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I. Summary

In March 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the Centers for Disease Control and Prevention (CDC), National Centers for Environmental Health (NCEH). This request was made in conjunction with the CDC EPI-AID investigation (EPI 93-55-1) which was requested by the Connecticut State Department of Health. Specifically, NIOSH was asked to evaluate workers' exposures to the gasoline components methyl *tert*-butyl ether (MtBE), benzene, toluene, and xylene. Site visits were made to eight facilities (two automobile dealerships, two auto repair shops, and four municipal agencies) from April 5-8, 1993.

Five bulk samples of the various grades of fuel were collected from sites which dispensed gasoline and the liquid volume percent of benzene, toluene, xylene, and MtBE was determined. Air monitoring was performed on mechanics (technicians), service advisors, and other workers potentially exposed to gasoline and exhaust emissions during their workday. Thirty-seven personal-breathing-zone samples were collected and analyzed for benzene, toluene, xylene, and MtBE.

Since this environmental sampling was conducted in warm weather, dilution ventilation (from open windows, and service doors) may have played a significant role in reducing exposures and must be considered when assessing the results. Higher indoor work place exposures to MtBE and benzene may occur during the winter when the effect from dilution ventilation is at a minimum.

The bulk analyses revealed that the MtBE content of the fuels ranged from 13 to 17% and the benzene content was slightly higher than 1%. Personal-breathing-zone samples for toluene and xylene ranged from less than 0.03 to 0.65 parts per million (ppm), and less than 0.02 to 0.32 ppm, respectively. These levels are well below the pertinent occupational health exposure criteria. MtBE exposure levels ranged from less than 0.03 to 12.04 ppm; levels well below the American Industrial Hygiene Association (AIHA) Workplace Environmental Exposure Limit (WEEL) of 100 ppm. The benzene concentrations ranged from less than 0.004 to 0.427 ppm. Two samples exceeded the NIOSH Recommended Exposure Limit (REL) of 0.1 ppm. Although NIOSH has established this guideline which should not be exceeded, the Institute still urges that exposures be reduced to the "lowest feasible level."

The environmental data gathered during this investigation indicate that employees were exposed to potentially hazardous concentrations of benzene. In an effort to reduce workers' exposures, recommendations such as administrative and engineering controls, are provided in Section VIII of this report.

KEYWORDS: SIC 4173 (Maintenance facilities for motor vehicle passenger transportation), gasoline, methyl *tert*-butyl ether, MtBE, benzene, toluene, xylene, mechanics

II. Introduction

In 1992, the Environmental Protection Agency (EPA) required the use of oxygenated fuels during winter months in areas within the United States which exceeded the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO). Due to this mandate, areas within central and southwestern Connecticut used gasoline containing methyl *tert*-butyl ether (MtBE) or ethanol. Due to MtBE ground water contamination in specific areas within Connecticut, and the health complaints possibly associated with the use of MtBE in Alaska, the Connecticut State Health Department asked the Centers for Disease Control and Prevention (CDC), National Centers for Environmental Health (NCEH) to assist in performing a study of persons routinely exposed to motor vehicle exhaust and/or gasoline emissions. Stamford was selected for the site investigations since MtBE was still in use; however, the state and local health officials were unaware of any health complaints related to the use of MtBE in Stamford. On March 29, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the NCEH. NIOSH was asked to assess gasoline-related exposures to workers in conjunction with the EPI-AID investigation (EPI 93-55-1) conducted by NCEH. Specifically, NIOSH was asked to evaluate airborne concentrations of MtBE, benzene, xylene, and toluene in workers exposed to gasoline and exhaust emissions. The NCEH investigation included questionnaires and biological monitoring to evaluate exposures to MtBE. This joint investigation included surveys at eight facilities in Stamford from April 5-8, 1993. EPA also conducted ambient air sampling at the each of the investigation sites during the week of April 12th.

III. Background

Currently, the United States is the largest consumer of gasoline, using over seven million barrels per day.[1] Considering the amount of gasoline consumed, it is not surprising that motor vehicle exhaust is the greatest single source of air contamination in the U.S. In 1970, the Federal Clean Air Act was developed to reduce emissions of air contaminants, such as CO, hydrocarbons, nitrogen oxides, and ozone (as a secondary contaminant) due to the increasing number of cars in use.[2] In an effort to further reduce the levels of CO, amendments to the Clean Air Act required regions which exceed the NAAQS for CO to use oxygenated fuels containing no less than 2.7% oxygen by weight during the winter months. In most vehicles, an increase in the oxygen content in gasoline enhances the complete burning of the fuel and thereby results in a reduction in CO and hydrocarbon emissions. Typically, either ethanol or MtBE is used.[1]

MtBE reduces CO and unburned hydrocarbon emissions in the car's exhaust through fuel enleanment. Studies have shown that CO was reduced by 10 to 35% using 7- and

15-volume percent MtBE blends, whereas nitrogen oxides and aldehydes were only slightly reduced. However, the study also revealed that the fuel economy was reduced by one to 3% when using gasolines containing 7% MtBE blends.[3]

In 1992, there were 100,000 barrels of MtBE produced in the U.S. each day, and it is projected that by mid-1993 the demand for MtBE will be as much as 300,000 barrels per day due to the mandated use of oxygenated fuels. Most likely, the use of this oxygenated fuel will continue to rise because of the requirement to sell reformulated gasoline containing at least 2% oxygen content year round in ozone non-attainment areas beginning January 1995.[1]

IV. Facility Descriptions

A. City of Stamford, Department of Public Works

The Department of Public Works has approximately 16 employees working in the garage from Monday through Friday from 8 a.m. to 4 p.m. Ten of the 16 are mechanics.

