of air pollution to people, wildlife and the climate.
2. Appreciate the benefits of using a co-creation approach to investigate people's perceptions of air pollution.
3. Comprehend the way the community sees air pollution more holistically than researchers and the advantages of this more holistic approach for developing real-world solutions.

Background and Context

Air pollution harms the health of humans, nature and wildlife, agricultural crops and livestock and the climate. Air pollution is the leading environmental risk factor for human health after sanitation; humans can suffer respiratory illnesses, heart diseases and reduced resistance to infections (potentially including COVID-19), mainly due to particulate matter and ozone, as well as preterm births (Hoek *et al.*, 2013; DeFranco *et al.*, 2016; Ritchie and Roser, 2017; WHO, 2018). Ozone also reduces plant growth and productivity and has been reported to harm biodiversity. Several air pollutants contribute to climate change. As a result, air pollution hinders the attainment of Sustainable Development Goals 3 (Good Health and Wellbeing), 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities) and 13 (Climate Change).

According to the Global Burden of Disease 2015 study (Forouzanfar *et al.*, 2016), fine particulate matter (PM_{2.5}) was linked to an estimated 920,000 premature deaths in Africa each year. Informal settlements are often particularly exposed to outdoor and indoor particulate matter as they tend to be near roads and industries and contain homes with limited ventilation that rely on solid fuels for cooking (Bruce *et al.*, 2000; Shupler *et al.*, 2021). Like many cities in Africa, the Kenyan capital Nairobi has a high percentage of residents living in informal settlements (Goodfellow and Taylor, 2009), where high levels of PM_{2.5} have been recorded (Egondi *et al.*, 2016; Muindi *et al.*, 2016; deSouza, 2020). The city has a population of 4.4 million (KNBS, 2020), with an estimated 60–70% of people living in informal settlements (Beguy *et al.*, 2015).

In the past, interventions that have not accounted for local knowledge, cultural practices and priorities have failed. For example, projects to reduce air pollution exposure by increasing the use of cleaner cookstoves did not improve health (e.g., Rouse, 2000; Mobarak *et al.*, 2012; Mortimer *et al.*, 2017; McCarron *et al.*, 2020). This may have been because air pollution tends to be invisible and may not be as high on people's 'concern agenda' as challenges linked to income and making a living (e.g., Muindi *et al.*, 2014). Top-down interventions often fail and so there is an argument for putting people at the centre of developing the solutions (Rouse, 2000).

This study took the view that solutions should consider the priorities of the local population, ideally offer co-benefits in other areas, and be practical, affordable and coherent with local social and cultural understandings, practices and norms. By increasing affected communities' awareness and knowledge of air pollution, the project also aimed to encourage people to engage with the development of air pollution abatement policies.

The project used various techniques to achieve its aims, including creative methods to bring diverse stakeholders together to identify their own solutions to complex issues (Cinderby *et al.*, 2021). Participatory arts-based methods can use culturally-relevant practices to assimilate and analyse data and foster ownership of research findings (Coemans and Hannes, 2017). Conventional research and planning methods that rely on verbal or written responses may not capture people's perceptions, experiences and

fears that are difficult to verbalise (Brooks *et al.*, 2020). Marginalised groups may not be able to voice their experiences of their environment due to a number of factors, including social, linguistic and spatial disengagement from the mainstream (Olufemi and Reeves, 2004; Finney and Rishbeth, 2006). Using playful approaches to engage with communities can help understand social experience and facilitate collaborative effort (Gauntlett, 2007), as well as empower project participants (Jiang *et al.*, 2020).

Previous studies in informal settlements in Nairobi have used citizen science and portable low-cost particulate matter sensors to explore air pollution (West *et al.*, 2020), low-cost static air quality monitoring and personal exposure monitoring (Twigg *et al.*, 2017) and participatory stakeholder workshops (Dianati *et al.*, 2019).

The study in this current case was the first to explore perceptions of air pollution using mainly arts and humanities methods. It pushed the boundaries between disciplines, between research and action, and between experts by education and experts by experience.

Transdisciplinary Process

This case examines a novel transdisciplinary co-creation research approach that built an understanding of community perceptions and experiences of air pollution as well as proposed solutions (West *et al.*, 2021). The approach used multiple qualitative, participatory and creative methods. Academics and practitioners worked with residents from three neighbouring informal settlements in Kenya – Mukuru Kwa Njenga, Mukuru Kwa Reuben and Viwandani in the Embakasi South and Makadara sub-counties of Nairobi. The settlements are collectively referred to here as Mukuru. The area is home to around 100,000 households, living in small shacks made of sheet metal, with concrete or earth floors. Provision of services is extremely limited (Dianati *et al.*, 2019) and the community suffers significant health problems, including high levels of respiratory disease (Gulis *et al.*, 2004) and cardiovascular diseases that are important causes of death locally (Mberu *et al.*, 2015).

