Case Study Report

Participatory methods as tools for environmental monitoring in low income communities

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Abstract

Large cities in the global south continue to face the perennial socio-economic problems such as increase in slum dwellers, resource depletion, air and water pollution and rising urban poverty (Arku, G. and Marais, L. 2021).[1] These cities are also growing without adequate urban planning and are thus susceptible to environmental pollution and climate change impacts. Environmental pollution is described as "the contamination of the physical and biological components of the earth/atmosphere system to such an extent that normal environmental processes are adversely affected (Muralikrishna, I.V. and Manickam, V. 2017)[2].

According to the World Health Organisation, the combined effects of ambient and household air pollution is associated with 7 million premature deaths annually. This has effects that are deeply embedded in everyday economic, social and cultural realities that are difficult to change. They also hamper the attainment of the majority of the Sustainable Development Goals (SDGs) especially SDG 3, 11 and 12. Citizens and governments are increasingly aware of the toxic health risks from air pollution, but they don't have easily accessible, hyper-local and real-time data that would give users actionable information to help either avoid the effects or fight the causes. Even when sources are understood, the underlying causes of emissions may be deeply embedded in uncertainty or disagreement on what and who is responsible for air pollution can stall progress (Clean Air Catalyst. (2022.).[3]

This case-study shows an attempt to change this through the use of participatory community driven methods. It involves understanding pollution within lower middle and low income areas in Nairobi through grassroots community groups and NGOs. Participatory methods used include participatory mapping techniques to spatially locate the areas communities most believe are affected by pollution as well as the use of questionnaires to understand the lived experiences of those affected by pollution. This is followed by the deployment of African-designed and assembled low-cost sensors to ordinary people and civic watchdogs to

[1] Arku, G. and Marais, L. (2021). Global South Urbanisms and Urban Sustainability—Challenges and the Way Forward. *Frontiers in Sustainable Cities*, 3. doi:10.3389/frsc.2021.692799.
[2] Muralikrishna, I.V. and Manickam, V. (2017). Introduction. *Environmental Management*, pp.1–4. doi:10.1016/b978-0-12-811989-1.00001-4.
[3] Clean Air Catalyst. (2022.). *Approach*. [online] Available at: https://www.cleanaircatalyst.org/approach [Accessed 29 Jun. 2022].

monitor the quality of real-time air in communities. Regular reports of the air quality are issued to the communities and adequate training on how to interpret data is conducted.

The participatory mapping showcases the deep understanding of the local situations. As individual participants did the mapping independently, the strong correlations emerging from the exercise was a key spatial indicator on the locations that are most affected and in some cases the responsible sources. As part of the engagement, low cost monitors have been deployed at some of these sites while at others where there is security risk for sensor deployment, temporary devices are to be used for the assessment of the air quality situation. Other environmental factors like noise and water pollution were also mapped.

From previous engagements on this programme, resulting data has been instrumental in bringing about proactive change from the community and by the civil authorities. Engaging the communities with active data and sharing this with both authorities as well as journalists has helped in bringing about change including control of emissions, shutting down of polluting factories and increased awareness of the dangers of air pollution among the general citizenry.

Even at the early points, the study shows that using citizen science can enhance participation in the planning process, more so in what seem to be unplanned neighbourhoods in the global south. The methods can be replicated in other African countries where those from marginalised groups, especially women, persons with disability and the poor continue to be the largest victims of environmental pollution in urban areas.

Keywords

Environment, Community, Urban, Pollution,

1. Introduction

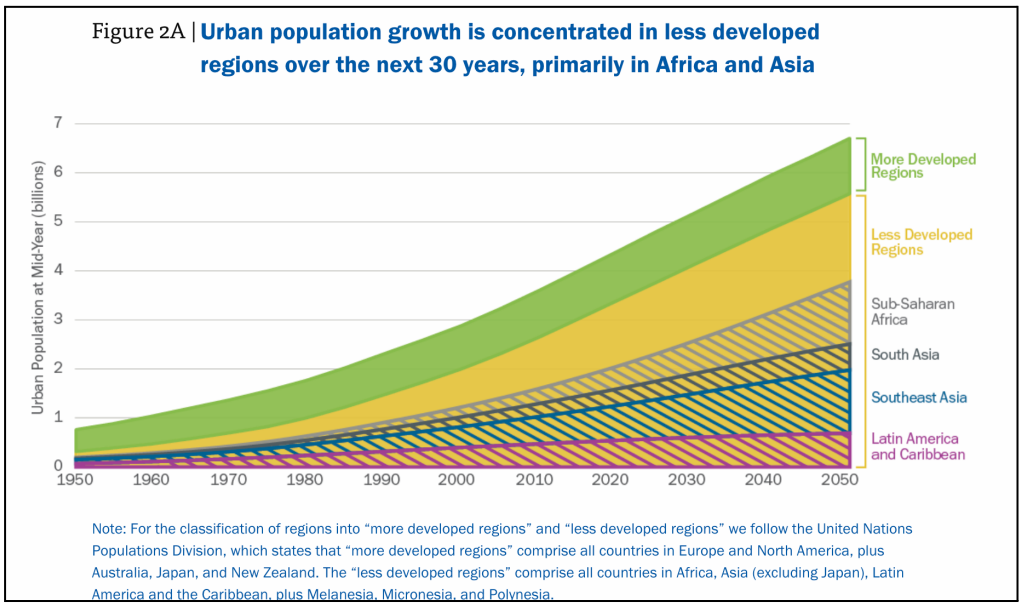
1.1. Urban Growth and Development

Cities have always been centres of development, innovation and growth. In spite of this, even in the developed world, cities at one point in time brought disease, environmental degradation and poverty. Through policy changes and investment they were able to change this, but it appears that the cycle is now repeating itself in the global south (Mahendra et al.).

Most urban population in the 21st century is expected to happen in the global south with an estimated increase of 64% from 2015 to 2030 (Mahendra et al.). The rate of urbanisation in the developing world has now surpassed that in the much urbanised developed world. Urban attractions including employment and industrial growth continue to encourage more rural to urban migration (Oyedepo, Sunday, 2012). The rate of urbanisation has been affected by poor land use management, affecting new poor residents negatively and many end up in the peripheries as well as riparian reserves and unused public land. (Venter et al.).

Unfortunately, however, incomes in the global south have remained stagnant (Mahendra et al.). Two thirds of the urban dwellers live within informal settlements, emerging where planning is lax and affordable housing is in short supply or unaffordable for them (Mahendra et al.)

The negative results of these include increased environmental pollution including noise pollution and the continuous increase in the number of people living in slums. Oyedepo, Sunday. (2012). Urban populations are expected to increase globally by two billion in the next 30 years (UNEP, 2022). Urban growth in Sub-Saharan Africa (SSA) is largely unplanned and marked by significant environmental pollution (Arku, 2021). Without adequate innovations, these cities will continue to experience increased carbon-intense growth accompanied by environmental degradation and increased GHG emissions (Mahendra et al.)



Graph showing Urban Population growth, Source: (Mahendra et al.)

1.2. Environmental Degradation

Vehicle emissions, burning of waste and industrial effluent are leading causes of environmental pollution in many developing countries. These all affect human health and have continued to increase with urban population growth (UNEP, 2022).

While many of these — notably waste, biodiversity loss and warming — are already well-documented, there is another often ignored environmental threat having an increasingly significant impact on city dwellers: noise(UNEP, 2022b). At the same time, the few measurement studies in the region show that air and noise pollution, which come from diverse sources, are now a major growing public health concern in cities. There is, however, little data on the health impacts of urban air and noise pollution in the SSA setting to support policy and behavioural decisions, particularly with regards to child survival and development. The shortage of data is a major challenge as it hampers the development of adequate policies and actions within the region (Arku, 2021).

Groundwater extraction is depleting aquifers, sewerage and industrial wastewater is discharged into rivers and lakes while expansion and sprawl are affecting agricultural hinterlands, urban green cover and wetlands (Mahendra et al.)

Though Africa are not a major contributor to greenhouse gas emissions as compared to the rest of the world, the continent has made commitments towards combating climate impacts including the Nairobi Declaration on the African Process for Combating Climate change which calls for nations in the North to reduce emissions and compensate African nations for economic and environmental losses (Beer, 2014). Urbanization tends to be one of the key factors affecting environmental change, and cities have been identified as hotspots for air pollution (UNEP, 2022).

2. Pollution in the Urban Environment

2.1. Air Pollution

Air pollution has highly affected residents in low and middle income countries causing long term health effects (Mahendra et al.).Outdoor Air pollution causes up to 49,000 premature deaths every year while household air pollution (HAP), or indoor air pollution causes 8 times this value (Dieter, 2012). Poorer people are the biggest victims of this, with most being exposed to higher concentrations of fine particulate matter (PM 2.5) due to the use of biomass fuels, congested neighbourhoods and lack of awareness(Dieter, 2012). PM 2.5 is the leading cause of diseases associated with air pollution causng mortality and disease (Martin et al., 2019).

Though cities in the global south are not major contributors to carbon dioxide emissions, their share is expected to exceed from 27% to 56% within the next 30 years. (Mahendra et al.). Efforts are being made to contain this and one of these includes 10 African cities who have signed the C40 Clean Air Cities Declaration on Air pollution and slow human caused changes in climate. These include Abidjan, Accra, Addis Ababa, Dakar, Ekurhuleni, Freetown, Johannesburg, Lagos, Nairobi and Tshwane. Durban was already a signatory to this (Dieter, 2012).

Unfortunately, there is insufficient monitoring of $PM_{2.5}$ in the developing world leading to lack of adequate actionable data. Worldwide,only 24 out of 234 countries have more than 3 monitors per million inhabitants and 141 have no regular PM2.5 monitoring. This makes it difficult to understand the patterns and extent of air pollution (Martin et al., 2019). There have been, however, attempts to use low-cost sensors combined

with remote sensing technology to better understand air pollution and produce actionable data (UN - Environment, 2020). It is possible to use these low-cost sensors and combine them with Satellite observations to improve spatial coverage of estimates. This has been done in the United States (UN - Environment, 2020).

2.2. Noise Pollution

Noise Pollution is any form of unwanted environmental sound that annoys, distracts or harms people (Goines and Hagler, 2007). These tend to interfere with our day to day activities including work, sleep, thought process or basic conversations (Rugg and Andrews, 2010). Sounds become noise when they are unwanted thus affecting the quality of life by hampering concentration, thinking, memory, quality of sleep and work. Poor sleep leads to fatigue and stress during the day (Bhatia, 2014). There are many causes of noise pollution in urban areas, these include: road traffic, industry, and construction. Noise levels in many cities are a serious concern due to the long term health effects.

Much like air pollution, noise pollution is far from being a mere nuisance, it also has long term effects on human health, including seriously impair our physical wellbeing (WHO, 2019), heart disease due to chronic annoyance (Bai et al., 2020) and sleep disturbance (Halperin, 2014). Other problems include disorders such as diabetes (Shin et al., 2020), hearing impairment and poorer mental health.(UNEP, 2022b). Both the young and the eldlerly among vulnerable groups (van Kamp and Davies, 2013) are affected by noise. It has a negative effect on childhood cognitive development (Bhatia, 2014). Those most affected tend to live close to high traffic roads and industrial areas in contrast to tose who live close to green spaces (Barton, 2015).