There are 14 service bays for repair of gas and diesel public works vehicles. Each service bay is connected to an underfloor ventilation system to remove exhaust contaminants. The outlets are equipped with flexible tailpipe adaptor hoses and are located at each end of the service bay. A portion of the building is also used for vehicle storage. Prior to leaving the building, the vehicles' engines are started and allowed to warm-up for approximately five minutes. No mechanical exhaust system is used during this procedure.

B. City of Stamford, Division of Traffic and Parking

The Division of Traffic and Parking has 18 employees. Of these 18, 11 work in the Parking Department, an agency responsible for the maintenance of the city's parking garages, as well as meter collection and deposits. The Traffic Department installs, removes, and repairs road signs, and paints traffic markings on roadways and parking stalls. The laborers and supervisors are potentially exposed to gasoline and exhaust emissions from vehicle refueling, driving city vehicles, and from surrounding traffic while traveling.

C. DeMott Auto, Inc.

DeMott Auto, Inc., established in 1968, is a vehicle repair shop. The 5,250 square feet, single-story facility has six service bays. During vehicle repair, it is sometimes necessary to operate the engine; however, there is no mechanical ventilation system to remove the vehicle's emissions. Instead, the shop relies on

the pressure created by the vehicle's exhaust system to push the emissions through flexible hoses which are connected to the exhaust pipe and extend out of the garage.

There are six full-time mechanics, working from 8 a.m. until 5:30 p.m. The mechanics wear surgical gloves, and sometimes, particulate respirators.

D. Minchin Buick-GMC Truck, Inc.

Minchin Buick-GMC Truck, Inc. has used its present location for automobile and truck sales and service since 1969. Approximately one-third of the floor space is dedicated to the dealership which consists of the showroom and sales offices. The remaining space contains the service and parts departments and repair shop.

There are 20 employees. Of these, six are mechanics; however, two others (new car prep person and janitor) work in this general area. The mechanics work Monday through Friday from 8 a.m. to 5 p.m.

Fourteen service bays are used to perform repairs and warranty work on Buick and GMC vehicles. Periodically, it is necessary to run the vehicle's engine in the garage during servicing. An above-ground mechanical exhaust system with a retractable tailpipe adaptor hose is used to remove the vehicle's emissions, and the outlets are located at each end of the service bay.

E. City of Stamford, Water Pollution Control

Water Pollution Control has 30 employees over three shifts. Of these 30, five are mechanics, working from 7 a.m. to 3 p.m. Approximately 40-50% of their time is spent inspecting and repairing the equipment at the 21 pumping stations. Their responsibilities also include cleaning and maintaining the grounds surrounding the pumping station. The other portion of their time is spent maintaining and repairing the equipment at the Municipal Solid Waste facility. The mechanics are potentially exposed to gasoline and exhaust emission during refueling and driving their vehicles during the workday.

F. Suburban Cadillac Pontiac Corp.

Suburban Cadillac Pontiac Corp. has both a dealership and service department; however, the exposure monitoring was performed only in the service department. The service department is open Monday through Friday from 8 a.m. to 5 p.m., processing approximately 30 cars each day. Of the 12 employees in the service department, two are service advisors. The service advisor interfaces between the

customer and the mechanic. The advisor writes up a brief description of the problem and has the customer move the vehicle into the garage for repair.

Suburban Cadillac Pontiac Corp. has 10 mechanics. There are ten service bays in the large garage and four in the garage in the back building. The large garage uses an underfloor exhaust system (with a retractable tailpipe adaptor hose) to remove the vehicle's emissions. Outlets are located at each end of the service bay. The smaller garage in the back building does not have any mechanical ventilation. Instead the shop relies on the pressure created by the vehicle's exhaust system to push the emissions through the flexible hoses and out the garage.

G. 3-D Service, Inc.

3-D Service, Inc., established in 1968, has approximately eight mechanics in the general repair and body shop. The mechanics work Monday to Friday from 7:30 a.m. until 7:30 p.m. The mechanics may work up to 15 hours each day when necessary.

3-D Service, Inc. has approximately five service bays. The facility relies on the pressure created by the exhaust to move the emissions from the adaptor hoses out of the garage.

The proprietor of 3-D Service, Inc. also owns PJ's Variety, a 24-hour convenient store which sells self-serve gasoline next to 3-D Service, Inc. Approximately 60,000 gallons of gasoline is purchased each month, whereas only 20,000 gallons of diesel fuel is sold each year.

V. Methods

The environmental evaluation focused primarily on air monitoring, but also included the collection of bulk samples, and walk-through evaluations of environmental and safety conditions. Air monitoring included evaluation of exposures to MtBE, benzene, toluene, and xylene.

A. Liquid Volume Percent (LV%) of MtBE, Benzene, Toluene, and Xylene

Bulk samples of each gasoline grade dispensed at the facility were collected in separate 10 milliliter glass vials. Samples were diluted in carbon disulfide and were analyzed for LV% of MtBE, benzene, toluene, and xylene by gas chromatography according to the NIOSH Method 1615 with modifications.[4] The analytical limit of detection (LOD) for MtBE is 0.07% volume, and 0.006% volume for benzene. The LOD for toluene, and xylene is 0.06% volume.

B. MtBE, Benzene, Toluene, and Xylene

Personal-breathing-zone (PBZ) air samples for MtBE, benzene, toluene, and xylene were collected onto two sorbent tubes connected in series; the front tube contained 400 milligrams (mg) of coconut shell charcoal and the back tube contained 200 mg. The charcoal tubes were connected via Tygon® tubing to Gillian Lo Flow Sampler® battery-operated personal sampling pumps. Air was sampled through the tubes at a nominal flow rate of 0.2 liters per minute (ℓ/min) for approximately eight hours. After sampling, the charcoal tubes were removed and desorbed in carbon disulfide; an aliquot of this solution was analyzed using gas chromatography-flame ionization detection (GC-FID) in accordance with the NIOSH Method 1615 with modifications.[4] The analytical LOD for MtBE, toluene, and xylene is 0.01 milligram per sample (mg/sample), and 0.002 mg/sample for benzene. Due to potential interferences commonly associated with the analysis, gas chromatography with a mass spectrophotometer (GC/MS) screening was also performed to confirm the identity of the benzene and MtBE peaks on random samples.

