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Study of the Evolution of Air Pollution in the City of Bamako

Yacouba Maiga[1*], Ousmane Coulibaly[1], Boubacar Kola Touré[1], Sékou Sako[1], Hamidou Kodio[3], Ibrahima Yattara[1], Mohamed Maiga[1], Cheikh Diop[2]
[1]Faculty of Sciences and Techniques, University of Sciences, Techniques and Technologies of Bamako. BP E 423, Mali
[2]Institute of Environmental Sciences, Faculty of Sciences and Techniques, Cheikh Anta Diop University of Dakar. B.P. 5005 Dakar-Fann, Senegal
[3]Institute of Rural Economy, Bamako, Mali
* Corresponding author: E-mail: acpmfr@yahoo.fr

Abstract— *Air pollution depends on dispersion factors and sources of pollution. It can also vary over time. To diagnose this phenomenon, an inventory of air pollution with measurements of ambient air quality at a certain number of points, as well as traffic counts was made. The purpose of this study is to analyze the evolution of pollution, of the different sources of emissions, the modeling of the health impact of the quality of the ambient air for the different scenarios, the proposal of a actions to limit emissions, and the simulation of emissions and ambient air quality by 2015 and 2020 with and without an action plan. The results of the two air quality measurement campaigns show lower or substantially equal concentration levels between those of July 2019 and those of the 2009 data. concentration guidelines set by the WHO. The assessment of emissions and their health impact for 2015 and 2020 shows that pollution by volatile organic compounds and dust will become unacceptable if nothing is done. The number of benzene-related cancers will increase to 686 cases and the increase in dust-related mortality to an average figure of 38.7%. Proposals have been made on improving the living environment, the quality of fuel and the vehicle fleet.*

Keywords— *Dispersal factors, pollution, Bamako, Mali.*

I. INTRODUCTION

Air pollution is a complex and major environmental problem that arises all over the world. The associated studies carried out in America, Europe and Asia show that this pollution is mainly caused by human activities, whether industrial, domestic, agricultural, urban, etc. [14] ; [5]. Africa, not escaping this situation, is confronted with this pollution, its multiple impacts, namely on the climate and on the health of the populations. Although data on air pollution in Africa are very scarce, recent estimates from the World Health Organization (WHO)

count approximately one million premature deaths each year in the world attributable to the effects of pollution, including 5% in Africa alone [38]. Moreover, the sources of this pollution in Africa are increasing considerably given the rapid and sustained urban growth of cities (World Bank, 2003).

This sustained population growth and the strong rural exodus, concentrated in large metropolises in Africa, are central elements of the very rapid increase in urban pollution [8]. This is a general but particularly poorly documented effect in Africa of the close relationship between pollutant emissions and human activities. Estimated at 819 million inhabitants in 2000 (13.4% of the world population), the African population increased in 2010 to 1033 million (about 15% of the world population) and could reach 2 billion in 2050, i.e. 22% of world population [38]. This very strong demographic growth, combined with strong urbanization (39% of urban population in 2008) is associated on the one hand with a strong increase in the demand for transport, but also with rapid demographic changes in sub-Saharan Africa, constitute a cause major cause of gaseous and particulate emissions in urban areas [2] ; [17]. West Africa favors the importation of second-hand European "France bye" motor vehicles which are pouring into African ports. These old cars, not being equipped with the recent technologies required to limit the release of the most harmful components (oxides of sulfur dioxide, fine particles, carbon monoxide, lead, etc.) constitute a serious threat to air quality. In addition to its automobile emissions, there are those of two-wheeled vehicles with two-stroke engines that use very poor quality adulterated or falsified fuel mixtures [18]. In rural areas and even in urban areas, biomass fires, domestic fires and the incineration of waste (agricultural and domestic) also contribute to a very large part to the emissions of atmospheric pollutants. All of these pollutants are potential sources of respiratory diseases and allergies, whether chronic diseases such as asthma or cancers for exposed populations [9].

