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## I. Summary

In February 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the National Centers for Environmental Health (NCEH), Centers for Disease Control and Prevention (CDC). NIOSH was asked to assess workers' exposures to gasoline and exhaust emissions in conjunction with a CDC EPI-AID follow-up investigation (EPI 93-13) conducted by NCEH and the Environmental Protection Agency (EPA) in Fairbanks, Alaska. NIOSH was specifically asked to evaluate the occupational exposures to benzene, xylene, toluene, methyl *tert*-butyl ether (MtBE), and carbon monoxide (CO). This investigation included site visits at 11 facilities from February 9-19, 1993.

Environmental monitoring was performed on service station attendants, technicians (mechanics), service and parts advisors, and other persons potentially exposed to gasoline and exhaust contaminants during their workday. A total of 48 personal breathing zone and three area samples were collected and analyzed for benzene, xylene, toluene, MtBE, and CO.

Worker exposures to toluene and xylene ranged from less than 0.03 to 2.99 parts per million (ppm), and less than 0.02 to 15.7 ppm, respectively. These levels were well below the pertinent occupational health exposure criteria. ***At the time of the survey, MtBE was only used as an octane enhancer (generally, less than 1% of the fuel) in gasoline.*** MtBE exposure levels ranged from less than 0.03 to 0.45 ppm, concentrations which were expected due to the low MtBE percent volume content of the fuel and which were well below the American Industrial Hygiene Association Workplace Environmental Exposure Limit of 100 ppm. The benzene concentrations ranged from 0.02 to 0.57 ppm, levels which were above the NIOSH Recommended Exposure Limit (REL). Although the maximum benzene concentration reported was below the *current* American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV)® and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL), it was above the OSHA action level of 0.5 ppm. Some of the CO levels, which ranged from none detected to 69 ppm, exceeded the ACGIH TLV® of 25 ppm, as well as the NIOSH REL of 35 ppm, and OSHA PEL of 50 ppm.

The environmental data gathered during this investigation indicate that employees were exposed to potentially hazardous concentrations of benzene and carbon monoxide. 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, carbon monoxide, mechanics

## II. Introduction

Fairbanks, Alaska was one of the 39 areas in the United States which did not meet the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO) and therefore, was required by the Environmental Protection Agency (EPA) to use oxygenated fuel. In October 1992, 15% (by weight) methyl *tert*-butyl ether (MtBE) was added to the gasoline. Within two weeks of the implementation of MtBE blended gasolines, symptoms such as headaches, dizziness, and nausea were reported to a local citizen hotline and an epidemiologic study was initiated. In November 1992, the National Centers for Environmental Health (NCEH), Centers for Disease Control and Prevention, and the Environmental Protection Agency (EPA) performed a study of persons routinely exposed to motor vehicle exhaust and/or gasoline emissions. The investigation included questionnaires, biological monitoring, and ambient air sampling to evaluate exposures to MtBE. In January 1993, the use of the MtBE to oxygenate fuel was discontinued; however, it was still used as an octane enhancer in premium gasoline. On February 4, 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 follow-up investigation (EPI 93-13) conducted by NCEH and EPA. Specifically, NIOSH was asked to evaluate airborne concentrations of MtBE, benzene, xylene, toluene, and carbon monoxide (CO) in workers exposed to gasoline and exhaust emissions. This investigation included surveys at 11 facilities in Fairbanks from February 10-18, 1993.

## 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 of the Clean Air Act required regions which exceed the NAAQS for CO to use oxygenated fuels containing no less than 2.7 percent 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 are 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. Seekin's Ford-Lincoln-Mercury, Inc.*

Seekin's Ford-Lincoln-Mercury, Inc. has used its present location for automobile and truck sales and service since 1982. 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 light and heavy garages. The exposure monitoring was performed only in the service and parts departments, and heavy garage.

The service department is open Monday through Friday from 7 a.m. to 6 p.m., processing an average of 50 to 70 cars each day. Of the five persons in the service department, four are service advisors and one performs emission testing. The service advisor interfaces between the customer and the line technician (mechanic). The advisor writes up a brief description of the problem and moves the vehicle into the garage for repair.

