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Analysis of NO_x, NO and NO_2 ambient levels in Dhahran, Saudi Arabia

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ABSTRACT

NO_x, NO, and NO_2 concentrations and meteorological parameters, temperature, wind speed, relative humidity and pressure were measured continuously in Dhahran from May to July 2015. Concentrations of NO_x, NO, and NO_2 were found to be highly influenced by traffic emission and meteorological conditions. The temperature and wind speed showed negative correlation coefficients while relative humidity showed positive correlation coefficient with NO_x, NO, and NO_2 concentrations. NO_2 was found to exceed international air quality standards, which indicates the existence of possible NO_2 air pollution problem in Dhahran.

1. Introduction

Nitrogen oxides ($NO_x = NO + NO_2$) are considered one of the main pollutants in urban areas. They are very reactive and play a significant role in the chemistry of the atmosphere (Han et al., 2011; Richter et al., 2005; Wang and Mauzerall, 2006). Their concentrations in ambient air are the result of processes of accumulation, dispersion, transformation and removal (Mazzeo et al., 2005). In general, NO_x concentrations vary rapidly in urban areas over the course of the day with a typical residence time of about few days (Andrews et al., 2004).

Although significant amount of NO_x is produced naturally, for example, during lightning and from microbial activities in soils, the main source of NO_x production in urban and industrial areas is from fossil fuel combustions, in particular, emissions from car engines (Agudelo–Castaneda et al., 2014; Carslaw, 2005; Itano et al., 2014; Kurtenbach et al., 2012; Zhao et al., 2015), which depend on vehicle type/size, fuel used and the manner of driving (Clapp and Jenkin, 2001).

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NO_x may further lead to the formation of other harmful pollutants such as ozone (O_3), acid rain, and photochemical smog through photochemical reactions (Notario et al., 2012). Also, they may react with other compounds available in the atmosphere to form small particles that can be harmful to human health (Kampa and Castanas, 2008). For example, it was found that nitrogen dioxide (NO_2) has a certain positive correlation with a number of cancer cases in Saudi Arabia (Al-Ahmadi and Al-Zahrani, 2013).

Many regulatory environmental agencies around the world set safe limits for NO_2 concentration in ambient air. Usually two safe limits are established for this purpose, one for long-term exposure averaged over one year, and the second is for short-term exposure averaged over 1 h. Where the units of measure for the standards are parts per billion (ppb) by volume. The US Environmental Protection Agency (US EPA) has set a safe limit of 53 ppb averaged over one-year and 100 ppb averaged over 1 h (EPA, 2008). The Directorate-General for Environment (DG Environment), which is the European Commission department responsible for EU policy on the environment, has set even a tighter safe limit for long-term exposure of 20 ppb averaged over one year, while setting the same safe limit for short-term exposure of 100 ppb but not to be exceeded more than eighteen occasions each year (DG ENV, 2016). The World Health Organization (WHO) has set similar safe limits to that of the European environmental legislation for universal use (WHO, 2000).

To the best of our knowledge, this paper is the first study of NO_x concentrations in ambient air in Dhahran, Saudi Arabia. Dhahran is one of the major cities in Saudi Arabia, which is rapidly expanding and is the host of the largest oil company in the world, Saudi ARAMCO. Ghawar oil field, which is the largest conventional oil field in the world, is located at a distance of about 85 km from Dhahran. In addition, Dhahran is located at 5 km and 25 km from two big cities that are expanding quickly: Khobar and Dammam. Dhahran is about 100 km from Jubail, which is the biggest industrial city in Saudi Arabia and the host of many different chemical and industrial plants. Traffic has also rapidly increased in Dhahran and its surroundings. A high number of vehicles per capita and a dense road network characterizes Dhahran today. It should be noted that the almost total absence of urban public transportation in Dhahran would certainly lead to more NO_x emissions. For example, it was found that diesel cars produced quadruple the NO_x emissions of large buses in city driving conditions according to a report from the Norwegian Centre for Transport Research (TØI, 2015).

In this paper, we study the hourly and daily variations of NO_x, NO, and NO_2 concentrations in ambient air in Dhahran from 07 May to 30 July 2015. The correlation between these variations and the meteorological parameters (temperature, wind speed, relative humidity and pressure) is also investigated.

2. Methodology

2.1. Study area and monitoring site

Fig. 1 shows the location of Dhahran in the Arabian Peninsula and the monitoring site and its surroundings. Dhahran is located on the western coast of the Arabian Gulf with an elevation of about 45 m above sea level and at a latitude of 26.24° N and a longitude of 50.04° E. Dhahran is one of the important cities in Saudi Arabia with about 100,000 inhabitants. It is part of Dammam metropolitan area, which includes the nearby cities of Dammam and Khobar and has an estimated population of about 4 million inhabitants (census of 2012). The climate of Dhahran is characterized by warm and humid summers, and little rainfall with an annual average of about 10 mm. In summer, temperatures can rise to >40 °C coupled with humidity as high as 85%. Winds usually blow from north to south in the beginning of the summer and can last for up to six months, bringing dust storms.

The monitoring site is located at King Fahd University of Petroleum and Minerals campus in Dhahran. The campus is surrounded by three major high ways, number 80, 613, and 615, which makes it an excellent location to study the contribution of traffic emission to NO_x concentrations in the area. The monitoring site is at a distance of about 1.8 km from highway 613.

2.2. Instrumentation

NO_x concentrations are measured using a commercial nitrogen oxide analyzer model EC9841 from Ecotech with detection range from 0 to 20 ppm and detection limit of <0.5 ppb. Air samples are collected from the roof of a 10-m high building and are drawn through pipes to the instrument, which is located in

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