Added to this are special climatic conditions, with high temperatures in the dry season which favor photochemical pollution. Also, Saharan dust, by the frequency and intensity of its uprisings, constitutes an important characteristic [37]; [18], at the origin of large quantities of particles exceeding the values limits recommended by the WHO [20]. This desert dust is also the cause of certain respiratory infections (bacterial meningitis) [21] and cardiovascular diseases [16] ; [24].

With 3.4 million inhabitants, the district of Bamako concentrates a large number of anthropogenic activities (road traffic, industries, tertiary sector) and a high density of buildings generating high pollutant emissions. Its degraded Sudanese climate and its site with a rugged relief are rather favorable to the dispersion of atmospheric pollution [10]. However, exposure to exceptional concentrations of these pollutants (ozone, nitrogen dioxide and particles) for a few days or weeks causes respiratory, cardiovascular and cardiac problems [6]. Regular exposure to air pollution increases the risk of chronic respiratory or cardiovascular diseases, and cancers [16] ; [34]. Aerosols emitted in urban areas are mainly made up of small particles, called inhalable (PM10). These particles have specific properties and are most often associated with compounds known for their toxicity, such as metals and certain organic substances [23].

Furthermore, the smaller ones can reach the alveolar cells in contact with the bloodstream, and are even responsible in some cases for DNA modifications [18]).

At the same time, scientific research has evolved and we now know how to distinguish several dozen pollutants in the air, which can combine with each other and transform. Among these pollutants, there are PM (Particulate Matter in English), whose very variable rate in time and space, is quite often at the origin of alert bulletins intended to inform the population. For ten years, medical research has better defined the harmful role of these PM on health and their involvement in chronic respiratory and cardiovascular pathologies [1]. But, despite the relatively large number of studies [13]; [34], this field of research still suffers, on the one hand, from insufficient evaluation of levels of exposure experienced by each individual (volumes inhaled over long periods in particular) and, on the other hand, a lack of knowledge about the health effects, especially in the medium and long term, of the various types of PM. The special issue of the journal Pollution Atmosphérique published in November 2012 by the Association Pour la Protection de l'Air [3], on the theme "pollution by particles, impacts on health, air and climate" with more than 30 articles written by scientists from different disciplinary backgrounds is indicative of the diversity of research.

It is in this vast problem that this research is located to better characterize air pollution in Bamako, and to establish the relationship between the presence of PM in the air and chemical pollutants and the appearance of health problems in Bamako. individuals who are subject to highly variable levels of pollutants throughout their lives.

II. STUDY ZONE

Meteorological data comes from the weather station based at Bamako-Sénou airport (ISD reference number (Integrated Surface Database): 612910; Geographical coordinates: N 12°53'35.4; E 007°94'90.2 ") and downloaded from the National Oceanic and Atmospheric Administration (NOAA) database. Bamako's climate straddles the Sudanian climate zone (semi-arid to sub-humid zone) and the North Guinean or Sudano– Guinea (sub-humid zone) More generally, it is characterized by a dry season, between October and April, and a relatively intense rainy season between May and September with maximum rainfall between July and August (Figure 1)

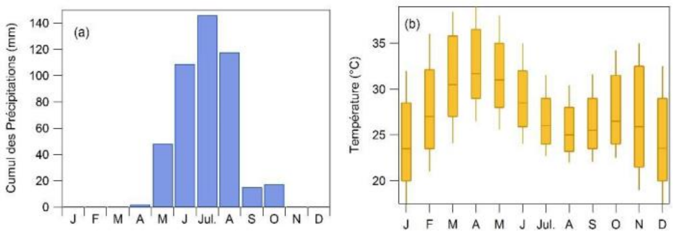


Figure 1: Summary (2009 – 2019) of temperature and precipitation data.

During the year, the temperature varies between 10 and 40°C with an average temperature of 27°C. Over the last decade (2008 – 2018), little or no variation in these temperature averages was observed. The average annual temperature profile over the last decade shows a cycle with an increase in temperatures (30 – 33°C) in the months preceding (March – May) the rainy season and a marked decrease (25 – 27°C) during the rainy season. The following months with a minimum reached between December and January (22°C).