In the heavy garage, there are 21 line technicians, working Monday through Friday from 7 a.m. to 5 p.m. Each technician has a service bay for vehicle repair. Periodically, it is necessary to run the vehicle engine in the garage during servicing. An underfloor exhaust system with a retractable tailpipe adaptor hose is used to remove the vehicle's emissions. Outlets are located at each end of the service bay. The exhaust fan is located on the south end of the building and runs continuously.

### *B. Totem Chevron*

Totem Chevron, established in 1977, is a service station which tows and repairs vehicles and sells self- and full-serve gasoline. There are a total of 10 employees, working staggered shifts from 7 a.m. to 10 p.m. each day.
The single-story facility has two service bays which are heated by a waste oil furnace. During vehicle repair, it is sometimes necessary to run 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 exhaust system to push the emissions through the flexible hoses and out of the garage.

Totem Chevron has two gasoline islands. Approximately 40% of all the gasoline sold is pumped by the service station attendants. Typically, 400 to 500 gallons of premium gas which contains MtBE are purchased each day.

### *C. Tundra Tours, Inc.*

Established in 1972, Tundra Tours, Inc. is a subsidiary of Arctic Slope Regional Corporation. Since 1980, Tundra Tours, Inc. has received the busing contract in the Fairbanks school districts. As part of the contract, Tundra Tours, Inc. is responsible for operating and maintaining diesel and gasoline-powered buses.

There are 215 employees, 10 of whom are mechanics. The mechanics work staggered shifts from 5 a.m. to 7 p.m. Tundra Tours, Inc. has approximately seven service bays. Each bay has access to the exhaust ventilation system through adaptor hoses which can be used on the bus' high tailpipe outlet to remove the exhaust emissions.

### *D. Sunshine RAE Motors*

Sunshine RAE Motors, established in 1974, has been at its present location since 1983. There are 13 employees, six of whom are mechanics. The mechanics work Monday to Friday from 8 a.m. until 6 p.m., whereas the employees in the parts department also work Saturdays from 10 a.m. to 2 p.m.

There are 12 service bays. The facility has a groundlevel ventilation system which has a 1.5 horsepower fan to remove the vehicle's exhaust. The system has retractable tailpipe adaptor hoses and outlets located at each end of the service bay.

### *E. Fairbanks Motors*

Fairbanks Motors was established in 1978 and has been at this present location since 1983. There are approximately 20 employees. Of these 20 employees, seven work in the service department. The service department is open Monday through Friday from 7:30 a.m. to 6 p.m., whereas the technicians work from 8 a.m. to 5 p.m.

Fairbanks Motors has eight service bays. Each service bay is connected to an underfloor ventilation system which has an exhaust discharge on the roof. The outlets are equipped with flexible tailpipe adaptor hoses and are located at each end of the service bay.

### *F. Aurora Motors*

Aurora Motors has used the present location for servicing vehicles since 1948. Originally a service shop, in 1954, Aurora Motors expanded to include a dealership. Currently, the facility has a showroom, sales offices, and a service department. There are 30 employees.

Aurora Motors has seven mechanics who work from 8 a.m. to 5 p.m. The service department has six repair stalls which are furnished with tailpipe adaptor hoses connected to the underfloor ventilation system for removal of the vehicle emissions.

### *G. Golden Valley Electric Association, Inc.*

Golden Valley Electric Association, Inc. (GVEA), a non-profit electrical utility, operates and maintains three power plant substations, four transmission substations,

22 distribution substations, and over 2,000 miles of transmission and distribution lines.

There are approximately 200 full-time employees. Of these, eight are meter technicians (linespersons), working from 8 a.m. to 4:30 p.m. and servicing over 25,000 meter locations. The meter technician is responsible for adding fuel to the vehicle prior to leaving the facility. Since a majority of time is spent driving to the meter locations, the technician is potentially exposed to both gasoline and exhaust emissions.

### *H. Fairbanks North Star Borough, Division of Animal Control*

The animal control program, established in the late 1960's, provides a shelter facility for approximately 7,000 animals each year and enforces the Borough's animal control ordinances.

