ANTHROPOGENIC EMISSIONS, AEROSOL POLLUTION AND HEALTH IN WESTERN AFRICA

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Abstract: This work highlights the main issues concerning the impacts of anthropogenic emissions on air pollution and population health in West Africa: (1) Aerosol levels in urban areas are 3 to 15 times higher than the standards recommended by the World Health Organization (WHO); (2) Air pollution is due to a mixture of anthropogenic urban sources (domestic fires, old vehicles, waste burning, etc..) and regional sources (desert dust, savannah fires), with strong seasonal variations; (3) Health effects in terms of inflammation and premature deaths are due to fine particles and (4) Projections in the future show an increasing importance of anthropogenic emissions, air pollution and health impacts if no mitigation is implemented.

Keywords: anthropogenic emissions, aerosol pollution, health, mitigation

Résumé: Ce travail montre l'impact des émissions anthropiques sur la pollution atmosphérique et la santé des populations en Afrique de l'Ouest : (1) Les niveaux d'aérosols en ville sont 3 à 15 fois supérieurs aux normes recommandées par l'Organisation mondiale de la santé ; (2) La pollution atmosphérique est due à un mélange de sources anthropiques (feux domestiques, vieux véhicules, brûlage de déchets, etc.) et de sources régionales (poussières désertiques, feux de savane), avec de fortes variations saisonnières; (3) les particules fines ont un rôle important sur la santé en termes d'inflammation et de décès prématurés et (4) les projections montrent une importance croissante des émissions anthropiques et de leurs impacts si aucune mesure de réduction n'est mise en œuvre.

Mots clés : émissions anthropiques, pollution particulaire, santé, réduction des émissions

Introduction

In a context of rapid urbanization, sub-Saharan Africa is confronted with increasing unregulated anthropogenic emissions of pollutants, which leads to a significant deterioration in the air quality of its cities and the health of its populations. However, those issues are poorly studied in this region of the world. First scientific projects focusing on these issues started around 2005 at different spatial scales (from the individual to the regional scale). The main results obtained by these projects, centered on West Africa with local studies in Bamako (Mali), Dakar (Senegal), Abidjan (Ivory Coast), Korhogo (Ivory Coast), and Cotonou (Benin) are discussed in this paper.

1. Anthropogenic emissions

During the last decade, African regional studies have started to point out the importance of anthropogenic activities and their associated emissions of air pollutant. Until then, most regional studies focused on the quantification on the emissions of savannah fires, as well as of desert dust, for example with the DECAFE (Dynamique et Chimie Atmosphérique en Forêt Equatoriale) and AMMA (African Monsoon Multidisciplinary Analysis) projects. Estimates of anthropogenic emissions were taken from global inventories that did not take into account the specificities of African emission sources.

We have developed regional and local anthropogenic emissions inventories in the frame of the DACCIWA and PASMU (Atmospheric Pollution in Urban Areas and Impact on Health) projects. We characterized and quantified the less-known emissions, i.e. domestic and commercial activities, charcoal making, road traffic taking into account the typical fleet of vehicles of African cities (old cars, 2 wheels, mini-buses ..), waste burning and flaring fires (Keita et al., 2018; Doumbia et al. 2018; Keita et al., 2021).

Figure 1 summarizes the relative importance of anthropogenic and biomass burning sources for the period 2003-2015 for black carbon, resulting from these projects.