Typically during the day, the temperature peaks are reached between 2 and 4 p.m. while the minimums are recorded between 5 a.m. and 6 a.m. A greater temperature amplitude is observed during the day in the dry period (13°C on average against 8°C in the wet period) (Figure 2).

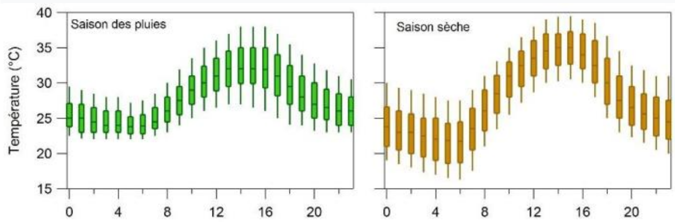


Figure 2: Diurnal profile of temperatures during the rainy season and the dry season.
Statistics based on data collected between 2008 and 2018.

The wind speeds recorded during the year are mainly low to moderate (<5m/s) with peaks reached between 9 – 12 am. The rainy season is dominated by a southwest wind and the dry season by a northeast wind, a hot and dry wind, called the Harmattan (Figure 3).

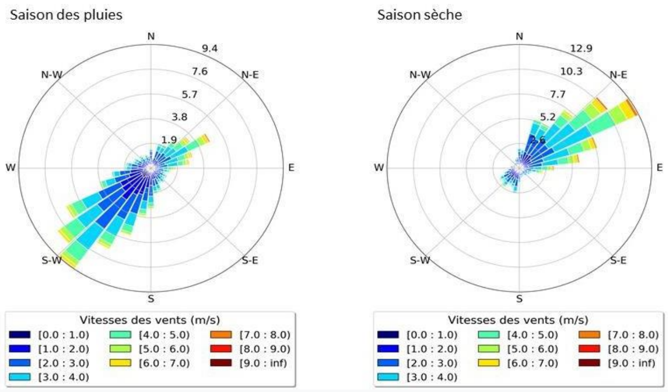
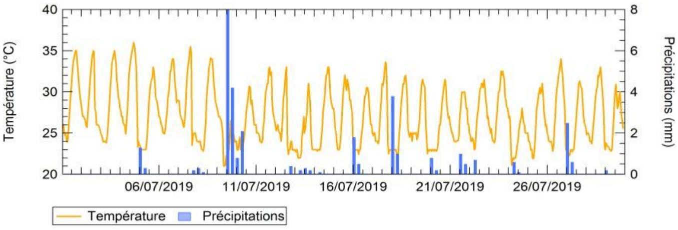


Figure 3: Rose of the winds during the rainy season and the dry season.
Statistics based on data collected between 2009 and 2019.

Analysis of meteorological data during the measurement campaign

During the sampling campaign, weather conditions were relatively stable. Several rainy episodes were recorded (Figure 4).



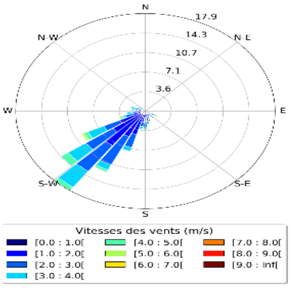


Figure 4 : Meteorology from July 1 to 30, 2019.

Precipitation : 98.4 mm of precipitation was recorded. This is below seasonal norms but it is not negligible in the context of this study. High levels of precipitation are likely to influence PM10 concentrations by promoting particulate deposition. Week 2 was the most rainy, especially the days of July 9 and 10. Precipitation is observed typically during the night during the passage of a cloud mass arriving from the north-northeast.
Temperatures: The average temperature observed is 27°C, with a minimum of 21°C and a maximum of 36°C. We are close to the average temperatures observed for the month of July over the last decade. There is a slight drop in average temperatures after July 10. The diurnal temperature profile for the entire campaign shows a minimum around 5 a.m. and a maximum around 4 p.m. The range of daily temperatures is on average 7°C.
Winds: The profile of the winds observed during the campaign is similar to the profile of the winds characteristic of the rainy season. The wind was from the southeast, with low (68%) to moderate (24%) speeds.

– Sand and dust storm: Images from the European EUMETSAT satellite did not show any episode during the period concerned.

