Commentary
Using citizen science to assess cumulative risk from air and other pollution sources in informal settlements

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Environmental challenges in informal settlements

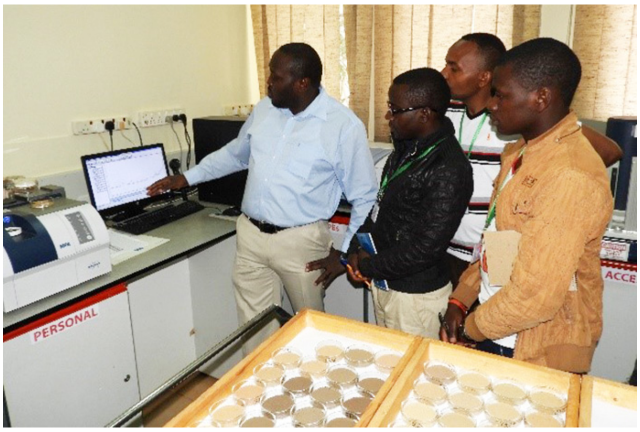
Residents of informal settlements in developing countries such as Kenya are faced with a myriad of environment challenges that exposes them to a combination of risks from multiple exposures to environment stressors, including pollution and environmental contamination. Researchers and development planners usually focus on and typically address a single environmental issue, such as air pollution, rather than to take a holistic approach that considers the combination of risks, that cumulatively affect these residents due to multiple exposure. This lack of a holistic approach is made worse in informal settlements that are considered illegal, unplanned and therefore ignored in urban development frameworks (McCartney& Krishnamurthy, 2018; Jones, 2017). The sustainable development goals (SDGs), including the New Urban Agenda (NUA), which emerged from SDG 11 presents policy opportunities for a holistic approach to urban development, given the attention paid to the progressive and democratic approaches such as liveable, inclusive, and just cities. The focus of the New Urban Agenda (NUA) of "leaving no one behind" has generated positive responses in some African countries, which, taken together with the African Union's Agenda 2063 can lead to sustainable cities in Africa (UN 2019).Given the uniqueness of cities in Africa, homegrown models present the most suitable opportunities for the realisation of sustainable cities, and to achievement of all the 17 SDGs. Transdisciplinary research models is central for African cities as it enables scientists, practitioners and local communities to work together to co-generate solutions that are embedded in local realities and context (International Council for Science 2020).

The case of Mukuru informal settlement in Kenya illustrates the challenges of cumulative risks from air and other pollution sources, and the opportunity that is presented by a trans-disciplinary approach to research that involves local communities, practitioners and policy makers to co-create solutions that are based on the local contexts. Mukuru, which comprises of three informal settlements (Mukuru Kwa Njenga, Mukuru Kwa Reuben, and Viwandani), is situated approximately 7km to the south eastern part of Nairobi CBD, and occupies an area estimated at 670 acres, with a population coverage of 100,561 households. Due to its unique circumstances, the

A group of youth from the Mukuru settlements (Community Champions) involved in soil sample collection. Photo credit: William Apondo, SEI

Nairobi City County Government (NCCG) declared Mukuru as a Special Planning Area (SPA) invoking, for the first time in Kenya's history, Article 23 of the Constitution of Kenya (2010), which give the County Governments power to designate an area as SPA, if distinguished by unique development problems and environmental potential while also raising significant urban design and environmental challenges.

The SPA approach embraces the spirit of urban inclusivity, which is supported by the Government of Kenya and other development partners that recognise the important role that informal settlements play in the urban economy and accommodation of a large section of urban residents. In Mukuru, the SPA process did not only focus on improvements to the physical infrastructure, but also provided for participatory frameworks that has allowed the urban poor to be able to engage with policy makers and present the issues affecting them, which was hitherto often downplayed. Historically, urban planners have tended to give preference to purely technocratic-driven interventions, that rarely addressed the wider environmental challenges such as the rampant pollution that is prevalent in informal settlements, leading to undetected exposure of residents to alarming levels of pollution, that is considered as the largest environmental cause of disease and premature death in the world (the Lancet Commission 2017) .