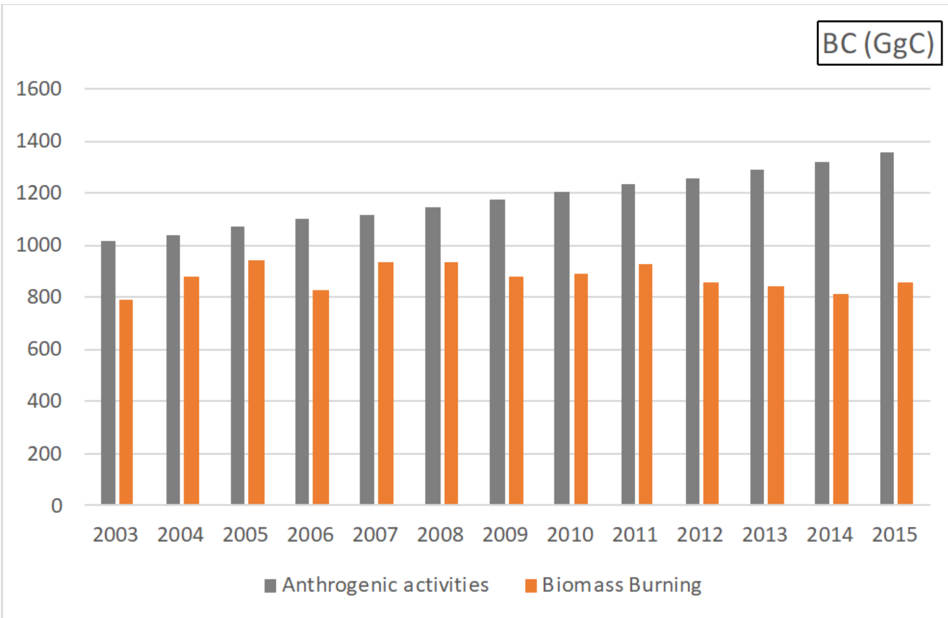

figure 1. Black carbon (BC) emissions in Africa.

While emissions from savannah fires show no significant variation during the past years, anthropogenic emissions are constantly increasing. For now, anthropogenic emissions are predominant, when compared to savannah fires. Anthropogenic emissions are expected to increase by a factor of 2 if no mitigation is implemented (Liousse et al., 2014).

These scientific studies continue today at the regional and city level. They are part of the African Emissions working group of the international GEIA (Global Emissions Initiative: igacproject.org) project on emissions. The emissions data are made available to the community through ECCAD database (eccad.aeris-data.fr and see presentation of Darras et al. in the conference).

2. Aerosol pollution

About ten years ago, there was few or no networks measuring gaseous and particulate pollutants in West African cities. In this context, we have developed several projects to characterize the levels of air pollution at the urban scale. Measurements were performed at sites close to the sources of emissions (traffic sites, waste burning sites, food cooking sites) and at urban background sites in the framework of the POLCA, DACCIWA and PASMU projects, in Abidjan (Ivory Coast), Cotonou (Benin), Korhogo (Ivory Coast), Dakar (Senegal) and Yaoundé (Cameroon). The results showed that the annual average concentrations of gaseous compounds do not exceed WHO standards (Bahino et al., 2018). However, the concentrations are 3 to 15 times higher for fine particulate matter (PM2.5) (Doumbia et al., 2012; Ouafo 2017; Djossou et al., 2018; Adon et al., 2020; Gnamien et al., 2020). Figure 2 summarizes these results. Note that there is a very large spatial variability among gaseous and particulate concentrations across African cities (Bahino et al., 2018; Gnamien et al., 2020).