III. Goals

– Study the evolution of air quality in Bamako

Specific objectives

- Carry out a campaign of air quality measurements and traffic counts
- Analyze the current situation, ambient air quality and emission characteristics.
- Propose an action plan to limit emissions
- Simulate changes in emissions and ambient air quality by 2015 and 2020 with and without the action plan

IV. Material and Method

Equipment

The measures taken:

– By passive tubes for SO2, NO2 and BTX (Passam brand);–

– Thermo Andersen ADR-1200S for particles: PM10 in real time, Accuracy of +/- 5% compared to standard method (gravimetric);

– - DragerPac III E:
Real-time CO measurement,
Recording of 8000 values,

Demko 02 ATEX 0135331 - EExia IIC T4 approval. The measuring devices used for CO and dust were as follows;

The strategy for setting up measurement points is in line with the conclusions of the exploratory study carried out in 2009. Two measurement sites were selected, the locations of which are shown in Figure.
Background site: Municipality of Bamako;
Fund site: Ministry of Finance.

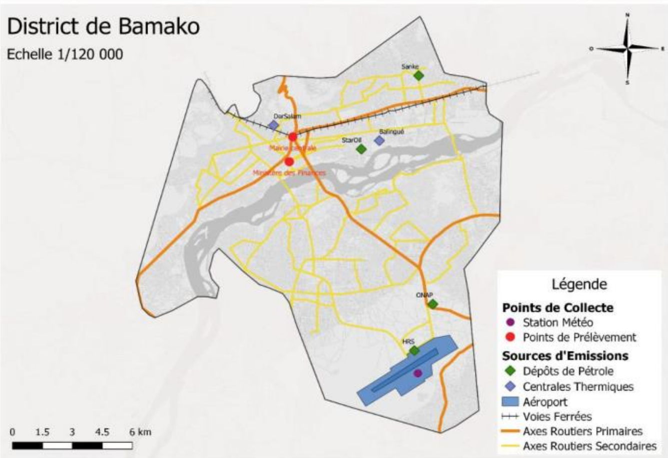


Figure 5: Location of points of interest.

V. Results and Discussion

The analysis of the results suggests that the sampling point located at the level of the ministry is less impacted than the point located at the level of the town hall, with the exception of ozone and carbon monoxide. We observed that the Mairie point is under a greater influence of road traffic than the Ministry point. This is confirmed from the higher measured levels of the direct tracers of road pollution (NO2 and benzene). In addition, the higher levels of O3 at the ministry point suggest an environment less saturated with NOx favorable to the production of ozone.

For carbon monoxide, the concentrations vary between 5.2 and 9.4 mg/m3. The levels remain roughly constant regardless of the sampling week. The average concentrations are comparable at the two sites (with higher values at the Ministère point) and with the concentrations recorded in December 2009 (5.8 mg/m3 on average). We can also point out that all the values measured are lower than the WHO guideline value (10

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mg/m3 over 8 hours). However, they remain very close to this value, reaching, occasionally over one of the weeks of measurements, 95% of the authorized threshold. With regard to the values observed in urban areas in Europe, for example, these so-called background levels remain extremely high.

Regarding nitrogen oxides, NOx measurements show concentrations between 16.2 and 37.7 µg/m3. The average concentration is 35.2 µg/m3 on the Town Hall site and 18.4 µg/m3 on the Ministry of Finance site. Few differences are observed between the samples of the different weeks. The Town Hall site systematically presents higher concentrations, of the order of a factor of 2. This disparity between the two sites can be partly explained by the parking lot in the immediate vicinity of the sensor of the Town Hall site. Nevertheless, the concentrations measured are of the same order of magnitude as the concentrations recorded in 2009. Considering the guide value, these values represent 88% and 46% (at the Town Hall and Ministry points respectively) of the guide value for the concentration of WHO NO210 (40 µg/m3 annual average).

For fine particles, PM10 measurements show concentrations between 69.0 and 172.8 µg/m3.

