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Roadway Emissions Monitoring

Developments in Monitoring

With the establishment of the U.S. Clean Air Act, air quality surveillance has relied on ambient air and stack emission monitoring to provide data for attainment determination, health studies, dispersion modeling, air quality trends, and industrial emission inventories. The establishment of U.S. National Ambient Air Quality Standards (NAAQS) has identified criteria pollutants that require monitoring due to their adverse health effects and other indirect impacts on human health and life style. With increased technical ability and further understanding of the pollutant behavior, ambient air monitoring has been expanded to include more focused groups, which pinpoint the pollutant sources affecting ambient air quality. Heavy emphasis of the specialized ambient air monitoring is currently geared toward roadway emission monitoring.

It is estimated that in the United States, more than 35 million people live within 300 feet of a major transportation infrastructure[1] and according to the U.S. Department of Transportation's Federal Highway Administration, there are approximately 250 million vehicles on the road.[2] Data from numerous studies and near-road monitoring research projects suggest that automobile exhaust is complex in composition, containing up to 1000 different compounds,[3] and poses a significant risk to human health with the variety of compounds emitted by cars, trucks, buses, and other commercial vehicles. Accounting for the proximity of human habitats to the extensive transportation systems and the number of vehicles present, it is evident that specialized near road monitoring stations play an important

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role in determining how mobile sources affect human health, what dispersion patterns are present, and what can be done to limit the exposure.

To achieve a comprehensive near-road monitoring study, several factors must be taken into consideration, including roadway design, traffic patterns, meteorology, air quality, and the population size affected by the road network. The network design includes careful planning on the number and type of analyzers, as well as site locations. This article focuses on the newest developments in roadway emission monitoring, in terms of monitoring techniques, as well as changes in the U.S. monitoring requirements and legislation.

Roadway Emissions Monitoring

The aim of any roadway monitoring is to provide real-time data to develop correlation between traffic patterns, meteorology, and air quality. The pollutants of interest at a near-road monitoring station include nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs, including 1,3 butadiene, benzene, toluene, ethylbenzene, and m&p/o-xylenes), and particulate matter

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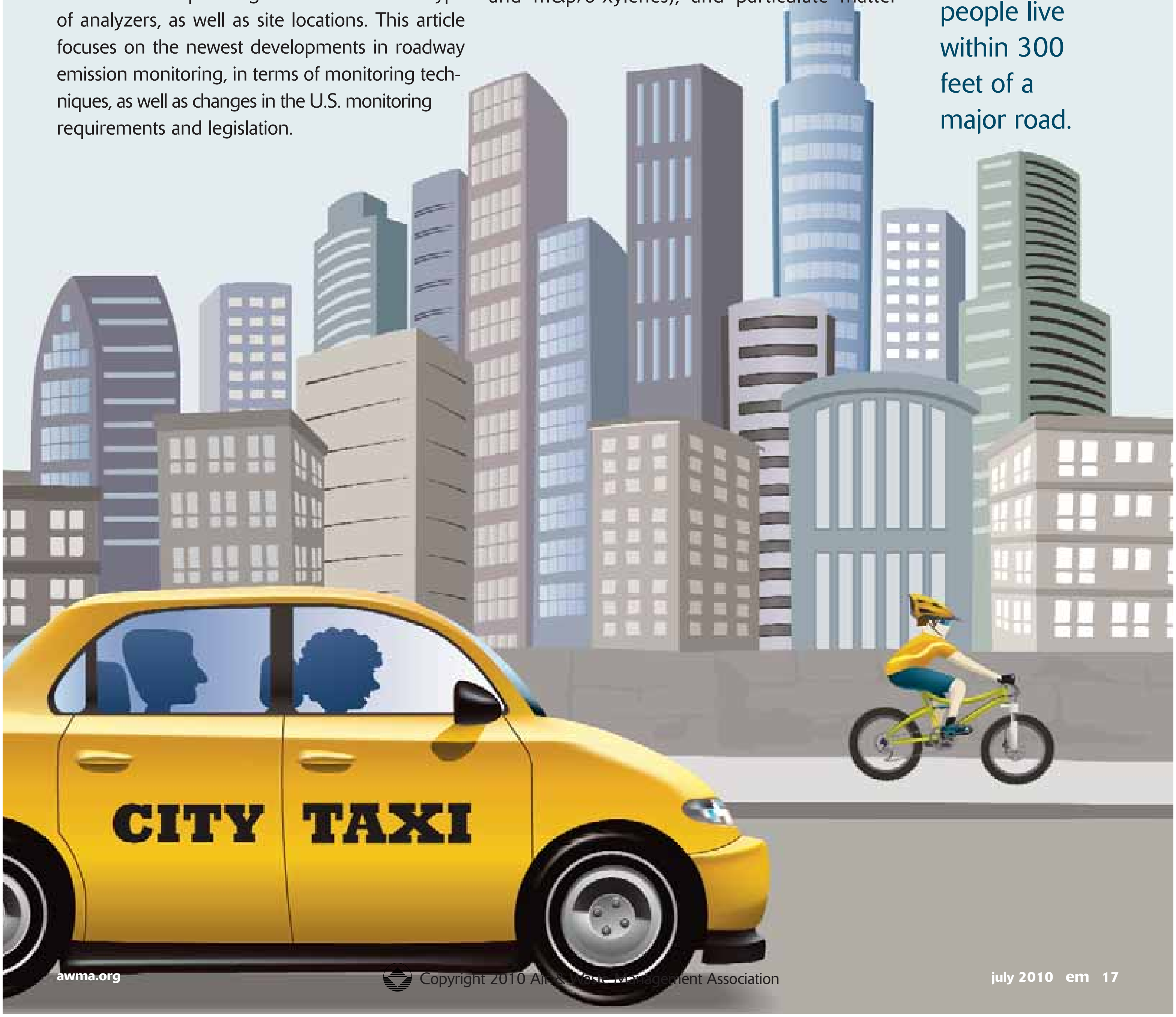