In the first step of the study, researchers and practitioners from Kenya, the UK and Sweden met in Nairobi with representatives from the informal settlement community to set up the AIR Network (Action for Interdisciplinary Air Pollution Research Network) (Fig. 1). The Network included 17 academics from a mix of specialisms such as anthropology, law, creative arts, chemistry, environmental sciences, storytelling, history and geography, and 19 community partners who live and/or work in the informal settlements, including teachers, health workers, visual artists and musicians, as well as local policy makers. Community partners were paid a day rate for their involvement in the project.

The team held a 4-day inception workshop in January 2018. Facilitated by researchers from Kenya and the UK, the meeting included activities to develop a shared understanding of air pollution from different perspectives. Mukuru residents attending included community champions from previous research projects (e.g., West *et al.*, 2020), and artists, school teachers and community health workers who had previously worked with Muungano, a community organisation affiliated to Slum Dwellers International (Muungano wa Wanavijiji, 2018). The residents were encouraged to become co-researchers by helping create project 'ground rules' and a 'contract for interdisciplinary working'. Residents also led a tour of the settlement (Fig. 2.) to establish a common understanding of the environmental challenges residents face, and co-developed four mini-projects on air pollution. These mini-projects were budgeted as flexible funds. Together, workshop participants set up a working group for each mini-project. Each focused on a topic identified by the community members – raising awareness, taking action, engaging with industry and prioritising policies. The projects used a variety of qualitative, participatory and creative methods to explore air pollution, including qualitative interviews, storytelling, participatory mapping, theatre, music and playful activities, such as counter exercises (see West *et al.*, 2021 for more information about each of the methods used). At the end of the study, representatives from each mini-project came together to discuss key emerging themes; each project both collected and disseminated data or information.

Throughout the project, participants filled in reflective diaries that were used to document the project, to evaluate and shape the project and to inform future projects. Participants filled in their diaries using an online form (Google Forms) that could be completed using a mobile phone, answering a series of questions (see Price *et al.*, 2023 for the list of questions).

The AIR Network arranged a one-day celebration event, the Hood2Hood festival, in September 2018 to mark the end of the study and share its outputs. Held at a local football ground, the festival had a stage



Fig. 1. Planning project activities. Image credit Steve Cinderby.



Fig. 2. Tour of Mukuru to understand context. Image credit William Apondo.

and presented stories, theatre and music from the AIR Network project alongside local music acts. Face painting and mural creation engaged children and youth in air pollution issues. Meanwhile, interactive boards near the football ground's entrances enabled the community to comment on the main cause of air pollution in Mukuru, and whose responsibility it is to reduce air pollution. Festival visitors dropped beans into containers made from recycled plastic bottles to vote on the answers provided by other parts of the project. The boards also facilitated conversations around understandings of air pollution.

Project Impact

Outputs from the project included interviews by community representatives with nine stakeholders – a politician, a doctor, a researcher, a teacher, a community health visitor, a cook, a community volunteer, a factory worker, and a car washer, all of whom apart from the doctor and researcher, lived in Mukuru. The interviewees were allowed to tell their own stories as narrative theory asserts that human beings have an innate capacity to organise their world through narratives (Bruner, 1990). They were also asked about the sources, effects of and solutions to air pollution using open-ended questions. Answers were mind-mapped using two layers, one that incorporated all the sources, effects and solutions proposed by interviewees and a second that included contradictory or opposing views to responses in the first layer (see West *et al.* (2021) for these mind maps).

The study's storytelling approaches resulted in digital stories about air pollution made by community members who took photographs around Mukuru and stitched them together with a voiceover into a 2–3 min long piece, drawn and written stories by schoolchildren (Fig. 3), forum theatre performances and legislative theatre performances (Figs. 4 and 5). Forum theatre has an audience of community members who share the oppressions that have been displayed, whereas legislative theatre performances are presented to an audience with policy making influence and powers (Boal, 2008). In both types of theatre the audience can join in as 'spect-actors' (Boal, 2008) and suggest solutions that the actors then push back against to represent the challenges of behaviour or systemic change.