The average concentration is 147.5 µg/m3 on the Town Hall site and 87.5µg/m3 on the Ministry of Finance site. Like the NOx measurements, the City Hall site systematically shows higher concentrations, of the order of a factor of 1.6, certainly linked to the high activity of vehicles in the direct environment of the sampling point. The concentrations recorded during this campaign significantly exceed the most penalizing concentration value recommended by the WHO (20µg/m3 on annual average). The levels are nevertheless lower than the levels measured during the 2009 measurement campaign (concentrations between 200 and 450 µg/m3). In addition to the improvement in combustion processes between 2009 and today, which contributes to limiting the emissions of certain pollutants, this disparity can be explained by higher rainfall during this campaign due to the start of the rainy season. Nearly 100 mm of precipitation was recorded. As already mentioned, rain causes the deposition of suspended matter and thus limits the concentrations of particles in the atmosphere. However, the 2009 campaign was carried out outside the rainy season and no rainfall was recorded during this period.

Sulfur dioxide (SO2) measurements show concentrations between 2.4 and 7.1 µg/m3. The average concentration is 4.9 µg/m3 on the Town Hall site and 3.1 µg/m3 on the Ministry of Finance site. With the exception of week 2, the Town Hall site systematically shows higher concentrations, of the order of a factor of 2. In general, the concentrations are also higher than those noted in 2009 [10] (<0.3– 3.1µg/m3). Regulatory values for SO2 are expressed over a short period of time due to the proven acute effects of the pollutant on health. Note that the values measured (weekly average) are 25% lower than the most penalizing value retained (50 µg/m3 hourly average).

BTEX: Toluene and benzene have the highest concentrations (5.7 – 25.0 µg/m3 all sites combined for toluene, and 3.6–11.7 µg/m3 for benzene). o-Xylene concentrations are the lowest (1.8–3.8µg/m3). Like the NOx, PM10 and SO2 measurements, the concentrations of the various BTEX are systematically higher on the Town Hall site, by a factor of 2 to 3. In addition, the concentrations of benzene on this site are higher than the European regulatory value (5 µg/m3 on annual average). On the other hand, the concentrations are slightly lower than the concentrations measured during the 2009 measurement campaign (26.7–53.5µg/m3 for toluene and 10.5–18.2µg/m3 for benzene). There is also a large difference in m-xylene measurements between 2009 (11.9–22.8 µg/m3) and 2019 (2.1 – 8 µg/m3). Ozone O3 measurements show concentrations between 22.5 and 50.2 µg/m3. In the case of ozone, the concentrations are higher on the site of the Ministry of Finance (average concentration of 44.8 µg/m3) than on the site of the Town Hall (average concentration of 26.8 µg/m3). This trend confirms the pollution levels associated with NOx and BTEX (and more generally with VOCs). Indeed, the regime observed at these two sampling points is a limiting regime for VOCs (given the high levels of BTEX). This regime is generally favorable to ozone production when NOx concentrations decrease, explaining the higher ozone levels observed at the Ministère point. As an indication, the ozone values measured are lower than the WHO regulatory value (100 µg/m3 over 8 hours), reaching a maximum of 50% of this value in week 3 at the Ministry point.

VI. Conclusion

The analysis of the results of the two measurement campaigns shows:

On the one hand, that the values obtained are consistent with those recorded in 2009. It should be noted that over a ten-year period, pollution levels are down for all pollutants. This decrease is reflected for gaseous pollutants by a potential reduction in direct emissions (with the exception of ozone, a secondary pollutant) and for fine particles, by episodes of intense rain observed during the campaign and characteristic of the start of the season. rains;

On the other hand, the alarming levels of CO, PM10 and BTEX observed in 2009 were also measured during the 2019 campaign [11]. This pollution is characteristic of residential emissions and road traffic. In particular, PM10 and benzene measurements greatly exceed international standards (WHO, USEPA, CE) on an annual average. In the case of CO, the levels are of the same order of magnitude as the reference value of 10 mg/m3. These values, although lower than the regulatory value, reflect an urban background situation and suggest a more worrying situation in the areas of the city under the direct influence of residential activities and road traffic. Finally, the share of diesel vehicles in Mali is slightly higher than the share of petrol vehicles (53% against 47%).

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