The sample pumps were calibrated prior to and after sampling using a Gillian Gilibrator®, which was calibrated against a primary standard. For subsequent calculations of sample volumes, the mean pre- and post flow rates were used. A minimum of 10% of the sampled charcoal tubes were prepared as blanks and submitted with the sample set.

VI. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ evaluation criteria for the assessment of a number of chemical (and physical) agents. The primary sources of environmental evaluation criteria for the workplace are the following: **1)** NIOSH Criteria Documents and Recommended Exposure Limits (RELs), **2)** the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs), and **3)** the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values® (TLVs).[5,6,7] The objective of these criteria for chemical agents is to establish levels of inhalation exposure to which the vast majority of workers may be exposed without experiencing adverse health effects.

Full-shift and shorter duration inhalation criteria are available depending on the specific physiologic properties of the chemical substance. Full-shift limits are based on the time-weighted average (TWA) airborne concentration of a substance that most workers may be repeatedly exposed to during a normal eight or 10-hour day, up to 40 hours per week for a working lifetime, without adverse effect. Some substances have recommended short-term exposure limits (STELs) or ceiling limits which are intended to supplement the full-shift criteria where there are recognized irritative or toxic effects from brief exposures to high airborne concentrations. STELs are based on TWA concentrations over 15 minute time periods, whereas ceiling limits are concentrations which should not be exceeded even momentarily.

Occupational health criteria are established based on the available scientific information provided by industrial experience, animal or human experimentation, and epidemiological studies. Differences between the NIOSH RELs, OSHA PELs, and the ACGIH TLVs® may exist because of different scientific philosophy and interpretations of technical information. When comparing the exposure criteria, it should be noted that ***employers are legally required to meet those levels (and any conditions) specified by an OSHA PEL***. The legal rulemaking process for promulgation of OSHA PELs is an arduous and time consuming task and the OSHA PELs may be required to take into account the technical and economical feasibility of controlling exposures in various industries where the agents are used. Hence, OSHA PELs may not be established based on the most current scientific information. In contrast, the NIOSH RELs are primarily based upon the prevention of occupational disease without assessing the economic feasibility of the affected industries and as such tend to be very conservative. ACGIH is not a governmental agency; it is a professional organization whose members are industrial hygienists or other professionals in related disciplines and are employed in the public or academic sector. TLVs® are developed by consensus agreement of the ACGIH TLV® committee and are published annually. The documentation supporting the TLVs® (and proposed changes) is periodically reviewed

and updated if believed necessary by the committee. It is not intended by ACGIH for TLVs® to be applied as the threshold between safe and dangerous inhalation exposure.

It is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these occupational health exposure criteria. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, previous exposures, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, or with medications or personal habits of the worker (such as smoking, etc.) to produce health effects even if the occupational exposures are controlled to the limit set by the evaluation criterion. These combined effects are often not considered by the chemical specific evaluation criteria. Furthermore, many substances are appreciably absorbed by direct contact with the skin and thus potentially increase the overall exposure and biologic response beyond that expected from inhalation alone. Finally, evaluation criteria may change over time as new information on the toxic effects of an agent become available. Because of these reasons, it is prudent for an employer to maintain worker exposures well below established occupational health criteria.

The pertinent evaluation criteria and toxicological background information for the chemical substances evaluated during this technical assistance are presented below:

Gasoline

Gasoline is a clear, volatile petroleum fuel used primarily in internal combustion engines. It is a complex mixture of hydrocarbons compounds, with an overall carbon number range of C_4-C_{12}. The chemical composition can widely vary and depends on the production techniques, seasonal variability, and the addition of additives.[8,9] Previous studies have found that the standard gasoline formulation contains 62% alkanes, 7% alkenes, and 31% aromatics.[10] From a health perspective, exposures to benzene and the lighter hydrocarbons (C_6 or lower) are the constituents of most concern.

Benzene

Benzene is an aromatic organic hydrocarbon containing a six carbon ring with alternating double bonds. Benzene was formerly an important solvent especially in the rubber and surface coating industries, but now is rarely used as a solvent because of its toxicity. It is, however, present as a trace contaminant in gasoline and other petroleum solvents.[11] The nationwide average of benzene content in gasoline is 1.5%, although studies have found benzene content as high as 5%.[10] A previous NIOSH evaluation involving six service stations measured benzene content in gasoline from 0.3 to 1.9%. The exposures to benzene among the service

station attendants were measured and the results of the PBZ samples associated with these gasolines ranged from 0.01 to 0.26 parts per million (ppm).[12]

Acute inhalation exposure to high concentrations of benzene can cause drowsiness, fatigue, nausea, vertigo, narcosis, and other symptoms of central nervous system (CNS) depression as noted with excessive exposure to other aromatic hydrocarbons.[7,13,14] However, the most remarkable health effects associated with benzene exposure are chronic effects due to repeated exposure to low concentrations over many years.[13]

Benzene is classified by the International Agency for Research on Cancer (IARC) as a known human carcinogen and has been associated with irreversible bone marrow injury and the development of hematopoietic toxicity, including aplastic anemia and leukemia in humans.[9,14,15] NIOSH classifies benzene as a human carcinogen, and recommends that occupational exposures be controlled to prevent employees from being exposed to concentrations greater than 0.1 ppm, determined as a TWA concentration for up to 10-hour work shift in a 40-hour work week. NIOSH further recommends a 15-minute STEL of 1.0 ppm. Although NIOSH has established these guidelines which should not be exceeded, the Institute still urges that exposures be reduced to the "lowest feasible level" (LFL) because it is not possible to establish thresholds for carcinogens which will protect 100% of the population. The OSHA PEL is 1 ppm for an 8-hour TWA with a 15-minute STEL of 5 ppm. However, the PEL does not apply to "... storage, transportation, distribution, dispensing, sale, or use of gasoline, motor fuels, or other fuels containing benzene subsequent to its final discharge from bulk wholesale storage facilities, except operations where gasoline or motor fuels are dispensed for more than four hours per day in an indoor location..." The current ACGIH TLV® is 10 ppm as a suspected human carcinogen. ACGIH has proposed to lower the TLV® to 0.1 ppm and classify it as a confirmed human carcinogen.