The Division of Animal Control has one part-time and 15 permanent full-time employees. Of these 16, six are animal control officers, working either from 8 a.m. to 7 p.m. or 6 a.m. to 5 p.m, four days each week. An animal control officer spends the majority of the time responding to complaints; however, a portion of the time is spent patrolling the region, feeding animals, cleaning cages, and performing euthanasia. The animal control officer is potentially exposed to gasoline and exhaust emission during refueling and driving the vehicle during the workday.

### *I. Mike's University Service, Inc.*

Mike's University Service, Inc., established in 1977, is a self- and full-serve service station with business hours from 7 a.m. to 10 p.m. There are approximately 15 employees, two of whom are mechanics.

The single-story facility, occupied in 1984, has service bays equipped with a mechanical ventilation system to remove the vehicle's emissions, although occasionally the system is not used and the emissions are removed by natural ventilation.

Approximately 20% of all the gasoline sold is pumped by the service station attendants. Typically, 250 gallons of premium gas, which contains MtBE, are purchased each day.

### *J. Gabe's Truck and Auto Repair*

Established in 1977, Gabe's Truck and Auto Repair has three repair shops consisting of 10,800 square feet. Shop 1, Shop 2, and Shop 3 have five, eight, and six service bays, respectively. All of the shops have an above ground mechanical ventilation system to remove the exhaust emissions; however, the systems have never been serviced.

Gabe's Truck and Auto Repair has 10 employees working from 8 a.m. to 5 or 6 p.m. Of these 10, seven are mechanics.

### *K. Fairbanks Public Works*

Fairbanks Public Works is responsible for repairing and maintaining the city buildings, roadways, and fire and city vehicles, collecting refuse, and performing burials for the city. Of the approximately 33 employees, nine are laborers. Laborers are typically responsible for sidewalk snow removal, surveying, ditch digging, and trash collection. During the winter, approximately 80% of their time is spent in trash collection and 20% in snow removal. The laborers are potentially exposed to gasoline and exhaust emissions from the refueling and driving of the vehicles.

## V. Methods

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

### *A. MtBE, Benzene, Toluene, and Xylene*

Area and 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 limit of detection (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.

### *B. Carbon Monoxide*

Area and PBZ samples were collected for CO using the Draegar Diffusion Tubes (50/a-D). Once the tube is opened, the CO molecules react with the palladium salts in the diffusion tube to form carbon dioxide and palladium. This reaction causes a color change from pale yellow to gray. The CO concentration is calculated by dividing the duration of measurement in hours by the detector tube indication. According to Draegar, the detector tubes have a relative standard deviation of ± 25%.

# 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-hr work shift in a 40-hr 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.

***Carbon Monoxide***

CO is a colorless, odorless, and tasteless gas produced by incomplete burning of carbon-containing materials. CO acts as a metabolic asphyxiant, causing a decrease in the amount of oxygen delivered to the body tissues. CO combines with hemoglobin (the oxygen carrier in the blood) to form carboxyhemoglobin, a compound with an affinity ranging from 210 to 240 times greater than that of oxygen. The carboxyhemoglobin formed is unavailable to carry oxygen. The initial symptoms of CO poisoning may include headaches, dizziness, and nausea. These initial symptoms may advance to vomiting and loss of consciousness if prolonged or high exposures are encountered. Coma and death may follow if high exposures continue without intervention. Loss of consciousness occurs at about the 50% carboxyhemoglobin level.[13]

The amount of carboxyhemoglobin formed is dependent on concentration and duration of CO exposure, ambient temperature, health, and metabolism of the individual, breathing rate, level of physical activity, and barometric pressure. The formation of carboxyhemoglobin is a reversible process. Recovery from acute poisoning usually occurs without sequelae unless tissue hypoxia (oxygen deficiency) was severe enough to result in brain cell degeneration.[13,39]