(PM, including $PM_{2.5}$ and PM_{10}); thereby, making each station a multipollutant monitoring station (see Figure 1). In addition, a full meteorological sensor suite is required for detailed weather pattern examination and the ability to quantify automobile volume, speed, and type. Combining all of the factors together will yield in a complete monitoring effort, allowing for mobile source air pollution characterization.

Changing Regulations

Whether it is mandated by the U.S. Environmental Protection Agency (EPA), taken on as a research study, or is the result of legal action, roadway monitoring is guided by specific regulations issued by EPA. In February 2010, EPA proposed amending Appendix D to 40 CFR Part 58, "Network Design Criteria for Ambient Air Quality Monitoring," to require NO_2 monitors at near-road monitoring locations. This change, published in the *Federal Register*,[4] specifies that at minimum, one microscale near-road NO_2 monitor is required in each area with a population greater than 500,000 persons. A secondary near-road NO_2 monitoring station is required for any area with a population of 2.5 million or more, or in any area with a population of 500,000 or more, and a major road system with an average annual daily traffic of 250,000 or greater.

The amendment further details that the roadway NO_2 monitoring stations must meet the following criteria: the location of the site must be adjacent to roadways where maximum hourly NO_2 concentration is expected and the monitoring location must meet all siting requirements, as established by EPA. In the event of multiple site identification meeting or exceeding the design criteria, a decision must be made based on the potential of population exposure. Further specifications mandate that in areas where a minimum of two roadway NO_2 monitoring stations are to be implemented, such as in case of an urban area with population of 2.5 million or greater, the sites may be located along the same roadway, if at least one site selection factor can be uncommon (e.g., traffic patterns, prevalent vehicle type, terrain or other). The secondary option for locating two monitoring sites within one populated area is to place the monitoring sites on unique roadways, such as state routes or interstate highways.

The final specification of this amendment requires that NO_2 measurements are taken using Federal Reference Method chemiluminescence monitors and must include at a minimum: NO, NO_2, and NO_x.

Figure 1. Near-road air monitoring station—dual sampling manifold system; quartz manifold for VOC sampling and pyrex manifold for gaseous criteria pollutants sampling.

Monitoring Technique Enhancement

Monitoring for the criteria pollutants—CO, NO_x, PM, and ozone—has been well established and there are various manufacturers offering monitoring equipment to suit those needs. One of the recent advances in near-road monitoring includes the use of field gas chromatographs.