Toluene

Toluene is a colorless, aromatic organic liquid containing a six carbon ring (a benzene ring) with a methyl group substitution. It is a typical solvent found in paints and other coatings, and used as a raw material in the synthesis of organic chemicals, dyes, detergents, and pharmaceuticals. It is also an ingredient of gasoline, ranging from 5-22%.[9,10] A previous NIOSH evaluation found toluene content of gasoline ranging from 2.4 to 12%, with exposure levels from none detected to 0.56 ppm.[12]

Inhalation and skin absorption are the major occupational routes of entry. Toluene can cause acute irritation of the eyes, respiratory tract, and skin. Since it is a

defatting solvent, repeated or prolonged skin contact will remove the natural lipids from the skin which can cause drying, fissuring, and dermatitis.[13,16]

The main effects reported with excessive (inhalation) exposure to toluene are CNS depression and neurotoxicity.[13] Studies have shown that subjects exposed to 100 ppm of toluene for six hours complained of eye and nose irritation, and in some cases, headache, dizziness, and a feeling of intoxication (narcosis).[17,18,19] No symptoms were noted below 100 ppm in these studies. There are a number of reports of neurological damage due to deliberate sniffing of toluene-based glues resulting in motor weakness, intention tremor, ataxia, as well as cerebellar and cerebral atrophy.[20] Recovery is complete following infrequent episodes, however, permanent impairment may occur after repeated and prolonged glue-sniffing abuse. Exposure to extremely high concentrations of toluene may cause mental confusion, loss of coordination, and unconsciousness.[21,22]

Originally, there was a concern that toluene exposures produced hematopoietic toxicity because of the benzene ring present in the molecular structure of toluene. However, toluene does not produce the severe injury to bone marrow characteristic of benzene exposure as early reports suggested. It is now believed that simultaneous exposure to benzene (present as a contaminant in the toluene) was responsible for the observed toxicity.[11,16]

The NIOSH REL for toluene is 100 ppm for an 8-hour TWA. NIOSH has also set a recommended STEL of 150 ppm for a 15-minute sampling period. The OSHA PEL for toluene is 200 ppm for an 8-hour TWA. The recently adopted ACGIH TLV® is 50 ppm for an 8-hour exposure level. This ACGIH TLV® carries a skin notation, indicating that cutaneous exposure contributes to the overall absorbed inhalation dose and potential systemic effects.

Xylene

Xylene is a colorless, flammable organic liquid with a molecular structure consisting of a benzene ring with two methyl group substitutions. Xylene is used in paints and other coatings, as a raw material in the synthesis of organic chemicals, dyes, and pharmaceuticals. It is also an ingredient of gasoline (ranging from 1-10%) and many other petroleum solvents.[11] A NIOSH investigation of service station attendants found xylene content in gasoline ranging from 3.3 to 22%.[12]

The vapor of xylene has irritant effects on the skin and mucous membranes, including the eyes and respiratory tract. This irritation may cause itching, redness, inflammation, and discomfort. Repeated or prolonged skin contact may cause erythema, drying, and defatting which may lead to the formation of vesicles. At

high concentrations, repeated exposure to xylene may cause reversible damage to the eyes.[13]

Acute xylene inhalation exposure may cause headache, dizziness, incoordination, drowsiness, and unconsciousness.[23] Previous studies have shown that concentrations from 60 to 350 ppm may cause giddiness, anorexia, and vomiting.[13] At high concentrations, exposure to xylene has a narcotic effect on the CNS, and minor reversible effects on the liver and kidneys.[13,23,24]

Historical accounts of hematopoietic toxicity as a result of xylene exposure are likely due to the high concentration of benzene contamination in xylene prior to 1940. These effects previously reported are no longer associated with contemporary xylene exposure.[23,25,26]

The current OSHA PEL, NIOSH REL, and ACGIH TLV for xylene are 100 ppm over an 8-hour TWA. In addition, OSHA and NIOSH have published STELs for xylene of 150 ppm averaged over 15 minutes.

MtBE

MtBE is a colorless, flammable liquid derived from the catalytic reaction of methanol and isobutene. It is a volatile organic ether containing 18.2% oxygen and has low odor threshold (0.06 ppm).[27] MtBE is manufactured in petrochemical plants and refineries. Originally, it was used as a fuel additive to increase the octane grade following the mandated EPA lead phase-down, and is currently used to reduce air pollution.[1] MtBE has also been used in clinical medicine to dissolve cholesterol stones in the biliary tract.[28,29]

The primary route of exposure to workers is through inhalation which may occur during production, blending, and transportation. The primary source of potential exposure to the general public is from vapors from the MtBE blended gasolines.