A variety of cardiovascular effects are associated with CO. Exposure to CO is especially serious for persons with chronic heart or lung disease. The reason for this is that the CO in the blood reduces the amount of oxygen available to an already

damage heart muscle. CO at low levels may initiate or enhance deleterious metabolism in the heart of individuals with restricted coronary artery blood flow. Breathlessness upon exertion, rapid or irregular heart rhythm, throbbing or fluttering of the heart, and chest pain may be present. Excess fluid in the lung tissue may occur. The victim may develop pneumonia. Exposure to 50 ppm of CO for 90 minutes may cause aggravation of angina pectoris (heart pain). The clinical effects of CO exposure are aggravated by heavy labor, high ambient temperature, and altitudes above 2000 feet.[13,24,38,40]

The NIOSH REL for CO is 35 ppm, whereas the OSHA PEL is 50 ppm for an 8-hour TWA. Both OSHA and NIOSH have set a recommended ceiling of 200 ppm. The recently adopted ACGIH TLV is 25 ppm for an 8-hour exposure level. Biological monitoring can also be used to assess the overall exposure to CO in the workplace by evaluating the amount of carboxyhemoglobin present in blood at the end of the shift. ACGIH has set its Biological Exposure Index (BEI) at less than 8% of carboxyhemoglobin in blood.

# VII. Results and Discussion

## *A. Overall Study Results*

A total of 48 personal and three area samples were collected at 11 facilities and were analyzed for benzene, toluene, xylene, MtBE, and CO. Tables 1-12 list the sample results for each individual company. The 8-hr TWAs were calculated assuming a similar exposure for the time period not sampled. In regards to the short duration samples, measured exposures may not accurately reflect these workers true 8-hr TWAs since unknown job activities and unmeasured exposures may have occurred. However, for the purpose of this report, the exposures during the time period not sampled were assumed to be similar to those measured during the sampling period. Worker exposures to toluene and xylene ranged from less than 0.03 to 2.99 ppm, and less than 0.02 to 15.7 ppm, respectively. These levels are well below the pertinent occupational health exposure criteria and are similar to the concentrations found in a previous NIOSH study of service station attendants.[12]

MtBE exposure levels ranged from less than 0.03 to 0.45 ppm, levels well below the AIHA WEEL of 100 ppm. ***When MtBE is used as an octane enhancer, the percent volume of MtBE is generally low (less than 1% of the fuel), and therefore, it is not surprising that the workers' exposures would also be low.*** However, it is interesting to note the highest MtBE exposure (0.45 ppm) occurred on a mechanic who had changed a fuel filter on the day of sampling.

Benzene concentrations ranged from 0.02 to 0.57 ppm, levels which are above the NIOSH REL. Although the maximum concentration reported is below the *current* ACGIH TLV® and OSHA PEL, that sample was above the OSHA action level of 0.5 ppm. The CO levels ranged from none detected to 69 ppm. Seven of the 28 samples were at or above the NIOSH REL of 35 ppm and 18 were at or above the ACGIH TLV® of 25 ppm, although the results from detector tubes have a relative standard deviation of ± 25%. These high concentrations indicate a potential problem with the ventilation exhaust systems and/or work practices.

At one facility, some workers declined to participate in the study, necessitating the use of area samples as surrogates for evaluating their exposure potential. Area samples were positioned in locations where emissions were generated and where workers were present a substantial amount of time. These samples may overestimate the workers' true exposure since time was spent in lower exposure areas. The results of the three area samples collected at select locations are shown in Table 2. The airborne concentrations of toluene, xylene, and MtBE are all below the NIOSH, OSHA, ACGIH, and AIHA exposure criteria for the individual substances. Benzene exposures ranged from 0.07 to 0.09 ppm, exceeding the NIOSH recommendation of lowest feasible level. One of the three samples exceeded the ACGIH® TLV for CO.

### *B. Results by Job Type*

Table 13 presents a summary of the results according to job type. The results were divided into four categories: commuters; technicians; parts and service advisors; and "other" which includes job titles not otherwise classified, such as shop foreman, cashier, service attendant, etc. The commuter classification was used to describe workers who spent a majority of their workday within a vehicle (actual mileage varied from 20 to 100). Typically, the parts and service advisors and the employees in the "other" category worked in the same work area as the technicians; however, they performed different job tasks.

