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Comparison of Measures of PM2.5 and Carbonaceous Aerosol in Air at Cotonou, Benin in 2005 and 2015 †

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Abstract: This study focuses on the comparison of carbonaceous aerosol measurements in the air at Cotonou in 2015 compared to 2005. Working within the framework of two international programs, African Monsoon Multidisciplinary Analysis (AMMA) and Dynamics Aerosol-Cloud-Chemistry Interactions in West Africa (DACCIWA), monitoring data for PM2.5 microns were collected at one of the most polluted urban site of Cotonou (Dantokpa) in Benin (West Africa) in 2005 and 2015, respectively. The obtained results indicate that the carbonaceous aerosol measures, black carbon (BC), and organic carbon (OC) were higher in 2005 than those obtained in 2015. PM2.5 concentrations related mainly to traffic sources for two wheeled vehicles were 34 g/m^3 in May 2005 and 28 µg/m^3 in May 2015. In May 2005, OC and BC concentrations were from 15 µg/m^3 and 2.3 µg/m^3, while in May 2015, they were from 8 µg/m^3 for OC and 1.3 µg/m^3 for BC. In May 2005 and 2015, the total carbon (TC) accounted for 50% and 32% of the PM2.5, respectively. In this study, the OC/EC ratio exceeded 2.0, which confirms the presence of secondary organic aerosols.

Keywords: carbonaceous aerosol; PM2.5; black carbon (BC); organic carbon (OC)

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1. Introduction

The pollution in African cities has become an important factor in West Africa and is amplified by climatic conditions (intense photochemistry) [1]. The follow-up of air quality in these African cities is practically non-existent and the regulation of pollutant emissions are lacking [1]. Preliminary studies led by researchers of Laboratoire d'Aérologie on atmospheric pollution in several big cities of Africa have confirmed the importance of this problem. We can cite, for example, the experience-test Pollution of African Capitals (POLCA1) (Yoboué, personal communication) that took place in February–March 2004 in eight African capitals: Abidjan, Dakar, Bamako, Niamey, Ouagadougou, Bangui, Brazzaville, and Yaoundé. Recently, in the Analysis Multiscale of the Monsoon African (AMMA) and Pollution of African Capitals (POLCA2) programs, experiments on such anthropogenic pollution have obtained evidence in Cotonou (Benin), and Bamako (Mali) [2,3]. For these reasons, the Dynamics Aerosol -Chemistry-Cloud Interactions in West Africa (DACCIWA) program was developed while creating the Pollution/Health axis.

The idea is to compare aerosol pollution before and after this change. For this purpose, in this paper, we will compare the same experimental site, called Dantokpa in Cotonou, looking at PM2.5 and carbonaceous aerosol concentrations and emissions in May 2005 and in May 2015.

Other dominant sources that can influence our sampling site at this time of the year are other domestic fire sources.

May is in the rainy season, with temperatures ranging from 24.1 °C to 30.8 °C in 2005 and 26.6 °C to 31.5 °C in 2015.

The same sampling system was used in the two periods to measure PM2.5 and carbon aerosol concentrations.

2. Materials and Methods

The experimental site is a "so-called" traffic site at 5 m above a big crossroad with high traffic density (see Figure 1 below). It was chosen as Cotonou traffic is characterized by a high density of 2 wheels. Experiments occurred in May 2005 and 2015.

Figure 1. Site of measurement in Cotonou.

For this work, the data were taken in Cotonou at the crossroads of the Dantokpa market on Teflon and quartz filters in order to measure the levels of PM2.5 mass and the levels of black carbon BC and organic carbon OC. The material and the methods of analysis are presented in [4].

3. Results

Concentrations of PM2.5 and carbonaceous aerosol collected on PM2.5 filters in 2005 and 2015 were calculated (Table 1). PM2.5 Concentrations were 34 $\mu g/m^3$ and 28 $\mu g/m^3$, respectively in May 2005 and 2015. The average concentrations of OC and BC in May 2005 are stronger than those of May 2015. In May 2005, OC and BC concentrations were 15 $\mu g/m^3$ and 2.3 $\mu g/m^3$, respectively, while in May 2015, they were 8 $\mu g/m^3$ for OC and 1.3 $\mu g/m^3$ for BC. The analysis of the composition of carbonaceous aerosol shows that the black carbon (BC) contributed 12% in 2005 and for 14% in 2015. Organic carbon (OC) contributed 88% in 2005 and 86% in 2015. In May 2005, BC/PM2.5 and OC/PM2.5 ratios were 6% and 44%, while in 2015 they were 4% for BC/PM2.5 and 28% for OC/PM2.5. The TC/PM2.5 ratio was higher in May 2005 (50%) than in May 2015 (32%) in Cotonou. These different ratios are presented in Table 1. For this study, the OC/EC ratio was 6.5 in 2005 and 6 in 2015. According to [5,6], the OC/EC ratio exceeding 2.0 was used to indicate the presence of secondary organic aerosols.

Table 1. Comparison of TC, OC, BC and PM2.5 in 2005 and 2015.

Years	TC ($\mu g/m^3$)	OC ($\mu g/m^3$)	BC ($\mu g/m^3$)	PM2.5 ($\mu g/m^3$)	BC/TC (%)	OC/TC (%)	BC/PM2.5 (%)	OC/PM2.5 (%)	TC/PM2.5 (%)
2005	17	15	2.3	34	12	88	6	44	50
2015	9	8	1.3	28	14	86	4	28	32

4. Discussion

Our results show that the PM2.5 concentrations were 34 $\mu g/m^3$ and 28 $\mu g/m^3$ in May 2005 and 2015, respectively. We can say that the PM2.5 concentration in 2005 is higher than the one found in 2015. In 2007, French Development Agency encouraged the implementation of an innovative program to curb air pollution in Cotonou. This program

makes it possible to switch from two-stroke vehicles to four-stroke vehicles, which emit close to 85% fewer greenhouse gases and are much less polluting. More than 10,000 two-stroke vehicles have been replaced by 10,000 four-stroke vehicles (approximately 10% renewal of Cotonou vehicles). The change from two wheels to four wheels contributed to the reduction in local pollution and greenhouse gases emissions of 15,000 tons/year (French Development Agency) and had a general impact on the development of urban transport. This confirms the decrease in PM2.5 particles and these constituents observed in 2015. The mass ratio of OC to EC can be used to identify the origins, emission, and transformation characteristics of carbonaceous aerosols [5]. Such a high OC/EC value could indicate the presence of secondary organic carbon at the Dantokpa site.

5. Conclusions

The results presented in this study permit a comparison of carbonaceous aerosol measurements in Cotonou in 2005 and 2015. At the end of this study, it appears that OC and BC concentrations in May 2015 were lower than those in May 2005. The OC/EC ratio was 6.5 in 2005 and 6 in 2015, clearly indicating a larger contribution of emissions from human activities, motorcycles, and vehicles at the Dantokpa site. This study could thus provide the first element of expertise for urban and environmental policies in Benin.

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Data Availability Statement: The PMs concentrations data used in this study are not available online in any database so we cannot provide a link to reach them. However, the datasets are available from the Dynamics-aerosol-chemistry-cloud interactions West Africa (DACCIWA) on reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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