ICRAF scientists conducting training for Community Champions and CHWs from Mukuru on soil sampling, analysis process and packaging of soil samples. Photo Credit: William Apondo, SEI.

Multiple cumulative exposure from air and soil pollution

The SPA provided a unique platform for the formation of a multi-stakeholder, multi-disciplinary and cross-sectoral team of over 40 organizations led by the NCCG and the Slum/Shack Dwellers International (SDI) that worked together in eight Consortia to develop the Integrated Plan for Mukuru (Horn et al., 2020). The Stockholm Environment Institute (SEI), as convener of the Environment and Natural Resources SPA Consortium, together with the NCCG (Environment Department), SDI, and the World Agroforestry (ICRAF) conducted studies on waste management, air pollution and soil contamination, to provide scientific evidence to inform the Mukuru Informal Settlement Plan. These studies followed a transdisciplinary approach, by using citizen science methods, training and working with community champions (selected individual youth) and community health workers (CHWs) drawn from the local communities in the process of data collection. The findings from the studies on waste management, air pollution and soil contamination, validated previous studies that highlighted the environmental threats to health and well-being among residents in Mukuru arising from both indoor and outdoor air pollution (West et. al., 2020; Dianati, et al., 2019; Muindi et al., 2014), soil contamination (Ondayo et. al., 2016), water pollution, and lack of sanitation and hygiene (University of California Berkeley: UCB, 2018).

The studies on the three environmental components; waste management strategies employed, air pollution, and soil contamination, may seem to deal with different aspects, but are in essence, combined in a way that exposes the multiple and cumulative exposure to the residents of Mukuru, and should therefore be addressed collectively and in an integrated manner; soil health, waste pollution and air pollution are intrinsically linked and were noted to contribute to overall quality of the environment in Mukuru. This is a rare cumulative analytical approach that would be suited for other high or a low-income urban settlement in Kenya and Africa, and is critical in analysis of informal settlements livability suitability by depicting the level and nature of pollution exposure and associated health risks at household and community levels. UN Habitat & WHO (2020) encourages application of detailed exposures and relative risk estimates to aid in deriving net health impact of combined exposures in everyday living in environment which should inform planning and decision-making processes around urban and territorial interventions.

Informal settlements are spatially located in delicate environments (often low-lying areas near river banks that are prone to flooding and other disasters) and are often without any form of buffers. These conditions exposes the already socially and economically vulnerable residents to harsh living conditions physically and financially. This creates high chances of the residents being trapped in poverty as they are forced to use their meager resources to treat illnesses that are caused by pollution, such as respiratory health conditions that is associated with cooking using dirty fuels, open burning of waste, and emissions from the industries, as well as contamination of food that is grown in polluted soils using water from polluted rivers and streams.

The air quality studies in Mukuru have focused on three major pollutants; particulate matter ($PM_{2.5}$) Nitrogen dioxide (NO_2) and Ammonia (NH_3). PM levels were found to be variable with indoor peaks in the mornings and evenings, and outdoor locations recording concentrations of between 15 – 70 µg m^{-3} for daily averages, against the World Health Organization (WHO) guidelines of 25 µg m^{-3}. Similarly, areas close to industries recorded high levels, exceeding the Kenyan and WHO standards (West et. al., 2020; Twigg, 2018). The NO_2 levels recorded across nine sites in Mukuru were below the annual national air quality regulations tolerance limits in Kenya of 150 µg m^{-3} and at least one location was above the WHO annual mean guideline of 40 µg m^{-3} (WHO, 2005). The NH_3 levels in Mukuru were found to be very high across the nine measurement sites, with an average concentration of 45.73 µg m^{-3}, compared to a low of 3.45 µg m^{-3} recorded at a reference background site located at the World Agroforestry Centre (ICRAF) in Gigiri, close to the Karura forest (Twigg, 2018). Open dumpsites littered with solid waste and free flowing human waste due to lack of proper sewerage system were identified as potential sources of NH_3 (Apondo, 2019). Previous studies suggest that, open waste burning is also an important contributor of PM source in the city (Gatari et al 2005). This may therefore require that planning interventions address simple guidelines of handling waste and proper siting of waste collection sites to reduce exposure to air pollution in such settlements through responsive urban design and air quality monitoring.