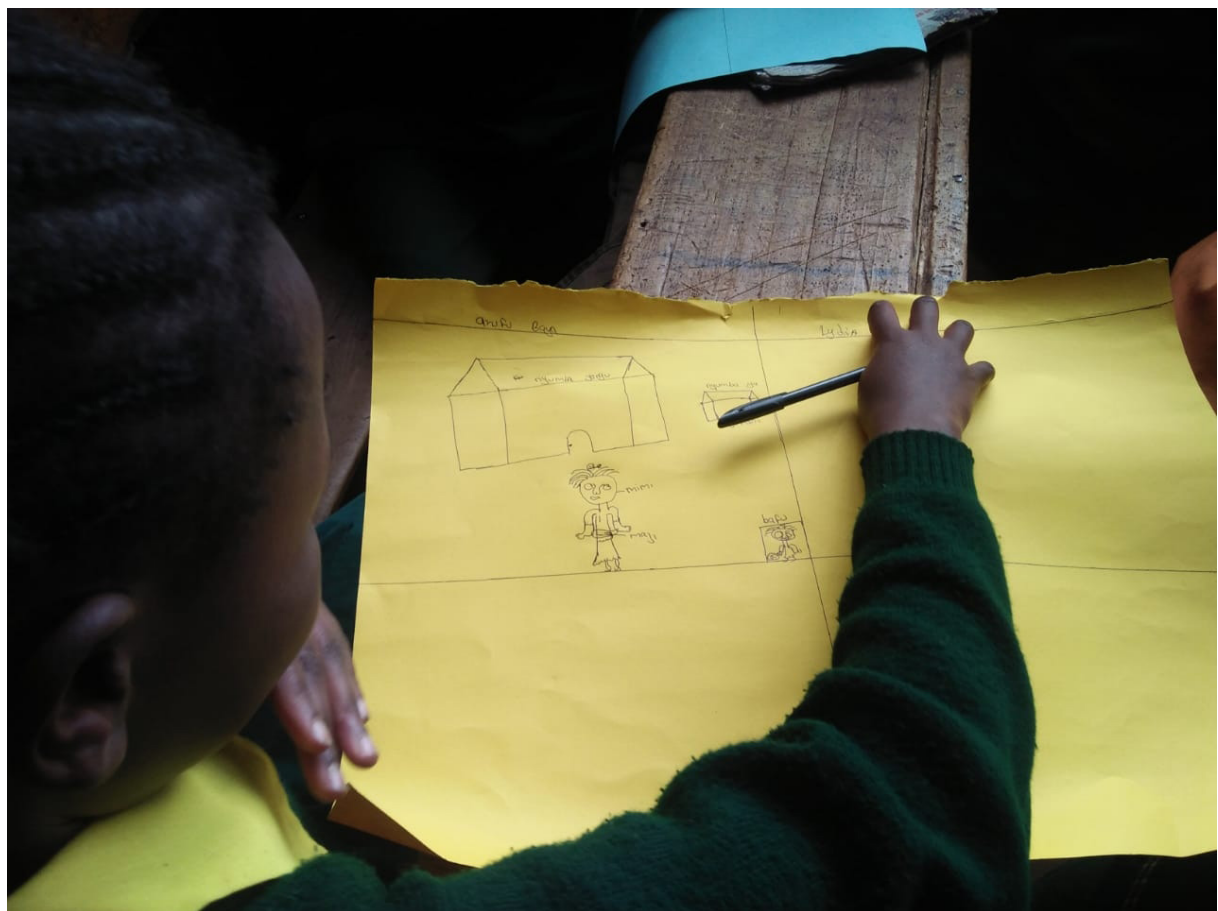


Fig. 3. Starting to create a story. Image credit Cindy Gray.



Fig. 4. Rehearsing a theatre piece. Image credit William Apondo.



Fig. 5. Using theatre techniques to understand perceptions of air quality. Image credit Steve Cinderby.

The forum theatre performances concerned air pollution and poor lung health and took place at a market, community centre and football ground. During the forum theatre, several Mukuru residents commented that they were beginning to see that they had 'normalised the abnormal' in their daily lives. The first legislative theatre piece focused on occupational exposure to air pollutants such as dust and gases from machinery while working in the factories bordering Mukuru. The piece depicted a worker experiencing severe respiratory problems. The second legislative theatre piece showed firefighters arriving to deal with a blaze in a home in Mukuru but running out of water and having to let the fire burn longer and create

more air pollution, as well as damage property and risk lives. After the legislative theatre performances, a workshop brought together 40 people including the actors, spect-actors and other audience members. Some of these participants had expertise in policy making from local- to county-level in the Environmental Protection, Health, Waste Management and Urban Planning departments.

The participatory mapping saw artists from the local Wajukuu Arts organisation (Available at: <https://wajukuuarts.wordpress.com/>, accessed 3 February 2024) create a large map for the three areas in Mukuru (Kwa Reuben, Kwa Njenga, Viwandani) featuring points of interest likely to be meaningful to residents. Each map was taken to the appropriate area and passers-by attached stickers to show where they experienced air pollution. They were also asked what the source of the pollution was and how to reduce it. More than 500 residents took part.

Several of the community researchers composed original musical arrangements and lyrics for the AIR Network and made music videos to accompany them. The lyrics were written in response to community views heard at the January workshop and during the mapping, storytelling and theatre activities. The authors and performers of creative works were given due credit for their input. One of the songs, 'Mazingira' by the Mukuru Kingz was played on national radio and television and is likely to have reached three million people. Some of its lyrics highlighted government inaction on air pollution in Mukuru – '...there's no way you care... what services are you providing—yet we pay taxes!'

The Mukuru Kingz also talked about the AIR Network on local TV and radio, and performed the song live at the World Environment Day concert in Nairobi, and at the Hood2Hood Festival. By August 2021, the video had 1840 views on YouTube, with 92 likes and 16 positive comments.