Several animal studies have been performed to evaluate the toxicity of MtBE. In rats, the acute oral lethal dose (LD_{50}) has been reported as 4 grams per kilogram. The acute lethal concentration (LC_{50}) for rats was reported from 23,630 to 33,000 ppm in air for a 4-hour period.[30,31] Studies performed with mice, rats, and rabbits indicate that the no observed effect level (NOEL) ranged from 800 to 2500 ppm.[32] MtBE was not found to be maternally toxic, embrotoxic, or teratogenic, and showed little adverse reproductive toxicity.[33,34]

In rats, the ethereal bond is broken in MtBE, producing tertiary butyl alcohol (TBA). MtBE and TBA concentrations in blood and brain of rats increased in a dose-dependent manner, although the MtBE concentration resulting from the 50

ppm exposures tended to decrease after a period of time. MtBE was also found in perirenal fat.[35]

The initial investigation in Alaska performed by NCEH in December 1992, in which the MtBE and its metabolite (TBA) were measured in human blood revealed a strong correlation between ambient MtBE concentrations and MtBE found in the blood.[36]

Previous studies have measured airborne MtBE levels below 5 ppm at manufacturing plants and a marketing terminal. The mean full-shift PBZ exposures increased to 15 ppm and 31 ppm for refineries and marine barges, respectively.[37,38] A NIOSH investigation of service station attendants reported MtBE concentrations ranging from none detected to approximately 4 ppm in facilities which used gasoline containing less than 1 to 12% of this additive.[12]

Acute exposures to MtBE may cause irritation to the skin, eyes, and mucous membranes. However, MtBE does not cause dermal sensitization. At extremely high concentrations, MtBE may induce CNS depression.[31] Based on the NOEL, the American Industrial Hygiene Association (AIHA) established a workplace environmental exposure level (WEEL) of 100 ppm for an 8-hr TWA.[32] At this time, NIOSH, OSHA, or ACGIH have not established exposure criteria for MtBE.

VII. Results and Discussion

A. Overall Study Results

Five bulk samples of gasoline were collected and the LV% of MtBE, benzene, toluene, and xylene was determined in the various grades of fuels dispensed at the facilities. The results are shown in Table 1. The MtBE content of the fuels ranged from 13 to 17%, with an average of 14.2 LV%. With the exception of the Traffic Department Supervisor, all of the city workers used either regular or unleaded gasoline containing 13% MtBE. The Traffic Department Supervisor used his private vehicle on the job and used gasoline containing 17% MtBE.

Thirty-seven personal-breathing-zone samples were collected to assess worker exposures to benzene, toluene, xylene, and MtBE at eight facilities. The TWA exposure concentrations and durations for each individual facility are presented in Tables 2-9.

Many factors influenced the results of this study. Since sampling was performed in April, dilution ventilation (which includes open windows and service doors) played a significant role in reducing indoor exposures. Also, some workers did not work on gasoline-powered vehicles or did not spend a majority of time in their vehicles

and therefore, the concentrations reported may under-estimate exposures for these job categories. Based on these factors, the levels discussed in this report may not be characteristic of the higher indoor workplace exposures to MtBE and benzene which may occur at other times, such as during the winter (with lower dilution ventilation rates) or changes in work activities.

Personal exposures to toluene and xylene ranged from less than 0.03 to 0.65 ppm, and less than 0.02 to 0.32 ppm, respectively. These levels are well below the pertinent occupational health exposure criteria and are slightly lower than the concentrations found in a previous NIOSH studies of service station attendants and mechanics.[12,39]

MtBE exposure levels ranged from less than 0.03 to 12.04 ppm, levels well below the AIHA WEEL of 100 ppm. Mechanics who worked on the vehicles' fuel systems tend to have slightly higher MtBE exposures. The highest MtBE exposure measured in this evaluation, 12.04 ppm, was obtained from a mechanic working for the City of Stamford in the Department of Public Works. The cause for this substantially higher exposure (compared to the remaining MtBE levels measured in this evaluation) is unknown. The next highest MtBE exposure, 2.1 ppm, was also obtained from a mechanic.

Some of the benzene levels, which ranged from less than 0.004 to 0.43 ppm, exceeded the NIOSH recommendation of 0.1 ppm. Although the maximum concentration (0.427 ppm) reported is below the *current* ACGIH TLV® and OSHA PEL, the sample was approaching the OSHA action level of 0.5 ppm.

B. Results by Job Type

Table 10 presents a summary of the results according to job type. The results were divided into three categories: mechanics (technicians), commuter, and "other" which includes job titles not otherwise classified (maintenance and assistant supervisor, service advisors, and manager). The commuter classification was used to describe workers who typically spent a majority of their workday within a vehicle (actual mileage varied from 0 to 39 miles). Except for the convenient store manager, the employees in the "other" category worked in the same work area as the mechanics; however, they performed different job tasks. *It is important to note that some of the mechanics who were monitored worked only on diesel-powered vehicles. Additionally, some of the workers were considered "commuters" (refer to Tables 1 and 5) even though they traveled less than five miles. However, these workers were classified according to their job title, even though some of their exposures may not be representative of the remaining people in these categories.*

Table 10 shows the range of concentrations for each contaminant and its geometric mean value. Since environmental exposure data tends to be log-normally distributed, the geometric means were calculated, using a value of $MDC/2^{1/2}$ for non-detectable samples.[40,41]

In general, the lowest geometric mean concentrations were measured on the commuters, followed by "other" category, and finally, mechanics. The workers' exposures to toluene, xylene, and MtBE in all three categories were all within applicable criteria. The mechanics had slightly higher exposures to toluene and xylene, due in part to the use of cleaning solvents which contained these products. The most noteworthy results were the benzene exposures among the mechanics. In this category, two mechanics were exposed to benzene levels in excess of the NIOSH REL of 0.1 ppm.