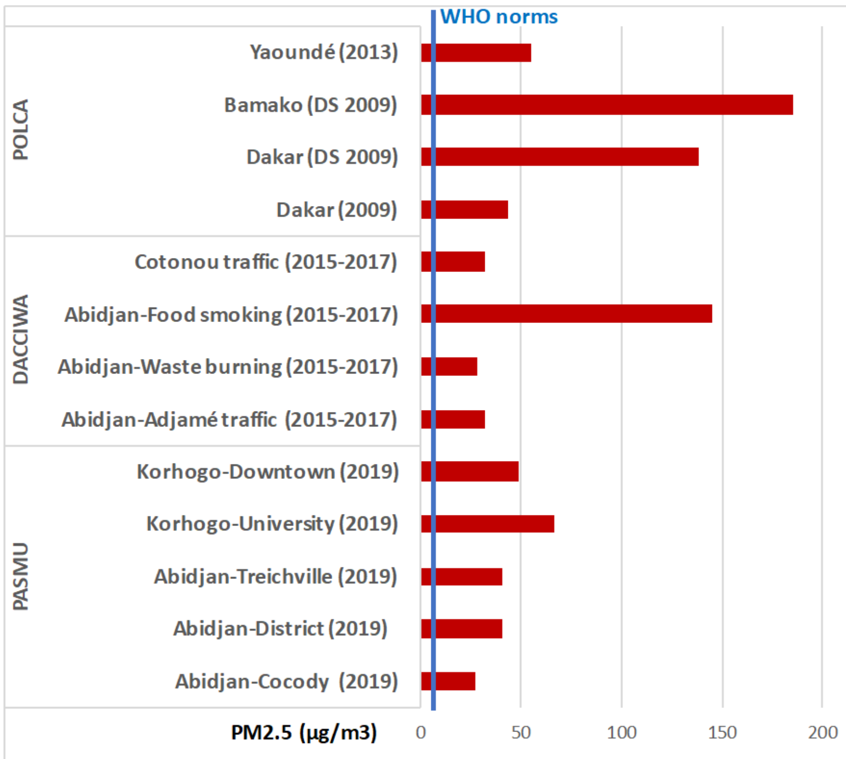

figure 2. Mean annual PM2.5 concentrations in different African cities. The blue line represents the recommended WHO standard. DS is for dry season.

Preliminary estimates of daily concentrations of PM2.5 in populations exposed to traffic, waste burning fires and food smoking were found to be 16 times higher than the WHO standard. We also measured the size speciated chemical composition of the urban aerosol. This step is essential because the chemical composition of the aerosol depends on the emission sources and produces more or less significant health and radiative effects. Figure 3 presents the aerosol chemical composition for fine particulate matter (PM2.5) measured in different sites during the POLCA, DACCIWA and PASMU programs for West Africa. The concentrations for four main compounds are represented: black carbon, organic carbon, dust and ions (sulphates, nitrates, etc.). The results are presented for the dry season only, when the contribution of dust from the Sahara and aerosols of savannah fires is the highest in the cities of West Africa due to harmattan winds. In general, organic carbon, desert dust and black carbon are the main contributors. It may be highlighted that the relative importance of each of these compounds depends on (1) the relative importance of local combustion sources and regional sources (aerosols from savannah fires and desert dust), (2) the interannual variabilities of regional sources and

(3) the more or less incomplete nature of local combustion sources (e.g. traffic versus wood burning). It is interesting to compare these results with those obtained during the dry season in Zamdela township in Sasolburg in South Africa. A predominance of ions and dust in the aerosol is found, which can be linked to the influence of the source «industry and thermal power» in this region of Africa.

