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Air pollution and non-communicable diseases in Sub-Saharan Africa

1. Background

In 2015, the World Health Organization (WHO) estimated that non-communicable diseases (NCDs) were responsible for 40 million of the world's 56 million deaths, where 15 million of these were premature deaths and over 80% had occurred in low- and middle-income countries, mainly in Sub-Saharan Africa (SSA) [1]. The increasing levels of urbanization with poor urban planning in SSA have contributed to the rising levels of air pollution and along with this, increased adverse health effects especially NCDs. It is estimated that outdoor air pollution and household air pollution (HAP) together caused more than 6 million deaths from cardiovascular diseases, chronic respiratory diseases and lung cancer in 2012 [2] and HAP was the highest contributor to NCD deaths in SSA in 2016 [3]. The epidemiological transition from predominantly infectious diseases to NCDs is already well underway in SSA where in 2004, more than half of all deaths in SSA were caused by infectious conditions, but by 2030, NCDs will have caused 46% [4].

While risk factors such as unhealthy diet, physical inactivity, overweight, obesity and high blood pressure have been recognized worldwide as determinants of NCDs [5], evidence has emerged of the relationship between exposure to environmental factors such as air pollution, tobacco smoke and chemicals and NCDs [3,6,7]. Outdoor air pollution is the most common form of air pollution studied in developed countries while indoor air pollution is heavily studied in SSA expectedly because SSA is characterized by heavy use of biomass fuels for cooking such as wood and crop residues which results in HAP [8].

Substantial evidence on the association between outdoor air pollution and NCDs such as cardiorespiratory diseases, chronic obstructive pulmonary disease (COPD), asthma, and stroke have largely been established in developed countries [7,9–11]. Studies on this relationship are very limited in Africa and therefore estimates characterizing the global burden of non-communicable disease are based on estimates which are mostly contributed by developed countries [12]. As a result, the contribution of air pollution to NCDs in Africa is not well characterized and consequently, not sufficiently recognized by the general public and policy makers in Africa as a potential threat to health.

There are several reasons for the paucity of data on air pollution and NCDs across the African continent. Perhaps the most apparent and yet important reason is the lack of expertise and infrastructure to conduct well quantified exposure assessment of air pollution. Due to lack of high quality and well monitored air monitoring stations, there is no designated index across African countries which can be used to determine air quality (Fig. 1). There is need for well-established air pollution monitoring stations and exposure assessment models that are specific to the region. By building an integrated network of air quality monitoring systems through the installation of high-quality ground level monitoring systems, reliable estimates of local air quality data can be generated, a requirement to drive effective air pollution exposure reduction policies while serving as a powerful tool to inform the public about the dangers of air pollution and indeed for epidemiological research [13].

Assessment of indoor household air pollution has largely been limited to self-reported use of biomass fuels for cooking and is widely used in epidemiological studies. However, there is need for more objective measures to quantify concentrations of particulate matter emitted in the household and in addition, objective measurements for markers of NCDs. This, however, may be costly for large studies, another important reason that may contribute to the gap in research between air pollution and NCDs. Therefore, based on these limitations, filling the gap on such evidence remains an uphill battle across the continent.

Levels of indoor particulate matter (PM_{10}) as high as excess of 200 $\mu g/m^3$ have been reported in SSA settings [14,15] above the 24-h WHO- air quality limits of 50 $\mu g/m^3$ for PM_{10} [16]. A new study in three major African cities, Addis Ababa in Ethiopia, Nairobi in Kenya and Kampala in Uganda reported that air pollution has increased 'significantly' over the past 45 years and that particulate matter pollution levels in the three cities are estimated to have increased by 182%, 162% and 62% respectively since the 1970s to the current period [17]. Within a span of this period cardiovascular disease accounted