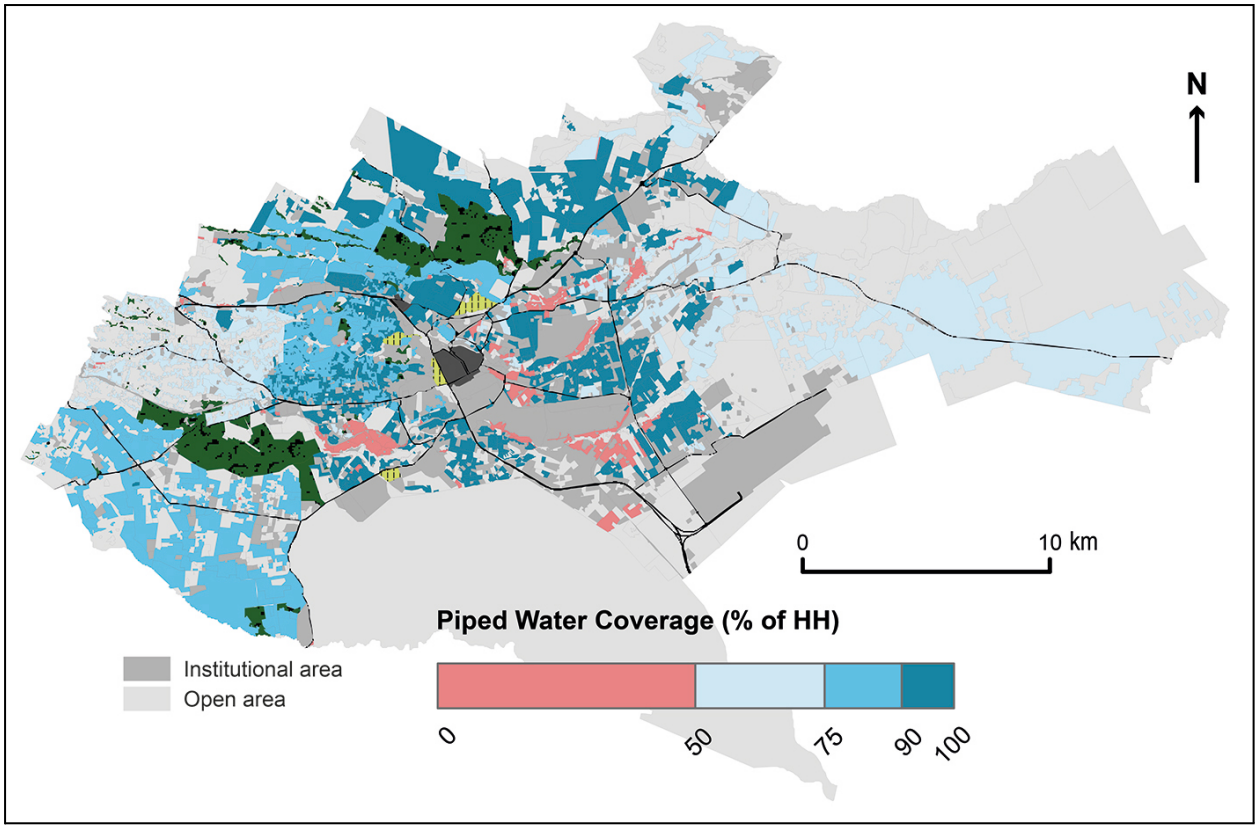
Sound is measured in decibels, which is a ratio to the power at the threshold of human hearing (Bhatia, 2014). In some parts of Nairobi, sound levels average 70 decibels (Wawa, Mulaku,2015).

There is also a lot of ignorance by the population on the dangers of noise pollution, especially as many assume that it is normal in urban areas(Oyedepo, 2012). There is a need for measurement, monitoring and assessment as well as awareness creation among communities.

2.3. Water and Sanitation in Urban Areas

Generally, Kenya has faced water challenges in both rural and urban areas for several decades. In rural areas, droughts have tended to occur occasionally while in urban areas water supply is a perennial challenge (Marshall, 2011). Water rationing is a common trend in most urban areas as supply cannot keep up with demand (Ledant, 2013) and residents of informal settlements are known to pay more for potable water than those who live in the more affluent areas(Bakker, 2007). Less than half of the urban population in Kenya has access to safe potable water. As regards sanitation it is even worse and only 40% of Nairobi is connected to the sewer line while 30% have access to some form of improved sanitation (World Bank Group, 2020).

These figures are common in urban areas that grow at a faster rate than service provision. This is rampant in the developing world and even for those who have access to tap water, some level of reliance on unregulated service providers or investment in storage tanks is a necessity (Ledant, 2013) .



Piped Water Coverage in Nairobi. Souce: (Ledant, 2013)

As cities grow they continue to be exposed to challenges of water scarcity which is on the increase in developing countries. About 60% of cities worldwide face one challenge to another relating to water scarcity and lack of adequate infrastructure. This has long term health and environmental problems (He et al., 2021).

With this urban growth, informal and low income settlements have also grown (World Bank Group, 2020). These areas are rampant with overcrowding and poor infrastructure, thus, water and sanitation is little or nonexistent and women and children are forced to walk long distances to get a small daily amount of water e.g. Kayole-Soweto (World Bank Group, 2020). This has an effect on the health of the people and cases of cholera and other water borne diseases have been reported in these areas e.g during December 2014-June 2015 Nairobi county reported 781 (19.0 %) cholera cases (attack rate, 18/100,000 persons), including 607 (78%) hospitalisations, 20 deaths (CFR 2.6%) and 55 laboratory-confirmed cases (7.0%). Scientific testing derived that 70% of the water samples from communal water points at the time were affected by cholera bacteria (Kigen et al., 2020). Which many linked to poor sanitation within the informal and low income neighbourhoods. Mwenda et al., 2019).

3. Citizen Science and Participative Methods

3.1 What is citizen Science

Since time immemorial, ordinary citizens have participated in scientific research through observation, experimentation and analysis, regardless of their training or background (Bonney Rick, et al, 2012). Citizen science is defined when non-professional scientists participate and give value to scientific research Land-Zandstra, Agnello and Gültekin, 2021). These non-professionals can be engaged at different levels for

example observations, such as kinds, numbers, and locations of plants and animals(Bonney Rick, et al, 2012). They are not employed as scientists but collaborate with scientists (trained professionals often with a postgraduate degree) in the process (Keyles, 2018)

It is important to understand what will motivate citizen scientists to be part of a project,as well as the potential benefots of the outcomes to the individual and communities at large. This helps in keeping them involved as well as enables the process to have higher quality data from the engagement process. (Land-Zandstra, Agnello and Gültekin, 2021).

3.2 Benefits of Citizen Science .

The National Institute for Public Health and the Environment lists the following as benefits of Citizen Science:

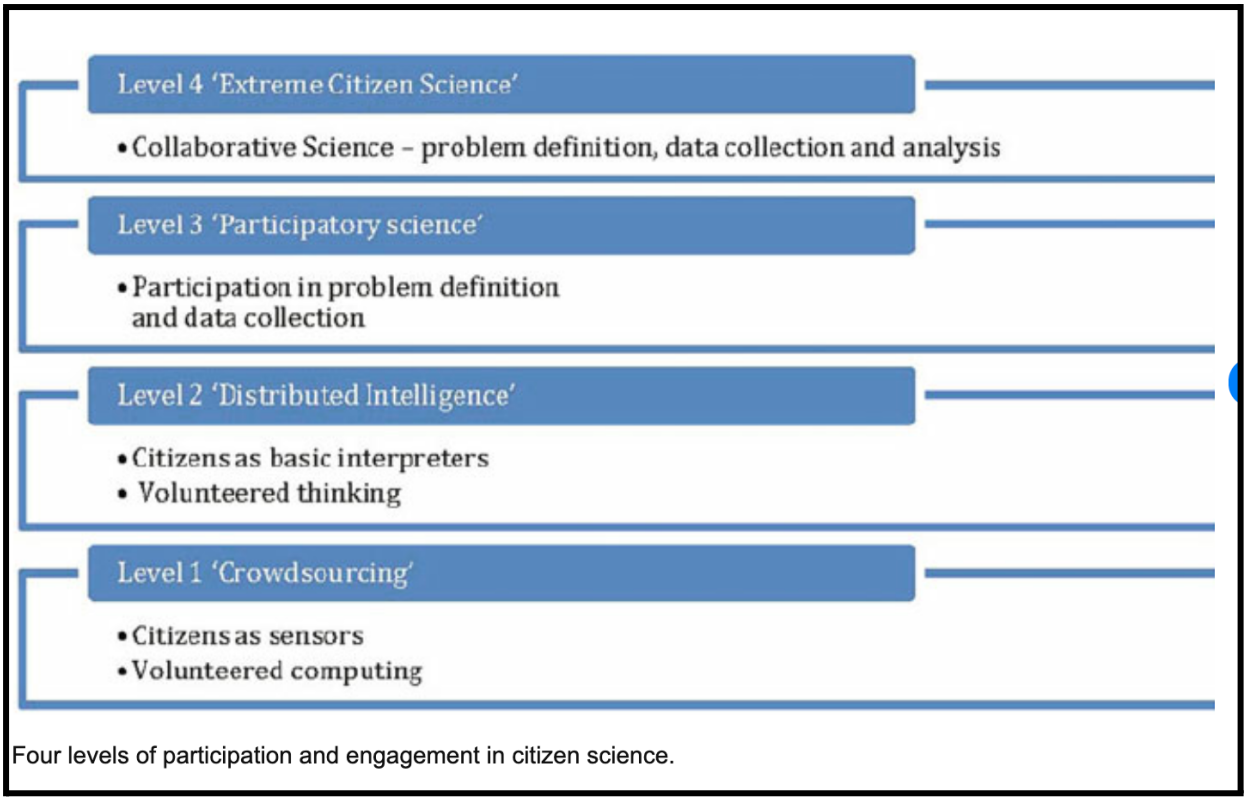
1. Increased participation in research
2. Widening the scale of research
3. Getting first hand information sources, many of which are new.
4. Creating better connections between citizens and scientists.
5. New methodologies emerge
6. Improving openness, transparency and reliability of research.
7. Improved understanding of science by citizens.
8. Assist scientists to have an undesrtsnfing of the challenges that citizens and society are facing.
9. Research can now be focused on priority areas for citizens.
10. Scientific literacy through citizens increasing their own knowledge and understanding about science.

(National Institute for Public Health and the Environment, n.d.)

3.3. Levels of Citizen Science

There are three ways in which citizen science is changing society: (1) contributive, where citizens gather data; (2) collaborative, where citizens may also analyse or interpret this data; or (3) co-created, where citizens participate in all levels of a project, from designing the research question to analysing data (Keyles, 2018). There are different levels at which citizens can be engaged. These are captured in the table below by (Shum et al, 2012).