Perceptions of sources

At the interactive boards at the Hood2Hood festival, 230 residents added a total of around 701 counters to vote for three options for sources that pollute the air most. Industry was most popular, with 45% of counters, drainage came in second place with 24% and waste burning (Fig. 6) was third with 17%. Dust



Fig. 6. Waste burning in Mukuru. Image credit Miranda Loh.

(8% of counters), smoke from cars (4%) and cooking (2%) were all seen as less important sources of air pollution in Mukuru. This is interesting, given that cooking is known to be an important source of indoor pollution in Mukuru and other informal settlements in Nairobi (Muindi *et al.*, 2014; Egondi *et al.*, 2016; West *et al.*, 2020) and elsewhere.

The mapping exercise gave a similar result – residents perceived there were hotspots of air pollution along the river, near the rubbish dump and from particular factories, for example, the chalk factory, but only a few residents placed dots on homes. Air pollution is often seen as an outdoor issue, typically resulting from industry and cars. In other studies, individuals have been found to rate their vulnerability to air pollution as low, despite facing high levels of household air pollution (Avis, 2018; Avis *et al.*, 2018). This may be a household-level equivalent of the 'neighbourhood halo effect' where individuals are less likely to perceive air pollution as a problem locally (Rankin, 1969; Bickerstaff and Walker, 2001).

In the children's stories, however, smoke from cookstoves was the most prominent form of air pollution, followed by road vehicles and people smoking. Occupational exposure to air pollution was identified only through the legislative theatre, where one story was set in a factory where air pollution was making workers sick.

The interviews highlighted poor drainage, stoves for cooking and heating, burning household waste, smoking, dust and industrial emissions as sources of air pollution. Some views were contrary – for example, many people cited burning household waste as a source of air pollution but others felt that more waste burning would clean up the local environment.

Insights into community perceptions

Conducting a transdisciplinary project provided more insight into community perceptions of air pollution in Mukuru. The project highlighted that residents of Mukuru see air pollutants as something that can be experienced – smelt (e.g., burning trash at dumping sites or sewage), seen (e.g., smoke from cooking fires) or heard (e.g., metalworking industries). The exception was carbon monoxide, which is scentless and invisible but was mentioned in interviews by five participants and was the focus of a forum theatre piece. This may be due to frequent public information broadcasts about the pollutant on radio and television.

Residents' definitions or framings of air pollution are vital. In this study, sewage smells from the drainage channels that cut across Mukuru was identified as air pollution in the participatory mapping, interviews and at the Hood2Hood festival. Muindi *et al.* (2014) described such a perception as 'flawed' knowledge and understanding. But drainage channels are a source of ammonia (Twigg *et al.*, 2017; West *et al.*, 2020), which contributes to the production of PM_{2.5} (Giannakis *et al.*, 2019). 'Bad smells' are caused by chemical emissions, and so should be counted as air pollution, especially as negative perceptions of the environment affect people's sense of well-being. By allowing community members to express their own knowledge, through song, stories and theatre, we reduced the risk of the views of privileged researchers excluding the views of the community about the issue and their thoughts on solutions (Marshall *et al.*, 2018).

Dialogue and learning

Several participants exhibited evidence of learning as a result of the project. For example, community researcher Dennis Waweru took photos for a digital story that highlighted cooking and lighting as two of the key sources of air pollution in Mukuru, as well as local industries, the polluted river (as a result of poor solid waste management) and the burning of waste, including medical waste. Waweru participated throughout the AIR Network and attended some of the interviews, which may have led to the inclusion of this wide variety of both indoor and outdoor air pollution sources in the story. Other community researchers said 'I've learnt about how air pollution happens from different sources...you are burning garbage and making it easy to dispose, but you are affecting a lot of people that are surrounding you including yourself which we don't know but now we know' and '...not only is air pollution outside but it is also inside'.

The project also forged relationships between academics and community members, created new forums for community dialogue and critical reflection on air pollution, engaged audiences (including youth) not usually involved in research, and provided a better understanding of the ways people perceive air pollution in Mukuru.

Potential solutions

People had divergent perspectives on solutions, ranging from those focused on individual action, such as residents maintaining sanitation around their homes, burning garbage further away from where people live, and reporting air pollution problems to the chief, structure owners (landlords), who some respondents felt should support civic action, build homes with windows and enforce tenants' obligations such as around using stoves and turning them out quickly after use, macro-level solutions such as economic empowerment, government monitoring, engagement with stakeholders and civic action (these were especially commonly mentioned by the doctor and researcher interviewees).

Most of the solutions generated by participatory mapping involved addressing outdoor sources of air pollution and relied on changes by those in positions of power, such as improved regulation of industries by the National Environment Management Authority (NEMA), educating the community on waste disposal, providing more toilets, tarmacking dusty roads, production of maps showing the location of waste disposal sites, and industries, such as the chalk factory, raising the height of their chimneys. At the Hood2Hood, the bean counter exercise showed the majority thought individuals were responsible for reducing air pollution (56% of beans) rather than the local community (18%), county government (18%) or national government (8%).