VIII. Conclusions and Recommendations

This technical assistance was initiated as a result of concerns regarding exposures to gasoline and exhaust emissions. *However, since the sampling was performed in late spring, natural convection through open windows and service doors added dilution air to the work areas and reduced the concentration of air contaminants. Therefore, the environmental results obtained from this evaluation may under-estimate the indoor workplace exposures to MtBE and benzene which may actually occur during the winter when the effect from dilution ventilation is at a minimum. In order to evaluate worst case exposures, it would be necessary to perform air monitoring during winter months.*

The results of the TWA samples for toluene and xylene were within the NIOSH RELs, OSHA PELs, and ACGIH TLVs®. Occupational exposures to MtBE were less than 13 ppm (median of 0.13 ppm or less, depending on the job type), levels which are well below the AIHA WEEL of 100 ppm. A comparison of the air sampling results to established criteria indicate that some employees may be over-exposed to benzene. In general, the exposures are in part due to the lack of effective industrial hygiene and safety programs. In particular, employees should be protected by administrative and engineering controls, and should receive training on the hazards working with gasoline, solvents, vehicular exhaust, and other substances associated with automotive repair. Specific recommendations regarding chemical exposures and safety issues are presented below. These recommendations are applicable to most of the sites evaluated.

1. Worker inhalation and dermal exposures to benzene, toluene, and xylene can be reduced by prohibiting the use of "raw gasoline" as a cleaning agent. An effective, but less hazardous cleaning product should be substituted for gasoline.

2. Additional environmental monitoring should be conducted to identify job tasks which are producing the most significant benzene exposures. A portion of this environmental data should be obtained during the winter to evaluate worse case exposures under conditions of minimal dilution ventilation.

3. Local exhaust ventilation should be installed at operations where solvents and other volatile substances are used. In situations where local exhaust ventilation is not feasible, general ventilation can be used to increase the amount of outside air introduced into a work area. Properly distributed, this outside air will dilute the contaminants and thereby, reduce the workers' exposures. Provisions should be made to ensure that outside air is provided throughout the year and is properly distributed.

   While improved ventilation is the best method for achieving reductions in workers' exposures, changes in work practices may also be used. Increased use of personal protective equipment may also be suitable. Finally, respirators should only be used where engineering and administrative controls would not effectively reduce the potential for employee exposures.

4. If respirators are issued, the company is responsible for the development and implementation of an effective respiratory protection program, in accordance with the requirements described in 29 CFR 1910.134. The NIOSH publications, such as NIOSH Respirator Decision Logic and NIOSH Guide To Industrial Respiratory Protection, should aid in developing an effective respirator program.[42,43] A respiratory program should include the following elements:

   a. written operating procedures
   b. appropriate respirator selection
   c. effective cleaning of respirators
   d. proper storage
   e. routine inspection and repair
   f. exposure surveillance
   g. program review
   h. medical approval
   i. use of approved respirators

   The written respiratory program should include information on the following topics: (a) the departments/operations which require respiratory protection; (b) the type of respirator required for each job/operation; (c) specifications that only NIOSH/MSHA approved respiratory devices should be used; and (d) the criteria used for the proper selection, use, storage, and maintenance of respirators, including their limitations.

5. Cigarette smoke may interact with chemical substances used at these sites. In addition, reports from the Surgeon General, the National Research Council and the EPA have concluded that exposure to environmental tobacco smoke (ETS) may be associated with a wide range of health (e.g., lung cancer) and comfort (e.g., eye, nose, and throat irritation and odor) effects. NIOSH has determined that ETS may be related to an increased risk of lung cancer and possibly heart disease in occupationally exposed workers who do not smoke themselves. NIOSH recommends that the use of tobacco products be curtailed in these situations and where non-smoking workers may be exposed to side-stream cigarette smoke. The best method for controlling worker exposure to tobacco smoke is to eliminate smoking from the workplace. Until this is achieved, smoking should be restricted to outside the facility or to a designated area such as a smoking room which has additional ventilation. The air from this area should be exhausted directly to the outside and not recirculated within the building.[44]

6. Labeling of chemicals, worker training, and other aspects of hazard communication should be improved. According to OSHA Hazard Communication rule 29 Code of Federal Regulations (CFR) 1910.1200, each company is required to transmit all information regarding the hazards of the chemicals used at this facility to the employees. This can be accomplished by means of a comprehensive hazard communication program, which includes a written program, labeling of chemical containers which includes identifying the contents and any known hazards that are associated with that material, distribution of accurate and updated Material Safety Data Sheets (MSDS), and employee training regarding the hazards of chemicals and protective measures which should be taken. Employee training should include identifying the physical and health hazards of the chemicals in the work area; the measures employees can take to protect themselves from these hazards; an explanation of both the labeling system and MSDS, and how the employees can obtain and use this information.

7. Eye trauma from foreign bodies is preventable. All facilities should institute and enforce programs requiring the use of protective eye wear, such as safety glasses and splash goggles.

8. Eating and drinking should be prohibited in areas where there is a potential for significant exposures to hazardous chemicals.

9. A noise survey, including both sound levels measurements and dosimetry, should be performed to determine whether a hearing conservation program is required. If required, the program should follow the guidelines established in the OSHA noise standard (29 CFR 1910.95). As part of the program, periodic

noise surveys, which include both sound level measurements and dosimetry, should be performed to determine the noise levels. Signs must be posted to distinguish the areas and job tasks where hearing protection is required. Each facility should require the use of hearing protection devices in areas which exceed a noise level of 85 decibels on an A-weighted scale. Workers should be trained on the effects of noise exposure and hearing loss, and encouraged to reduce both occupational and recreational noise to prevent noise-induced hearing loss.

10. Safety equipment, including eye wash stations, safety showers, and fire extinguishers should be installed, inspected on a routine basis, and maintained in good operating condition.