Land-Zandstra, Agnello and Gültekin, (2021) list of different ways in which citizens can engage in the scientific process. These include: development of research questions and hypotheses, data collection, data analysis, drawing conclusions, and disseminating data..Throughout the process, citizens can engage in a manner directed towards professionals or towards their colleagues (top-down vs bottom-up). Citizen science feeds into the participatory process which is key in facilitating development. The participatory process is best categorised through the ladder of participation.



Four levels of participation and engagement in citizen science.

3.4 The ladder of participation

Citizen participation concerns the many ways in which people interact with each other and ordinary citizens get involved in the decision making of bureaucrats (Kusi, 2022).

Sherry Arnstein proposed the ladder of participation in 1969 (Wikipedia Contributors, 2019) and it is now commonly used as a reference point by professionals, citizens and governments to rate the levels at which participation is taking place or intended to take place. The model also influenced many later models, including Elizabeth Rocha's Ladder of Empowerment and Roger Hart's Ladder of Children's Participation (Organizing Engagement, 2019).

Good participation makes people get a sense of ownership in the development process. It builds trust and in the long run, they end up contributing much more to their environment and neighbourhood than when they are not part of the whole process (Kusi, 2022). It also builds up motivation for people in the process. Though motivations may vary between citizens, it is important to keep them engaged throughout the process lest they feel detached and leave it (Land-Zandstra, Agnello and Gültekin, 2021) - (Land-Zandstra, Agnello and Gültekin, 2021).

Arnstein's ladder moves in an ascending manner with increasing ownership and involvement by citizens as one moves up, or as some put it 'different degrees of power'. It ranges from no power at all to complete control of the process by citizens. - (Organizing Engagement, 2019). Within the higher levels of participation, it is also possible to have more enjoyable activities that stimulate interest and feedback aside from mere lectures and traditional 'barazas' (meetings where one person informs everyone and hardly any engagement is done(Land-Zandstra, Agnello and Gültekin, 2021).

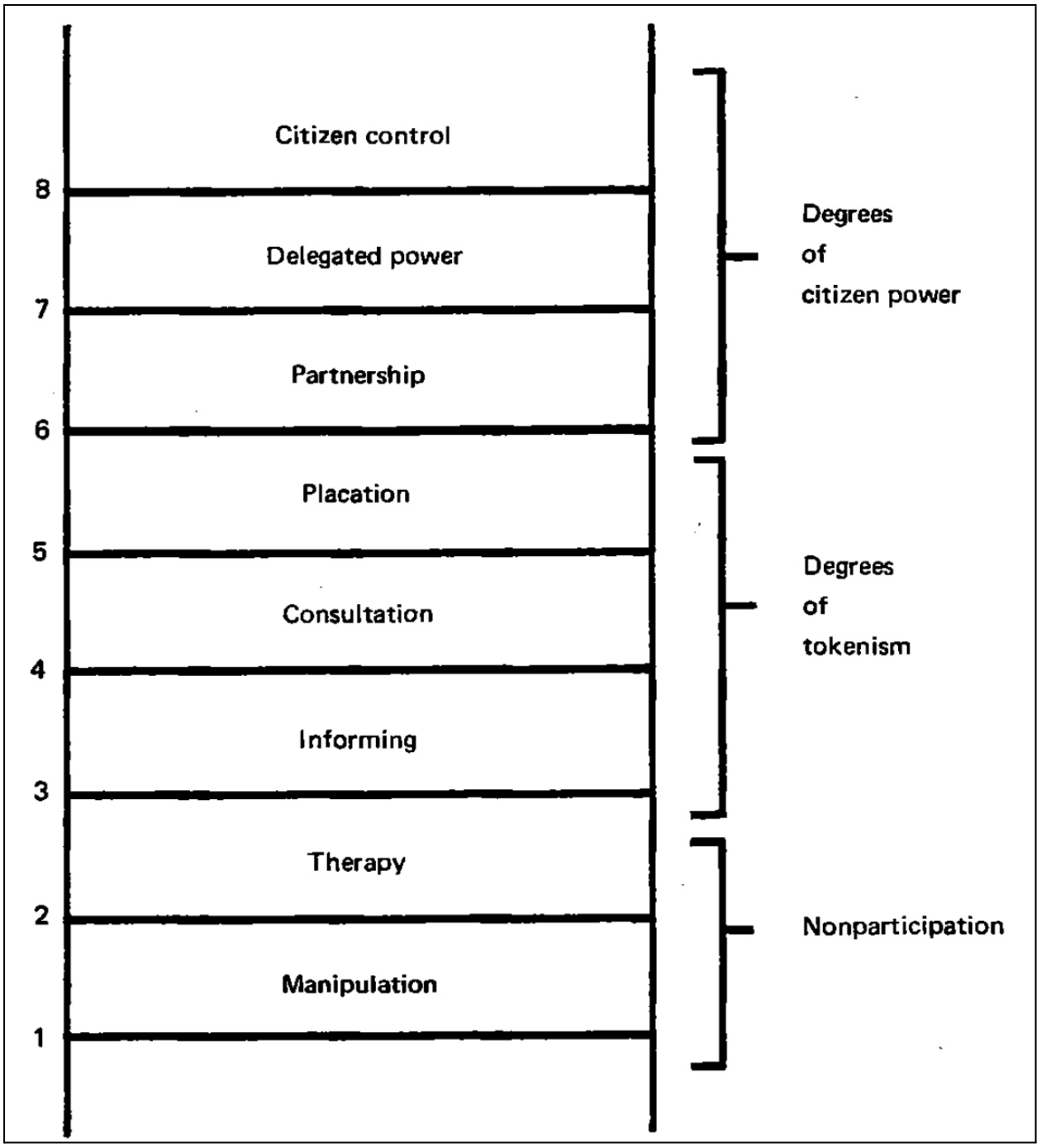


Image of Arnstein' Ladder. Souce: Organizing Engagement, 2019

Good participation requires early engagement and proper communication so that people can have time to reflect on projects and be aware of how they can make contributions. Good participation also recognizes aspects such as culture, age, ways of feeling appreciated and perception of benefits. These make participants feel accepted so that they can make adequate contributions (Land-Zandstra, Agnello and Gültekin, 2021).

3.4 Past participatory projects

There have been several citizen science based participatory projects that offer good examples of citizen engagement.

1. UN-Environment collaborated with IQAir to come up with am air pollution exposure calculator which brought together government, citizen crowdsources and satellite data on air quality together with population data(UNEP, 2022). Using AI, they are able to calculate a country's population exposure to air pollution. Trials for this have been done in Uganda and Ethiopia, showing that a large percentage of their urban population are breathing polluted air.
2. Environmental noise was measured, modelled and predicted in Ghana, West Africa in order to measure inequalities in the exposure to boise. This was donate 146 locations where weekly and annual monitoring was done. This data was combined with geospatial and meteorological precitor variables and land use regression to predict annual noise levels (LAeq24hr, Lden, Lday, Lnight). This work has been able to support environmental studies, disease assessments, policies and interventions in the Accra (Clark et al., 2022).

4. Methodologies

In this particular case study, a participatory citizen science approach is being used, taking into account the importance and value of citizen science as well as the ladder of participation. There are three key areas for the ongoing study these are:

a. Air Pollution
b. Water contamination
c. Noise Pollution

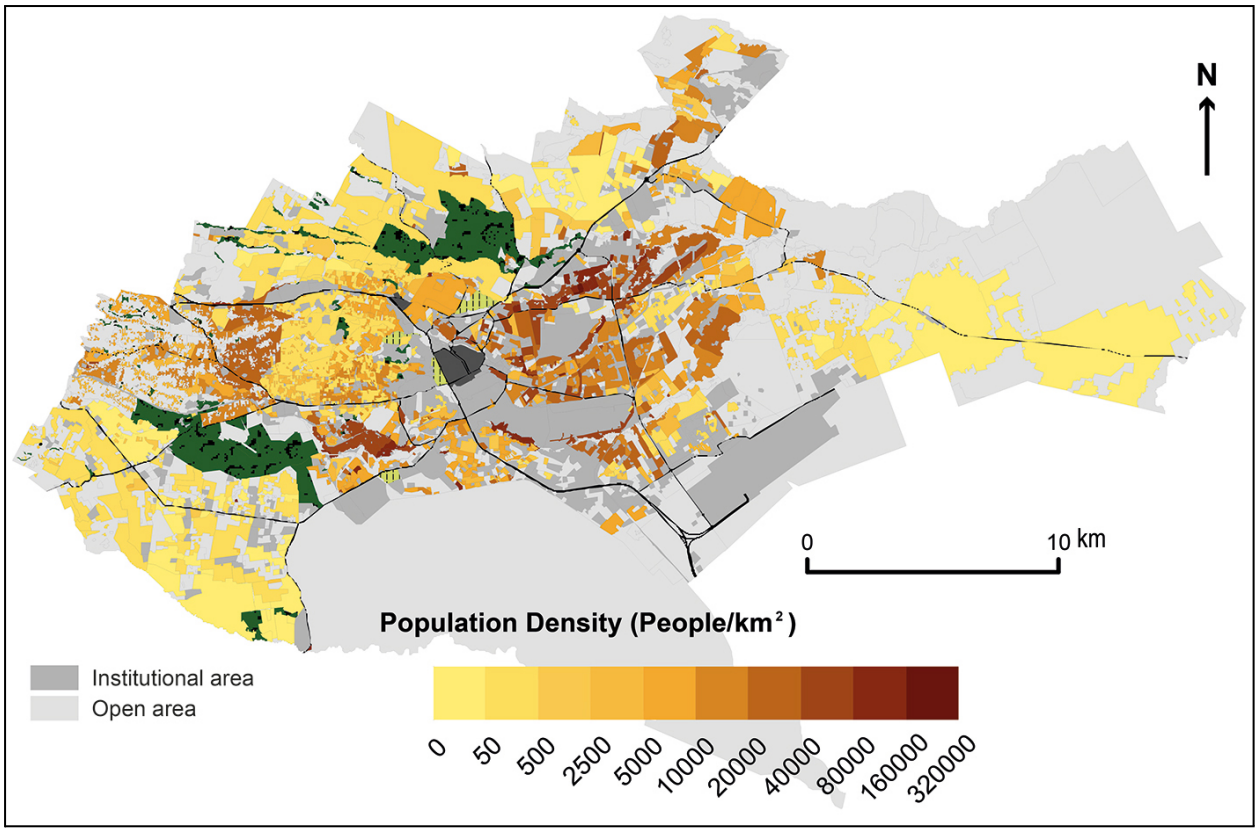
4.1 Selection of Communities

Communities to participate in the study are derived from different groups in Nairobi, particularly the eastern side of the city, which generally consists of poorer communities and has several informal settlements. Communities for the study were selected from areas that face different levels of poverty and have active ecological justice groups. Ecological justice groups consist of youth groups that are actively involved in the fight for a greener and cleaner city at neighbourhood level among vulnerable communities.

