Available online at www.sciencedirect.com
ScienceDirect
Atmospheric Environment 41 (2007) 5673–5683
ATMOSPHERIC ENVIRONMENT
www.elsevier.com/locate/atmosenv

Chemical characterization of volatile organic compounds near the World Trade Center: Ambient concentrations and source apportionment

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Received 20 October 2006; received in revised form 16 February 2007; accepted 28 February 2007

Abstract

Concentrations of 53 volatile organic compounds (VOCs) are reported from four locations near the World Trade Center (WTC) (New York, USA) complex for canister samples collected from September 2001 through January 2002. Across the four sampling sites, mean concentrations ranged from 94.5 to 219 $\mu g\,m^{-3}$ for total VOCs. The highest mean concentrations for individual VOCs at any site were for ethane (18.7 $\mu g\,m^{-3}$), isopentane (17.1 $\mu g\,m^{-3}$), and *m,p*-xylenes (17.0 $\mu g\,m^{-3}$). VOC concentrations were generally highest for samples collected north and west of the WTC complex. Concentrations of total VOCs (and most individual VOCs) decreased from the period when fires were present at the WTC complex (before 19 December 2001) to the period after fires. The EPA Unmix Version 5.0 receptor model was used to assess the impact of WTC fires and recovery efforts on ambient VOC concentrations. Four factors were identified: burning of building debris, a mixed recovery/heating source, motor vehicle exhaust, and a mixed gasoline source.
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Keywords: World Trade Center; Receptor modeling; Source apportionment; Building fire

1. Introduction

The collapse of the World Trade Center (WTC) stemming from the terrorist attacks on 11 September 2001 (9/11) led to a cloud of dust and debris that dispersed over lower Manhattan. In addition to the release of air pollutants from the initial collapse, fires at the WTC complex persisted for approximately three months after 9/11. Although air pollutants released to the atmosphere were expected to be similar in nature to previous building collapses and fires, the scale and duration of the WTC collapse and aftermath were without parallel.

Studies have reported health effects from populations exposed to contaminants released from the WTC collapse. Medical evaluations of firefighters were completed for a period of 6 months following 9/11 (Prezant et al., 2002). Of the 10 116 firefighters evaluated, 332 were diagnosed with persistent cough and other respiratory symptoms referred to as "World Trade Center cough" (Chen and Thurston, 2002; Scanlon, 2002). In a study of community

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1352-2310/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.atmosenv.2007.02.047

residents, medical questionnaires were completed by 2166 residents of lower Manhattan, and lung function was evaluated for a subset of that study population (Landrigan et al., 2004). For both asthmatic and non-asthmatic residents, increased respiratory symptoms were reported after 9/11 (Landrigan et al., 2004). More recently, Herbert et al. (2006) reported results from a medical screening program for rescue and recovery workers. Of the 9442 participants, 69% of workers reported new or worsening respiratory problems (Herbert et al., 2006). A more extensive discussion of possible health outcomes stemming from environmental and occupational exposures after 9/11 is provided elsewhere (Claudio, 2001; Berkowitz et al., 2003; Landrigan et al., 2004).

Research related to quantifying pollutant levels after the WTC collapse has focused on dust samples and ambient air samples (especially particulate matter). Preliminary sampling at the WTC complex focused on assessing occupational exposure, especially quantification of asbestos levels (Landrigan, 2001). A National Institute for Occupational Safety and Health (NIOSH) report (summarized in McKinney et al., 2002) describes general area and breathing zone samples collected from September to October 2001.

Recent studies (Lioy et al., 2002; Offenberg et al., 2003) have examined bulk dust samples collected within one week of 9/11, where the sum of 37 PAHs comprised as much as 0.4% by mass of the dust samples (Lioy et al., 2002). Researchers have also reported concentrations of particulate matter less than 2.5 μm ($PM_{2.5}$) and its constituents (Swartz et al., 2003; Olson et al., 2004; Pleil et al., 2004). Olson et al. (2004) reported concentrations of elemental carbon (EC), organic carbon matter (OM), $PM_{2.5}$, and reconstructed soil, trace element oxides, and sulfate from four locations near the WTC complex. Swartz et al. (2003) reported over 60 non-polar analytes, including numerous combustion markers (e.g., 30 PAHs, pristane, and phytane). Pleil et al. (2004) analyzed archived $PM_{2.5}$ filters for levels of stable PAHs (4–6 rings) and found the fires contributed a substantial portion of PAHs to the air in lower Manhattan during the first 100 days following 9/11. Cohen et al. (2004) reported PM measurements collected for 3 months from a site approximately 400 m from the WTC site, where the sum of 37 PAHs ranged from 0.01 to 1.5 $\mu g\,m^{-3}$ for October samples. Cahill et al. (2004) reported PM measurements from October 2001 from a site approximately 1.8 km from the WTC site and approximately 50 m above ground. Size fractions greater than 1 μm were comprised of concrete, gypsum, glass, soot-like materials, and metals.

Although several studies have reported concentrations of air pollutants after the WTC collapse, none have focused on volatile organic compounds (VOCs). In addition to the importance of VOCs on ozone production and secondary organic aerosol formation, numerous individual VOCs have known or suspected health effects, e.g., benzene (IARC, 1987) and 1,3-butadiene (Jackson et al., 2000). Furthermore, published data are available for the days and weeks following 9/11 for some air pollutants (especially PM), but no information is currently available on VOC levels over longer time intervals. The objective of this research component is to better characterize temporal and spatial trends in ambient VOCs near the WTC complex. To this end, ambient concentrations of 53 VOCs are reported from four locations where canister samples were collected from September 2001 through January 2002. The Unmix receptor model was also used to assess the impact of WTC fires and recovery efforts on ambient VOC concentrations.

2. Methods

2.1. Site description

VOC measurements were collected from three stationary outdoor locations surrounding the WTC complex and one additional location (see Fig. 1 in Olson et al., 2004); these sampling locations were also used to collect $PM_{2.5}$ measurements as described elsewhere (Olson et al., 2004). Gaseous grab samples were collected from September 2001 until January 2002. The north site was located at the intersection of West Broadway and Park Place (40°42.83′N; 74°00.63′W; hereafter referred to as site N), the east site was located at the intersection of Broadway and Cedar Street (40°42.59′N; 74°00.60′W; hereafter referred to as site E), and the west site was located at the intersection of West Street and Albany Street (40°42.59′N; 74°00.90′W; hereafter referred to as site W). In addition to the sites surrounding Ground Zero, samples were also collected at the US EPA Region 2 building located at 290 Broadway (40°42.91′N; 74°00.37′W; hereafter referred to as site NE). These samples were collected from the edge of the 16th floor offset on the southwest corner (of the 32-floor building),