Table 13 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.[41,42]

In general, the lowest geometric mean concentrations were measured on the commuters, followed by service and parts advisors and the "other" category, and then, technicians. The workers' exposures to toluene, xylene, and MtBE in all four categories were all within applicable criteria. The technicians had slightly higher toluene and xylene levels due in part to the use of cleaning solvents which contained these products. The most noteworthy results were the benzene and CO exposures in all of the categories, except the commuters. In these three categories, at least half of the workers were exposed to benzene levels in excess of 0.1 ppm, and 18 out of 22 workers had CO levels at, or in excess of, the ACGIH TLV® of 25 ppm.

## VIII. Conclusions and Recommendations

This technical assistance was initiated as a result of concerns regarding exposures to gasoline and exhaust emissions. The environmental investigation revealed potential overexposures to several compounds and identified numerous health and safety problems in these facilities.

Eight-hour TWA exposure to toluene and xylene were within the NIOSH RELs, OSHA PELs, and ACGIH TLVs®. Occupational exposures to MtBE were less than 0.5 ppm (median of 0.06 ppm or less, depending on the job type), levels which are well below the AIHA WEEL of 100 ppm. However, these low levels are not surprising since MtBE was used only as an octane enhancer at the time of the study. A comparison of the air sampling results to established criteria indicate that employees may be over-exposed to benzene and CO. 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. 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. The service station attendants' work practices should be modified and administrative controls used to reduce exposures. For example, workers should reduce the amount of the time in the vicinity of fuel dispensing nozzles and any gasoline spills in an effort to reduce benzene exposures.

3. Further research should be conducted to identify job tasks which are producing the most significant benzene exposures. Local ventilation devices which will remove the contaminants during high-risk procedures should also be installed. Also, the amount of outside air introduced into the work area should be increased to dilute the contaminants and thereby, reduce the workers' exposures. Improved ventilation is the best method for achieving reductions in workers' exposures. However, changes in work practices and increased use of personal protective equipment may be suitable as temporary solutions. 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.[43,44] 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. CO exposures can be reduced through the installation of a local exhaust ventilation system with overhead rigid and flexible ductwork to the tailpipes, and implementation and improved maintenance of such systems. Although most facilities were equipped with exhaust systems, their performance appeared to be poor, in part due to the lack

of maintenance. An engineering evaluation was outside the scope of this investigation, although some specific problems and recommendations for improvement are described here. Periodic evaluations and maintenance should be performed on the systems. Hoses should be checked for leaks on a routine basis, and breaks should be repaired. A written record of any performance tests, malfunctions, and repairs should be maintained.

6. Cigarette smoke contributes to the overall CO concentrations, and may interact with chemical substances used at these sites. 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.[45]

7. 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 MSDSs, 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 MSDSs, and how the employees can obtain and use this information.

8. 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.

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

10. 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.
11. 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.

12. Building upkeep and work practices should be improved. A number of problems were identified that could have safety significance. In particular, there was water and/or oil on the floor presents a potential slip hazard.

## IX. Authorship and Acknowledgements

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**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.**

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**Table 1**
**Full-Shift Personal Exposures**
***Seekin's Ford-Lincoln-Mercury, Inc.***
**HETA 93-606**
**February 10, 1993**

| Job Category | Sample Time (min) | Time-Weighted Average (parts per million) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Service Advisor | 400 | < 0.04 | 0.08 | 0.17 | 0.14 | 25 |
| Service Advisor | 385 | < 0.04 | 0.07 | 0.13 | 0.11 | 25 |
| Service Advisor | 335 | < 0.04 | 0.07 | 0.17 | 0.12 | 25 |
| Technician | 287 | < 0.04 | 0.08 | (0.14) | 0.13 | 25 |
| Technician | 375 | < 0.04 | 0.07 | 0.20 | 0.14 | 25 |
| Technician | 270 | < 0.04 | 0.08 | 0.17 | 0.14 | 25 |
| Shop Foreman | 375 | < 0.04 | 0.07 | 0.17 | 0.13 | 25 |
| Minimum Detectable Concentration (MDC) | | 0.04 | 0.004 | 0.04 | 0.03 | |
| Minimum Quantifiable Concentration (MQC) | | 0.13 | 0.01 | 0.12 | 0.10 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