Other aspects associated to exposure to air pollution in Mukuru included crowded housing with a density of 87,538 persons per km^2 (by comparison, this is higher than Kibera Slums with a density of 15,311 persons per km^2 and far much higher than Cape Town's Khayelitsha slums with a density of 10,120/km^2). This is worsened by the poor housing conditions, which are either completely lacking or have inadequate ventilations.

The soil contamination study focused on the following elements, arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), molybdenum (Mo) nickel (Ni) and zinc (Zn). The levels of heavy metals such as Cd ranged from 1.23-22.73 mg/kg, which was higher than the tolerable values of 3mg/kg. Zn ranged from 230.81-4979.67 mg/kg, which is extremely higher than the tolerable value of 300mg/kg. These values suggest contamination of Zn and Cd due to the waste dumping site and the industrial activities around the area. One of the most important analysis connecting solid waste and soil pollution to air pollution is that soils are the major sink for heavy metals released into the environment.

Soil contaminant limits for heavy metals in urban areas have not been developed in Kenyan. The contaminant limits for heavy metals have been developed for soil total element concentration values in attempts to determine and predict concentrations above which effects occur and below which effects do not occur (Chapman et al., 2003, Towett et al., 2013), these values however vary by jurisdiction. Airborne sources of metals in soils include all solid particles in smoke from fires including burning of waste, and in other emissions from factory chimneys which according to Smith et al (1995) are eventually deposited on land; most forms of fossil fuels contain some heavy metals, and this is, therefore, a form of contamination which is in large scale since the industrial revolution began. Previous studies in informal settlements in Nairobi including Mukuru found high concentrations of Pb, with children exposed to levels beyond the USEPA limits (Ondayo et. Al., 2016). Also, USEPA (1996) noted that very high concentration of Cd, Pb, and Zn has been found in plants and soils adjacent to smelting works. Another major source of soil contamination is the aerial emission of Pb from the combustion of petrol containing tetraethyl lead; this contributes substantially to the content of Pb in soils, especially those sampled along the roadsides in urban areas and in those adjacent to major roads. Zn and Cd may also be added to soils adjacent to roads, the sources being tyres, and lubricant oils.

Conclusion

Residents of informal settlements are faced with multiple risks including cumulative exposure to air, soil, and water pollution. These environmental issues are often addressed in isolation and rarely are there integrated and holistic approaches. Transdisciplinary studies, including citizen science approaches that brings together scientists, practitioners, policy makers and local communities in informal settlements to co-create solutions hold promise for promoting holistic and integrative approaches. In this commentary, we presented an example of how an inclusive and participatory policy approach for planning of an urban informal settlement in Nairobi has presented the opportunity for collaborative co-creation of solutions to address the multiple and cumulative challenges of pollution from air, soil and other sources in Mukuru informal settlements in Nairobi. Cumulative pollution analysis is likely to catalyse desired urban planning interventions to realise the goals of attaining inclusivity and liveability in informal settlements. This is useful in addressing the complex environmental quality challenges that the vulnerable urban community living in informal settlements experience on daily basis as demonstrated in the Mukuru case. Involvement of community champions in data collection is important in creating awareness and sensitization among the residents as they can use their knowledge and experience to help community aware of potential negative implications of soil pollution in certain locations of the settlements and possibly share these with the decision and policy makers.

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