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Passive samplers and community science in regional air quality measurement, education and communication

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ABSTRACT

Charlotte, in Mecklenburg County, North Carolina, was ranked in the top ten cities with the worst air quality for ozone in the United States by the American Lung Association from 2009 to 2011. Nearby counties that may experience similar air quality do not have state or county monitors. This study utilized NO_x and ozone Ogawa passive samplers and community scientists to monitor air quality in five counties surrounding Charlotte and increase public engagement in air quality issues. Community scientists deployed samplers weekly at a residential site within each county. Samples were analyzed using spectrophotometry and ion chromatography. Elevated NO_x concentrations were observed in four of the five counties relative to those with existing monitors. Ozone concentrations showed little county to county variation, except Iredell and Cabarrus which had higher concentrations than Rowan. Community involvement in this work led to an increase in local dissemination of the results, thus increasing air quality awareness.

1. Introduction

In the 2010 and 2011 State of the Air Reports published by the American Lung Association, the Charlotte-Gastonia-Salisbury region of North Carolina was named #10 in a ranking of most polluted cities by ozone. Additionally, Rowan was identified as #17 and Mecklenburg as #21 and #22 in the 2010 and 2011 reports, respectively, for most polluted counties by ozone (Fig. 1). Ozone is a secondary pollutant component of photochemical smog. Ozone, and other secondary organic pollutants within photochemical smog, forms when sunlight reacts with nitrogen oxides and other products of fossil fuel combustion including volatile organic compounds (Baird and Cann, 2005). Regional ozone concentrations are primarily affected by photochemical production, chemical destruction by nitric oxide and accumulation due to poor dispersion and they vary with light intensity, precursor concentrations, and meteorological parameters, respectively (Chang and Lee (2006), Tu et al. (2007), Blanchard et al., 2014, Mulholland et al., 1998). Fourth highest 8-h ozone values reported by the North Carolina Division of Air Quality (DAQ) and Mecklenburg County Air Quality (MCAQ) for the 2006–2009 period covered by the 2010 and 2011 State of the Air reports range from 69 to 96 ppb (NCDENR, 2014). Vehicular air pollutants, including nitrogen oxides (NO and NO_2) and ozone, have been shown to play a role in decreased lung function and increased susceptibility to lung infection in healthy and/or at-risk populations (Ayres, 1998; Bell et al., 2004; Brugge et al., 2007; Brunekreef and Holgate, 2002; Folinsbee, 1998; Samoli et al., 2006; White et al., 1994).

Beckerman et al. (2008) noted that concentrations of NO_2 are well-correlated with other pollutants and may therefore serve as a marker of a “pollution mixture.” Modeling studies have shown that relevant variables in the intraurban variation of NO_2 concentrations include traffic density, distance to major roads, the presence of major industries and total population (Jerrett et al., 2007; Luginaah et al., 2006). Rijnders et al. (2001) found a correlation between NO_2 concentrations and urbanization and traffic density. Monitoring studies have shown that the NO_x concentrations decrease as the distance to major highways increases (Gilbert et al., 2003; Kimbrough et al., 2013; Roorda-Knape et al., 1998; 1999; Singer et al., 2004). As might be expected, other studies have found a significant increase in the personal exposure of school children to traffic-related air pollutants when either their school (Singer et al., 2004) or their residence (Van Roosbroeck et al., 2006) was located near a busy road.

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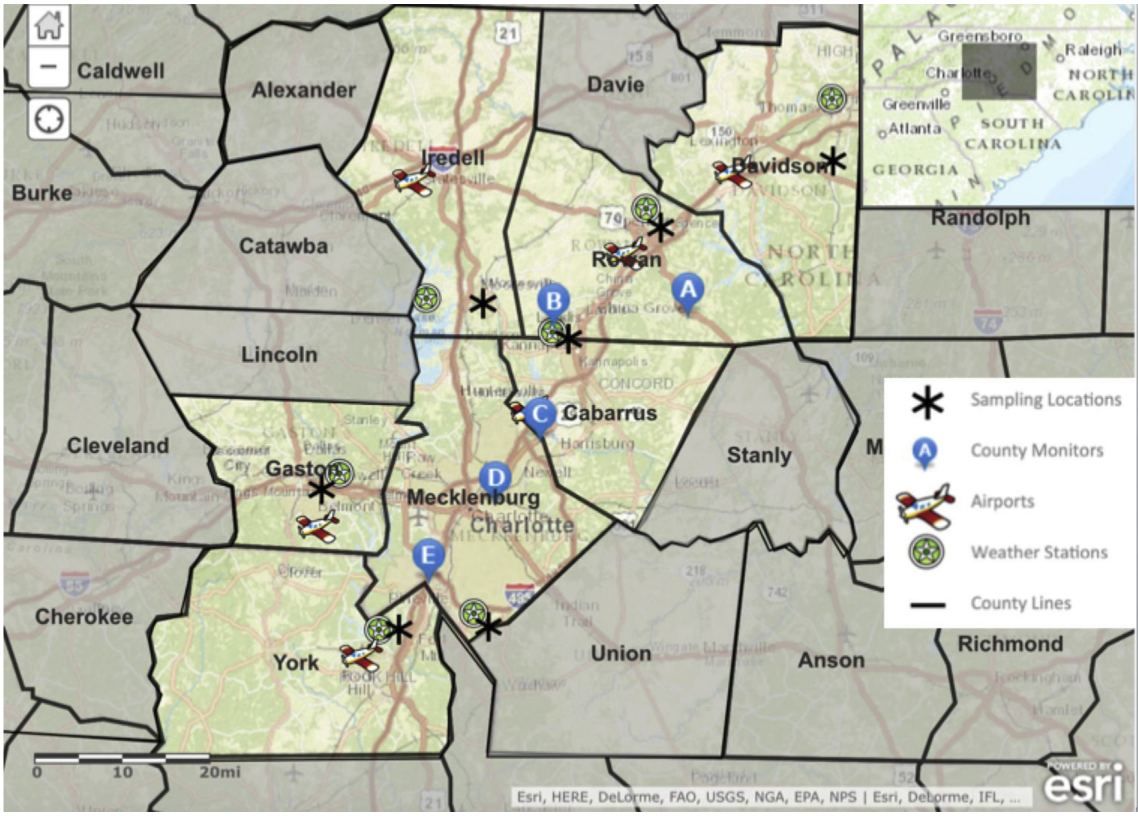

