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Fine particulate matter pollution in African urban area: An urgent need for action

[*1] Attoh Touré H, [2] Coulibaly M, [3] Kouao R, [4] Tiembré I, [5] Konaré A, [6] Dagnan NS

[1, 2, 3] Ph.D. Student, Inter-University Doctoral Program, Chairpol, Félix Houphouët-Boigny University of Abidjan, Côte d'Ivoire

[4, 6] Professor of Public Health, Department of Public Health and Medical Informatics Felix Houphouet-Boigny University of Abidjan, Côte d'Ivoire

[5] Professor of Atmospheric Chemistry and Climate Modeling, Laboratory of Physics of Atmosphere and Fluid Mechanics, Abidjan, Côte d'Ivoire

Abstract
For several decades, human activities generate significant amounts of pollutants in the atmosphere of the major African metropolises. Among these pollutants, the emission of fine particulate matter ($PM_{2.5}$) threatens the health of populations. However, few data are available on personal exposure and its health consequences. This review of the literature aims to summarize the published works on air pollution related to fine particulates in African urban area. A selection of 32 articles was made on Pubmed, Google Scholar and Science Direct. Rates ranging from 100 to 1161 µg/m^3/24h were recorded in Nairobi, Accra and Dar-es-Salam. One of the sources of fine particulates emission most often quoted by the authors is the intensity of urban traffic. The poorest households in urban areas using mainly biomass for fuel were particularly exposed. The health consequences described in urban areas were Acute Respiratory Infections, low birth weight and respiratory manifestations suggestive of asthma. Urgent measures based on more thorough research works must be taken.

Keywords: air pollution-fine particulates- exposure- Africa- developing countries

1. Introduction
For several decades, human activities generate significant amounts of pollutants in the atmosphere of major African metropolises [1]. Among these pollutants, the emission of particulate matter (PM), especially the finest, threatens the health of populations [1, 2]. Indeed, faced with the accelerated development of African metropolises, there is an increase in so-called environmental diseases [1]. Yet, little data are available on personal exposure to fine particulates, the factors that influence it, and the health consequences in African urban area. Most of the published surveys concern only indoor air pollution related to the use of biofuel in rural areas, which is a source of acute respiratory infections in children [3-5].
Local pollution, which is omnipresent in the African metropolises, is mainly linked to the inadequacy of urban development, bringing potentially polluting sites (industries, main roads) closer to homes, schools and shops [1]. The association between the presence of this type of local pollution sites and the appearance of so-called environmental diseases could be linked to a high level of exposure of urban populations to the finest particles. This exposure, even in the short term, represents a potential hazard and varies depending on the microenvironments in which one travels, the modes of transportation used and daily activities [6-9].The children under 5 years of age and carriers of chronic respiratory or cardiovascular diseases, who are more vulnerable, are at greatest risk [10-11]. The insufficiency of convincing data on personal exposure compromises the implementation of appropriate and effective strategies for these populations.
This review of the literature aims to summarize the published works on air pollution related to fine particulates in African urban area.

2. Methodology
2.2 Search for articles
The bibliographical search was conducted on Pubmed, Google Scholar and Science Direct. The search syntaxes were formulated from different combinations of the following keywords: air pollution- fine particulates- exposure- Africa- developing countries. The review was supplemented by articles and books that were not available on the databases consulted, but whose references were included in the articles identified. We also searched the grey literature using the Google search engine to view other relevant documents.

Inclusion criteria
Articles concerning the pollution by fine particulate matter (of diameter lower than 2.5 micrometers or $PM_{2.5}$) in African urban area published in French and English were included regardless of the year of publication.

Exclusion criteria
Were excluded articles concerning only the PM_{10}, focusing on countries outside Africa, to rural areas only, and articles containing little relevant informations.

2.2 Selection of articles
On the 307 articles identified, 230 were eliminated by the

study of titles. A second sorting by reading of the abstracts allowed to eliminate 29 articles. At the end of this selection, 48 articles with full texts were selected. Among them, 16 were not selected based to exclusion criteria.

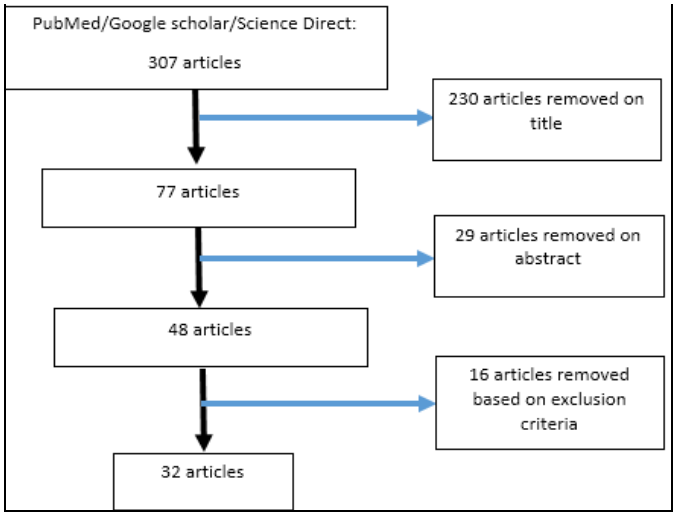

Fig 1: Articles Selection Strategy **(**Flow chart)