( ) 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 2**
**General Area Air Monitoring**
***Seekin's Ford-Lincoln-Mercury, Inc.***
**HETA 93-606**
**February 10, 1993**

| Location | Sample Time (min) | Time-Weighted Average (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Service Area | 440 | < 0.04 | 0.09 | 0.17 | 0.14 | 23 |
| Parts Dept | 395 | < 0.04 | 0.09 | 0.17 | 0.12 | 23 |
| Shop/SE Wall | 380 | < 0.04 | 0.07 | 0.19 | 0.15 | 31 |
| Minimum Detectable Concentration (MDC) | | 0.04 | 0.004 | 0.04 | 0.03 | |
| Minimum Quantifiable Concentration (MQC) | | 0.13 | 0.01 | 0.12 | 0.10 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

( ) 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 3**
**Full-Shift Personal Exposures**
***Totem Chevron***
**HETA 93-606**
**February 11, 1993**

| Job Category | Sample Time (min) | Time-Weighted Average (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Day Manager | 510 | 0.10 | 0.20 | 1.61 | 1.04 | 35 |
| Attendant/Mechanic | 465 | 0.15 | 0.28 | 1.09 | 1.13 | 32 |
| Mechanic | 480 | (0.06) | 0.25 | 2.99 | 1.80 | 50 |
| Minimum Detectable Concentration (MDC) | | 0.03 | 0.003 | 0.03 | 0.02 | |
| Minimum Quantifiable Concentration (MQC) | | 0.09 | 0.01 | 0.09 | 0.08 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

( ) 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 4**
**Full-Shift Personal Exposures**
***Tundra Tours, Inc.***
**HETA 93-606**
**February 11, 1993**

| Job Category | Sample Time (min) | Time-Weighted-Average (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Mechanic | 530 | < 0.03 | 0.06 | 0.11 | 0.17 | 17 |
| Mechanic | 290 | < 0.03 | 0.09 | (0.09) | 0.13 | 27 |
| Mechanic | 500 | < 0.03 | 0.07 | 0.15 | 0.25 | 21 |
| Maintenance Foreman | 290 | < 0.03 | 0.05 | (0.09) | (0.12) | 21 |
| Minimum Detectable Concentration (MDC) | | 0.03 | 0.004 | 0.03 | 0.03 | |
| Minimum Quantifiable Concentration (MQC) | | 0.11 | 0.01 | 0.11 | 0.09 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

--- 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 5**
**Full-Shift Personal Exposures**
***Fairbanks Motors***
**HETA 93-606**
**February 12, 1993**

| Job Category | Sample Time (min) | Time-Weighted Average (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Technician #4 | 94 | < 0.03 | 0.31 | 0.47 | 15.7 | ⇔ |
| Technician #7 | 415 | 0.12 | 0.31 | 0.48 | 0.73 | ⇔ |
| Technician #8 | 510 | 0.11 | 0.27 | 0.41 | 0.58 | 59 |
| Technician #9 | 525 | 0.13 | 0.32 | 0.47 | 0.73 | 69 |
| Shop Foreman | 535 | 0.11 | 0.35 | 0.60 | 0.78 | 56 |
| Honda Mechanic | 440 | 0.10 | 0.33 | 0.49 | 0.61 | ⇔ |
| Lot Attendant | 540 | 0.10 | 0.28 | 0.44 | 0.65 | ⇔ |
| Minimum Detectable Concentration (MDC) | | 0.03 | 0.003 | 0.03 | 0.03 | |
| Minimum Quantifiable Concentration (MQC) | | 0.11 | 0.01 | 0.11 | 0.09 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

⇔ Monitoring not performed
--- 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 6**
**Full-Shift Personal Exposures**
***Sunshine Rae Motors***
**HETA 93-606**
**February 12, 1993**

| Job Category | Sample Time (min) | Time-Weighted Average (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Mechanic | 143 | (0.10) | 0.48 | 0.73 | 1.03 | ⇔ |
| Mechanic[a] | 435 | 0.45 | 0.35 | 0.54 | 1.07 | 20 |
| Mechanic | 295 | 0.35 | 0.57 | 1.29 | 0.38 | 20 |
| Mechanic | 525 | 0.18 | 0.27 | 0.46 | 1.04 | 25 |
| Mechanic | 422 | 0.22 | 0.29 | 0.50 | 0.99 | 20 |
| Minimum Detectable Concentration (MDC) | | 0.05 | 0.005 | 0.04 | 0.04 | |
| Minimum Quantifiable Concentartion (MQC) | | 0.15 | 0.02 | 0.14 | 0.12 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