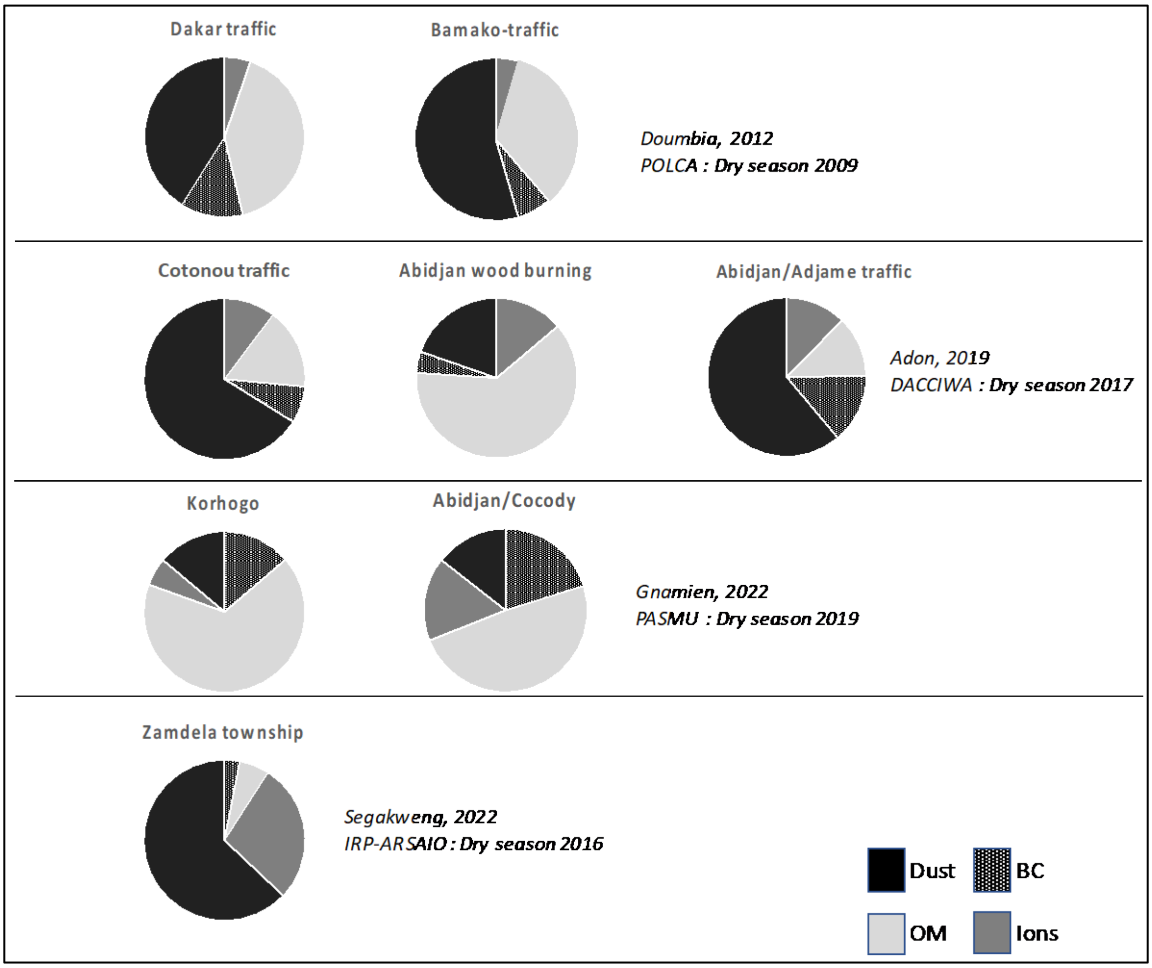

Figure 3. Aerosol chemical composition in different African cities (BC = Black Carbon, OM = Organic matter).

3. Health effects due to air pollution

3.1. Aerosol inflammatory impact (in vitro and oxidative potential measurements)

The inflammatory capacity of the aerosol was studied in Bamako and Dakar in POLCA program, and at the DACCIWA sites in Abidjan and Cotonou. To do this, aerosols collected from the different measurement sites mentioned above were put in contact with human cells in the laboratory and the pro-inflammatory reactions related to the presence of particles were measured using different markers (e.g. GM-CSF, IL6, IL8). The most important reactions were generally obtained for ultra-fine and fine particles and for traffic and food smoking sites. It was shown that the pro-inflammatory impact of aerosols was rather correlated with carbonaceous aerosol (Val et al. 2013; Tran et al., in prep.). More recently, as part of the PASMU project, this protocol has been simplified by measuring the oxidizing potential of the aerosol directly on the samples, a parameter that allows us to simulate the inflammatory capacity of the aerosol. The carbonaceous aerosol showed the strongest correlations with the oxidizing potential of the aerosol (Gnamien, 2022).

3.2. Aerosol and premature deaths

Using the regional model (RegCM) and the emission inventories described above and following Anenberg et al., (2011), maps of the spatial distributions of fine particles were obtained at the scale of the African continent and excess mortality (all causes combined) due to fine particles was calculated for the month of January 2015 (period when particulate matter concentration is the highest in West Africa). Figure 4 shows the number of premature deaths in different African countries (N'Datchoh et al., in prep). The relative importance of Nigeria, Egypt and South Africa may be noted. On a continental scale, fine particulate pollution could be responsible for 1 million deaths.