3. Results

The 32 scientific articles selected covered the period 2010-2017 (62.5%), 2000-2009 (34.3%) and mostly concerned English-speaking countries (75%), such as Ghana, Nigeria, Tanzania and the South Africa. These were essentially descriptive cross-sectional and / or analytical studies (87.5%). About 43.7% were limited to measuring fine particulates in an open or closed environment, 18.7% measured personal exposure, 28.1% sought associations between this exposure and the occurrence of diseases and finally 9.4% examined the chemical composition of particulate matter. Indoor air pollution accounted for 40.6% of the surveys. The clinical research focused on the Acute Respiratory Infections (44.4%), The tuberculosis (11.1%), the mortality (11.1%), and the respiratory Symptoms suggestive of asthma (33.3%) in children and incidentally in mothers.

Rate of fine particulates ($PM_{2.5}$) in suspension [12-13-14-15-16-17-18-19-20]

As early as 1974, rates of $PM_{2.5}$ reaching 260 µg/m3/24h were recorded in Yaoundé, Cameroon [12] in an open environment. Rates of up to 431 µg/m3/24h were recorded at Nairobi for threshold values not to exceed 25 µg/m3/24h [13, 14]. In Uganda, rates ranging from 100 to 138.6 µg/m3/24h were recorded in residential neighborhoods [15-16]. Finally, in Dar-es-Salam (Tanzania), the average quantity of suspended particles ranged between 98 and 1161 µg/m3/24h [17].

Concerning the air inside houses, Dionisio in the Gambia found an average rate in $PM_{2.5}$ of 219 µg/m3/24h [18]. This average was 226 µg/m3/24h in a similar survey conducted by Fullerton in Malawi [19]. In schools, average rates of 56 µg/m3/24h were measured in Accra, Ghana [20].

Source of emission of fine particulates [13, 20, 21, 22, 23, 18, 24, 25, 26, 27, 28]

One of the sources of fine particulates emission most often cited for several decades is the intensity of urban traffic [13, 21, 22, 23, 18, 24, 25, 26]. The Rooney suvey [23] in Accra, Ghana, highlighted significant linkages after adjustment between the levels of $PM_{2.5}$ and the density of use of wood stoves, the smoking of fish, the burning of household waste and the presence of a busy highway. Liden [27] finds similar results in Burkina Faso where 3 years of measurements from 2007 to 2010 highlighted the role of suspended dust particles, the use of biomass and highways in the pollution related to fine particles. Zhou [28] revealed that, after adjustment on other factors, living in a community where all households use biofuels would be associated with fine particle levels 1.5 to 2.7 times above accepted standards. The same author [21] highlighted the role of biomass combustion, pollution related to vehicles but also that from unpaved roads on indoor air pollution. Finally, in the classrooms, the main sources of emissions were the proximity of a high-traffic lane, the use of biofuels in the vicinity of schools and the presence of unpaved roads [20].

Personal exposure of the African populations [29, 20, 30, 26, 28, 29, 31, 32]

Very few surveys directly or indirectly measured personal exposure [29, 20, 30, 26, 31, 32]. Some of them measured exposure to biomass smoke in closed environment [29, 20, 31, 32]. According to Armah [30], urban populations were less exposed to fine particulates than those living in rural areas ($p < 0.01$). The poorest households in urban areas using mainly biomass for fuel were also exposed [28]. The survey of Arku in urban area, in Accra, Ghana, focused on personal exposure to $PM_{2.5}$ and the factors that influence this exposure [20]. The young girls in schools, for example, were more at risk than the young boys (67 vs 44 µg/m3, $p = 0.001$) [20]. The Wylie longitudinal survey conducted in urban areas highlighted that exposure to fine particulates increased significantly with the use of charcoal in kitchens [29]. For Ngo in Nairobi (Kenya), some occupations (public transport drivers, street vendors, garage owners) were particularly exposed to traffic-related air pollution [26].

Health Consequences of Exposure to Fine Particulate Matter PM2.5 [2, 29, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43]

Three in vitro surveys conducted in Benin, Côte d'Ivoire and Senegal highlighted the cytotoxic properties of fine particulates samples and their ability to generate a biological response [33, 2, 34].

Several surveys established links between air pollution and the high prevalence of acute respiratory infections in children under 5 [35, 36, 37, 38]. Others were interested in mortality rates related to fine particulates [38, 39]. In an univariate analysis, the use of solid fuel for cooking was statistically associated with the occurrence of tuberculosis but not during the adjustment [40]. In South Africa, fine particulates air pollution in urban areas was estimated at 1.1% of national mortality attributable to acute respiratory infections in children under 5, at 3.7% of mortality due to cardiopulmonary diseases and 5.1% of mortality attributable to tracheal, bronchial and lung cancers in adults over 30 years of age [38].The burning of Biomass was responsible of about accounted 370,000 deaths in 2010 [41].

