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Characterization and aerosol mass balance of $PM_{2.5}$ and PM_{10} collected in Conakry, Guinea during the 2004 Harmattan period

Jason P. Weinstein [a,*], Scott R. Hedges [b], Sue Kimbrough [a]

[a] US EPA, 109 Alexander Drive, Durham, NC 27711, USA
[b] US EPA, 1200 Pennsylvania Avenue, N.W., Washington, DC 20460, USA

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ABSTRACT

Background $PM_{2.5}$ and PM_{10} levels were determined during Harmattan (West African wind blown dust) at a background site in Conakry, Guinea. The study was conducted from January to February, 2004 when Harmattan dust appeared to be most pronounced. $PM_{2.5}$ concentrations at the Nongo American housing compound ranged from 38 $\mu g\,m^{-3}$ to 177 $\mu g\,m^{-3}$, and PM_{10} ranged from 80 $\mu g\,m^{-3}$ to 358 $\mu g\,m^{-3}$, exceeding standards set by EPA and European Commission Environment Directorate-General. PTFE filter samples were analyzed for insoluble and soluble inorganic constituents by XRF and IC, respectively. Sulfur and associated SO_4^{2-} concentrations were notably consistent among $PM_{2.5}$ and PM_{10} samples which marked a relatively stable S background signal from anthropogenic sources. Enrichment factor (EF) analysis and aerosol mass reconstruction (AMR) techniques were used to isolate potential PM source contributors. The EF's for SiO_2, TiO_2, Al_2O_3, Fe_2O_3, and MnO were near unity which suggests a crustal origin for these elements. EF's for Na_2O and K_2O were above unity and highly variable, these elements were elevated due to widespread mangrove wood combustion as a fuel source in Conakry. The EF's for Cr were notably high with a median of 7 and interquartile range from 5 to 16, the elevated levels were attributed to unregulated point source and mobile source emitters in and around Conakry.

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1. Introduction

The United States EPA conducted a 6 week air quality screening survey of the city of Conakry, Guinea, West Africa in 2004 at the request of the US Embassy in Conakry. The study was conducted to assess the background levels of anthropogenic and natural particulate matter (PM) and to investigate the local and regional sources of those pollutants. This paper presents the first reported concentrations of airborne particulate from one of the world's dirtiest cities (Luck, 2008).

The air quality survey was conducted from January 11 through February 22, 2004. This period was selected because Conakry was in the middle of the dry season when visible air pollution appears to be most pronounced. The survey period overlaps with the Harmattan dust season where cool, dry trade winds blow from the Sahara Desert toward the southwest from November to March every year (Breuning-Madsen and Awadzi, 2005).

Conakry has a wide range of environmental and public health problems including respiratory illnesses due to elevated levels of air pollution (World Health Organization, 2006a). Local pollution sources include: unregulated combustion and processing emissions from industrial point sources, unregulated emissions from leaded gasoline vehicles, widespread open pit burning of household and vegetative waste, and residential wood burning cooking ovens. The local industrial point source emitters include: an asphalt manufacturing plant, cement manufacturing plant, diesel and fuel oil combustion electric power plants, brick manufacturing operation, fish processing and smoking facilities, brewery, soft drink bottling plant, soap manufacturing facility, plastic injection molding facility, steel smelter, paint formulation plant, medical waste incinerator, and major bauxite, alumina, and cement operations (Fig. 1; Bermudez-Lugo, 2006).

This paper presents concentrations of $PM_{2.5}$ integrated and real-time samples and PM_{10} integrated samples. The integrated samples were chemically characterized by XRF for inorganic constituents, ion chromatography (IC) for soluble species, and a limited number of elemental carbon (EC) and organic carbon (OC) measurements using a thermo-optical method. The paper explores the relative contributions of local pollution sources, the

* Corresponding author. Address: US EPA, MD-E205-03, 109 Alexander Drive, RTP, NC 27711, USA. Tel.: +1 919 541 2717; fax: +1 919 541 0960.
E-mail address: weinstein.jason@epa.gov (J.P. Weinstein).