The different methods generated many overlapping solutions but also showed differences, indicating the value of using a number of techniques to paint a broader picture. The methods also allowed discussion of more systemic issues, including wider social, environmental and economic issues associated with urban poverty and urban development. For example, the theatre pieces, which focused on air pollution, ended up exploring the absence of job opportunities away from local industries, absence of basic water and sanitation services, and the residents' lack of agency (Muindi *et al.*, 2014). The workshop following the legislative theatre (explained further in West *et al.*, 2021) then split participants into four groups that each addressed a key systemic issue raised by the piece: lack of labour law enforcement, the need for job creation, fire risk and lack of infrastructure (and planning) in Mukuru. Each group generated solutions, for example, setting up a community-based organisation to provide small start-up loans to youth interested in starting a business, to reduce reliance on local factories for jobs.

The solutions proposed in this way address the air pollution problems perceived by community members and so better address the concerns of the community than if researchers addressed the problems they had observed. While the researchers had a narrow focus on air pollution, for residents air pollution was inextricably linked to other aspects of their lives. Community perceptions of air pollution incorporated issues around drainage, water and toilets, not areas typically considered by air pollution scientists. That said, Clasen and Smith (2019) called for much greater integration of those working on WaSH (water, sanitation and hygiene) and those working on air pollution, as they both affect health, require individual, community and policy action to resolve, and impact the same populations.

Sharing control over the aims, approaches and outcomes of the project moved the researchers away from methodological imperialism and made use of indigenous and local knowledge and ways of knowing (Chilisa, 2017). Such community-level knowledge co-creation is central to building capacity for transformative development outcomes (Ziervogel *et al.*, 2021). Mukuru residents approached the air pollution problem more holistically than the researchers, something that could be crucial when looking to deliver real-world impact. Solutions that arise from co-created discussions are more likely to be sustainable, effective and culturally appropriate. Any resulting air pollution solutions for Mukuru will also benefit urban and peri-urban agro-ecosystems downwind, as well as climate.

Project Outlook and Recommendations

The AIR Network has led to other collaborations, for example, the Tupumue (Kiswahili for 'Let us breathe') project, which looked at the determinants of young people's lung health in Mukuru and the neighbouring, wealthier, area of Buruburu (Meme *et al.*, 2023). Community participants from the AIR Network helped develop the Tupumue funding proposal, and were crucial for designing and delivering the sensitisation campaign which raised awareness about the project among school children and the wider community. Experiences working on the AIR Network and Tupumue have led community members to form a social enterprise, Zindua Creatives Organisation, which uses creative methods such as music, mural making, puppetry and storytelling to inform, educate and entertain the community on different issues.

Recommendations for those undertaking transdisciplinary research

The researchers have the following recommendations for those conducting transdisciplinary research on sustainability issues (Price *et al.*, 2023), based on their experiences during the project, divided by project stage:

Before the project starts

- Ensure that the team has sufficient budget to reflect, integrate the knowledge formed during the transdisciplinary research process and produce outputs for academic and non-academic audiences.
- Incorporate stakeholders' views into the funding bid, paying them for their time if possible to ensure that the project meets their needs.
- If possible, include a flexible budget for co-created activities to allow the project to adapt to stakeholders' needs.

During the project

- Consider issues of intellectual property and ownership of project 'outputs' in advance of the start of the project and reinforce these along the way.
- Prepare non-academic stakeholders for the typically slower academic timescales.
- Speed up academic bureaucracy as much as possible, for example, signing of contracts.
- Conduct preparatory work such as stakeholder mapping to identify power imbalances at different levels (e.g., north–south; intra community; gender-based) and plan how to address these.
- Build trusting relationships among the team by sharing food and playing games. Such connections are crucial when project challenges arise or when initial enthusiasm and excitement begin to wane.
- Select appropriate meeting venues within the community, to reduce travel times, increase convenience and ideally enable all team members to better understand the context.
- Use an 'interdisciplinary working contract' (or similar mechanism) to outline how the team wishes to work together collaboratively, and to ensure shared project expectations. We would recommend revisiting the contract as needed throughout the project, for example, to update it or to use it to help mitigate conflicts.
- Explicitly address capacity-building by asking team members questions such as 'What unique skills and experiences do you bring to the project? Which skills would you like to learn through participating in the project?' Revisit these questions periodically to highlight progress in learning and where gaps remain; this may help to maintain team members' enthusiasm.
- We particularly found community walks, art and storytelling to be useful methods for breaking down barriers between stakeholders by moving people out of their comfort zones and usual ways of working.
- Consider having a 'journal club' for sharing articles (academic or otherwise) to build a common understanding of the context and issues.
- Use reflection diaries (or similar mechanism) for formative evaluation throughout the project, as they allow continuous monitoring and adjustment of project activities. Make the diaries simple for people to complete and submit (e.g., using audio, online or written forms, or a combination of these), and analyse them in near real-time. Budget adequately for everyone's time to complete the reflection diaries.
- Keep in touch regularly. If using informal tools such as WhatsApp, set boundaries to maintain work/life balance.
- Identify potential future funding opportunities early to continue collaborative activities, given the commonly long funding cycle timescales.