VOC compounds are typically sampled using metal canisters with either passive or active collection techniques followed by laboratory chromatography analysis. Sampling is normally conducted on a 1-in-12-day schedule, with the sample being integrated over 24-hr period. In roadway monitoring, sampling frequency must be increased to compensate for traffic variations, which can result in up to 10 canister samples per day, integrated in advanced statistical models over 365 days to achieve the desired 1-hr averaging interval.

The use of a continuous gas chromatograph at a near-road monitoring station offers several advantages over the existing canister sampling method. One of the main benefits is the continuous data stream. Data are generated on a 15–30 minute analysis cycle, which is crucial in determining the daily maximum and minimum concentrations of ambient VOCs (see Figure 2). Diurnal traffic patterns (i.e., morning and evening rush hour) will have effect on the ambient VOC concentrations. However, an integrated canister sample will only show a single concentration for the 24-hr sampling period.

Another benefit of using a continuous gas chromatograph is the reduced operation cost as compared to canister sampling methods. Conducting analysis on site eliminates the need for shipping and handling costs, laboratory analysis costs, canister cleaning, canister purchasing or renting, and operator time.

Continuous gas chromatography has been successfully employed in various air monitoring efforts around the world and has been adapted to specifically suit field applications. The optimal continuous gas chromatograph unit is fully autonomous, self calibrating, requiring little to no human interaction, and is fully integrated into the industry standard 19-inch instrument enclosure. Data are presented in terms of a chromatogram with individual compound concentrations that are provided to researchers for data comparison and atmospheric chemistry analysis.

Setting up a near-road monitoring site may carry numerous expenses, including purchasing of a new monitoring station, all necessary equipment, sensors and analyzers, additional operator time, and energy costs. Other costs may include purchasing or leasing land space or easements for the proposed site location, obtaining necessary building permits, electrical connections, and other civil engineering costs. When examining instrumentation costs, however, one important aspect to recognize is that the capital cost of the investment in a real-time gas chromatograph is quickly offset by the reduced operating cost and typical laboratory costs involved in canister sampling.

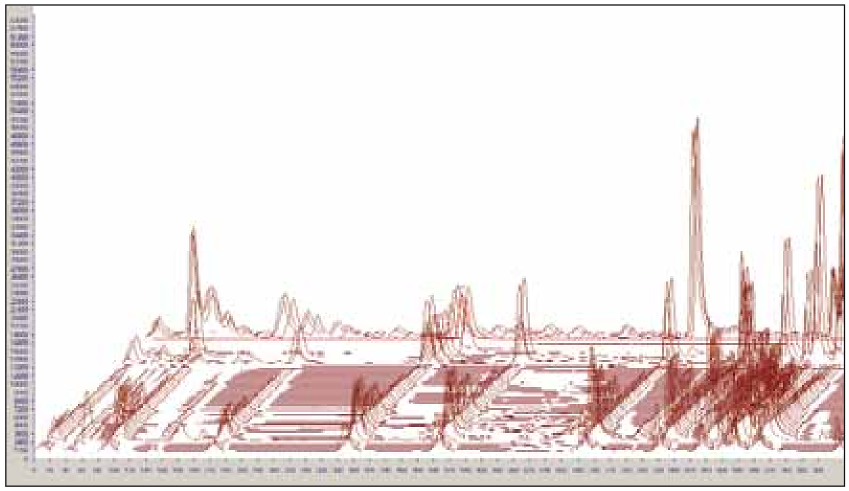

Figure 2. Gas chromatograph results of air toxics—3D chromatogram for diurnal traffic pattern analysis.cks, medium/heavy trucks, and buses.[3] Highway vehicles accounted for 47.2%, 32.7%, and 19.5% of CO, NO_X, and VOC emissions, respectively, from all sources in the United States in 2007.[4]

Conclusions

The objective of roadway emissions monitoring is to characterize the mobile source emissions, define factors affecting the pollutant concentrations, improve modeling tools for exposure assessments, and further the understanding of health effects attributed to roadway emission exposures.[1] With the changing regulations affecting and/or establishing the near-road monitoring protocols, and the enhanced capabilities of monitoring equipment, roadway monitoring projects around the country can provide scientists and researchers with data to produce detailed health impact assessment reports and develop human exposure models.

The necessary decision-making involved in the establishment of a new near-road monitoring station/network can be complicated, especially in difficult economic times; however, the costs and the effort required to successfully launch such a site or network must be weighed against the value of improved data collection used to further understand the human exposure and human health impact from road-way emissions. **em**

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