( ) Denotes value between MDC and MQC
⇔ Monitoring not performed
a Changed a fuel filter
--- 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 7**
**Full-Shift Personal Exposures**
***Aurora Motors, Inc.***
**HETA 93-606**
**February 15, 1993**

| Job Category | Sample Time (min) | Time-Weighted Average (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Service Advisor | 475 | < 0.03 | 0.10 | 0.19 | 0.32 | 38 |
| Parts Manager | 450 | < 0.03 | 0.13 | 0.21 | 0.34 | 40 |
| Technician/Bay #3 | 435 | < 0.03 | 0.13 | 0.24 | 0.48 | 28 |
| Technician/Bay #4 | 450 | 0.18 | 0.22 | 0.51 | 0.49 | 27 |
| Shop Helper | 395 | < 0.03 | 0.08 | 0.13 | 0.17 | 11 |
| Minimum Detectable Concentrtaion (MDC) | | 0.03 | 0.004 | 0.03 | 0.03 | |
| Minimum Quantifiable Concentration (MQC) | | 0.11 | 0.01 | 0.09 | 0.10 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

--- 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**
**Full-Shift Personal Exposures**
***Golden Valley Electric Association, Inc.***
**HETA 93-606**
**February 16, 1993**

| Job Category | Sample Time (min) | Time-Weighted Average (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Meter Technician/Vehicle #92[a] | 440 | < 0.03 | 0.02 | < 0.03 | < 0.03 | ND |
| Meter Technician/Vehicle #93[b] | 450 | < 0.03 | 0.07 | (0.03) | < 0.03 | ND |
| Meter Technician/Vehicle #95[c] | 440 | < 0.03 | 0.02 | < 0.03 | < 0.03 | ND |
| Meter Technician/Vehicle #145[d] | 450 | < 0.03 | 0.07 | (0.06) | (0.05) | ND |
| Minimum Detectable Concentration (MDC) | | 0.03 | 0.004 | 0.03 | 0.03 | |
| Minimum Quantifiable Concentration (MQC) | | 0.11 | 0.01 | 0.09 | 0.10 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

( ) Denotes value between MDC and MQC
ND None detected
a Drove 50 miles
b Drove 100 miles
c Drove 33.5 miles
d Drove 80 miles
--- 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**
**Full-Shift Personal Exposures**
***Fairbanks North Star Borough***
***Division of Animal Control***
**HETA 93-606**
**February 17, 1993**

| Job Category | Sample Time (min | Time-Weighted Average (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene | Carbon Monoxide |
| Animal Control Officer[a] | 510 | < 0.03 | 0.03 | < 0.03 | < 0.02 | 3 |
| Minimum Detectable Concentration (MDC) | | 0.03 | 0.003 | 0.03 | 0.02 | |
| Minimum Quantifiable Concentration (MQC) | | 0.09 | 0.01 | 0.09 | 0.08 | |
| **EVALUATION CRITERIA** | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | 0.1‡ | 100 | 100 | 35 |
| OSHA Permissible Exposure Limit | | --- | 1 | 200 | 100 | 50 |
| ACGIH Threshold Limit Value | | --- | 10† | 50* | 100 | 25 |

a Drove 77 miles
--- 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 10**
**Full-Shift Personal Exposures**
***Fairbanks Public Works***
**HETA 93-606**
**February 18, 1993**

| Location | Sample Time (min) | Time-Weighted Average (ppm) | | | |
|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene |
| Laborer | 465 | < 0.03 | 0.02 | < 0.03 | < 0.02 |
| Minimum Detectable Concentration (MDC) | | 0.03 | 0.003 | 0.03 | 0.02 |
| Minimum Quantifiable Concentration (MQC) | | 0.09 | 0.01 | 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 |

