# HETA 99-0173-2856
# Turnbull National Wildlife Refuge
# Cheney, Washington

---

**Steven A. Lee, CIH**

# PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

# ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Steven A. Lee of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing was performed by Pat Lovell. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800-356-4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

**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.**

# Highlights of the NIOSH Health Hazard Evaluation

## Exposure to Chainsaw Exhaust among Foresters

*This NIOSH Health Hazard Evaluation (HHE) was requested by management at Turnbull National Wildlife Refuge (TNWR) in Cheney, Washington. It was conducted in April 1999 and May 2000 to document exposure to chainsaw emissions among foresters thinning pine trees.*

### What NIOSH Did

- We visited the TNWR to conduct an environmental investigation of exposure to chainsaw emissions.

- We collected air samples for carbon monoxide (CO), benzene, aldehydes, and polynuclear aromatic hydrocarbons (PNAs).

- We measured CO in exhaled breath to give us an estimate of each forester's carboxyhemoglobin (COHb) level.

- We interviewed foresters to see if they had any work-related health problems.

### What NIOSH Found

- Exposure to CO exceeded recommended limits when foresters cut larger trees on calm days.

- COHb levels in foresters also exceeded recommended limits.

- We found airborne exposure to low levels of the following potential occupational carcinogens: benzene, formaldehyde, acetaldehyde, and PNAs.

- All of the foresters reported having recurring musculoskeletal symptoms, such as soreness of the fingers, wrists, elbows, and back.

### What Managers Can Do

- Reduce full-shift exposure to chainsaw exhaust and musculoskeletal strains by replacing some of the sawyer work with other duties during the shift.
- Ensure that new employees are thoroughly trained in proper felling techniques and safe work practices.

- Enforce the safety procedures applicable to the felling of larger trees in accordance with OSHA 29 CFR 1910.266.

### What the Employees Can Do

- Keep your chainsaws as sharp as possible to reduce the duration of peak CO exposure, especially when cutting larger trees.

- Avoid excessive muscle fatigue during tree-cutting to help reduce the possibility of accidents and musculoskeletal problems.

- Closely follow proper safety procedures when felling larger trees.

**What To Do For More Information:**
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513/841-4252 and ask for HETA Report # 99-0172-2856

**Health Hazard Evaluation Report 99-0173-2856**

**U.S. Park Service**
**Cheney, Washington**
**July 2001**

**Steven A. Lee, CIH**

# SUMMARY

In April 1999, the U.S. Park Service, Turnbull National Wildlife Refuge (TNWR), Cheney, Washington, asked NIOSH to evaluate exposure to chainsaw exhaust among forestry workers. Although workers had not reported any symptoms related to chainsaw exhaust, management wanted to have some documentation of their exposure.

Six to eight foresters are employed to thin the forest of pine trees up to 22 inches in diameter. Exposure to airborne carbon monoxide (CO), benzene, aldehydes, and polynuclear aromatic hydrocarbons (PNAs) was evaluated during four days of sampling with wind conditions ranging from calm to 11 miles per hour (mph). Also, carboxyhemoglobin (COHb) levels in each forester were estimated by measuring CO in exhaled breath.

On two days of cutting larger trees during light wind conditions (up to 7 mph), full-shift exposure to CO ranged from 8 to 31 parts per million (ppm), with 40% of the exposures exceeding the most protective evaluation criterion of 25 ppm. Peak CO exposures (up to 1100 ppm) were found to occur primarily when foresters were bent or kneeling to cut the stumps of larger trees close to ground level. Estimated COHb levels ranged up to 4.9% with 33% of COHb levels exceeding the evaluation criterion of 3.5%. On two days of cutting smaller trees during wind conditions up to 11 mph, no full-shift CO exposures exceeded the evaluation criterion.

Full-shift time-weighted average (TWA) exposures to the following occupational carcinogens were found: (1) benzene ranged from 0.03 to 0.1 ppm, with a mean of 0.05 ppm, (2) formaldehyde ranged from 0.013 to 0.029 ppm, with a mean of 0.018 ppm, (3) acetaldehyde ranged from 0.008 to 0.015 ppm, with a mean of 0.01 ppm, and (4) low levels of eight PNAs were detected including five that are known to have carcinogenic potential.

All of the interviewed foresters reported having some recurring musculoskeletal problems associated with working with chainsaws. These primarily consisted of soreness in the fingers, wrists, elbows, and back.

According to the most protective evaluation criteria, there was overexposure to CO among foresters at TNWR. Also, exposures to benzene, formaldehyde, acetaldehyde, and PNAs were detected. NIOSH recommends that exposure to occupational carcinogens be reduced as low as possible. Recommendations were provided to reduce exposure to chainsaw emissions by reducing the amount of chainsaw work per shift and to keep chainsaws as sharp as possible to reduce the duration of peak exposure when cutting larger trees.