The Communities selected were:

a. Kamukunji
b. Mathare
c. Kayole
d. Baba Dogo
e. Mwiki/Kasarani
f. Korogocho

These are all informal and lower income settlements that are located within close range of polluting industries, polluted rivers and with generally low level of basic services like water, sanitation and garbage collection.



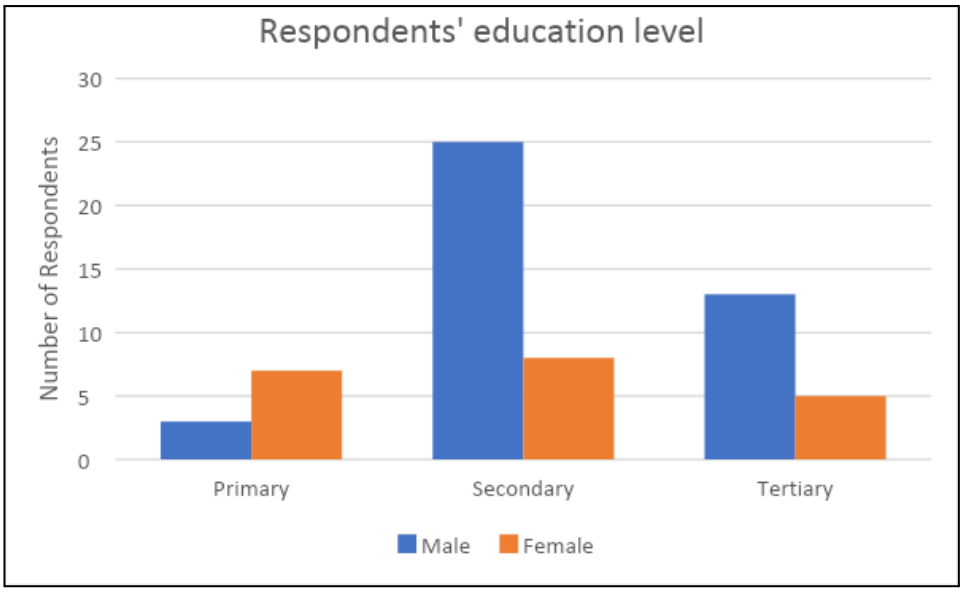
Map showing Population density in Nairobi.: Source: (Ledant, 2013)

4.2 Selecting participants

Participants were selected from the groups within these neighbourhoods. Each group had a representation of 10 participants which enabled us to reach out to 61 different active citizens involved in environmental justice work. There was no bias towards level of education, age, gender or tribe.

The survey was conducted with 61 community members (41 males, 20 females) from different neighbourhoods in Nairobi between 16th March to 1st April 2022. Majority of respondents were between 18-30.

Age Group	Male	Female
18-30	30	8
30-40	7	10
40-50	3	2
50-60	1	0
TOTAL	41	20



Type of work	Male	Female	Total
Daily labourer	2	0	2
Employed	5	1	6
Self-employed	20	12	32
Unemployed	5	3	8
Did not respond	9	4	13

4.3 Participatory Mapping

Participatory mapping is a map-making process that attempts to make visible the association between land and local communities by using the commonly understood and recognized language of cartography. As with any type of map, participatory maps present spatial information at various scales (IFAD, 2009). For this particular exercise, participants were given pre-printed maps of their neigbourhood and asked to identify places that experienced air, water and noise pollution and the main causes of these pollutants. Identification was done by stickers, with one colour for air pollution, another colour for noise pollution and another colour for water pollution. Water pollution included pollution of rivers, leaking sewage water and burst pipes where community members may go out to collect water for various domestic purposes.

4.4 Questionnaires.

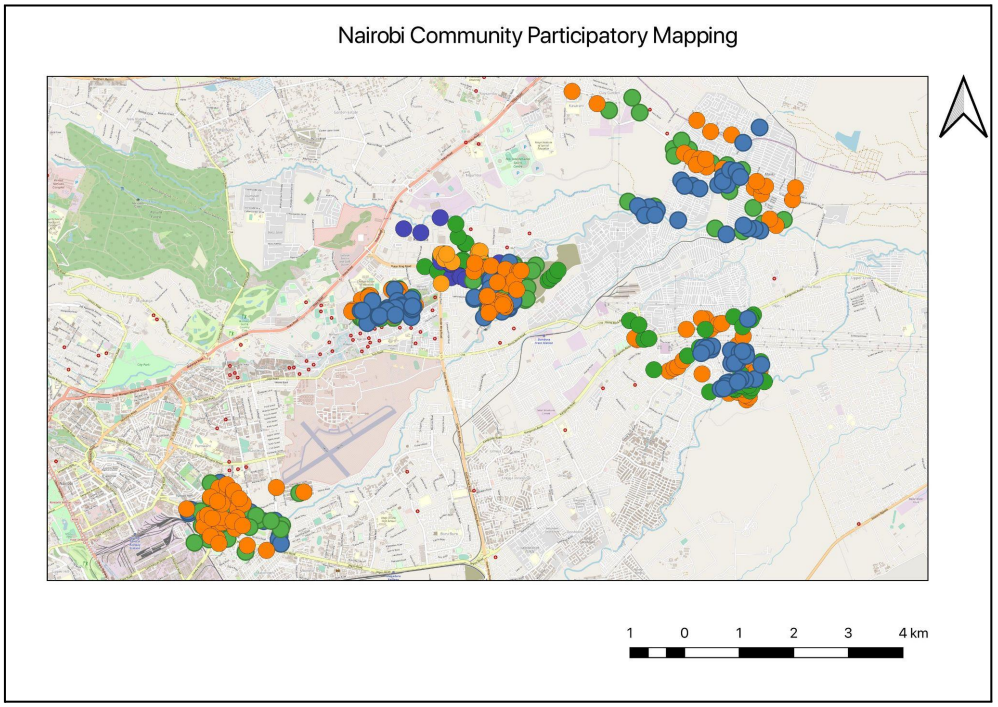
Participants were also given questionnaires (see appendix) to understand the challenges they face based on air, water and noise pollution. These had been prepared in advance and once completed, the data was entered into google forms for easier analysis.

Both the questionnaires and the mapping were done by individuals in order to avoid any bias. The participants were also exposed to different IoT devices that will be used at further stages of the projects including the sensors.AFRICA air quality monitor and the Omnivis cholera detection device.

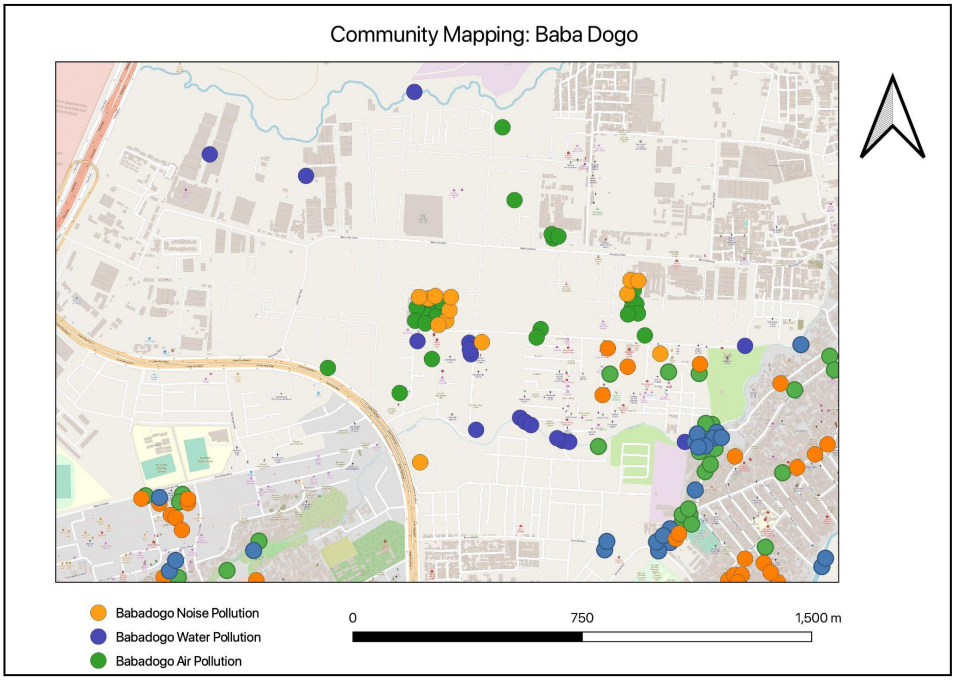
5. Outcomes so far

5.1 Mapping Outcomes

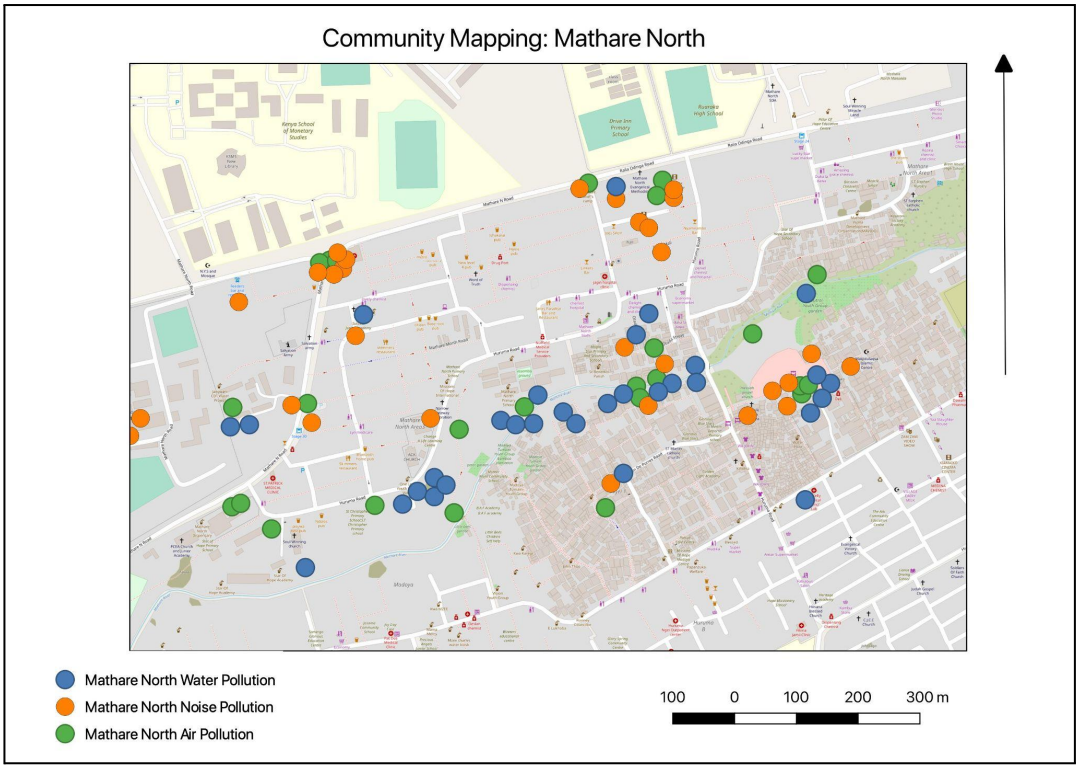
The most interesting outcome so far are the similarities in data output from the mapping exercise. In most places almost all participants pointed out the same areas being of concern.



