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Ambient nitrogen dioxide and sulfur dioxide concentrations over a region of natural gas production, Northeastern British Columbia, Canada

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HIGHLIGHTS

- Ambient concentrations were associated with proximity to gas development activities.
- Highest biweekly average ambient concentrations of NO_2 and SO_2 were found in Taylor.
- The maximum biweekly concentrations were 9.1 ppb for NO_2 and 1.91 ppb for SO_2.
- Levels were below annual AQ objectives but may still exceed short-term objectives.
- Passive monitoring is a reliable approach for baseline air quality studies.

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ABSTRACT

The Peace River district of Northeastern British Columbia, Canada is a region of natural gas production that has undergone rapid expansion since 2005. In order to assess air quality implications, Willems badge passive diffusive samplers were deployed for six two-week exposure periods between August and November 2013, at 24 sites across the region to assess the ambient concentration of nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). The highest concentrations of both species (NO_2: 9.1 ppb, SO_2: 1.91 ppb) during the whole study period (except the 1st exposure period), were observed in Taylor (Site 14), which is consistent with its location near major industrial sources. Emissions from industrial activities, and their interaction with meteorology and topography, result in variations in atmospheric dispersion that can increase air pollution concentrations in Taylor. However, relatively high concentrations of NO_2 were also observed near the center of Chetwynd (site F20), indicating the importance of urban emissions sources in the region as well. Observations of both species from the other study sites document the spatial variability and show relatively high concentrations near Fort St. John and Dawson Creek, where unconventional oil and gas development activities are quite high. Although a few sites in Northeastern British Columbia recorded elevated concentrations of NO_2 and SO_2 during this investigation, the concentrations over the three-month period were well below provincial annual ambient air quality objectives. Nonetheless, given the limited observations in the region, and the accelerated importance of unconventional oil and gas extraction in meeting energy demands, it is imperative that monitoring networks are established to further assess the potential for elevated ambient concentrations associated with industrial emissions sources in the Peace River region.

1. Introduction

In 2014, the total production of natural gas in British Columbia (B.C.) was 4.62×10^{10} m^3 (oil was 1.18×10^6 m^3) with total estimated reserves (proven plus probable recoverable) of 1.44×10^{12} m^3 (oil was 1.81×10^7 m^3). This is a 212% increase over

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the natural gas reserves estimated in 2006 (OGC, 2014a). The trend of increasing reserve estimates is largely due to the successful development of unconventional gas extraction (the application of horizontal drilling and hydraulic fracturing technology, popularly called “fracking”) in the Montney formation and the Horn River Basin of Northeastern B.C. in 2005 (OGC, 2014a). These two formations are accounted for 66% of B.C.'s total natural gas production for the year 2014 (OGC, 2014a). It is also expected that natural gas from unconventional sources will continue to increase while conventional pools will be depleted in the next few years (OGC, 2013). The exploitation of these vast reserves of natural gas is a significant economic driver and revenue generator in the province, and as such the B.C. provincial government is planning on expanding this industry by promoting development of liquefied natural gas (LNG) for export. It is estimated that 8.50×10^{10} m^3 per year will be produced in order to meet the goal of developing three LNG facilities by 2020 (MEM, 2012). The province of British Columbia is currently the second largest natural gas producer in Canada, and Canada is the 5th largest in the world (CAPP, 2013).

Concerns have arisen recently in Northeastern B.C. about air pollution resulting from accelerated natural gas production (Fraser Basin Council, 2013; Krzyzanowski, 2012; MoE, 2014; MoH, 2014) without simultaneous implementation of available technological advances to control emissions (Krzyzanowski, 2009). According to the 2014 emissions data reported to Canada's National Pollutant Release Inventory (NPRI) database (Environment and Climate Change Canada, 2015a), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are the dominant species among all gaseous air pollutants in Northeastern B.C. emitted from various stages of oil and gas activities but mostly from the production phase such as processing (flares, engines, and compressors), distribution (leaks of pipelines and flanges), and also vaporization from storage tanks (Krzyzanowski, 2012; OGC, 2014b). However, oil and gas industries are exempt from reporting emissions during the well development phase to the NPRI (e.g., in pilot, exploration, or drilling phases) (URL: ec.gc.ca/inrp-npri/default.asp?lang=En&n=02C767B3-C9FD-4DD7-8072; accessed 20.03.15). Therefore, it has been suggested that both of these gaseous species are under-reported (Krzyzanowski, 2009) and under-monitored (Krzyzanowski, 2011). These two species are criteria air contaminants (CAC) and may directly impact human health through a number of pathways including the formation of photochemical oxidants (Krzyzanowski, 2012). Furthermore, previous studies in Colorado, USA, reported that people who live in the close proximity of unconventional wells have a greater risk of developing health effects from short-term exposure to the high emissions of hydrocarbons than those living farther away (Mckenzie et al., 2014; McKenzie et al., 2012).