The survey of Wylie in Tanzania of a cohort of pregnant

women followed for two years showed the influence of $PM_{2.5}$ on the low birth weight of newborns [29]. Only three surveys investigated the links between fine particle exposure and asthma and highlighted the role of major highways and industries in the development of clinical symptoms suggestive of asthma [24, 42, 43]. In the survey of Ana in Ibadan, Nigeria, the proximity of schools to certain sources such as the garbage burning and the main roads seemed to favor the risk of respiratory morbidity (asthma, bronchitis) [42].

4. Discussion

Too few scientific articles are interested in air pollution in fine particulates in the big African metropolises. The atmospheric pollution is one of the main risks to global public health, but its magnitude in cities in numerous developing countries in Africa is not known [16]. In addition, most of the surveys were conducted in English-speaking countries that are certainly more advanced in environmental issues than French-speaking countries.We note a very clear increase of the surveys over the period 2010-2015 reflecting a recent awareness of researchers in developing countries in Africa on the necessity of having convincing data allowing the action.

Developing countries currently have levels of fine particulate matter similar to or greater than developed countries with fine particulates concentrations that vary considerably between countries [44, 2]. There are also significant differences in sources and concentrations between urban and rural areas, and between indoor and outdoor environments [44, 30]. The Sources of pollution are mainly anthropogenic in the surveys analyzed. The industries, the road traffic, the charcoal manufacturing, the open burning of garbage, the smoking of fish and the household pollution (use of biofuels) are the different sources of fine particulate emissions reported in the environment in African urban zone [21, 28, 23, 26, 22, 27]. The main cause could be the increase of vehicles [13, 21, 22, 23, 18, 24, 25, 26]. Most of the time they are obsolete vehicles, more than ten years old imported from Europe [45]. The virtual absence of pollutant emission regulations could explain these high rates [45]. However, the high concentrations reported in sub-Saharan Africa could also be related to natural sources of fine particulates from the Sahara [46].

The personal exposure mainly concerned the biomass smoke in rural areas [30, 31, 32]. Since a few years, the exposure to biomass smoke constitute a public health problem in rural areas [3, 4, 5, 47]. Yet, in urban areas, the lack of regular access to clean fuels is an obstacle to fuel substitution in the low-income neighborhoods [28]. In Côte d'Ivoire, for example, the proportion of biomass consumed in cities relative to total consumption increases over time [48]. In 90% of cases, this biomass combustion concerns charcoal [48]. Several factors other than ambient air contribute to personal exposure requiring a better understanding of the ways of daily exposure [49, 50, 51]. In developed countries, Van Ryswyk [10] and Gauvin [52] confirmed the impact of the microenvironments and the activities on personal exposure. The research should focus on personal exposure and the factors that influence it in order to put in place appropriate and effective strategies. Most of the surveys reviewed measured indoor air pollution in closed or open environments, but not personal exposure [16, 41, 21, 15, 23, 27, 18, 19, 17].

The health effects of pollutants depend on several elements that need to be known; the type of pollutant, its concentration, the duration of exposure and the sensitivity of each individual [53]. Several authors selected in our survey sought through their works the links existing between the exposure to fine particulates and the appearance of diseases [43, 36, 40, 37, 38, 35, 42]. The acute respiratory infections are the leading cause of death in children under 5, and exposure to fine particulates is a risk factor found in several surveys [3, 4, 5, 47]. The links between exposure to fine particulates and the occurrence of chronic respiratory, cardiovascular and cancer diseases remained very little or unexamined in the surveys analyzed. This gap in research must be filled by more in-depth cohort studies.

Even if all the populations living in an urban environment are affected by this pollution, for some authors the health consequences are first of all prejudicial to the health of the children because of the immaturity of their immune and pulmonary system [54, 55]. The children with chronic respiratory conditions such as asthma are particularly at risk [10, 11]. Several surveys noted that the prevalence of asthma in urban areas increased steadily over the last 20 years in developing countries in Africa [56, 57, 58, 59, 60]. The role played by fine particulates in triggering, exacerbation, hospitalization during pollution peaks or difficulties in controlling the disease remains little known in Africa. Indeed, the lack of monitoring of air quality does not allow to establish such links [45].

According to Fourn [61], the health consequences of this pollution led to an awareness of the populations who are increasingly concerned about these environmental issues. However, the lack of data does not allow for public awareness and advocacy for the implementation of public health strategies. Moreover, none of the surveys in this review proposed interventions to prevent or control particulate matter pollution in African urban areas.

5. Conclusion

This review of the literature highlights the insufficiency of research on fine particulates pollution in African urban area. However, the synthesis of the published works demonstrate that the populations living in the big metropolises of Africa are exposed to levels of pollution higher than the standards admitted by the WHO impacting negatively the health of the populations. Too few developing countries in Africa are addressing prevention and control of outdoor and indoor air pollution despite the health situation. Urgent measures must be taken in this period of epidemiological transition in these countries characterized by the development of so-called environmental diseases. Such measures require thorough research works allowing to have reliable data.

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