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GASOLINE AND METHANOL EXPOSURES FROM AUTOMOBILES WITHIN RESIDENCES AND ATTACHED GARAGES

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ABSTRACT

When an automobile is driven into a residential garage, evaporating fuel from the warm fuel tank can exceed the capacity of the emission control systems resulting in the volatile components of the fuel being released into the air. This causes an elevation of the concentration of fuel vapors within the garage and within rooms of the attached home. A pilot study was conducted to evaluate the characteristics of the air concentrations witin a garage microenvironment. The air exchange rate between the garage and the house, the windspeed in front of the garage door, the fuel tank temperature, and the air concentrations of benzene (from gasoline) and methanol (from M100 fuel) were measured after an automobile containing US summer grade gasoline or a fabricated fuel tank containing M100 fuel entered the garage and its door was closed. The air concentrations in the garage were greatly elevated after the car or M100 fuel tank entered the garage compared to the ambient levels which were present prior to the car's entry. A steady state concentration was often reached within 90 minutes of the automobile or fuel tank entering the garage and the air concentration remained level until the fuel tank temperature returned to ambient levels, several hours later. The maximum concentration obtained was a function of the fuel tank temperature. Sulfur hexafluoride was used as a tracer to determine the exchange rate between the garage and the attached house. The SF_6 indoor air concentrations in the room adjacent to the garage was approximately 3% of the air concentration in the garage. These studies indicate that parking an automobile in residential garages results in increased exposures to persons spending time within the home and in the garage microenvironment. Estimates of the daily exposure to automobile evaporative emissions should consider these microenvironments prior to the substitution of alternate fuels, such as methanol, for gasoline since the methanol levels within the garage may approach occupational standards which are set for the healthy adult population not the general public which includes more sensitive individuals.

INTRODUCTION

The daily human exposure to a contaminant is the sum of all of the concentrations within microenvironments where an individual spends his or her day multiplied by the time spent within each microenvironment. Automobile fuel is one source of volatile organic compound exposures to the general population. Currently, gasoline is the predominant fuel used globally, but alternate fuels are being actively pursued within the US and elsewhere, with methanol being one candidate. Automotive fuel emissions occur both from tailpipe emission and from evaporation of fuel in the engine block and fuel tank (1). If emissions occur within an enclosed area, such as the cabin of an automobile or a garage, the

concentrations will be elevated relative to the ambient levels or other microenvironments. For example, previous studies have shown that the interior of automobile cabins have concentrations of gasoline derived compounds elevated compared to ambient air and that the time spent commuting is a major contributor to the daily exposure for these compounds (2,3). Model estimates of various microenvironments impacted by automobiles have suggested that a residential garage would result in elevated exposure if an automobile is parked there after it is driven in on a hot summer day (4). A series of experimental measurements were therefore made to test the hypothesis that elevated exposure would occur because of large increases in the air concentrations of benzene and methanol within a residential garage due to evaporative emissions from an automobile fuel tank containing gasoline and M100 fuel, respectively. These tests were a pilot study to evaluate the characteristics of the air concentrations in the garage microenvironments. The actual emissions and resulting measured concentrations provide an example to demonstrate important characteristics for planning future studies. Research is ongoing to determine the potential exposures to larger populations.

METHODS

The benzene and methanol air concentration within a residential garage in Raleigh, NC, USA was measured during the summer of 1992 before and after gasoline powered automobiles were driven into it or a fabricated fuel tank containing M100 fuel was pulled in. The fabricated fuel tank was wrapped with a heating blanket in order to raise the tank's temperature up to 45°C, stimulating the heating that occurs when an automobile is driven during the summer. The fabricated fuel tank and one of the gasoline powered vehicles had temperature probes within the fuel tank and on the surface of the fuel tank to measure the temperature of the fuel and tank surface, while a thermalcouple was place on the outer surface of the fuel tank of the second vehicle whenever it was driven into the garage. Each car was driven for approximately 30 minutes prior to entering the garage, during which time the temperature of the fuel tank reached its maximum, which varied between 30° and 42°C. The maximum fuel tank temperature was a function of the ambient air temperature, the roadway temperature and the amount of sunshine. The M100 tank's temperature was adjusted to between 30° and 45°C prior to its being placed in the garage. The temperature of the automobile's fuel tank remained elevated for several hours due to the high heat capacity of the automobile. The methanol tank's temperature was programmed to mimic the automobile's tank temperature. Two experiments were also done placing either 5 mL gasoline or M100 fuel were on a glass evaporating dish and allowing the fuel to evaporate to characterized the increase and falloff that might be associated with a small spill of gasoline or M100 fuel.