Once the project ends

- Remember not to overlook the post-funding phase of the project but appreciate that people may not be able to participate at this stage. Designing simple data collection tools to document impacts, which often take place after the project finishes, may make it easier to collate information beyond the end-date of the project.

Recommendations for funders of transdisciplinary research projects

- Funders need to have a more flexible approach to commissioning and funding work that involves non-academic partners, acknowledging that transdisciplinary projects will likely require additional funding to co-develop research plans, and a higher degree of flexibility.
- Funders should consider developing specific requirements for transdisciplinary projects, for example, ensuring projects budget for knowledge integration and provide plans for applying the knowledge generated.
- Funders should insist that sufficient budget is allocated for formative and summative evaluation, so that projects can learn and improve as they go along, as well as share those learnings with future projects.

Conclusions

Working in this transdisciplinary co-created way, using a combination of qualitative, participatory and creative methods, enabled the researchers to reveal aspects of air pollution in Mukuru that they would not have identified otherwise. The approach provided a more complex, nuanced and holistic understanding of how Mukuru residents perceive air pollution and gave the community new opportunities for dialogue and critical reflection about the topic. All parties gained new skills in different research methods and a greater understanding of air pollution. The diverse research and communication methods used allowed the team to reach large (and varied) audiences. Developing strong, long-term partnerships between researchers and the communities in which they are working is vital to achieving real and sustainable impact. Sustainable Development Goal 17 highlights this by calling for a strengthening of the means of implementation and a revitalized global partnership.

Group Discussion Questions

1. What are the advantages of using a transdisciplinary co-created approach?
2. What challenges and difficulties might a transdisciplinary co-created approach bring?
3. How much did using this approach affect the outcomes of this study and their likely future impact?
4. What did the different types of participant (e.g., academic, community member) learn as a result of taking part?
5. Which of the recommendations do you think are most practical or suitable for transfer to other projects?

Conflict of interest

The authors have no conflicts of interest to declare.

Acknowledgements

This project was funded by the Medical Research Council and the Arts and Humanities Research Council (grant reference AH/R006059/1). The authors wish to thank all those who took part in the AIR Network activities: the community members who led and participated in mini-projects, the community members who led and attended performances, Muungano wa Wanavijiji staff, the researchers and other stakeholders who took part in the inception workshop and policy workshop, and our project advisory group members.

Further Reading

Air Pollution in Mukuru – A digital story. Available at: <https://www.youtube.com/watch?v=NjetxTMHfaE> (accessed 3 February 2024).

From reflection diaries to practical guidance for transdisciplinary research: Learnings from a Kenyan air pollution project. Available at: <https://link.springer.com/article/10.1007/s11625-023-01317-0> (accessed 9 February 2024).

Rafat Dehgamba x evaredimc x suby – Mazingira. Available at: <https://youtu.be/AtH0-NreUxA> (accessed 3 February 2024).

This article is based on Protecting human health, climate and environment through abatement of air pollution using participatory approaches. Available at: <https://panorama.solutions/en/solution/protecting-human-health-climate-and-environment-through-abatement-air-pollution-using> (accessed 9 February 2024).

Using a co-created transdisciplinary approach to explore the complexity of air pollution in informal settlements. Available at: <https://doi.org/10.1057/s41599-021-00969-6> (accessed 9 February 2024).

