Focus on the impact of two wheel vehicles on African combustion aerosols emissions

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I. Introduction

Air pollution is of paramount importance, particularly in Africa, though its effects and impacts have to the present been largely underestimated there (Findings, 2002; Mage et al., 1996; Olvera et al., 2007). Air quality is becoming of national concern in a large number of countries on the African continent, where anthropogenic emissions of combustion particles have considerably increased (Boko et al., 2003). All activities are affected, particularly the transport sector which lacks rational organization, mainly because of persistent economic crises in many regions (Adolehoume et al., 2005). In order to cope with economic pressures, two-wheel vehicles are widely used in West Africa. For example, two-wheel taxis, locally termed "zemidjans", first appeared in Benin during the late 1980's and have since been largely adopted in neighboring countries Nigeria, Togo and Niger (Agossou, 2003). These "zemidjans" emit large amounts of carbonaceous particles, partly due to the very poor quality fuel used (Wane et al., 2001; Diallo, 2001). In spite of these important anthropogenic pollution with regional specificities (high presence of "zemidjans"), there is only global emission inventory (Junker and Liousse, 2008; Bond et al., 2004) and a severe lack of regional anthropogenic emissions inventories. As a result there are still relatively large uncertainties in fuel consumption data estimates and their associated emission factors for the region (Cooke et al., 1999; Junker and Liousse, 2008; Bond et al., 2004). There is great need to produce inventories including such regional based emissions, due particularly to the rapid increase in the used of two-wheel taxis in developing large West African cities but also to better take into account the other specific traffic components (for example trucks, old cars,…). As the first phase of an on-going study, this paper specifically aims at assessing the BC and OC particulate emissions in West Africa using new data (consumption and emission factor) for the two-wheel "zemidjans" (Agossou, 2003). Focus is on the year 2002, with a comparison between our regional inventory and a global inventory aiming to demonstrate the need for the present regional based approach.

II Methodology

Emissions are computed through the relationship : E = C * EF, where E are emissions (in grams), C fuel consumption (in kilograms) and EF, emission factor (in grams per kilograms).
Firstly, fuel consumption data for West Africa for two-wheel vehicles has been collected beginning with the number of such vehicles in 2002. For this year, the numbers tentatively are 1000000 in Nigeria, 300000 in Benin and Mali, 100000 in Ghana, Burkina-Faso, Togo and Ivory Coast, 60000 in Cameroon and Guinea, 10000 in Senegal and Sierra Leone and 5000 in Chad, Guinea-Bissau and Niger (Agossou, 2003; Semde, 2005; MEHU, 2002; Olvera et al., 2007; Plat et al., 2004; Regional Workshop, 2002). Two-wheel vehicles have, in general, two-stroke engines (Findings, 2002; Regional workshop, 2002). For this study, a distinction is made between very polluting "zemidjans" and other two-wheel vehicles (with a ratio of approximately 50% (Worou, 2005)). For each of the two-wheel vehicle types, two scenarios are considered (cf. Table 1), a "low" scenario and a "high" scenario. For the "low" and "high" scenarios, the daily fuel consumptions are in the respective ranges, 1 to 3 litres for two-wheel vehicles and 4 to 6 litres for the "zemidjans". Also considered (Diallo, 2001) is the fuel mix ratio with fuel for the "low" scenario considered as 96% petrol, 4% oil, for the "high" scenario as 75% petrol and 25% oil. Emission factors measured during the 2005 AMMA-campaign (Guinot et al., 2008) were used for the "zemidjans", whilst European values (Guillaume and Liousse, 2008) here used for the "cleaner" two-wheel vehicles. Calculation of the total annual consumption was based on 5 and 7 days of circulation per week (Agossou, 2004; Plat et al., 2004) for the "low" and "high" scenarios respectively.

	"low" scenario		"high" scenario	
	"clean" two wheels	« zemidjans »	"clean" two wheels	« zemidjans »
Number of traffic days	5 days per week		7 days per week	
Daily consumption (in l)	1	4	3	6
Emission factors (in g/kg)	BC = 0.55 OC = 2.55	BC = 0.79 OC = 9.10	BC = 0.79 OC = 9.10	
Fuel volumic mass (in kg/m^3)	4% oil : ρ = 754.2		25% oil : ρ = 776.25	

Table 1 : Characteristics of the "low" and "high" scenarios.