The air concentration was measured using portable gas chromatographs with selective detectors set either for benzene or methanol (Microsensor Inc. Model MSI301 and MSI301M). Two portable MSI gas chromatographs were available for benzene measurements and one for methanol. They were calibrated prior to the field program and the calibration was checked by drawing of air containing known quantities of the contaminants from a gas sampling bag or a Summa canister. The MSI gas chromatographs were placed at breathing height within the garage and run continuously, which resulted in samples being drawn and analyzed automatically every 5 minutes for methanol or 6 minutes for benzene. In addition, samples were collected using tedlar sampling bags and analyzed using the MSI gas chromatographs after an experimental run was complete to examine the spacial distribution of the contaminant within the garage.

Prior to the benzene and methanol experiments the ventilation rate from the garage and the air exchange rate between the garage and the attached house was determined by releasing a set amount sulfur hexafluoride over ten minutes and determining its decay using syringe samples which were programmed to sample at specific time intervals. Sulfur hexafluoride releases were also done during the fuel evaporative emissions studies at a limited number of sites to confirm that the exchange rates was the same during the garage characterization and the evaporative emissions experiments.

RESULTS

The gasoline benzene and methanol air concentration within the garage rapidly increased following the placement of 5 mL of gasoline and M100 fuels in the center of the garage. The air concentration exponentially declined during the subsequent hour since no additional source of these material were present (figure 1 and 2). Benzene air levels of 0.8 ppm and methanol air concentrations of 20 ppm were measured during these experiments. The decline observed was consistent with the air exchange between the garage and the surrounding environment.

Gasoline and methanol vapors would also to be expected to emitted into the garage from evaporation from the fuel tank. The gasoline fuel tank was observed to increase to as much as 45°C following a drive during sunny summer day. On cooler, rainy days the fuel tank temperature only reached 32°C. The air concentration within the garage was elevated for benzene and methanol compared to the ambient levels whenever the automobile or fabricated tank containing M100, respectively, was placed into the garage. The benzene air concentration profiles with time since the automobile entered a garage is shown in figure 3. The gas tank temperature at the beginning of these two runs were 37°C and 43°C. The benzene concentration was measured with two different GC's located within 2 meters of each other. Differences in absolute concentrations are noted between the GC's, but the temporal pattern observed were similar, including a single elevated point that occurred approximately 50 minutes after the experiment started. The concentrations of benzene increased then declined as the fuel tank temperature decreased. The concentrations measured were much greater when the fuel tank was hotter, with the benzene air concentration peaking at approximately 0.5 ppm.

The M100 fuel tank was heated to three different temperatures: 32°C, 39°C and 45°C; and placed in the garage, during three consecutive time periods of a single day. The garage door was opened and near complete air exchange with ambient air occurred. Higher methanol air concentrations were measured within the garage as the fuel tank temperature was increased. The tank was continually heated throughout the experiment until a steady state appeared to be reached. A vertical profile of methanol concentrations was also determined during these three experiments, at a position several meters from the monitor by collecting the air in tedlar bags at 2 meter height intervals. This sampling site was measurement were further from the M100 tank than the GC, thus had lower overall values. They showed a minimum concentration between 2 and 4 meters with maximum concentration near the floor and between 6 and 8 meters, the height of the ceiling.

DISCUSSION

Potential exposure to volatile components of automobile fuels will result from placing an automobile within a residential garage after being driven on a hot, sunny day. Volatile components from the fuel within the heated tank can breakthrough the charcoal canister that provides the evaporative emissions control. One of automobiles used in this study was an older vehicle for which the canister had been subject to extensive use and testing. In addition, this vehicle had a carburetor engine which retains fuel in the engine block that is released via evaporation when it is stopped. A second vehicle with a fuel injection system was also used and lower air concentrations were measured with this vehicle. However, it was not operated on the two hottest days during the experiments. The canister on the M100 fuel tank was not regenerated during the 10 days of testing and may have saturated by the end of the experimental period. However, saturation of the canister might occur in normal automotive operation when numerous short trips are taken, so this test represents a valid, though possibly worse case, emission test. The ventilation rate of the garage when the door was closed is within the range expected for residential garages and was found to vary with the windspeed and direction relative to the door. When the garage door was opened the air exchange rate from the garage and the air concentrations returned to ambient levels within minutes.