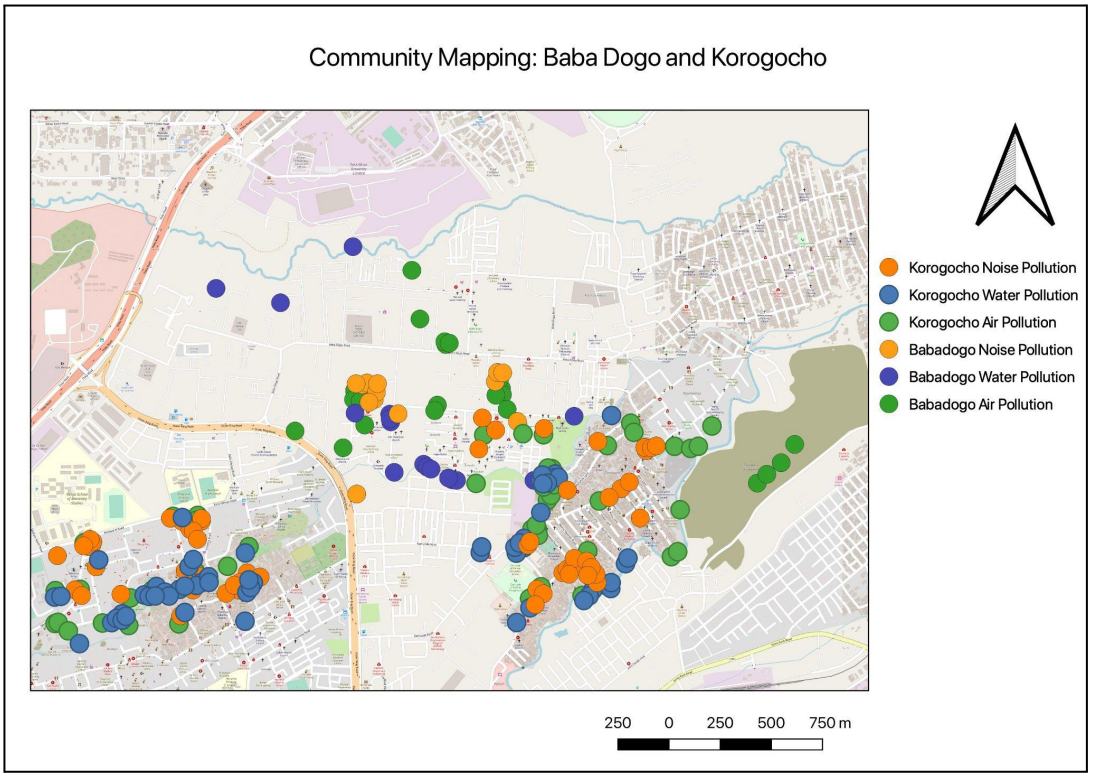
Map showing outcomes of Nairobi Community Participatory Mapping