⇔ Monitoring not performed
--- 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
ND None detected

**Table 11**
**Full-Shift Personal Exposures**
***Mike's University Service, Inc.***
**HETA 93-606**
**February 17, 1993**

| Job Category | Sample Time (min) | Time-Weighted Average (ppm) | | | |
|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene |
| Service Attendant | 490 | (0.03) | 0.15 | 0.22 | 0.17 |
| Cashier | 455 | <0.03 | 0.12 | 0.14 | 0.18 |
| Mechanic | 495 | (0.06) | 0.18 | 0.30 | 0.26 |
| Mechanic | 485 | (0.03) | 0.17 | 0.26 | 0.22 |
| Minimum Detectable Concentration (MDC) | | 0.03 | 0.003 | 0.02 | 0.03 |
| Minimum Quantifiable Concentration (MQC) | | 0.10 | 0.011 | 0.08 | 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 12**
**Full-Shift Personal Exposures**
***Gabe's Truck & Auto Repair***
**HETA 93-606**
**February 18, 1993**

| Job Category | Sample Time (min) | Time-Weighted Average (ppm) | | | |
|---|---|---|---|---|---|
| | | MtBE | Benzene | Toluene | Xylene |
| Truck Technician/Shop 1 | 525 | (0.05) | 0.19 | 0.23 | 0.20 |
| Technician/Shop 2 | 480 | (0.09) | 0.27 | 1.01 | 0.39 |
| Technician/Shop 2[a] | 490 | (0.06) | 0.25 | 1.15 | 0.53 |
| Technician/Shop 3 | 485 | <0.03 | 0.12 | 0.28 | 0.23 |
| Technician/Shop 3 | 475 | (0.03) | 0.15 | 0.28 | 0.30 |
| Tow Truck Driver | 460 | <0.03 | 0.08 | 0.15 | 0.16 |
| Office Assistant | 500 | <0.03 | 0.08 | 0.21 | 0.14 |
| 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 |

a Changed fuel filter
( ) Denotes value between MDC and MQC
‡ Human carcinogen
† Suspected human carcinogen
* Skin notation
--- There are recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.

# Table 13
# Summary of Results by Job Category
# (parts per million)
# HETA 93-606

| Job Category | n | MtBE | | BENZENE | | TOLUENE | | XYLENE | | CO* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean[G] | Range | Mean[G] | Range | Mean[G] | Range | Mean[G] | Range | Mean[G] |
| Technicians | 26 | <0.03-0.45 | 0.06 | 0.06-0.57 | 0.19 | 0.09-2.99 | 0.39 | 0.13-15.7 | 0.47 | 17-69 | 31 |
| Service & Parts Advisors | 5 | <0.03-<0.04 | 0.03 | 0.07-0.13 | 0.09 | 0.13-0.21 | 0.17 | 0.11-0.34 | 0.18 | 25-40 | 30 |
| Commuters | 6 | <0.03 | 0.02 | 0.02-0.07 | 0.03 | <0.03-0.06 | 0.03 | <0.02-<0.05 | 0.02 | ND-3 | 1.2 |
| Other | 11 | <0.03-0.11 | 0.04 | 0.05-0.35 | 0.13 | 0.09-1.61 | 0.26 | 0.12-1.04 | 0.27 | 11-56 | 20 |
| **Evaluation Criteria** | | | | | | | | | | | |
| NIOSH Recommended Exposure Limit | | --- | | 0.1‡ | | 100 | | 100 | | 35 | |
| OSHA Persmissible Exposure Limit | | --- | | 1 | | 200 | | 100 | | 50 | |
| ACGIH Threshold Limit Value | | --- | | 10‡ | | 50** | | 100 | | 25 | |

* Carbon Monoxide samples were not collected on all workers
ND None detected
‡ Human carcinogen
† Suspected human carcinogen
** Skin notation
Mean[G] Geometric mean
--- There are recommended exposure limits developed by NIOSH, OSHA, or ACGIH. However, the AIHA workplace environmental exposure level is 100 ppm for an 8-hr TWA.