IX. Authorship and Acknowledgements

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X. Distribution and Availability of Report

 Single copies of this report will be available for a period of 90 days from the date of this report from the NIOSH Publications Office, 4676 Columbia Parkway, Cincinnati, Ohio 45226. To expedite your request, include a self-addressed mailing label along with a written request. After this time, copies may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. Information regarding NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

Copies of this report have been sent to:

1. City of Stamford, Department of Public Works
2. City of Stamford, Division of Traffic and Parking
3. DeMott Auto, Inc.
4. Minchin Buick-GMC Truck, Inc.
5. City of Stamford, Water Pollution Control
6. Suburban Cadillac Pontiac Corp.
7. 3-D Service, Inc.
8. National Centers for Environmental Health, Atlanta, Georgia
9. Teamsters, Local Union Number 145
10. Municipal Administrators Association, Local Union Number 2657
11. U.S. Environmental Protection Agency, Region 1
12. Occupational Safety and Health Administration, Region I

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

XI. References

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Table 1
Bulk Sample Gasoline Results
HETA 93-802

Location	Liquid Volume %			
	MtBE	Benzene	Toluene	Xylene
City of Stamford - Regular	13	1.20	3.8	5.5
City of Stamford - Unleaded	13	1.10	3.7	5.5
City of Stamford - Traffic	17	0.95	9.2	6.7
Convenient Store - Regular Unleaded	13	1.1	6.1	5.3
Convenient Store - Premium Unleaded	15	1.0	5.4	7.3

Table 2

Personal-Breathing-Zone Exposures
City of Stamford - Department of Public Works
HETA 93-802
April 5, 1993

Job Title	Sample Time (min)	Time-Weighted Average Concentrations (parts per million)			
		MtBE	Benzene	Toluene	Xylene
Master Mechanic	410	12.04	0.427	0.23	0.26
Mechanic[a]	490	(0.03)	<0.007	<0.03	0.11
Mechanic[a]	480	0.16	(0.010)	<0.03	(0.07)
Mechanic[a]	472	<0.03	<0.007	<0.03	0.05
Mechanic[a]	470	0.45	0.028	(0.06)	0.10
Equipment Mechanic #1	465	(0.09)	(0.014)	<0.03	0.14
Equipment Mechanic #2	470	<0.03	<0.007	<0.03	0.16
Assistant Supervisor[a]	455	<0.03	(0.011)	<0.03	(0.03)
Vehicle Maintenance Supervisor[a]	475	<0.03	<0.007	<0.03	<0.03
Minimum Detectable Concentration (MDC)		0.03	0.007	0.03	0.03
Minimum Quantifiable Concentration (MQC)		0.10	0.015	0.010	0.08
EVALUATION CRITERIA					
NIOSH Recommended Exposure Limit		---	0.1‡	100	100
OSHA Permissible Exposure Limit		---	1	200	100
ACGIH Threshold Limit Value		---	10†	50*	100

( ) Denotes value between MDC and MQC
--- There are no recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation
a Diesel vehicles only

Table 3
Personal-Breathing-Zone Exposures
City of Stamford - Traffic Department
HETA 93-802
April 5, 1993

Job Title	Sample Time (min)	Time-Weighted Average Concentrations (ppm)			
		MtBE	Benzene	Toluene	Xylene
Laborer[a]	335	<0.04	<0.005	<0.04	<0.04
Laborer[a]	330	<0.04	(0.005)	<0.04	<0.04
Laborer[b]	330	<0.04	(0.005)	<0.04	<0.04
Minimum Detectable Concentration (MDC)		0.04	0.005	0.04	0.04
Minimum Quantifiable Concentration (MQC)		0.14	0.016	0.13	0.12
EVALUATION CRITERIA					
NIOSH Recommended Exposure Limit		---	0.1‡	100	100
OSHA Permissible Exposure Limit		---	1	200	100
ACGIH Threshold Limit Value		---	10†	50*	100

( ) Denotes value between MDC and MQC
--- There are no recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation
a 39 miles driven
b 25 miles driven

Table 4
Personal-Breathing-Zone Exposures
DeMott's Auto, Inc.
HETA 93-802
April 6, 1993

Job Title	Sample Time (min)	Time-Weighted Average Concentrations (ppm)			
		MtBE	Benzene	Toluene	Xylene
Mechanic/Service Bay #1	465	0.27	0.025	0.32	0.11
Mechanic/Service Bay #3	535	0.24	0.023	0.35	0.11
Mechanic/Service Bay #4	365	0.46	0.048	0.06	0.16
Mechanic/Service Bay #5-6	480	0.25	0.025	0.28	0.09
Mechanic	535	0.12	0.015	0.13	(0.07)
Minimum Detectable Concentration (MDC)		0.03	0.003	0.03	0.05
Minimum Quantifiable Concentration (MQC)		0.09	0.010	0.09	0.08
EVALUATION CRITERIA					
NIOSH Recommended Exposure Limit		---	0.1‡	100	100
OSHA Permissible Exposure Limit		---	1	200	100
ACGIH Threshold Limit Value		---	10†	50*	100

( ) Denotes value between MDC and MQC
--- There are no recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation

Table 5
Personal-Breathing-Zone Exposures
Minchin Buick-GMC Truck, Inc.
HETA 93-802
April 6, 1993

Job Title	Sample Time (min)	Time-Weighted-Average Concentrations (ppm)			
		MtBE	Benzene	Toluene	Xylene
Mechanic/Service Bay #1	470	0.33	0.037	0.15	0.15
Mechanic/Service Bay #2	480	0.11	0.056	(0.08)	0.14
Mechanic/Service Bay #3	320	<0.03	<0.004	<0.03	<0.03
Mechanic/Service Bay #3.5	448	(0.06)	0.013	(0.03)	(0.05)
Mechanic/Service Bay #4	465	(0.06)	0.014	(0.03)	(0.05)
Mechanic/Service Bay #5	475	<0.03	(0.007)	<0.03	(0.02)
Minimum Detectable Concentration (MDC)		0.03	0.004	0.03	0.03
Minimum Quantifiable Concentration (MQC)		0.11	0.012	0.10	0.09
EVALUATION CRITERIA					
NIOSH Recommended Exposure Limit		---	0.1‡	100	100
OSHA Permissible Exposure Limit		---	1	200	100
ACGIH Threshold Limit Value		---	10†	50*	100