After having computed these emissions for each country, data were spatialized according to population density. Up to the present, such densities were given at 1° *1° resolution. Now, however, SEDAC*** (http://sedac.ciesin.columbia.edu/) population densities have come available, with 0.25° * 0.25° resolution. A comparison between the results for both spatial resolutions, using our global emissions inventory for West Africa (Junker and Liousse, 2008) is presented in figure 1. Significant differences are evident between these two images. It is clear that when combining fuel consumption and population density data, the use of the 0.25° resolution data results in a far more realistic final product.

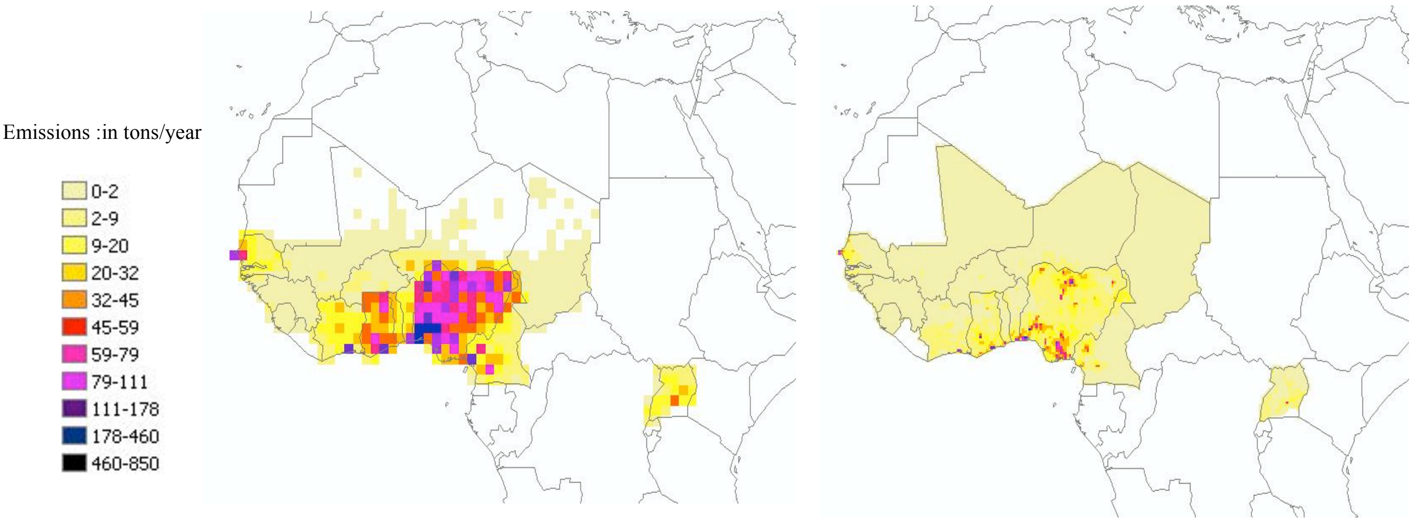

Figure 1 : OC emissions from UN (2002) : 1° * 1° on the left vs 0.25° * 0.25° on the right.

III. Results

III.1. Consumptions

Fuel consumption data are compared for two-wheel vehicles and all road traffic (including two-wheel vehicles) using the UN database for the year 2002 (Junker and Liousse, 2008). “Low” and “high” scenarios shown in figure 2 indicate that the fuel consumption ratios between two-wheel vehicles and all vehicles is small in Ivory Coast, Ghana, Guinea, Guinea-Bissau, Niger, Nigeria, Senegal, Sierra Leone, Chad and Uganda. In Burkina-Faso and Mali, however, these ratios reach 23% and 66% for the “low” scenario and 97% and 279% for the “high” scenario respectively. In Benin and Togo where “zemidjans” are predominant (Agossou, 2003), fuel consumption are respectively 47% and 33% for the “low” scenario and 119% and 84% for the “high” scenario. These results indicate that fuel consumption is underestimated in Burkina-Faso, Mali, Benin and Togo, where two-wheel engines are the most commonly used vehicles (Wane, 2001; Abotsi, 2005; Agossou, 2003).

