Environment International 92–93 (2016) 119–129

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Evaluation of air quality indicators in Alberta, Canada – An international perspective

Md. Aynul Bari *, Warren B. Kindzierski

School of Public Health, University of Alberta, 3-57 South Academic Building, 11405-87 Avenue, Edmonton, Alberta, T6G 1C9, Canada

ARTICLE INFO

Article history:
Received 31 August 2015
Received in revised form 16 March 2016
Accepted 17 March 2016
Available online xxxx

Keywords:
Alberta
Urban air quality
Indicators
Trends
Regulatory limits
Exceedances

ABSTRACT

There has been an increase in oil sands development in northern Alberta, Canada and an overall increase in economic activity in the province in recent years. An evaluation of the state of air quality was conducted in four Alberta locations – urban centers of Calgary and Edmonton, and smaller communities of Fort McKay and Fort McMurray in the Athabasca Oil Sands Region (AOSR). Concentration trends, diurnal hourly and monthly average concentration profiles, and exceedances of provincial, national and international air quality guidelines were assessed for several criteria air pollutants over the period 1998 to 2014. Two methods were used to evaluate trends. Parametric analysis of annual median 1 h concentrations and non-parametric analysis of annual geometric mean 1 h concentrations showed consistent decreasing trends for NO_2 and SO_2 (<1 ppb per year), CO (<0.1 ppm per year) at all stations, decreasing for THC (<0.1 ppm per year) and increasing for O_3 (≤0.52 ppb per year) at most stations and unchanged for $PM_{2.5}$ at all stations in Edmonton and Calgary over a 17-year period. Little consistency in trends was observed among the methods for the same air pollutants other than for THC (increasing in Fort McKay <0.1 ppm per year and no trend in Fort McMurray), $PM_{2.5}$ in Fort McKay and Fort McMurray (no trend) and CO (decreasing <0.1 ppm per year in Fort McMurray) over the same period. Levels of air quality indicators at the four locations were compared with other Canadian and international urban areas to judge the current state of air quality. Median and annual average concentrations for Alberta locations tended to be the smallest in Fort McKay and Fort McMurray. Other than for $PM_{2.5}$, Calgary and Edmonton tended to have median and annual average concentrations comparable to and/or below that of larger populated Canadian and U.S. cities, depending upon the air pollutant.

1. Introduction

Exposure to important air quality indicators such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), fine particulate matter ($PM_{2.5}$), ground-level ozone (O_3) and carbon monoxide (CO) is of potential concern due to their chronic and acute health effects. Epidemiological studies suggest associations between short- and long-term exposure to NO_2, SO_2, $PM_{2.5}$ and O_3 and increased morbidity, mortality, and emergency hospital admissions for cardiovascular, cerebrovascular (stroke) and pulmonary diseases including acute myocardial infarction, arrhythmias, ischemic heart disease as well as diabetes and neurological disorders (Weichenthal et al., 2014; Zanobetti et al., 2014; Neuberger et al., 2007; Bell et al., 2005; Dockery et al., 2005; Ruidavets et al., 2005; Burnett et al., 2004; Künzli et al., 1997). Apart from their potential deleterious effects on public health, they are also implicated with acidic deposition, photochemical smog and visibility (Cheung et al., 2005; Cooper and Alley, 2002).

Alberta is the fourth largest province of Canada with an area of 661,848 km^2 and an estimated population of 4,175,409 as of April 1, 2015 (Statistics Canada, 2015). It is located in western Canada and bounded by the provinces of British Columbia to the west and Saskatchewan to the east, the Northwest Territories to the north and the U.S. State of Montana to the south. The Rocky Mountains to the southwest hinders any strong influence from the Pacific Ocean and the province has a semi-arid/semi-humid continental climate with wide variations in seasonal temperatures e.g., long, cold winters and short, warm summers. Prevailing upper level wind directions are west-northwesterly and annual precipitation including snowfall ranges from 30 to 60 cm. To the north and northeast of Alberta underlies the oil sands deposits, which play an important role in the Alberta and Canadian economy and at the same time bring attention to the national and international level about their potential impact to the environment and public health.

