Commentary
AfriqAir's mission towards cleaner air for Africa and a call to action

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Poor air quality has long been recognized as one of the major threats to human health. Particulate matter (PM) exposure in particular has been linked to cardiovascular and cerebrovascular diseases as well as asthma, respiratory infections, and cancer (WHO 2013). In Africa, this problem is especially acute: recent work has estimated that poor air quality causes nearly 800,000 premature deaths in Africa every year (Bauer et al., 2019). Indeed, this number has been steadily increasing over the past few decades, from an estimated 180,000 premature deaths in 1990 and 246,000 in 2013 (Roy, 2016; though there are methodological differences between these two papers, the qualitative trends should still hold). There is a major caveat to these estimates: these are estimates based on limited air quality measurements over the continent. Instead, these estimates relied on models and satellite retrievals, which are also constrained by the unavailability of measurements that enable accurate ground-truthing (Anenberg et al., 2020). Herein lies the crux of the problem for most of Africa: over the vast majority of the continent, there exists a significant data and knowledge gap with regards to air quality.

The extent of the knowledge gap over Africa spans multiple issues. First and foremost, there is simply a lack of air quality monitoring infrastructure. In Western Africa, there is approximately 1 reference-grade $PM_{2.5}$ (PM with an aerodynamic diameter less than 2.5 micrometers) monitor per 10 million people. In Eastern Africa, the problem is even worse with approximately 1 reference-grade monitor per 100 million people (Malings et al., 2020). Second, this lack of monitoring is compounded by the fact that the sheer diversity of sources of PM and other atmospheric pollutants (e.g., ozone precursors, NO_x, SO_x) is much greater than the sources in most of the OECD or Global North (Kiesewetter, 2016). The emission profiles for the majority of these sources are still unknown. Lastly, the atmospheric chemistry and physics that occurs between these anthropogenic emissions and natural and biogenic emissions from sources endemic to the continent (e.g. the Sahara, Congolian rainforests) are likewise broadly unknown. The good news is that there is currently work being done to shrink these knowledge and data gaps to improve African air quality.

One such group working on this problem is Africa qualité de l'air (AfriqAir). Hosted by the Kigali Collaborative Research Centre, AfriqAir is a consortium of 15 institutions across the globe with members in Western Africa, Eastern Africa, South Africa, the US, and Australia who are dedicated to improving air quality in Africa. The founding members of the organization are Kofi Amegah (Ghana), Timothy X Brown (Rwanda), Rebecca Garland (South Africa), Jimmy Gasore (Rwanda), Paulina Jaramillo (USA), V. Faye McNeill (USA), Albert Presto (USA), R Subramanian (USA, France), Emilia Tjernström (Australia), and Daniel Westervelt (USA). AfriqAir's mission statement is to develop long-term, sustainable air quality monitoring efforts over the continent. To accomplish this, AfriqAir takes a three-pronged approach:

- help build the physical infrastructure required for air quality monitoring,
- help build the capacity to locally manage, analyze, and use this physical infrastructure, and
- ensure that the knowledge generated from these efforts are accessible and actionable.

From AfriqAir's perspective, meeting all three of these goals is the best way to move towards cleaner air in Africa.

To accomplish the first of these goals, the physical infrastructure for air quality monitoring, AfriqAir is helping implement hybrid networks of low-cost air quality monitors centered around reference-grade monitors. The benefits of using low-cost sensors, particularly in Africa, to increase the spatiotemporal resolution of air quality monitoring efforts have been noted elsewhere (Rahal, 2020). The drawback of low-cost sensors, however, is that they require calibration to ensure their output can be trusted. The hybrid network approach helps mitigate this issue by offering a local calibration point. Currently, AfriqAir has hybrid networks deployed in Abidjan, Côte d'Ivoire (with reference-grade $PM_{2.5}$, NO_x, and O_3), Nairobi, Kenya (reference-grade $PM_{2.5}$, and NO_x), and Accra, Ghana (reference-grade O_3 and NO_x). AfriqAir also currently has a number of other low-cost sensors deployed around the continent in Ghana, Côte d'Ivoire, Niger, Democratic Rep. of Congo, Rwanda, Uganda, Kenya, and South Africa, with plans to deploy reference-monitors to create hybrid networks in the near future (Fig 1). Part of this effort includes deploying 25 reference-grade $PM_{2.5}$ monitors (TEOM-FDMS 1400ab, Thermo Fisher Scientific, Waltham, MA, USA) that AfriqAir obtained as a gift from the UK Environment Agency, around the continent over the coming year. Overall, this approach of hybrid networks to increase the physical