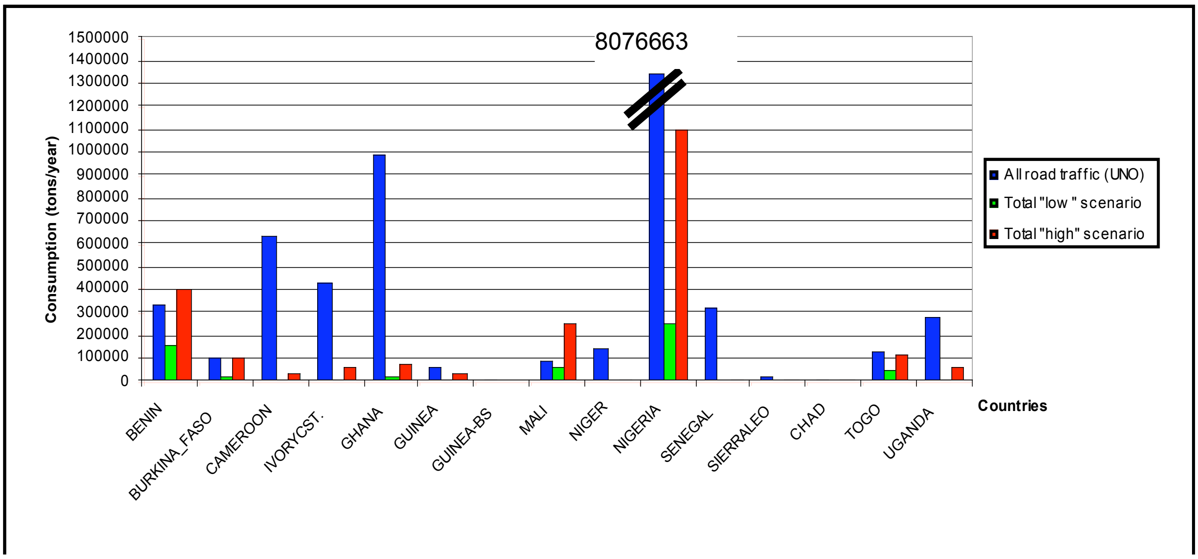

Figure 2 : Fuel consumptions in the “low” and “high” scenarios for “clean” two-wheel vehicles and zemidjans.

III.2. Emissions

In figure 3 BC and OC combustion aerosol emissions for two-wheel vehicles are displayed for the year 2002. These emissions are compared with those of total road traffic emissions (BC (figure 3a) and OC (figure 3b) from Junker and Liousse (2008) and UN database).

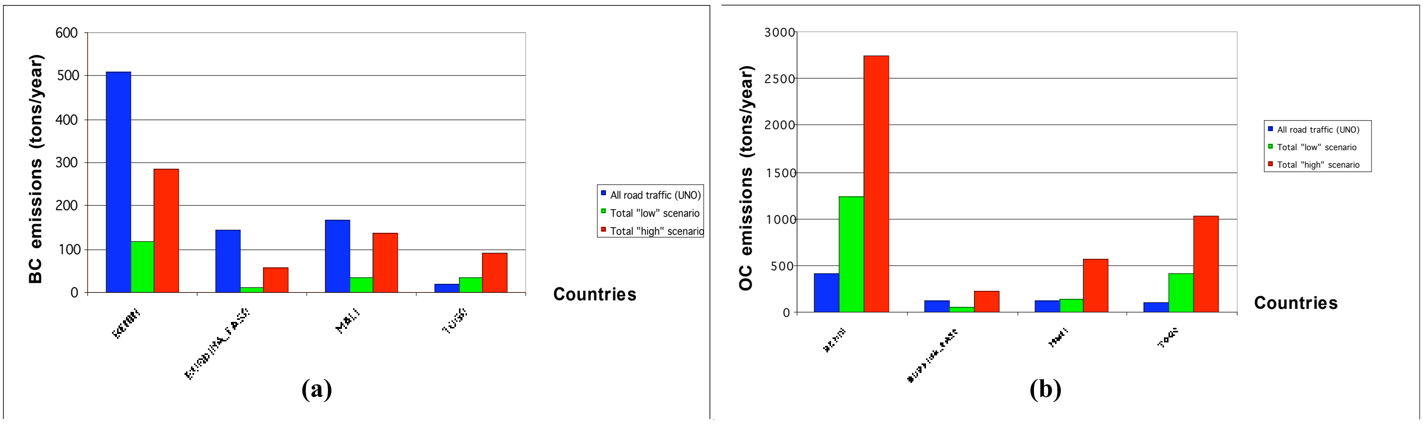

Figure 3 : Total emissions in the "low" and "high" scenarios for "clean" two-wheel vehicles and zemidjans : (a) Black Carbon (BC). (b) Organic Carbon (OC).