--- There are no recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.
( ) Denotes value between MDC and MQC
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation

Table 6
Personal-Breathing-Zone Exposures
City of Stamford - Water Pollution Control
HETA 93-802
April 7, 1993

Job Title	Sample Time (min)	Time-Weighted Average Concentrations (ppm)			
		MtBE	Benzene	Toluene	Xylene
Maintenance Mechanic[a]	395	<0.04	(0.004)	(0.04)	<0.06
Maintenance Mechanic[b]	365	<0.04	<0.004	<0.04	<0.06
Machinist Millwright[c]	405	<0.04	(0.004)	<0.04	<0.06
Minimum Detectable Concentration (MDC)		0.04	0.004	0.04	0.06
Minimum Quantifiable Concentration (MQC)		0.12	0.014	0.12	0.11
EVALUATION CRITERIA					
NIOSH Recommended Exposure Limit		---	0.1‡	100	100
OSHA Permissible Exposure Limit		---	1	200	100
ACGIH Threshold Limit Value		---	10†	50*	100

( ) Denotes a Value between MDC and MQC
--- There are no recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation
a 2 miles driven
b 0 miles driven
c 5 miles driven

Table 7
Personal-Breathing-Zone Exposures
City of Stamford -- Traffic Department
HETA 93-802
April 7, 1993

Job Title	Sample Time (min)	Time-Weighted Average Concentrations (ppm)			
		MtBE	Benzene	Toluene	Xylene
Traffic Maintenance Supervisor	445	<0.03	(0.010)	(0.06)	(0.03)
Minimum Detectable Concentration (MDC)		0.03	0.072	0.03	0.03
Minimum Quantifiable Concentration (MQC)		0.10	0.015	0.10	0.09
EVALUATION CRITERIA					
NIOSH Recommended Exposure Limit		---	0.1‡	100	100
OSHA Permissible Exposure Limit		---	1	200	100
ACGIH Threshold Limit Value		---	10†	50*	100

( ) Denotes value between MDC and MQC
--- There are no recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation

Table 8
Personal-Breathing-Zone Exposures
Suburban Cadillac Pontiac Corp.
HETA 93-802
April 8, 1993

Job Title	Sample Time (min)	Time-Weighted Average Concentrations (ppm)			
		MtBE	Benzene	Toluene	Xylene
Service Advisor	320	(0.13)	0.023	(0.08)	0.15
Service Advisor	485	0.15	0.021	(0.08)	0.11
Technician/Service Bay Near Parts Dept.	490	0.10	0.016	(0.08)	0.12
Technician	205	<0.04	(0.008)	<0.04	<0.03
Technician/Back Garage	350	(0.08)	(0.014)	0.65	0.26
Minimum Detectable Concentration (MDC)		0.04	0.004	0.04	0.03
Minimum Quantifiable Concentration (MQC)		0.12	0.014	0.12	0.10
EVALUATION CRITERIA					
NIOSH Recommended Exposure Limit		---	0.1‡	100	100
OSHA Permissible Exposure Limit		---	1	200	100
ACGIH Threshold Limit Value		---	10†	50*	100

( ) Denotes value between MDC and MQC
--- There are no recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation

Table 9
Personal-Breathing-Zone Exposures
3-D Service, Inc.
HETA 93-802
April 8, 1993

Job Title	Sample Time (min)	Time-Weighted Average Concentrations (ppm)			
		MtBE	Benzene	Toluene	Xylene
Mechanic[a]	520	2.10	0.158	0.58	0.32
Mechanic[b]	490	0.23	0.031	0.16	0.08
Mechanic[a]	515	(0.08)	0.020	(0.08)	(0.05)
Mechanic[b]	490	0.56	0.053	0.21	(0.07)
Convenient Store Manager	420	<0.03	(0.008)	<0.03	<0.02
Minimum Detectable Concentration (MDC)		0.03	0.003	0.03	0.02
Minimum Quantifiable Concentration (MQC)		0.10	0.011	0.09	0.08
EVALUATION CRITERIA					
NIOSH Recommended Exposure Limit		---	0.1‡	100	100
OSHA Permissible Exposure Limit		---	1	200	100
ACGIH Threshold Limit Value		---	10†	50*	100

( ) Denotes value between MDC and MQC
--- There are no recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation
a Changed one fuel filter
b Changes two fuel filters

Table 10
Summary of Results by Job Type
(parts per million)
HETA 93-802

Job Type	n	MtBE		BENZENE		TOLUENE		XYLENE	
		Range	Mean[G]	Range	Mean[G]	Range	Mean[G]	Range	Mean[G]
Mechanics	28	<0.03 - 12.04	0.11	<0.004-0.427	0.019	<0.03 - 0.65	0.07	<0.02 - 0.32	0.09
Commuters	7	<0.03 - <0.04	0.03♦	<0.004-0.010	0.005	<0.4 - 0.06	0.03	0.03 - <0.06	0.05
Others	4	<0.03 - 0.15	0.05	<0.007-0.023	0.012	<0.03 - 0.08	0.04	<0.02 - 0.15	0.05
Evaluation Criteria									
NIOSH Recommended Exposure Limit		---		0.1‡		100		100	
OSHA Permissible Exposure Limit		---		1		200		100	
ACGIH Threshold Limit Value		---		10‡		50**		100	

Mean[G] Geometric mean
‡ Human carcinogen
† Suspected human carcinogen
** Skin notation
♦ Value is estimated since none of the actual measurements were above the minimum detectable concentration