Figure 1: *AfriqAir network map (including monitors run by affiliated partners)*

infrastructure for air quality monitoring is the best balance between cost, accuracy, and high spatiotemporal resolution to provide air quality monitoring coverage to the largest areas and number of people.

Increasing the physical infrastructure for air quality monitoring is, however, insufficient without ensuring that local partners are trained and provided with necessary supplies to operate and maintain said infrastructure. Having local partners and stakeholders running these monitoring networks is the only way to ensure there is a long-term, sustainable future for these monitoring solutions. Current partners include the University of Rwanda, University of Cape Coast, Université Félix Houphouët-Boigny, University of Nairobi, Jomo Kenyatta University, Kenyatta University, University of Ghana, North-West University, and the network is expanding. From AfriqAir's perspective, local partners and stakeholders should be able to not only run air quality monitors but also be able to analyze their data and work towards applying the data towards value-added products such as air quality reports, air quality management plans, interventions, and air quality models. To this end, AfriqAir is part of multiple efforts across the continent to build air quality monitoring and management capacity. Some of these efforts are in collaboration with other multi-national projects such as CAMS-Net. Furthermore, AfriqAir provides technical assistance and training to our African partners if requested. Without local

buy-in of monitoring efforts, such efforts will not contribute to long-term, sustainable improvements in African air quality.

Finally, the ultimate goal of improving air quality in Africa cannot be attained if air quality data are not public (as is the usual practice in the Global North). Open and accessible data allow local populations access to important health information, can alert regulators and officials to potential problems, and can help drive international collaborations to address issues. AfriqAir therefore abides by an open-data framework and we aim to make all calibrated data for all of our sensors openly available through our website or upon publication of academic papers. We also encourage everyone who operates air quality monitors on the continent to follow this framework. Of course, there is an important point to recognize that open-data can sometimes lead to a lack of attribution and recognition for those that spent time, money, and effort in collecting the data. For researchers whose professional standing and growth depends on being recognized as a source of data, open-data frameworks can pose some problems. To address this concern, AfriqAir will be using a Creative Commons Attribution-ShareAlike 4.0 International License for all its available data. Under the terms of this license, users can share and adapt our data but are required to provide attribution, describe any changes to the data, and share any derivative materials under the same license. Similarly, any journal paper derived from the AfriqAir efforts will include access to the data through an open-access data repository (e.g. Zenodo, Figshare, Kilthub, or global air quality repositories such as OpenAQ). Developed under the European OpenAIRE program and operated by CERN, Zenodo is a general-purpose open-access repository that allows researchers to deposit data sets, research software, reports, and any other research-related digital artifacts. An advantage of Zenodo is that each submission is linked to a digital object identifier, making the stored items easily citable. We believe that making data available through these mechanisms will increase interest and help generate sustainability in air quality monitoring in Africa.

Ultimately, using these three specific approaches may not fit everyone in the air quality space in Africa, but we reiterate that there is a desperate need for actions to improve air quality to start now. Reducing the number of premature deaths and overall mortality due to poor air quality is of utmost importance all over the African continent. For AfriqAir, the three approaches described here work well but regardless of how the problem is approached, we as a community can make real strides in improving air quality over Africa if we work together and pool our expertise. We invite you to contact us at AfriqAir if you agree with this mission. We are an open community trying to coordinate efforts at tackling one of the great health issues of our time and would be honored to work alongside you. You can contact us through our website (afriqair.org), Twitter (@AfriqAirQuality), or email (mike@afriqair.org, pjaramil@kcrc.rw, airquality@kcrc.rw).

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