BC emissions for the "low" scenario amount to 9% and 173% of total traffic emissions from the global inventory in Burkina-Faso and Togo respectively. Under the "high" scenario, these ratios are all over 35%, with 39% in Burkina-Faso, 39% in Benin, 82% in Mali and as much as 438% in Togo. Such underestimations are even more important for OC, since OC emission factors are larger, due to incomplete combustion, such as occurs with the use of "zemidjans"; with emission factors reaching at least ten-fold higher than for BC (cf. Table 1). Annual OC inventories for Togo under the regional "low" scenario indicate that two-wheel vehicle emissions are 411% of those for total road traffic emissions from the global inventory of Junker and Liousse (2008). Large ratios also occur in a number of other countries with, 45% in Burkina-Faso, 111% in Mali and 298% in Benin. In the case of the "high" scenario, two-wheel vehicle emissions are as high as 188% in Burkina-Faso, when compared to the previous global road-traffic inventory for Africa. They amount to as much as 469% 665% and 1037% of total vehicle emissions in Mali, Benin and Togo respectively. These results illustrate the real need to account for such regional specificities as the predominant use of two-wheel vehicles for transport.

IV. Conclusion

This study has emphasized the large underestimations of fuel consumption in the West African region, as a result of large-scale fuel smuggling which is unaccounted for in inventories, as well as uncertainties associated with combustion emission factors. Figure 4 shows the relative difference between the total traffic OC emissions from Junker and Liousse (2008) and our inventory. Large differences especially observed in Benin, Nigeria and Togo indicate that two-wheel vehicles must be specifically considered in West African regional inventories, and more generally, that all traffic inventories urgently need to be updated.

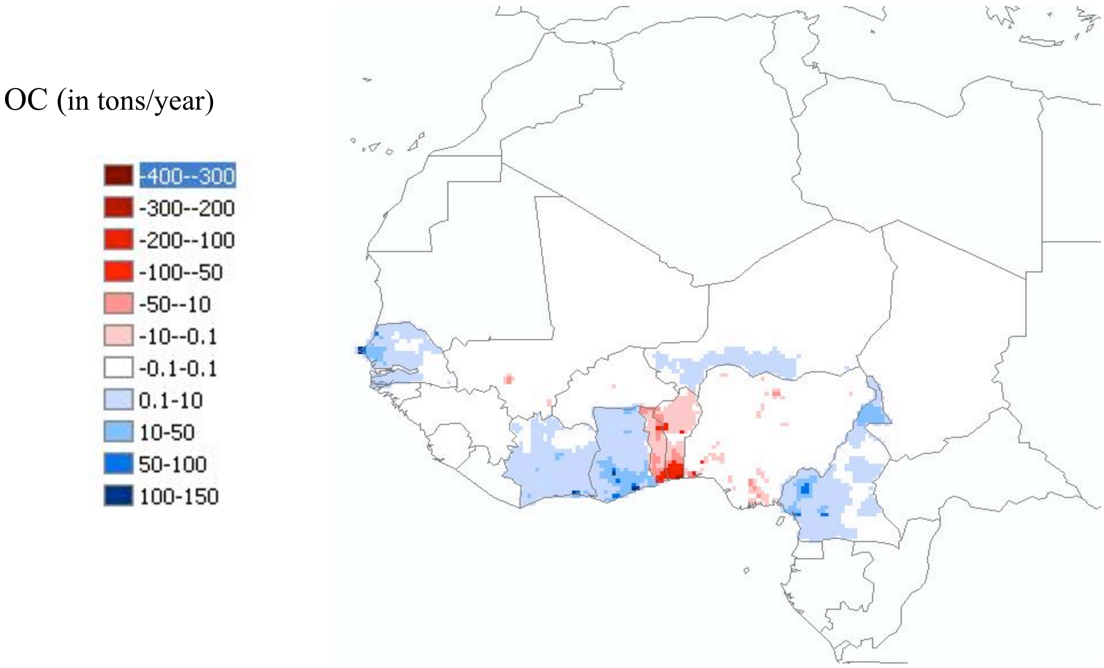

Figure 4 **:** Differences in OC emissions for 2002 between global UN derived inventory and the present regional "high" one.

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