Outcomes of the community mapping in Baba Dogo

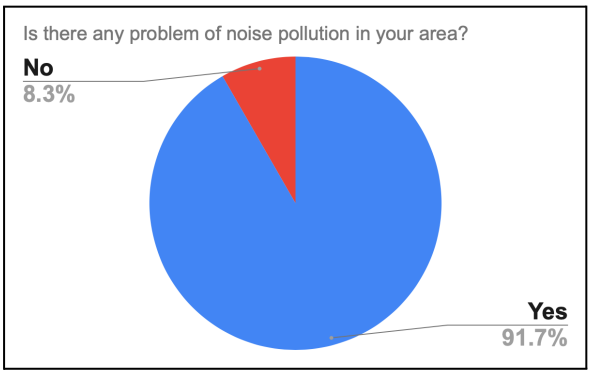


Map Showing Outcomes of the community mapping in Mathare North

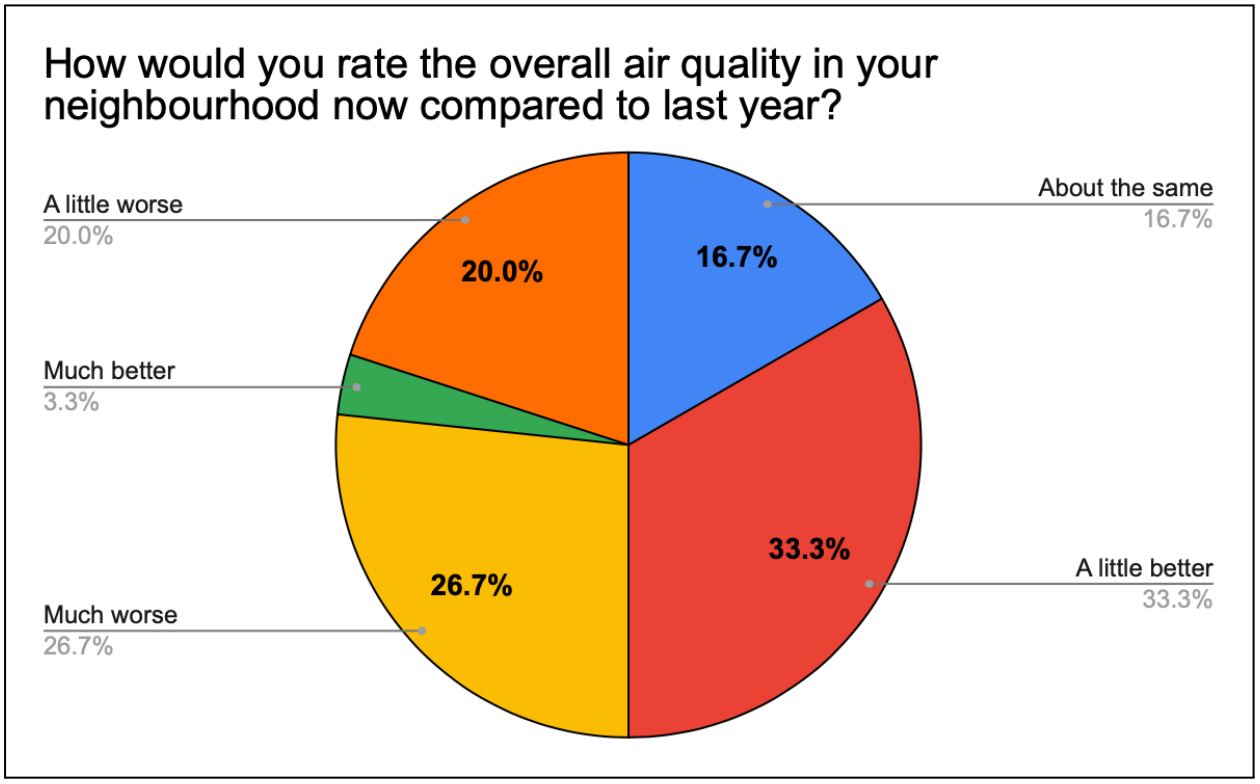


Mapr showing Outcomes of the community mapping in Baba Dogo and Mathare North

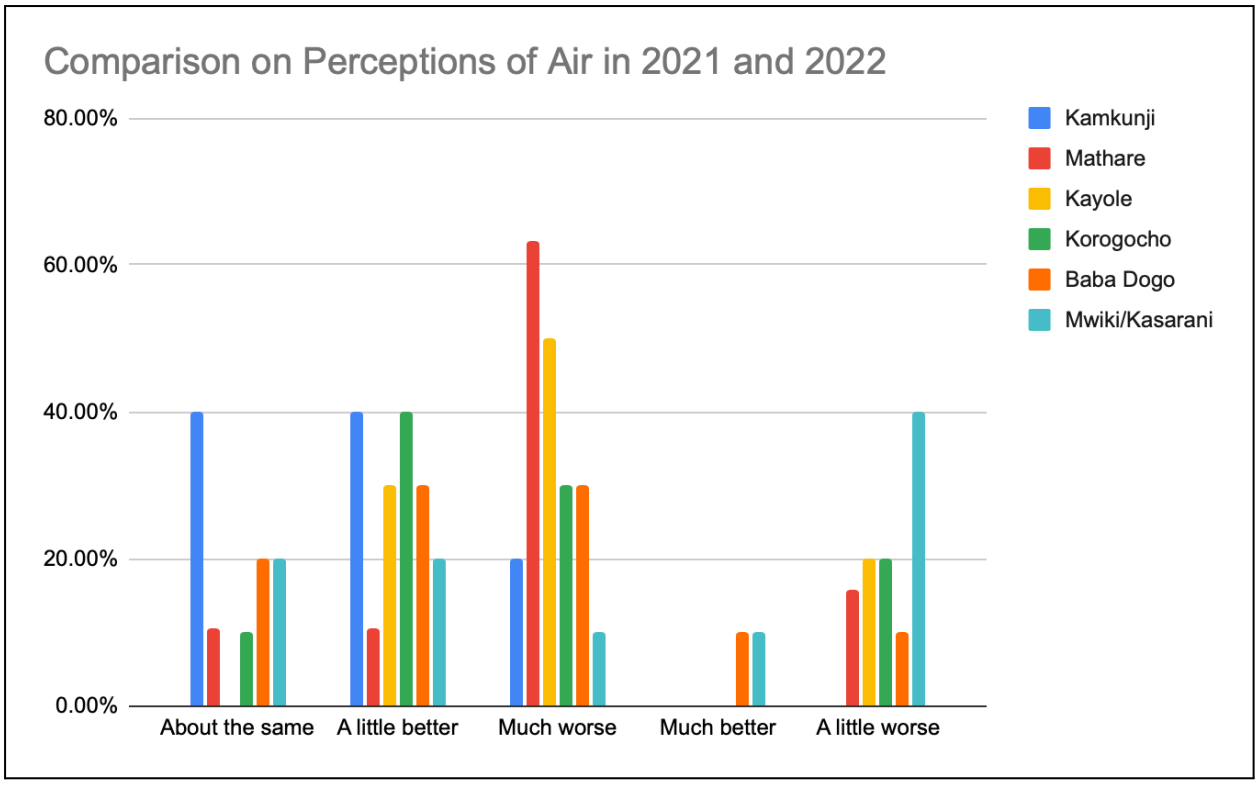
5.2 Data Output from Community meetings

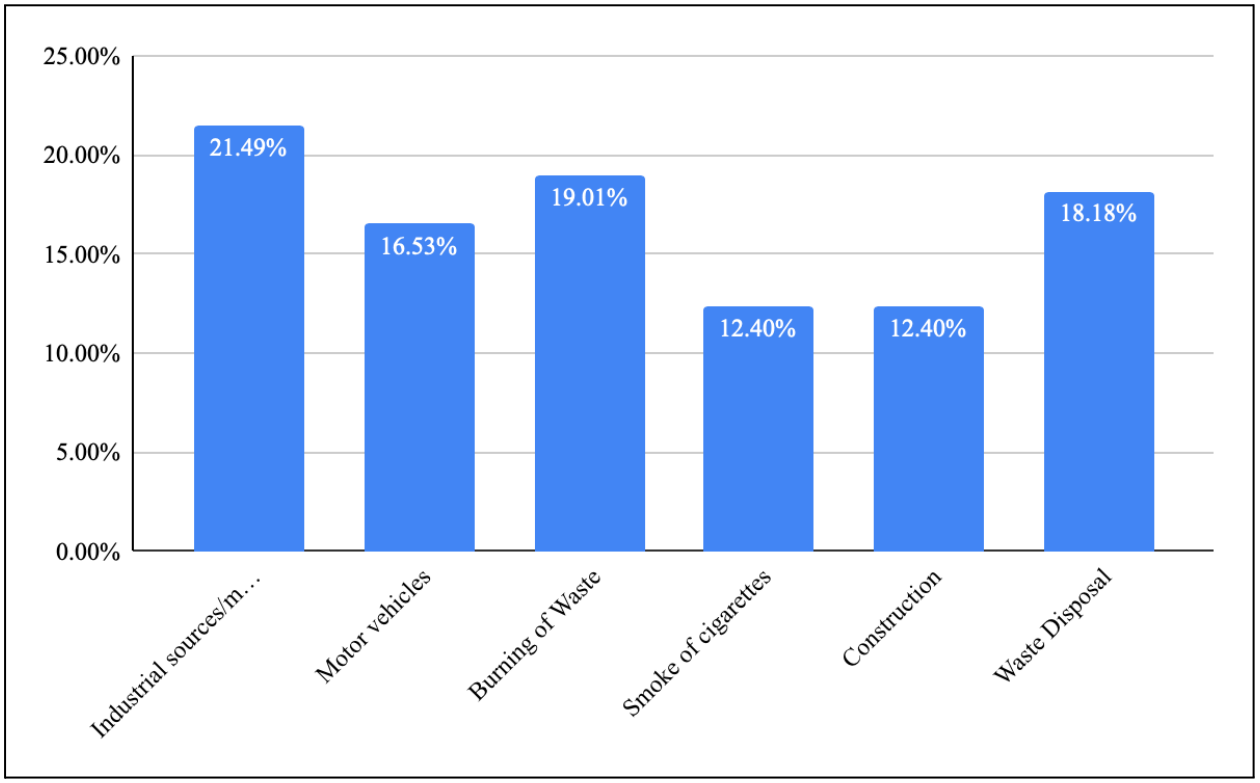


91% of the respondents indicated that noise pollution was a major concern within their neighbourhood. Only 8.3 % did not find it a concern.



Compared to the previous year, only 33% said that the air quality was a little bit better and 3.3 % stated that it was much better. For the rest (over 50%) it was either the same or worse. This can be broken down to neighbourhood level as shown below


Comparison on Perceptions of Air in 2021 and 2022
80.00%
60.00%
40.00%
20.00%
0.00%
About the same
A little better
Much worse
Much better
A little worse
Kamkunji
Mathare
Kayole
Korogocho
Baba Dogo
Mwiki/Kasarani


25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
21.49%
16.53%
19.01%
12.40%
12.40%
18.18%
Industrial sources/m…
Motor vehicles
Burning of Waste
Smoke of cigarettes
Construction
Waste Disposal

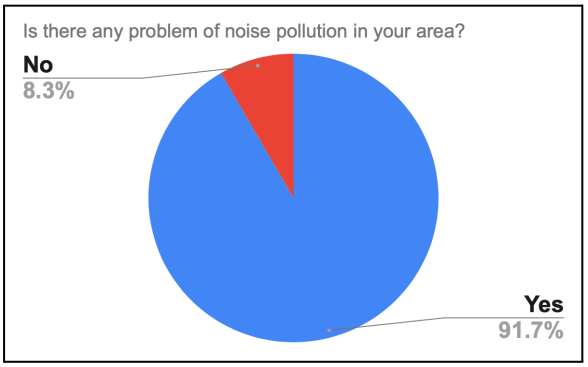
Respondents listed the different causes of air pollution that affected their neighbourhoods. Industrial sources were the leading cause followed by burning of waste and waste disposal. Some of the neighbourhoods are located near the Dandora dumpsite which is a major air pollutant.

Community members were also asked on their perceptions concerning how the problems of pollution should be approached. Most strongly agreed towards polluting companies being fined, the government doing more, police checking on emissions and the fact that environmental sustainability is also a citizen duty.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Polluting companies should be fined even if it puts some jobs at risk	64.29%	23.21%	3.57%	3.57%	5.36%
“Power stations and factories should switch to cleaner processes even if consumer bills and prices have to go up."	33.33%	46.30%	5.56%	5.56%	9.26%
“Government should do more to promote and encourage a better environment even if our taxes have to go up slightly.”	61.82%	19.64%	5.45%	3.64%	9.09%
“Police should stop and check car emissions more frequently even if it causes traffic delays.”	38.18%	30.91%	7.27%	16.36%	7.27%
“Improving the environment is the responsibility of every citizen.”	86.79%	7.55%	1.89%	1.89%	1.89%

	“Recycling programs should be put in place and promoted across the whole city.”	***“I am actively involved in cleaning up the environment.”***	***“The pollution is out of my control and I cannot do anything to change it.”***	***“I do not see the pollution as a problem.”***	***“If I knew how to better contribute to a cleaner environment, I would take action.”/***
Strongly Agree	71.43%	84.00%	7.55%	0.00%	58.82%
Agree	21.43%	12.00%	9.43%	0.00%	25.49%
Undecided	0.00%	0.00%	1.89%	3.85%	3.92%
Disagree	1.79%	2.00%	37.74%	11.54%	1.96%
Strongly Disagree	5.36%	2.00%	43.40%	84.62%	9.80%

Most respondents are involved in cleaning up the environment and agree that they can do something about it. They see pollution is a problem and are looking for other ways of contribution towards change. They are also very much pro-recycling programmes.



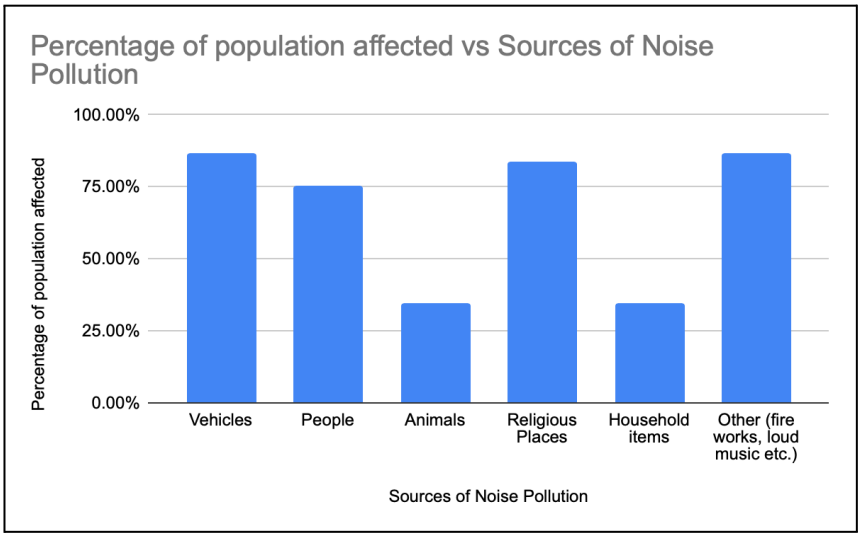
Have you ever lodged a complaint about a neighbour being too noisy?		
Yes	33	56.90%
No	25	43.10%

Slightly more than half are aware that there are noise pollution regulations and a similar percentage have made reports, an even larger group have discussed the issue with neighbours (71.19%). Interestingly, 91% state that there is a noise pollution problem in their neighbourhood.

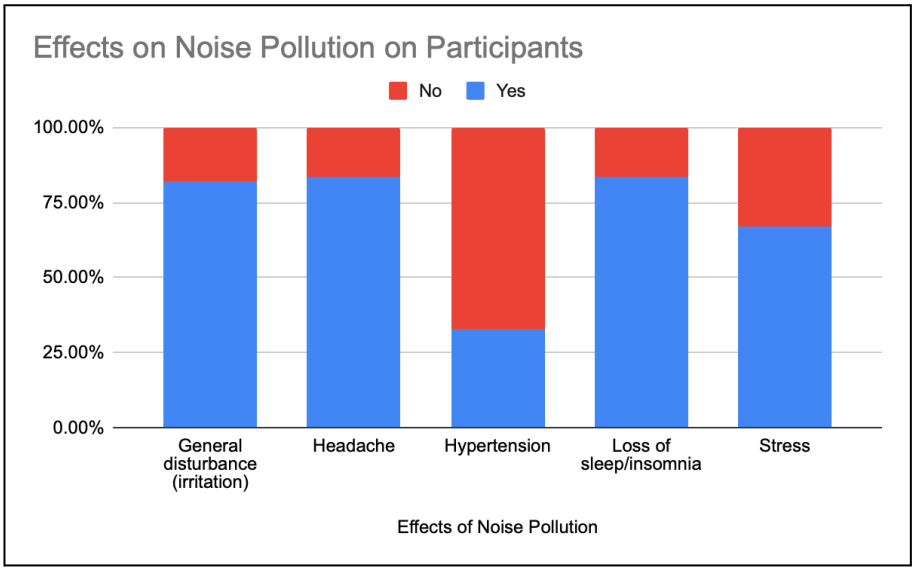
Are you aware that there are rules and regulations regarding noise?		
Yes	33	56.90%
No	25	43.10%

Engaged in conversation with your neighbours about the noise pollution that affects the community?		
Yes	42	71.19%
No	17	28.81%

The sources of noise pollution were mostly caused by vehicles and religious places. Other major causes are bars and nightclubs, which have featured in the news quite a lot.



The participants recognized some of the effects that noise pollution has had on them including disturbance, hypertension, loss of sleep and stress.



There was also interesting information on the levels of Knowledge about Cholera:

- Knowledge of cholera and prevention methods are fairly well known, however you would hope that 100% would start boiling or cleaning their water if cholera is detected in their local area. This leads to the conclusion that more community sensitization and awareness raising would be beneficial.
- It is also interesting to note that responses depending on education level did not differ significantly, so general awareness raising is not targeted on particular groups.
- Most people hear about cholera through radio or tv and therefore using this channel might be more effective as people are already used to receiving this type of information this way.
- Hearing about cholera through phone or SMS is completely new, so if a new warning/ alert scheme was to be done, it would have to be carefully managed, so as not to cause panic or misinformation in a targeted community. More piloting would be necessary.