Recently, there has been a growing interest at the national and international level about the status of air quality in the oil sands region of Alberta. Alberta's oil sands are the third largest reservoir of crude oil in the world with proven oil reserves of 170 billion barrels, consisting of bitumen (about 168 billion barrels) and conventional crude oil (1.7 billion barrels) after Venezuela and Saudi Arabia, covering an area of

* Corresponding author.
E-mail address: mdaynul@ualberta.ca (M.A. Bari).

http://dx.doi.org/10.1016/j.envint.2016.03.021
0160-4120/

Fig. 1. Location of the selected urban cities and communities in Alberta (i.e., Edmonton, Calgary, Fort McKay, and Fort McMurray (source: Government of Alberta, 2014).

142,200 km^2 in the Athabasca, Cold Lake and Peace River regions (Government of Alberta, 2014, Fig. 1). Earlier projections had oil sands production increasing from the present-day level of 1.98 million barrels/day (2013) to 3.7 million barrels/day by 2020 and 5.2 million barrels/day by 2030 (CERI, 2014); however the current price of oil in the $30 to $50 US per barrel makes these projections unlikely. An existing belief is that air quality in the northeastern Alberta in the Athabasca Oil Sands Region (AOSR) is poor and it is adversely affected by oil sands development (Weinhold, 2011; Timoney and Lee, 2009). However, Bari and Kindzierski (2015) and the Royal Society of Canada (RSC, 2010) have reported that, along with continuing oil sands development, ambient air quality monitoring data in AOSR communities show minimal air quality changes over time. It is of particular interest to further understand the state of air quality in AOSR communities compared with other locations (i.e., urban centers) in Alberta and Canada and internationally.

Ambient air quality in Alberta depends on a number of factors, including various natural emission sources (e.g., vegetation, forest fire), anthropogenic emission sources (e.g., traffic, industrial and commercial activities, fossil fuel (coal, oil and gas) extraction and processing) as well as meteorological conditions (e.g., inversions with poor vertical mixing) (Bari et al., 2015a,b; Jeong et al., 2011; Myrick et al., 1994). According to Environment Canada's National Pollution Release Inventory (NPRI), major emission sources of criteria air pollutants in Alberta were transportation, industrial emissions including upstream and downstream petroleum industry, coal- and gas-fired electric power generation, open sources such as agriculture, construction operations and natural events like wildfire smoke (Environment Canada, 2015a). Bari and Kindzierski (2015) summarized NPRI-reported releases of NO_2 and SO_2 from industrial facilities/operations within a 70-km radius of the AOSR community of Fort McKay for the period 2002–2012.

Evaluating ambient air quality monitoring data is important for characterizing and understanding the state of air quality and whether it is changing. In this study, we undertook a detailed evaluation and comparison of the state of air quality indicators in major urban cities of Alberta and two smaller AOSR communities. Different measures e.g., trend analysis, diurnal hourly and monthly average concentration profiles, and exceedances of provincial, national and international air quality standards and guidelines were assessed. In addition, levels of air quality indicators in Alberta were compared with other major Canadian cities and international urban centers to understand how Alberta's air quality compares to other areas.

2. Methodology

2.1. Study areas

Data from six monitoring stations (2 in Edmonton, 2 in Calgary, 2 in AOSR communities – one in Fort McKay and one in Fort McMurray) were used for the study (Fig. 1, Fig. S1). Edmonton (central station: 53°32′39.97″N, 113°29′55.54″W, east station: 53°32′53.56″N, 113°22′5.11″W) is the capital and second largest city in Alberta with a population within its municipal boundaries of 877,926 in 2014 (Municipal Census, 2015). Edmonton covers an area of of 680 km^2, and along