STATEMENT

Synopsis of Research Report 172

HEALTH EFFECTS INSTITUTE

Potential Air Toxics Hot Spots in Truck Terminals and Cabs

BACKGROUND

Motor vehicles and other combustion sources emit many air toxics whose ambient concentrations are not regulated by the U.S. Environmental Protection Agency (EPA) but that are known or suspected, with sufficient exposure, to cause adverse human health effects. Among these are mobile source air toxics (MSATs), compounds that the EPA has identified as being derived, at least in part, from motor vehicles and whose emissions need to be reduced. Although ambient concentrations of air toxics are generally low, so-called hot spots might exist where concentrations of one or more air toxics, and consequent exposures of area populations, could be elevated. Such areas may be in proximity to one or more pollution sources or may be affected by transient or sustained localized conditions that lead to elevated concentrations of some pollutants. In 2003, HEI targeted research to identify and characterize potential air toxics hot spots.

APPROACH

Dr. Thomas Smith of the Harvard School of Public Health and his colleagues measured concentrations of selected volatile organic compounds (VOCs) and particular matter (PM) in locations with potentially high levels of air pollution that could make them hot spots for human exposure, that is, around the perimeter of terminals for pick-up and delivery trucks and in truck cabs during daily runs. The premise underlying the selection of the sampling sites was that locations upwind of the terminals would have lower concentrations than downwind locations. The investigators hypothesized that the upwind locations' concentrations would be influenced by "industrial parks and other commercial zones" while the downwind locations' concentrations would reflect the added contribution from truck traffic inside the terminal and could be representative of exposures in nearby downwind residential neighborhoods.

The investigators had access to the terminals as part of a then-ongoing study funded by the National Cancer Institute (NCI) that involved truck drivers, loading-dock workers, and mechanics at 36 truck terminals chosen randomly in major metropolitan areas across the United States. At the time of the authors' application to HEI, 15 of these terminals had not yet been visited for exposure assessment. For these 15 terminals, concurrent measurements of air toxics were added. This phase is referred as Phase 1. During Phase 2, Dr. Smith and colleagues went back to six of the 15 terminals to make additional measurements.

Dr. Smith and colleagues measured VOCs (hydrocarbons and carbonyls) and PM with an aerodynamic diameter $\leq$ 2.5 µm ($PM_{2.5}$) at the following locations:

- At the upwind fence line (also referred to as the "terminal background") and downwind fence line of the terminal perimeter. Sampling entailed consecutive 12-hour integrated sampling periods for five days in a row at each terminal. In Phase 2, sampling was repeated at six terminals, and continuous sampling for total VOCs and $PM_{2.5}$ was added at each of the four primary wind directions to allow more flexibility in classifying upwind or downwind locations during sampling. Downwind contributions were expressed as ratios of the mean downwind and upwind concentrations for various pollutants by terminal.
- In the docks and repair shops (at the six repeat-visit terminals). Sampling in these two indoor locations were added in Phase 2 of the study.

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. Thomas J. Smith of Harvard University, Boston, Massachusetts, and colleagues. The complete report, *Potential Air Toxics Hot Spots in Truck Terminals and Cabs* (© 2012 Health Effects Institute), can be obtained from HEI or our Web site (see last page).

- In truck cabs during 8-hour daily pick-up and delivery trips (for a total of 36 trips). Continuous sampling for total VOCs and $PM_{2.5}$ was added in the cabs of two trucks equipped with a global-positioning-system unit to allow correlation of the exposure measurements with the route characteristics.

The compounds measured with the integrated monitors are listed below. The compounds in italics were those targeted in the original Request for Applications.

- Hydrocarbons: *1,3-butadiene,* aromatic compounds (*benzene, toluene, xylenes, ethylbenzene,* and *styrene*), alkane compounds (n-*hexane*, trimethylpentane, dimethylpentane, 2-methylhexane, methylpentane, 3-methylhexane, and methylcyclohexane);
- *Methyl* tert-*butyl ether* (*MTBE*); and
- Carbonyls: aldehydes (formaldehyde and acetaldehyde) and acetone.

$PM_{2.5}$ was characterized as part of the NCI study for mass by gravimetric analysis. In Phase 2 of their study, the investigators made continuous mass measurements using a $PM_{2.5}$ aerosol monitor.

Structural equation modeling was used to identify the indirect effects of intermediate variables (including temperature, wind speed, distance of the terminal to a major road, and regional census variables) on primary dependent variables, which were the fence-line upwind concentrations of 1,3-butadiene, benzene, toluene, and formaldehyde.

RESULTS AND INTERPRETATION

The results of the sampling at terminals' fence lines indicated that overall there was little or no difference between the concentrations at the upwind and downwind sites. Concentrations at terminal upwind locations were generally lower than those at indoor locations.