6. Way forward

As urbanisation in developing world continues at pace, local data on exposure and health effects of air and noise pollution, and the role of socioeconomic factors, are urgently needed to enable behavioural and local policy efforts to be evidence-based, designing interventions to protect population health - (Arku, 2021)

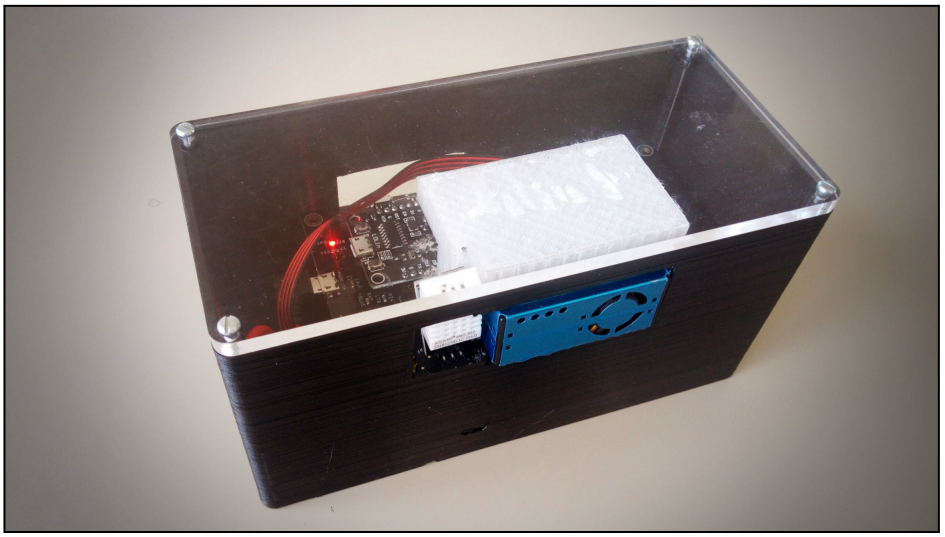
Access to information on emissions and the use of cheap and reliable low carbon technologies are critical for this change. Urban planners and environmentalists must be key in driving this change as we look to examples from elsewhere like *London's Ultra-Low Emission Zone, "noise radar" in Paris and Berlin's new cycle lanes on wide roads to Egypt's national plan to combat noise and Pakistan's 10bn trees "tsunami"*.(UNEP, 2022b)

The next steps of this program will guide towards obtaining his actionable data that will be helpful in ensuring that communities are able to use data to advocate for better living conditions, a better environment and higher quality of life.

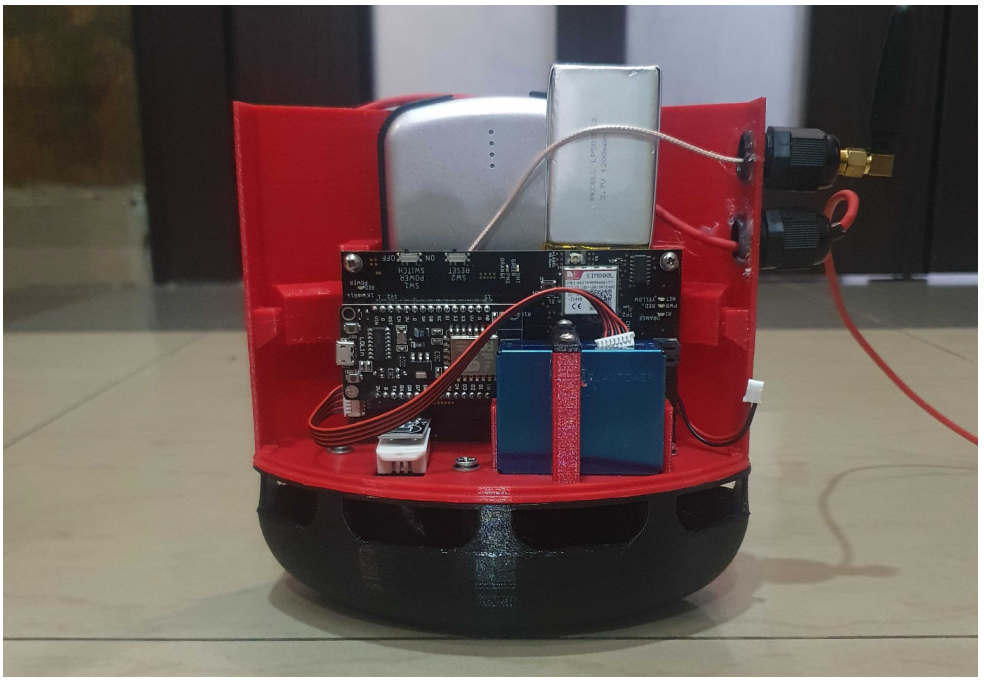
7 Next Steps

Development of AQ and Noise Monitors—> Calibration of Monitors + Deployment with community groups —> Using Community driven + partners with data for advocacy work —-> Action by Authorities

7.1 Examples of monitors for deployment



Sensors.AFRICA locally developed indoor Air Quality monitor



Sensors.AFRICA locally developed outdoor Air Quality monitor

Sensors.AFRICA locally developed outdoor Air Quality monitor

Sensors.AFRICA low cost air quality monitors detect PM 1, PM 2.5, PM 10, temperature and humidity. Data from deployed monitors is realdity available on the sensors.AFRICA dashboard and open.AFRICA repository.

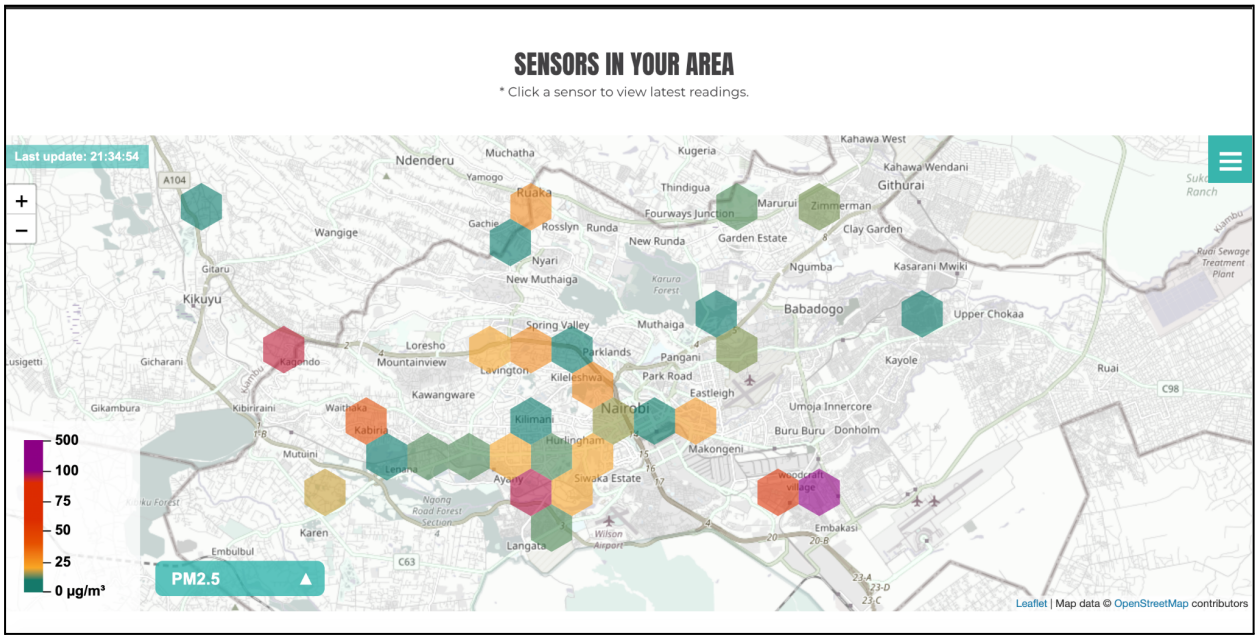
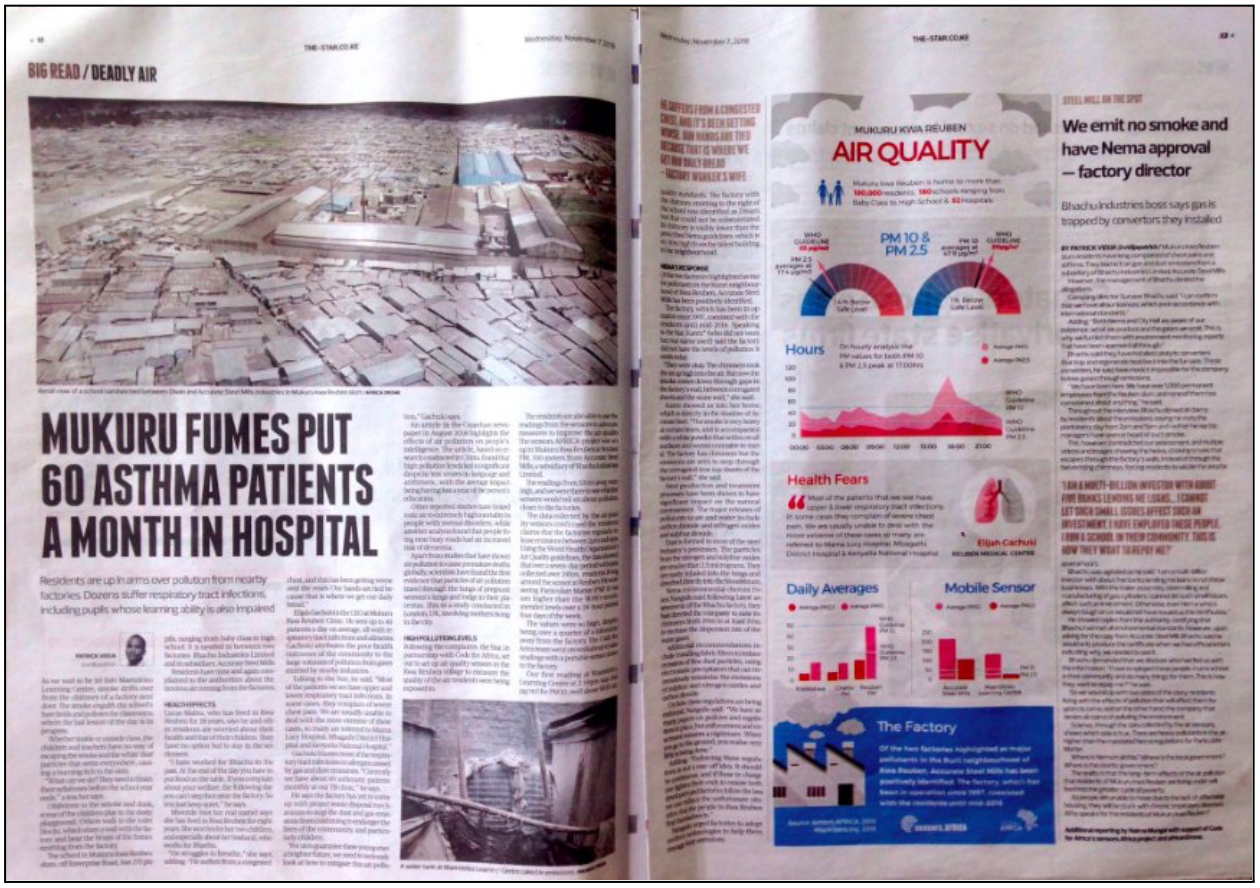


Image of the Sensors.AFRICA live Dashbboard

7.2 Data driven work in the past



Newspaper article using IoT citizen science data to drive change

Journalists have used such data to develop stories that can enable public authorities to take action when there are problems with environmental pollution.