Fig. 1. Charlotte-Gastonia-Salisbury region of North Carolina including Sampling Locations, State and County Operated Monitors, Weather Stations and Regional Airports. NCDAQ/MCAQ monitors are located at China Grove (A), Enochville (B), County Line (C), Garinger (D) and Arrowood (E). Wind data was also obtained from the indicated airports through the State Climate Office of North Carolina for comparison. Additional details regarding sites are provided in Table 1.

Where as NO_x are primary pollutants whose concentrations increase with proximity to major roadways, studies on the spatial variability of ozone support effective titration of ozone by elevated nitric oxide concentrations resulting in decreasing concentrations of ozone, as a secondary pollutant, closer to major roadways in and around the urban source region and higher values downwind (Beckerman et al., 2008; Ainslie and Steyn, 2007). Sillman (1993) similarly observed peak concentrations in suburban or rural locations downwind from sources. Blanchard et al. (2014) predicts that the Ozone Production Efficiency (OPE) is higher at rural compared to urban sites. Paoletti et al. (2014) on the other hand, found a convergence of urban and rural ozone concentrations between 1999 and 2010 in European and US cities.

However, in the absence of awareness about spatial trends in ozone concentrations, residents, educators, advocacy groups and policy makers in counties between and adjacent to pollutant sources could experience a false sense of complacency about actions needed to improve their air quality and protect their health. Often the air quality in adjacent areas is simply not monitored. Individuals and news outlets often make the assumption that the lack of being included on a warning list indicates that the air quality is better when, in many cases what it indicates is the lack of any data. Federal or state monitoring in all counties is neither economically feasible nor necessary for the protection of community health. Knowledge about local data, however, is one of the most effective methods to increase community engagement in issues that affect personal health (Israel et al., 1998). Similarly, involving communities in the collection of that data (community science or citizen science) has demonstrated an increase in the level of engagement around environmental issues (Bonney et al., 2014; Carr, 2004; Ballard et al., 2010; Corburn, 2007). Communities and scientists mutually benefit in participatory based research, community science and citizen science including insight into questions relevant to a given community through multiple ways of knowing (Trumbull et al., 2000) and an extension of the monitoring network beyond what is feasible for single PI (Bonney et al., 2009; Carr, 2004).

In this study, community volunteers deployed Ogawa Passive Sampling Devices to measure 7-day average NO_x and Ozone concentrations to assess air quality in five counties which border Mecklenburg and Rowan counties and are currently not monitored by the Environmental Protection Agency. Passive Sampling Devices like the ones used provide concentrations comparable to those obtained by continuous air monitors and are a cost-effective, non-intrusive, and non-labor intensive methods of measurement (Namiesnik et al., 2005) that can be used to measure the average concentration of airborne pollutants when hourly concentrations are not necessary (Manning et al., 1996; Mukerjee et al., 2004; Ray,

Table 1
Sampling sites, corresponding weather stations and average wind directions.

County	Latitude	Longitude	Station code	Average wind direction
Cabarrus	35°30′21.34″N	80°38′15.91″W	KNCKANNA5	SSW
Davidson	35°47′57.16″N	80° 6′7.17″W	KNCTHOMA5	SSW
Gaston	35°15′30.62″N	81° 8′10.11″W	MLOWN7	ESE
Iredell	35°59′04.66″N	80°86′12.29″W	KNCMOORE11	SSE
Mecklenburg	35° 1′49.11″N	80°47′52.90″W	KNCCHARL52	SSE
Rowan	35°41′20.47″N	80°27′5.39″W	KNCSALIS8	SW
York	35° 1′33.76″N	80°58′47.82″W	KSCTEGAC1	SSW