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Characterization of large fleets of vehicle exhaust emissions in middle Taiwan by remote sensing

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Abstract

Measurement of fleet emissions by means of remote sensing was conducted in middle Taiwan and the distributions and governing factors were characterized and examined. Results show the type of sampling sites is a dominant factor for the emission levels, and driving speeds and accelerations of the vehicles. In this study, the mean CO, HC, and NO concentrations at the urban and rural sites are apparently higher. The quantitative relationship between the pollutant concentration and mean speed or acceleration was established. Analysis of effect of the vehicle model year on the average fleet emissions was also conducted. It indicates those relatively older vehicles are higher emitters and contribute significantly more to total fleet emissions. On the other hand, the variation trends with model year are independent of the site characteristics and the effect of vehicle age on CO, HC, and NO emission is similar.

Keywords: Emissions; Remote sensing; Vehicle exhaust

1. Introduction

Remote sensing technology measuring vehicle emissions has been widely applied in numerous locations around the world. It is capable of accurately and efficiently measuring the exhaust emissions of on-road vehicles, without affecting the normal traffic flow or the drivers. Taiwan EPA imported the remote sensing technique and instruments in 1996. Several studies have been conducted to routinely characterize automobile exhaust emissions since then, in order to evaluate its applicability and feasibility in Taiwan. The data set used in this paper is collected from October, 1999 to December, 2000 from the survey funded by Taiwan EPA (Taiwan EPA, 2000).

Measurement of exhaust emissions by remote sensing is influenced by many factors, including the physical characteristics of sampling sites, sampling times, vehicle speed and acceleration, and operating mode of

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the vehicles (Sjödin and Lenner, 1995; Sadler et al., 1996). The highly skewed distributions indicating that a large fraction of the overall fleet emissions was attributed to a small minority of the highly polluting vehicles have been consistently observed (Zhang et al., 1993, 1996a; Muncaster et al., 1996; Revitt et al., 1999). Works investigating the characteristics of fleet emissions also report the strong relationship between the model year of vehicles and their emission concentrations (Zhang et al., 1993, 1995, 1996b; Muncaster et al., 1996; Revitt et al., 1999; Sjödin and Andréasson, 2000).

On the other hand, vehicle emission factors have been derived from remote sensing measurements by a number of studies (Ntziachristos and Samaras, 2000; Chan et al., 2004; Ekström et al., 2004) and their dependence with vehicle speed or speed dynamics was examined. Since emission model evaluation is not included in the present work and remote sensing technique is intended as the screening tool for automobile exhaust emissions in Taiwan, tailpipe exhaust concentrations were used directly in this study. The objectives of this research are to characterize the statistical distributions of the fleet emissions by means of remote sensing in Middle Taiwan. Measurement of three gaseous pollutants, CO, HC, and NO, was made and their characteristic variations were compared. Additionally, factors influencing the fleet emissions, including monitoring sites, velocity and acceleration, and model year were also discussed.

Recent legislation for automobile exhaust emissions measured by the remote sensing technique has been enacted by the Taiwan EPA. According to Article 42 in the Air Pollution Control Act (Taiwan EPA, 2002), the latest revisions of which were promulgated on June 19, 2002, those in-use motor vehicles whose air pollutant emissions are determined through visual inspection, visual observation or remote sensing failing to comply with the emission standards or the remote sensing screening standards shall be repaired and undergo testing at a designated location by the deadline designated in the competent authority notification. The remote sensing screening standards for petrol vehicles was announced on January 24, 2003 and shown in Table 1.

Table 1
The remote sensing screening standards for petrol vehicles

Category	CO (%)	HC (ppm)
For those in-use motor vehicles manufactured or imported after August 1, 1992	1.2	220
For those in-use motor vehicles manufactured or imported between July 1, 1990 and July 31, 1992	3.5	900
For those in-use motor vehicles manufactured or imported before June 30, 1990	4.5	1200

2. Materials and methods

2.1. Remote sensing measurements

CO, HC, and NO concentrations in the exhaust plume of passing vehicles on a single traffic lane were measured simultaneously using a remote sensing vehicle exhaust emissions testing system (RSD 3000, Remote Sensing Technologies Inc., MD). This instrument is based on the same principle as the remote sensor originally developed by the University of Denver (Bishop and Stedman, 1996). CO and HC exhaust concentrations at tailpipe were measured as a proportion to CO_2 by means of infrared radiation; whereas those of NO were conducted by an ultraviolet diode-array spectrometer. On-site calibration is performed daily with a certified gas mixture containing known concentration ratios of CO, CO_2, HC, N_2, and NO. Acceptable recovery is between 90% and 110% of the expected value. The linearity of the instrument was checked and certified by the manufacturer once every six months.

In this system, the source detector module (SDM) and the vertical transfer mirror units were positioned on the opposite sides of a single traffic lane. Speed and acceleration results for each vehicle were measured by a device consisting of a laser emitter and a detector, which locates 5 ft from the SDM. The license plates of passing vehicles were recorded on a video system accompanying with the remote sensor. The video camera is coupled directly into the data analysis computer and the information was read for license plate identification. The plates which appeared to be readable were forwarded to the Motor Vehicles Licensing Authority records to determine their model, manufacturer, and model year information. Vehicle-specific information was matched with the corresponding emission