The microenvironmental air concentrations measured can be used to generate a statistical distribution of exposures associated with automotive evaporative releases, when combined with probabilistic distribution of activity patterns. The data generated is also being used to evaluate theoretical models of the concentration distribution of gasoline constituents and methanol from M100 within garage based on source emission data collected in controlled laboratory conditions, diffusion rates and ventilation rate assumptions. The air exchange rate into the home was a conservative estimate, since the doorway was kept closed during the rate exchange measurements. Increased infiltration of fuel components into the home would be expected to be greater than the 3% measured in this study if there was frequent movement between the home and garage. Measurements in these microenvironments should be done to validate the human exposure models prior to implementing any large alteration to the automobile fuel supply.

ACKNOWLEDGEMENTS

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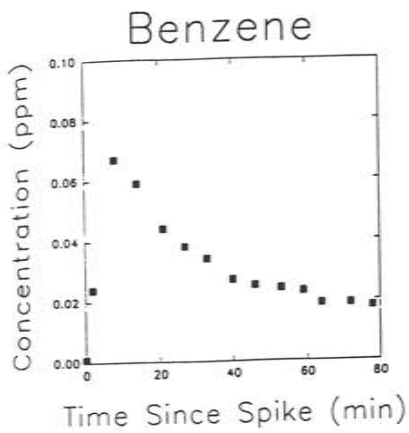

Fig. 1.Time profile after 5 ml gasoline evaporated in garage.

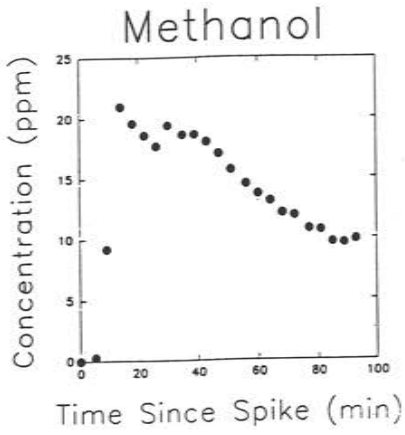

Fig. 2. Time profile after 5 ml M100 fuel evaporated in garage.

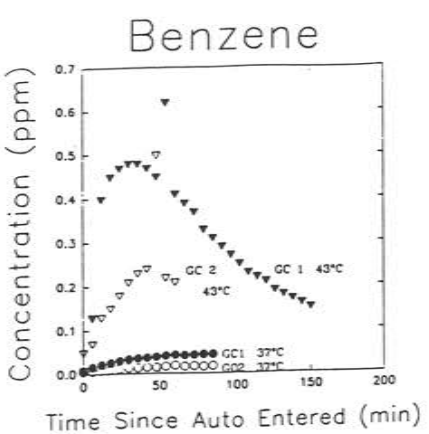

Fig. 3. Time profile after automobile entered garage.

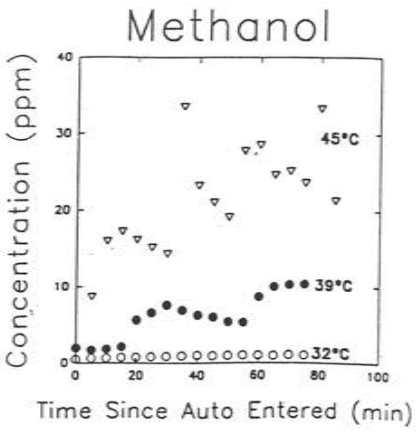

Fig. 3. Time profile after M100 fuel tank entered garage.

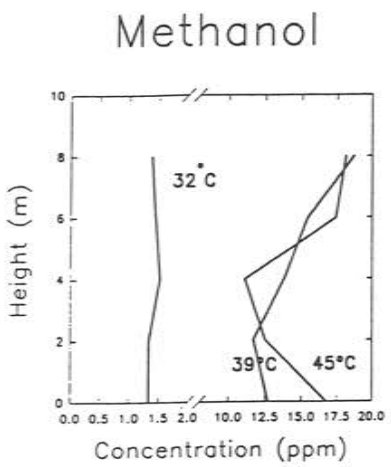

Fig. 5. Height profile of methanol from emissions from a M100 fuel tank at three temperatures.