Keywords: SIC Code 0851(Forestry Services) chainsaw exhaust, carbon monoxide, CO, carboxyhemoglobin, COHb, benzene, formaldehyde, acetaldehyde, polynuclear aromatic hydrocarbons, PNAs, PAHs

# TABLE OF CONTENTS

# INTRODUCTION

In April 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the U.S. Department of Interior to evaluate exposure to chainsaw exhaust among forestry workers at the Turnbull National Wildlife Refuge (TNWR), Cheney, Washington. Workers had not reported any adverse health effects that they associated with chainsaw exhaust. The requester was aware of studies demonstrating elevated carboxyhemoglobin (COHb) levels in loggers using chainsaws and wanted some documentation of exposure for workers at TNWR.

In April 1999, a NIOSH industrial hygienist conducted an initial evaluation of forestry workers using chainsaws at the TNWF. Exposure to carbon monoxide (CO) was assessed, and employee interviews were conducted. Environmental monitoring results along with recommendations to reduce exposure to chainsaw exhaust and ergonomic strains were presented at the end of the NIOSH visit. In May 2000, a follow-up study was conducted to evaluate exposure to CO, benzene, polynuclear aromatic hydrocarbons (PNAs), total hydrocarbons, formaldehyde, acetaldehyde, and benzaldehyde.

# BACKGROUND

The Turnbull National Wildlife Refuge is a wetland habitat that was nearly lost in the early 1900s as settlers attempted to drain the area for agriculture. Failure of the lake beds to produce crops combined with the efforts of conservationists resulted in the creation of the refuge in 1937. Many of the lakes and marshes have been restored and the refuge is now used by migrating waterfowl of the Pacific Flyway. The refuge also has large areas of Ponderosa pine forest consisting of an unnaturally thick growth of stunted trees due to many years of fire suppression. This limits the variety of grasses and forbs needed to support a variety of wildlife. Also, unnaturally thick forests are susceptible to wildfires that are more destructive than those that occur in thin forests.

Eight foresters are employed by the TNWR to thin out some of the thicker growth of pine trees. Thinning involves cutting all trees less than eight inches in diameter, except in thick stands of larger trees where trees up to 22 inches in diameter may be cut. Larger trees are initially cut about four feet above the ground, and the stump is then cut to within four inches of the ground. Larger trees are cut into pieces and scattered, and controlled burns are later conducted in some areas. The chainsaws primarily used are Stihl Models 036 and 044. The Model 036 has a two-stroke 4.6 horse power (hp) engine and was fitted with 20-inch guide bars during the initial NIOSH visit. The Model 044 has a 5.4 hp engine and a 25-inch guide bar. During the NIOSH follow-up visit, all saws of both models had 25-inch guide bars. Both models are equipped with anti-vibration systems and quick-stop chain brakes. Fuel consists of Chevron Mid-Grade (87 octane) gasoline mixed at a 50:1 ratio with L-J two-stoke engine oil.

Foresters wear hard hats with attached Stihl Promark ear muffs in addition to foam ear plugs, safety glasses with side shields, and cotton or leather gloves. They work a 9-hour shift that includes a 30-minute lunch break and two 15-minute rest breaks. Chains are sharpened one to three times per shift which requires about 10 minutes. One hour is used for cleaning and maintaining equipment at the end of the shift. The total amount of time spent operating chainsaws is about 5 hours per shift.

# METHODS

On April 27-28, 1999, the NIOSH investigator conducted an evaluation of forester exposure to CO, and conducted private interviews to determine the extent of work-related health problems. Each forester's exposure to CO was measured using Biosystems Toxi-Ultra or Toxilog single-sensor gas detectors. These dataloggers continuously monitor by diffusion through an electrochemical sensor specific for CO. The monitors were worn in the personal breathing-zone (PBZ) of the employees during the eight hours they were working in the forest. Each instrument was pre- and post-calibrated using 50 ppm CO span gas. The units displayed the 8-hour time-weighted average (TWA), the maximum 15-minute exposure, and the maximum peak exposure for each worker. The peak exposure audible alarm of the monitors was set at 400 ppm and the foresters were asked to note what task they were performing each time the alarm sounded. Wind velocities were measured each day with a Kurz Mini Anemometer Model 490.