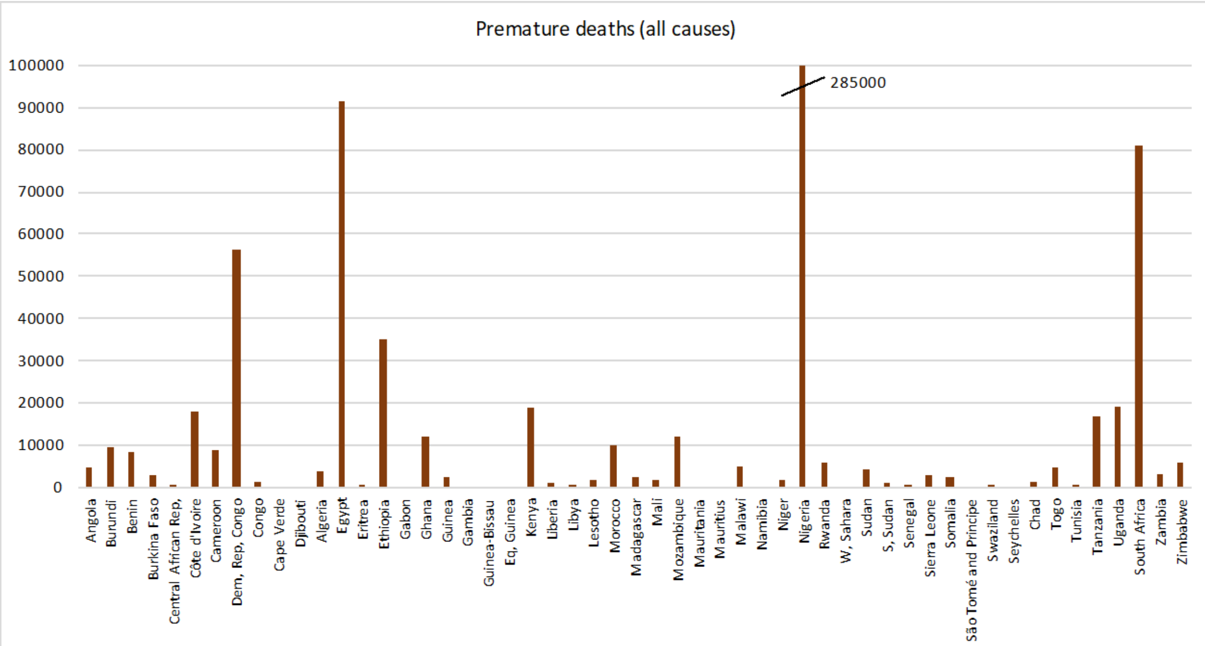

figure 4. Simulated premature deaths due to fine particles for African countries in January 2015.

Similar studies were also conducted for the year 2030 from two emission scenarios with or without anthropogenic emission reductions. Our calculations show that implementing mitigation measures would reduce the number of premature deaths by a factor of 3.

Conclusion

In West Africa, urban pollution is increasing fast, and could become rapidly worse if no mitigation is implemented. Using the measurements of emission factors of the super emitters, we have determined solutions to reduce air pollution and health problems in African cities. But, as shown in Becerra et al. (2020), air pollution is one of the hazards faced by people on a daily basis, linked to poverty and/or the social hierarchy. Health risks in the long term are often not a priority, in favor of short-term risks. In order to take into account such issues, we have developed a new interdisciplinary program with a participatory approach including scientists, the civil society and local and national policy makers. This 3-year project is called APIMAMA (Air PollutIon Mitigation Actions for Megacities in Africa) and will focus on the city of Abidjan as a real-world laboratory study.

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Acronyms:

AMMA: African Monsoon Multidisciplinary Analyses (2002-2009)
APIMAMA: Air PollutIon Mitigation Actions for Megacities in Africa (2022-2025)
DACCIWA: Dynamics-aerosol-chemistry-cloud interactions in West Africa (2014-2018)
DECAFE : Dynamique Et Chimie de l'Atmosphère en Forêt Equatoriale (1990-1994)
ECCAD: Emissions of atmospheric Compounds and Compilation of Ancillary Data
GEIA: Global Emission InitiAtives (existing from 1990)
IRP-ARSAIO: International Research Project-Atmospheric Research in Southern Africa and Indian Ocean (2019-2023)
PASMU Côte d’Ivoire : Pollution de l'Air et Santé dans les Milieux Urbains (2018-2022)
POLCA : Pollution des Capitales Africaines (2008-2011)
WHO: World Health Organization