Though significant emissions during production have been reported in the NPRI, until 2014 there were only four permanent SO_2 monitoring sites and no permanent NO_2 sites in the region of Northeast B.C. (BC Air Quality, 2014; MoE, 2014). However, due to growing public concern and as recommended in a risk assessment of the health impacts of oil and gas activities in this region (MoH, 2014), the MoE is considering the expansion of the continuous monitoring network in Northeast B.C. The baseline information needed to upgrade the monitoring network is not quite enough due to the limited number of monitoring sites, so new monitoring locations should be assessed. Decisions on where to install new stations should be based on background information such as which pollutants related to oil and gas development activities are changing over time in ambient air.

The overall purpose of this study was to assess the spatial pattern of ambient concentrations of NO_2 and SO_2 over portions of Northeastern B.C. undergoing an expansion in natural gas production. Ambient concentrations of these species were measured using passive diffusive samplers, which have been widely used across North America and Europe for the assessment of atmospheric NO_2 and SO_2 concentrations (e.g. Bari et al., 2015; Bytnerowicz et al., 2010; Campos et al., 2010; Cape et al., 2004; Cox, 2003; Hafkenscheid et al., 2009; Hagenbjork-Gustafsson et al., 1999; Hsu, 2013; Kirchner et al., 2005; Legge et al., 1996; Tang et al., 1999, 1997, 2001; Van-Reeuwijk et al., 1998; Vardoulakis et al., 2009; Zbieranowski and Aherne, 2012a) and for filling gaps in monitoring networks (Zbieranowski and Aherne, 2012a). Consequently, the spatial distributions of these two pollutants obtained from passive monitoring in this study could be used to inform decisions on upgrades to the continuous monitoring network in northeast B.C. To the best of our knowledge, there are no peer-reviewed published studies available that describe the ambient air concentrations across Northeastern B.C. using passive diffusive samplers. Although, industry-run passive monitoring exists in this region, the data are generally not publicly available (MoE, 2014; Taylor, 2015), and these studies usually only monitor at specific industry source locations. The advantages of diffusive passive samplers include that they are: inexpensive, easy to deploy in the field for long-term assessment, easy to operate, do not require electricity, are able to produce accurate results in indoor and outdoor environments, and are reliable for monitoring ecosystem exposure to gaseous pollution over longer averaging periods (Cox, 2003; Hafkenscheid et al., 2009; Kot-Wasik et al., 2007; Namieśnik et al., 2005; Seethapathy et al., 2008; Zbieranowski and Aherne, 2012a, 2012b). Despite having many advantages, passive samplers also have some disadvantages, such as sensitivity to environmental factors (temperature, relative humidity, wind, and rain), unsuitability for short-term monitoring, time-integrated (average) measurements during the exposure period, and the need to be validated (or calibrated) with colocated continuous active monitors (Cox, 2003; Kot-Wasik et al., 2007; Krupa and Legge, 2000; Runeckles and Bowen, 1999; Seethapathy et al., 2008).

2. Methods

2.1. Study area and design

Northeast B.C. is a region of plains, bordered by the Yukon and Northwest Territories to the north, the Rocky Mountains to the southwest and the province of Alberta to the east. It is the largest of B.C.'s regions, representing 21.8% of the land area of the province (20,494,470 ha), but the least populated, with 1.6% of the population (69,068 people). Of those residing there, approximately 13% consider themselves to be of aboriginal (i.e., First Nations) descent. The Northeast region has one of the most active economies in B.C. and this active economy is mainly driven by oil and gas exploration and production. Due to this, the population of the northeast is expected to rise to almost 80,000 by 2030 (URL: www.welcomebc.ca/Live/about-bc/regions/northeast.aspx; accessed 25.09.14). There are large differences in temperature between the warmest and coldest months of the year, e.g., in Fort St. John, average daily temperature can range from −21 °C in January to +14 °C in July. Major communities are located in Fort St. John, Fort Nelson, Taylor, Dawson Creek, Chetwynd and Hudson's Hope where oil and gas development activities are happening. In the present study, passive air quality samplers were deployed around each of these communities (Fig. 1), except Fort Nelson, which is geographically separated.

Two-week average ambient concentrations of NO_2 and SO_2 were measured at 24 sites across Northeastern B.C., Canada (Fig. 1, Table 1) during the period August 2013–November 2013. In order to assess the representativeness of this period, an analysis of the monthly distribution of hourly ambient SO_2 levels between 2007