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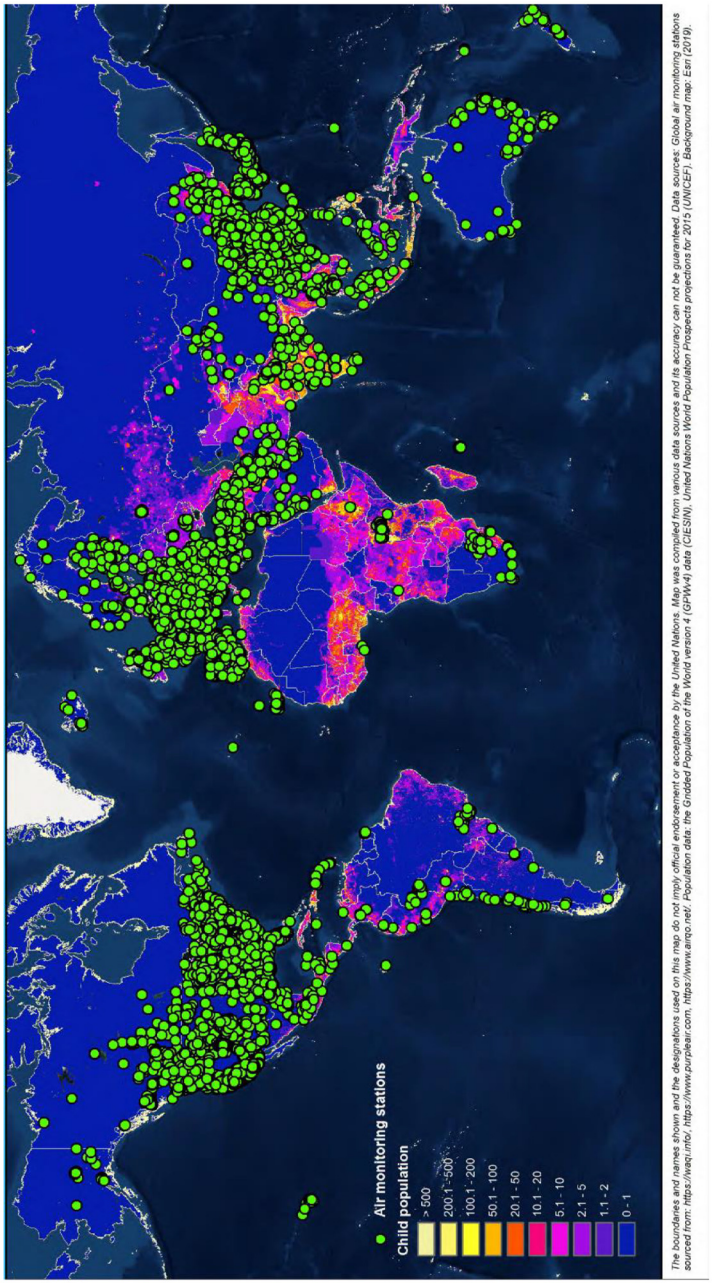

Fig. 1. Map showing real time air monitoring stations globally. *Source UNICEF report: Silent suffocation in Africa [13].

for 3%-12.6% of hospital admissions in Ethiopia and this increased between 1970s and 2000s [18]. Similarly, deaths due to NCDs increased from 35% of total deaths in 2003 to 45% in 2010 [19] in Kenya and overall, between 1990 and 2017, the total number of disability adjusted life years due to NCDs for all ages increased rapidly in SSA, from around 90.6 million (95% confidence interval 81.0–101.9) to 151.3 million (133.4–171.8), representing a 67% increase [20]. However, the efforts to reduce air pollution in SSA clearly do not match the level of public health concern it presents as evidenced by the lack of investment in air quality monitoring systems, well-resourced environmental health research institutes and the hesitance to adopt and enact air quality policies.

Studies on associations of indoor or outdoor air pollution with a myriad of NCDs have been reported in relation to (chronic) respiratory diseases in Africa [15,21,22] but rarely in relation to ischemic heart disease, cancer and high blood pressure. For example so far only one study has investigated the relationship between HAP and overweight and obesity in Africa where protective associations were observed [23]. Whether the scarcity of data is due to lack of research in the field or poor documentation and dissemination of studies conducted, it is evident that this is a burgeoning public health problem which requires high quality research and urgent attention.

The mechanisms through which air pollution exposure may lead to NCDs is not very well understood, complex and may depend on the timing of exposure [24,25]. Briefly, air pollution exposure is known to cause oxidative stress, inflammatory responses, and tissue remodeling [26,27]. Oxidative stress can trigger redox-sensitive pathways that lead to different biological processes such as inflammation and cell death [28]. Inflammation plays a central role in asthma, is a hallmark of lung function decline and eventually COPD in adults [29] and is a key pathway leading to atherosclerosis and subsequent cardiovascular events [30]. The interplay between air pollution exposure and genetics has also been acknowledged to play a role in the development of NCDs mainly cardiovascular diseases [31]. However, whether the mechanisms involve genetic changes first and subsequently air pollution exposure induced susceptibility or whether exposure to air pollution causes genetic changes first that result in increased susceptibility to cardiovascular disease remains unclear.

The lack of general public awareness on the potential contribution of such exposures on health, heavily contributes to lack of tangible action towards combating both outdoor and HAP in SSA settings. As a result, citizens rarely demand policy makers to be accountable when it comes to regulation of emission levels. While many African governments have made claims to tackle air pollution [32] implementation of these measures remains to be seen. The report from the UN Environment Program, on 'Action on air quality' focusing on ten measures to improve air quality, organized around six categories: including indoor air pollution, fuels and vehicles, and air quality laws and regulations revealed that majority of African countries are yet to adopt these air quality policy actions [33].

The need for more research to inform policy is dire and the lack of specific data on air pollution and NCDs in Africa is a huge obstacle towards policy action. Unless researchers, governments and stakeholders in SSA recognize this, the importance of the role of air pollution on NCDs will continue to be neglected and efforts to curb down NCDs related to air pollution exposure will be fruitless. Air pollution exposure is a significant health multifaceted challenge which will require holistic multidisciplinary efforts to quantify and understand its role in relation to NCDs especially considering the emerging interaction of air pollution exposure effects with nutrition and lifestyle. More well-designed studies are required to accumulate evidence from SSA such that policy decisions drawn by international and global forums such as the WHO can incorporate such evidence. These studies can also inform efforts to reduce exposure in general through use of cleaner fuels, strict environmental legislation and protected working environments.

Declaration of Competing Interest

All authors declare no competing interests.

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