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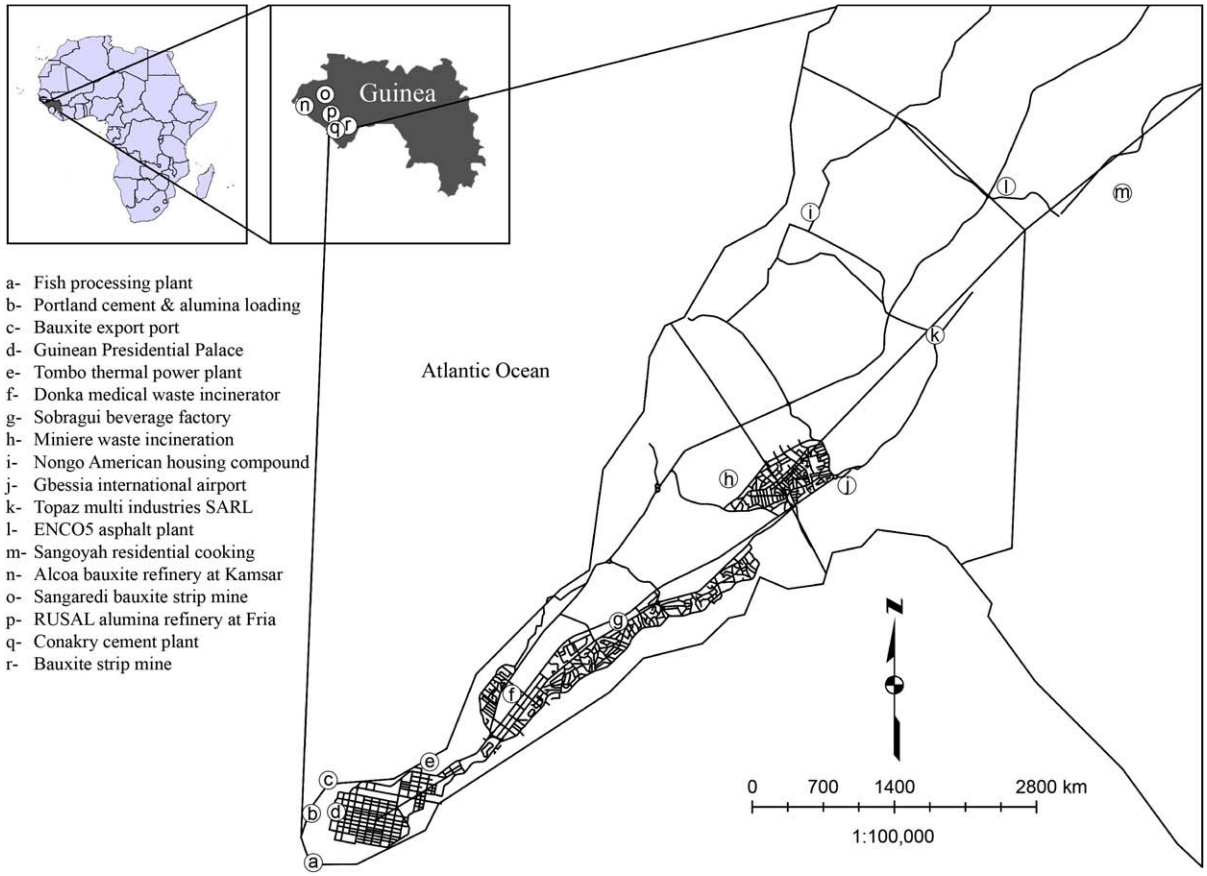

Fig. 1. Map of Conakry, Guinea, West Africa with monitoring sites and local points of interest.

influence of Harmattan dust influx, and the possible sea salt aerosol contribution.

2. Methods

2.1. Study area

Guinea is located on the Atlantic coast of West Africa and is bordered by Guinea-Bissau, Senegal, Mali, Cote d'Ivoire, Liberia, and Sierra Leone. The country is divided into four geographic regions: a narrow coastal belt (Lower Guinea), the pastoral Fouta Djallon highlands (Middle Guinea), the northern savannah (Upper Guinea), and a southeastern rain forest region (Forest Guinea). Lower Guinea has a tropical climate with a rainy season lasting from April to November, relatively high and uniform temperatures, and high humidity. The dry season spans November to March and features a cool, dry, dust-laden trade wind originating from the Sahara Desert, termed Harmattan wind (Adepetu et al., 1988).

The capital of Guinea, Conakry, is located on the west coast of the country on a peninsula extending into the Atlantic Ocean. Conakry has a population of approximately 2 million people located on the peninsula and partially on the mainland toward the east with a total area of approximately 135 km^{-2} (The World Bank Sub-Saharan Africa Transport Policy Program, 2004). Conakry's year round average high temperature is 29 °C and the low is 23 °C with an average annual rainfall of 430 cm. During Harmattan, Conakry is uniquely situated on the Inclined Meteorological Equator (IME) which forms the west–east boundary between the northeast trade winds and the southwest monsoon in the West African region (Giresse, 2008). The IME migrates seasonally which establishes the wet and dry seasons in West Africa; the northerly migration establishes the rainy season and southerly migration establishes the dry season (Dupont and Weinelt, 1996).

2.2. Sampling and analysis

The bulk of the air quality monitoring was conducted at a secure background site located at the northeast corner of the Nongo American housing compound. The background site was located north of the geographic center of Conakry and had no major emission sources within 100 m, as such, it meteorologically and geographically represented typical ambient PM in the Conakry area. The PM sampling devices were located on scaffolding 4.3 m above the ground per the US Code of Federal Regulations 40 CFR 58, Appendix E for ambient air quality monitoring (US Code of Federal Regulations, 2002).

Point source air quality monitoring was conducted at 15 sites in addition to the background PM sampling effort at Nongo. A variety of sampling technologies and techniques were employed during the air quality survey. This paper presents the quantitative results from the most robust sampling techniques, namely, the 24 h PM filter samples. One 24 h filter sample was collected at a home in the Sangoyah district of Conakry to measure PM from prolific residential outdoor cooking. Another 24 h filter sample was collected at the Guinean government's Presidential Palace site which is in strikingly close proximity to the alumina, bauxite, and cement ship loading operations (Fig. 1).

Two MiniVol (Airmetrics) portable, battery-powered samplers were used to collect 24 h $PM_{2.5}$ and PM_{10} (particle equivalent aerodynamic diameter less than or equal to 2.5 μm and 10 μm, respectively) on 47 mm polytetrafluoroethylene (PTFE) and quartz filters at the Nongo background site (Hill et al., 1999). The MiniVol