8. References

Arku, R.E. (2021). *Urban air and noise pollution in sub-Saharan Africa: A study of prenatal exposures, birth outcomes, and sleep disturbances in infants*. [online] Health Effects Institute. Available at: https://www.healtheffects.org/research/ongoing-research/urban-air-and-noise-pollution-sub-saharan-africa-study-prenatal-exposures [Accessed 13 Sep. 2022].

Bai, L., Shin, S., Oiamo, T.H., Burnett, R.T., Weichenthal, S., Jerrett, M., Kwong, J.C., Copes, R., Kopp, A. and Chen, H. (2020). Exposure to Road Traffic Noise and Incidence of Acute Myocardial Infarction and Congestive Heart Failure: A Population-Based Cohort Study in Toronto, Canada. *Environmental Health Perspectives*, 128(8), p.087001. doi:10.1289/ehp5809.

Barton, A. (2015). Toxic Communities: Environmental Racism, Industrial Pollution, and Residential Mobility by Dorceta E. Taylor. *Natural Resources Journal*, [online] 55(1), p.236. Available at: https://digitalrepository.unm.edu/nrj/vol55/iss1/12/ [Accessed 16 Sep. 2022].

Beer, C.T. (2014). Climate justice, the global south, and policy preferences of Kenyan environmental NGOs. *The Global South*, 8(2), p.84. doi:10.2979/globalsouth.8.2.84.

Bhatia, R. (2014). *Noise Pollution: Managing the Challenge of Urban Sounds | Earth Journalism Network*. [online] Earthjournalism.net. Available at: https://earthjournalism.net/resources/noise-pollution-managing-the-challenge-of-urban-sounds [Accessed 13 Sep. 2022].

BONNEY, RICK, et al. "Overview of Citizen Science." *Citizen Science: Public Participation in Environmental Research*, edited by RICK BONNEY and JANIS L. DICKINSON, 1st ed., Cornell University Press, 2012, pp. 19–26. *JSTOR*, http://www.jstor.org/stable/10.7591/j.ctt7v7pp.8. Accessed 13 Sep. 2022.

Clark, S.N., Alli, A.S., Ezzati, M., Brauer, M., Toledano, M.B., Nimo, J., Moses, J.B., Baah, S., Hughes, A., Cavanaugh, A., Agyei-Mensah, S., Owusu, G., Robinson, B., Baumgartner, J., Bennett, J.E. and Arku, R.E. (2022). Spatial modelling and inequalities of environmental noise in Accra, Ghana. *Environmental Research*, [online] 214(2), p.113932. doi:10.1016/j.envres.2022.113932.

Dieter, S. (2012). Review of Urban Air Quality in Sub-Saharan Africa Region. *World Bank*. [online] Available at: http://hdl.handle.net/10986/26864 [Accessed 8 May 2021].

Goines, L. and Hagler, L. (2007). Noise Pollution: A Modern Plague. *Southern Medical Journal 2007*, [online] 100(3). Available at: https://docs.wind-watch.org/goineshagler-noisepollution.html [Accessed 15 Sep. 2022].

Halperin, D. (2014). Environmental noise and sleep disturbances: A threat to health? *Sleep Science*, [online] 7(4), pp.209–212. doi:10.1016/j.slsci.2014.11.003.

He, C., Liu, Z., Wu, J., Pan, X., Fang, Z., Li, J. and Bryan, B.A. (2021). Future global urban water scarcity and potential solutions. *Nature Communications*, [online] 12(1), p.4667. doi:10.1038/s41467-021-25026-3.

IFAD (2009). *Enabling poor rural people to overcome poverty Good practices in participatory mapping A review prepared for the International Fund for Agricultural Development (IFAD)*. [online] Available at: https://www.ifad.org/documents/38714170/39144386/PM_web.pdf/7c1eda69-8205-4c31-8912-3c25d6f90055#:~:text=Participatory%20mapping%20is%20a%20map [Accessed 16 Sep. 2022].

Keyles, S. (2018). *Citizen Science, Important Tool for Researchers*. [online] Science Connected Magazine. Available at: https://magazine.scienceconnected.org/2018/09/citizen-science-important-tool/#:~:text=Citizen%20Science%20Informs%20Research%20and%20Policy&text=This%20is%20great%20help%20for [Accessed 13 Sep. 2022].

Kigen, H.T., Boru, W., Gura, Z., Githuka, G., Mulembani, R., Rotich, J., Abdi, I., Galgalo, T., Githuku, J., Obonyo, M., Muli, R., Njeru, I., Langat, D., Nsubuga, P., Kioko, J. and Lowther, S. (2020). A protracted cholera outbreak among residents in an urban setting, Nairobi county, Kenya, 2015. *Pan African Medical Journal*, 36. doi:10.11604/pamj.2020.36.127.19786.

Kusi, N. (2022). *Arnstein's Ladder of Citizen Participation explained*. [online] www.commonplace.is. Available at: https://www.commonplace.is/blog/arnsteins-ladder-of-citizens-participation-explained [Accessed 13 Sep. 2022].

Land-Zandstra, A., Agnello, G. and Gültekin, Y.S. (2021). Participants in Citizen Science. *The Science of Citizen Science*, pp.243–259. doi:10.1007/978-3-030-58278-4_13.

Ledant, M. (2013). Water in Nairobi: Unveiling inequalities and its causes. *Les Cahiers d'Outre-Mer. Revue de géographie de Bordeaux*, [online] 66(263), pp.335–348. doi:10.4000/com.6951.

Mahendra, A., King, R., Du, J., Dasgupta, A., Beard, V.A., Kallergis, A. and Schalch, K. (2022). The Realities of Current Urbanization in the Global South | Seven Transformations for More Equitable and Sustainable Cities. *publications.wri.org*. [online] Available at: https://publications.wri.org/transformations-equitable-sustainable-cities/current-urbanization-global-south-realities#2.1-urbanization-shifting-to-low-and-middle-income-countries.

Marshall, S. (2011). The Water Crisis in Kenya: Causes, Effects and Solutions. *Global Majority E-Journal*, [online] 2(1), pp.31–45. Available at: https://www.american.edu/cas/economics/ejournal/upload/marshall_accessible.pdf.

Martin, R.V., Brauer, M., van Donkelaar, A., Shaddick, G., Narain, U. and Dey, S. (2019). No one knows which city has the highest concentration of fine particulate matter. *Atmospheric Environment: X*, [online] 3, p.100040. doi:10.1016/j.aeaoa.2019.100040.

Mwenda, V., Niyomwungere, A., Oyugi, E., Githuku, J., Obonyo, M. and Gura, Z. (2019). Factors associated with cholera outbreaks, Nairobi County, July 2017: a case control study. doi:10.1101/719641.

National Institute for Public Health and the Environment (n.d.). *10 benefits of citizen science | RIVM Magazines*. [online] magazines.rivm.nl. Available at: https://magazines.rivm.nl/en/2018/10/citizen-science/10-benefits-citizen-science.

Oyedepo, Sunday. (2012). Noise Pollution in Urban Areas: The Neglected Dimensions. Environmental Research Journal. 6. 259-271. 10.3923/erj.2012.259.271

Organizing Engagement (2019). *Ladder of Citizen Participation*. [online] Organizing Engagement. Available at: https://organizingengagement.org/models/ladder-of-citizen-participation/ [Accessed 13 Sep. 2022].

Rugg, M. and Andrews, M. (2010). Ask the Brains. *Scientific American Mind*, [online] 21(1), pp.74–74. doi:10.1038/scientificamericanmind0110-74.

Shum, Buckingham & Aberer, S & Schmidt, K & Jelasity, M & Karpištšenko, M & Kohlhammer, A & Lewis, Jerome & Pitt, Jeremy & Sumner, J & Buckingham Shum, Simon & Aberer, Karl & Schmidt, Albrecht & Bishop, S & Lukowicz, Paul & Anderson, S & Charalabidis, Yannis & Domingue, John & Freitas, S & Dunwell, Ian & Helbing, Dirk. (2012). How to cite: Towards a global participatory platform Democratising open data, complexity science and collective intelligence. The European Physical Journal Special Topics. 214.

Shin, S., Bai, L., Oiamo, T.H., Burnett, R.T., Weichenthal, S., Jerrett, M., Kwong, J.C., Goldberg, M.S., Copes, R., Kopp, A. and Chen, H. (2020). Association Between Road Traffic Noise and Incidence of Diabetes Mellitus and Hypertension in Toronto, Canada: A Population-Based Cohort Study. *Journal of the American Heart Association*, 9(6). doi:10.1161/jaha.119.013021.

UN - Environment (2020). *Why low-cost sensors? Opportunities and Challenges*. [online] UNEP - UN Environment Programme. Available at: https://www.unep.org/explore-topics/air/what-we-do/monitoring-air-quality/why-low-cost-sensors-opportunities-and [Accessed 13 Sep. 2022].

UNEP (2022a). *In Africa, cities embrace clean air targets*. [online] UNEP. Available at: https://www.unep.org/news-and-stories/story/africa-cities-embrace-clean-air-targets [Accessed 13 Sep. 2022].

UNEP (2022b). *The world's cities must take on the cacophony of noise pollution*. [online] UNEP. Available at: https://www.unep.org/news-and-stories/opinion/worlds-cities-must-take-cacophony-noise-pollution [Accessed 13 Sep. 2022].

van Kamp, I. and Davies, H. (2013). Noise and health in vulnerable groups: A review. *Noise and Health*, 15(64), p.153. doi:10.4103/1463-1741.112361.

Venter, C., Mahendra, A. and Lionjanga, N. (2021). *Chapter 15 - Urban expansion and mobility on the periphery in the global South*. [online] ScienceDirect. Available at: https://www.sciencedirect.com/science/article/pii/B9780128198223000134.

Wainaina, C. (2018). *Nairobi is at Risk From Another Cholera Outbreak. Why This isn't Necessary*. [online] APHRC. Available at: https://aphrc.org/blogarticle/nairobi-is-at-risk-from-another-cholera-outbreak-why-this-isnt-necessary/ [Accessed 13 Sep. 2022].

Wawa, E.A. and Mulaku, G.C. (2015). Noise Pollution Mapping Using GIS in Nairobi, Kenya. *Journal of Geographic Information System*, 07(05), pp.486–493. doi:10.4236/jgis.2015.75039.

WHO (2019). *Environmental Noise Guidelines for the European Region (2018)*. [online] www.euro.who.int. Available at: https://www.euro.who.int/en/publications/abstracts/environmental-noise-guidelines-for-the-european-region-2018 [Accessed 15 Sep. 2022].

Wikipedia Contributors (2019). *Sherry Arnstein*. [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Sherry_Arnstein [Accessed 16 Sep. 2022].

World Bank Group (2020). *Providing Sustainable Sanitation and Water services to Low-income Communities in Nairobi*. [online] World Bank. Available at: https://www.worldbank.org/en/news/feature/2020/02/19/providing-sustainable-sanitation-and-water-services-to-low-income-communities-in-nairobi [Accessed 13 Sep. 2022].