Analyses of the downwind–upwind pollutant ratios showed wider ranges for VOCs than for aldehydes and $PM_{2.5}$. The investigators acknowledged that wind directions were not constant during the 12-hour sampling periods and that this probably contributed to reducing the differences between the upwind and downwind locations. The analyses of continuous total VOC measurements made in Phase 2 provided a more detailed pattern of concentration variations in relation to changes in wind directions. Here, unlike the results in Phase 1, analyses combining data from all six terminals showed significant upwind-to-downwind differences for about 60% of the sessions. Although these data were not fully analyzed and were limited to total VOCs, they pointed to the importance of wind direction in determining the impact of pollutant sources.

Higher temperatures were associated with higher concentrations of formaldehyde and lower concentrations of 1,3-butadiene. Wind speed was inversely correlated with the concentrations of all four pollutants. Distance to an interstate highway was significantly and inversely associated only with toluene and benzene. An analysis by U.S. census regions (i.e., Midwest, Northeast, and West) showed much variability across the regions, with higher concentrations of benzene in the West and of formaldehyde in the Northeast; the reason for this regional pattern is not clear.

Analyses of the in-cab measurements showed that the concentrations of benzene, MTBE, styrene, and hexane measured in the cabs of the nonsmoking drivers were higher on average than those measured at the upwind locations and indoor work locations. Analysis of the effects of open or closed windows on in-cab concentrations showed that when the windows were "predicted to be open" there were significantly lower concentrations of aldehydes and higher concentrations of $PM_{2.5}$ and 1,3-butadiene. The authors suggest that some of the pollutants (such as aldehydes) are generated within the truck's own cab, and that others originate from the surrounding traffic.

Hot Spot Determination

The authors used different criteria to determine whether the terminals were hot spots in different sections of the report, and their conclusions depended on the comparison being made. They compared the concentrations found in their study with those measured by the EPA air toxics monitoring network (which included urban, suburban, industrial, and rural locations throughout the United States), those reported in various exposure studies conducted in urban areas and inner-city neighborhoods in the United States, and the EPA's screening values for noncancer and cancer risk. The authors reported that the means and medians of upwind concentrations of the VOCs that were also measured at the EPA air toxics monitoring sites were very similar to the mean concentrations measured at the EPA sites. The measured concentrations of 1,3-butadiene and aldehyde concentrations were comparable to those measured in exposure studies in urban

areas, and all the aromatics (such as benzene, toluene, and the xylenes) were lower in the current study.

In their comparison with the EPA screening values, the investigators found that 100%, 93%, 61%, and 6% of the upwind mean concentrations of formaldehyde, acetaldehyde, 1,3-butadiene, and benzene, respectively, exceeded the screening values for cancer risk. These values were calculated by the EPA using the cancer unit risk value as a starting point, with various corrections that resulted in more conservative (i.e., health protective) values.

Finally, as planned, the investigators compared the fence-line upwind measurements with the downwind measurements, primarily using time-integrated measures, and found that they were similar.

The HEI Review Committee, which conducted an independent review of the study, noted that a limitation of the study as a hot spot study was the lack of parallel measurements at suitable background sites (i.e., sites at an appropriate distance from the terminals and not impacted by local sources) and of discussion of the local context of the terminals (such as the quality and quantity of the sources around and within the terminals).

CONCLUSIONS

The Review Committee thought that a major strength of the study was to document concentrations of air toxics in various environments in and around truck terminals and inside truck cabs. The Committee noted that the terminals were not selected to meet the initial hypothesis of there being industrial areas upwind of the terminals and neighborhoods downwind. In addition, the upwind location was defined operationally as being upwind with respect to the prevailing wind direction, whereas in fact wind direction proved to be variable over the course of a day and from day to day.

The investigators made several comparisons for hot spot determination and concluded that the terminals were hot spots when compared with EPA screening values. This comparison is problematic, however, because the screening values are often exceeded in many urban areas, as can be observed by comparing them with the concentrations measured at the EPA air toxics monitoring sites. Comparisons with measures from other studies did not support defining the terminals as hot spots; comparison of upwind and downwind measurements also showed little or no difference because of shifting wind patterns. Measurements at appropriately selected background sites would be needed to establish exactly how "hot" the terminal fence-line locations were at any given time. Overall, the Committee noted that the study does not provide conclusive evidence as to whether the truck terminals were pollution hot spots, but pointed out the existence and variability of localized elevated pollutant levels that could affect human health. The measurements represent potential exposures of workers who work at the terminals frequently and for prolonged periods of time.

With regard to the in-cab measurements, the continuous and time-weighted-average measurements in the truck cabs did document elevated concentrations of a range of components compared with the fence-line measurements. The Committee thought that these should be considered occupational exposures.

Overall, this study provides useful information on measurements of a series of air toxics at truck terminals. It also illustrates the challenges encountered in defining and documenting air pollution hot spots without accounting for the role of meteorologic conditions or establishing adequate background sites for comparison.

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Investigators' Report *by Thomas J. Smith et al.*

Critique *by the Health Review Committee*

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