References

- Avis, W. (2018) Air pollution exposure amongst waste pickers in Dandora Dumpsite. In: *ASAP-East Africa Vulnerability Scoping Study no. 2*. University of Birmingham, Birmingham, UK.
- Avis, W., Mariga, S. and Singh, A. (2018) Air pollution exposure in low income house-holds in Kampala. In: *ASAP-East Africa Vulnerability Scoping Study no. 6*. University of Birmingham, Birmingham, UK.
- Beguy, D., Elung'ata, P., Mberu, B., Oduor, C., Wamukoya, M., Nganyi, B. and Ezech, A. (2015) Health & demographic surveillance system profile: The Nairobi Urban Health and Demographic Surveillance System (NUHDSS). *International Journal of Epidemiology* 44, 462–471. DOI: 10.1093/ije/dyu251.
- Bickerstaff, K. and Walker, G. (2001) Public understandings of air pollution: the “localisation” of environmental risk. *Global Environmental Change* 11, 133–145. DOI: 10.1016/S0959-3780(00)00063-7.
- Boal, A. (2008) *Theatre of the Oppressed*, 3rd edn. Pluto Press, London.
- Brooks, R., Lainio, A. and Lažetić, P. (2020) Using creative methods to research across difference. An introduction to the special issue. *International Journal of Social Research Methodology* 23, 1–6. DOI: 10.1080/13645579.2019.1672281.
- Bruce, N., Perez-Padilla, R. and Albalak, R. (2000) Indoor air pollution in developing countries: A major environmental and public health challenge. *Bulletin of the World Health Organization* 78, 1078–1092. DOI: 10.1590/S0042-96862000000900004.
- Bruner, J. (1990) *The Jerusalem-Harvard lectures. Acts of Meaning*. Harvard University Press, Cambridge, MA.
- Chilisa, B. (2017) Decolonising transdisciplinary research approaches: An African perspective for enhancing knowledge integration in sustainability science. *Sustainability Science* 12, 813–827. DOI: 10.1007/s11625-017-0461-1.
- Cinderby, S., de Bruin, A., Cambridge, H., Muhoza, C. and Ngabirano, A. (2021) Transforming urban planning processes and outcomes through creative methods. *Ambio* 50. DOI: 10.1007/s13280-020-01436-3.
- Clasen, T. and Smith, K.R. (2019) Let the “A” in WASH Stand for Air: Integrating Research and Interventions to Improve Household Air Pollution (HAP) and Water, Sanitation and Hygiene (WaSH) in Low-Income Settings. *Environmental Health Perspectives* 127, 2. DOI: 10.1289/EHP4752.
- Coemans, S. and Hannes, K. (2017) Researchers under the spell of the arts: Two decades of using arts-based methods in community-based inquiry with vulnerable populations. *Educational Research Review* 22, 34–49.
- DeFranco, E., Moravec, W., Xu, F., Hall, E., Hossain, M. *et al.* (2016) Exposure to airborne particulate matter during pregnancy is associated with preterm birth: a population-based cohort study. *Environmental Health* 15, 6. DOI: 10.1186/s12940-016-0094-3.
- deSouza, P. (2020) Air pollution in Kenya: A review. *Air Quality, Atmosphere & Health* 13, 1487–1495. DOI: 10.1007/s11869-020-00902-x.
- Dianati, K., Zimmermann, N., Milner, J., Muindi, K., Ezech, A. *et al.* (2019) Household air pollution in Nairobi's slums: A long-term policy evaluation using participatory system dynamics. *Science of the Total Environment* 660, 1108–1134. DOI: 10.1016/j.scitotenv.2018.12.430.
- Egondi, T., Muindi, K., Kyobutungi, C., Gatari, M. and Rocklöv, J. (2016) Measuring exposure levels of inhalable airborne particles (PM_{2.5}) in two socially deprived areas of Nairobi, Kenya. *Environmental Research* 148, 500–506. DOI: 10.1016/j.envres.2016.03.018.

- Finney, N. and Rishbeth, C. (2006) Engaging with marginalised groups in public open space research: The potential of collaboration and combined methods. *Planning Theory & Practice* 7, 27–46. DOI: 10.1080/14649350500497406.
- Forouzanfar, M.H. *et al.* (2016) Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: A systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 388, 1659–1724. DOI: 10.1016/S0140-6736(16)31679-8.
- Gauntlett, D. (2007) *Creative Explorations*. Routledge, London.
- Giannakis, E., Kushta, J., Bruggeman, A. and Lelieveld, J. (2019) Costs and benefits of agricultural ammonia emission abatement options for compliance with European air quality regulations. *Environmental Sciences Europe* 31, 93. DOI: 10.1186/s12302-019-0275-0.
- Goodfellow, T. and Taylor, W. (2009) Urban poverty and vulnerability in Kenya: The urgent need for co-ordinated action to reduce urban poverty, Oxfam GB. Available at: <https://policy-practice.oxfam.org/resources/urban-poverty-and-vulnerability-in-kenya-the-urgent-need-for-co-ordinated-action-123932/> (accessed 21 October 2021).
- Gulis, G., Mulumba, J.A.A., Juma, O. and Kakosova, B. (2004) Health status of people of slums in Nairobi, Kenya. *Environmental Research* 96, 219–227. DOI: 10.1016/j.envres.2004.01.016.
- Hoek, G., Krishnan, R.M., Beelen, R., Peters, A., Ostro, B., Brunekreef, B. and Kaufman, J.D. (2013) Long-term air pollution exposure and cardio-respiratory mortality: A review. *Environmental Health* 12, 43. DOI: 10.1186/1476-069X-12-43.
- Jiang, Z., Kobylinska, T. and The Voice of Domestic Workers (2020) Art with marginalised communities: Participatory video as a tool of empowerment and resistance for migrant domestic workers in London. *City* 24, 348–363. DOI: 10.1080/13604813.2020.1739460.
- KNBS (2020) 2019 Kenya population and housing census, vol I: Population by county and sub-county—Kenya National Bureau of Statistics [WWW Document]. Available at: <https://www.knbs.or.ke/?wpdmpo=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county> (accessed 2 August 2021).
- Marshall, F., Dolley, J. and Priya, R. (2018) Transdisciplinary research as transformative space making for sustainability: Enhancing poor transformative agency in Periurban contexts. *Ecology and Society* 23, 8. DOI: 10.5751/ES-10249-230308.
- Mberu, B., Wamukoya, M., Oti, S. and Kyobutungi, C. (2015) Trends in causes of adult deaths among the urban poor: Evidence from Nairobi urban health and demographic surveillance system, 2003–2012. *Journal of Urban Health* 92, 422–445. DOI: 10.1007/s11524-015-9943-6.
- McCarron, A., Uny, I., Caes, L., Lucas, S.E., Semple, S., Ardrey, J. and Price, H. (2020) Solid fuel users' perceptions of household solid fuel use in low- and middle-income countries: A scoping review. *Environment International* 143, 105991. DOI: 10.1016/j.envint.2020.105991.
- Meme, H., Amukoye, E. and Bowyer, C. *et al.* (2023) Asthma symptoms, spirometry and air pollution exposure in schoolchildren in an informal settlement and an affluent area of Nairobi, Kenya, Thorax Published Online First: 06 June 2023. DOI: 10.1136/thorax-2023-220057.
- Mobarak, A.M., Dwivedi, P., Bailis, R., Hildemann, L. and Miller, G. (2012) Low demand for nontraditional cookstove technologies. *Proceedings of the National Academy of Sciences of the United States of America* 109, 10815–10820. DOI: 10.1073/pnas.1115571109.
- Mortimer, K., Ndamala, C.B., Naunje, A.W., Malava, J., Katundu, C. *et al.* (2017) A cleaner burning biomass-fuelled cookstove intervention to prevent pneumonia in children under 5 years old in rural Malawi (the Cooking and Pneumonia Study): a cluster randomised controlled trial. *Lancet* 389, 167–175. DOI: 10.1016/S0140-6736(16)32507-7.
- Muindi, K., Egondi, T., Kimani-Murage, E., Rocklov, J. and Ng, N. (2014) “We are used to this”: A qualitative assessment of the perceptions of and attitudes towards air pollution amongst slum residents in Nairobi. *BMC Public Health* 14, 226. DOI: 10.1186/1471-2458-14-226.
- Muindi, K., Kimani-Murage, E., Egondi, T., Rocklov, J. and Ng, N. (2016) Household air pollution: Sources and exposure levels to fine particulate matter in Nairobi slums. *Toxics* 4, 12. DOI: 10.3390/toxics4030012.

- Muongano wa Wanavijiji (2018) Available at: <https://www.muungano.net/> (accessed 23 October 2021).
- Olufemi, O. and Reeves, D. (2004) Lifeworld strategies of women who find themselves homeless in South Africa. *Planning Theory & Practice* 5, 69–91. DOI: 10.1080/1464935042000185071.
- Price, H.D., Bowyer, C.J., Büker, P. *et al.* (2023) From reflection diaries to practical guidance for transdisciplinary research: Learnings from a Kenyan air pollution project. *Sustainability Science* 18, 1429–1444. DOI: 10.1007/s11625-023-01317-0.
- Rankin, R.E. (1969) Air pollution control and public apathy. *Journal of the Air & Waste Management Association* 19(8), 565–569. DOI: 10.1080/00022470.1969.10466523.
- Ritchie, H. and Roser, M. (2017) Air Pollution. Available at: <https://ourworldindata.org/air-pollution> (accessed 26 February 2021).
- Rouse, J.R. (2000) Indoor air pollution: Issues for Bangladesh. UK-Water, Engineering and Development Centre (WEDC), Loughborough University. Available at: <https://www.bioenergylists.org/stovesdoc/Rouse/rouiap.pdf> (accessed 13 October 2021).
- Shupler, M. *et al.* (2021) COVID-19 impacts on household energy and food security in a Kenyan Informal Settlement: The need for integrated approaches to the SDGs. *Renewable and Sustainable Energy Reviews* 144. DOI: 10.1016/j.rser.2021.111018.
- Twigg, M. *et al.* (2017) Investigating the drivers of air pollution and personal exposure within informal settlements in Nairobi, Kenya [poster]. In: Air quality—the wider picture. Current issues and new technologies, Royal Society of Chemistry, London.
- West, S.E., Büker, P., Ashmore, M., Njoroge, G., Welden, N. *et al.* (2020) Particulate matter pollution in an informal settlement in Nairobi: Using citizen science to make the invisible visible. *Applied Geography* 114, 102133. DOI: 10.1016/j.apgeog.2019.102133.
- West, S.E., Bowyer, C.J., Apondo, W. *et al.* (2021) Using a co-created transdisciplinary approach to explore the complexity of air pollution in informal settlements. *Humanities and Social Sciences Communications* 8, 285. DOI: 10.1057/s41599-021-00969-6.
- WHO (World Health Organisation) (2018) Ambient (outdoor) Air Pollution. Available at: [https://www.who.int/en/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health) (accessed 2 August 2021).
- Ziervogel, G., Enqvist, J., Metelerkamp, L. and van Breda, J. (2021) Supporting transformative climate adaptation: Community-level capacity building and knowledge co-creation in South Africa. *Climate Policy* 22(5), 607–622. DOI: 10.1080/14693062.2020.1863180.