Estimates of COHb levels in each employee were calculated by collecting exhaled breath in a balloon by the method described in the documentation of the American Conference of Governmental Industrial

Hygienists (ACGIH®) Biological Exposure Index.[1] Mid- and post- shift exhaled breath measurements were conducted on the first day of sampling, and pre-, mid-, and post- shift measurements were conducted on the second day. The exhaled breath was measured for CO using the dataloggers, and the estimated percentage of carboxyhemoglobin in the blood was calculated using the formula: -0.5 + (expired CO in ppm/5).[1]

Seven (88 %) of the foresters were privately interviewed by the NIOSH investigator who asked them, "have you experienced any health problems that you think might be related to your work?"

On May 2-3, 2000, exposure to CO was again measured along with estimates of COHb levels in each of the six foresters working at TNWR at that time. Full-shift PBZ air samples were collected on charcoal tubes at a flow rate of 0.2 liters per minute and analyzed by gas chromatography for benzene and total hydrocarbons according to NIOSH Methods 1501 and 1550, respectively.[2] PBZ air samples for PNAs were collected on Teflon filters followed by Orbo 43 sorbent tubes at a flow rate of 2.0 liters per minute and analyzed by high performance liquid chromatography (HPLC) according to NIOSH Method 5506.[2] PBZ air samples for formaldehyde, acetaldehyde, and benzaldehyde were collected on DNPH-treated silica gel cartridges at a flow rate of 0.3 liters per minute and analyzed by HPLC according to NIOSH Method 2016.[2] A bulk sample of the chainsaw fuel was analyzed for benzene by gas chromatography according to NIOSH Method 1501.[2]

# EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[3] (2) the ACGIH® Threshold Limit Values (TLVs®),[4] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[5] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5.(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short term.

## Carbon Monoxide

Carbon monoxide is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials; e.g., gasoline. Carbon monoxide displaces oxygen in the blood and combines with hemoglobin to form COHb. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[6]

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should not been exceeded.[7] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with COHb levels in excess of 5%.[6] The ACGIH recommends a TLV of 25 ppm as an 8-hour TWA, and this is designed to protect workers from health effects associated with COHb levels in excess of 3.5%.[1] COHb concentrations in the blood are most accurately determined by analyzing blood samples. However, COHb levels can be estimated more easily by measuring CO in exhaled breath. A person with 20 ppm of CO in their exhaled breath has a COHb level of approximately 3.5%.[1] The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.[5] In addition to these standards, the National Research Council has developed a CO exposure standard of 15 ppm, based on a 24 hours per day, 90-day TWA exposure.[8]

## 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.[1] The nationwide average of benzene content in gasoline is 1.5%, although studies have found benzene content as high as 5%.[9] 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).[10]

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.[11] However, the most remarkable health effects associated with benzene exposure are chronic effects due to repeated exposure to low concentrations over many years.[12]

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.[11,13,14] 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 a 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 0.5 ppm as a confirmed human carcinogen.

## Polynuclear Aromatic Hydrocarbons

Polynuclear aromatic compounds (PNAs) are chemical species that consist of two or more fused aromatic rings. They are often associated with the combustion or pyrolysis of organic matter, especially coal, wood, and petroleum products. Materials associated with these processes have been demonstrated to contain compounds that have been shown to cause cancer in laboratory animals and, in some cases, humans. There are few dose-related relationships for the PNA mixtures that may be found in these industrial processes, and no "safe" exposures to PNA aerosols have been established. Since the application of laboratory animal data for PNA compounds to estimate human risk is very difficult, any occupational exposure to potentially carcinogenic matter is a cause for concern and exposures should be kept to an absolute minimum.

NIOSH recommends that occupational exposures to coal tar be controlled so that employees are not exposed to coal tar, coal tar pitch, creosote, or mixtures of these substances at a concentration greater than 0.1 milligrams per cubic meter ($mg/m^3$) of the benzene- (or cyclohexane-) extractable fraction of the sample, determined as a TWA concentration for up to a 10-hour work shift in a 40-hour work week. Both ACGIH and OSHA set their standards at

0.2 mg/m$^3$ for a normal 8-hour workday or 40-hour work week. Individual PNA measurements serve to establish the presence of coal tar pitch volatiles (CTPVs) and indicate the presence of known or suspected carcinogens or other genotoxic compounds in the workplace, which would dictate additional control measures.

The potential adverse health effects of PNAs are well recognized.[15,16,17,18] Several PNAs, such as benzo(a)anthracene and pyrene, have been shown to be carcinogenic in animals. Excess risk of lung cancer, oral cancer, and skin neoplasms (benign and malignant) have been found in working populations handling coal tar products which NIOSH has defined to include coal tar, coal tar pitch, and creosote. A TWA exposure of 0.2 µg/m$^3$ was recommended by the coke oven advisory committee for benzo(a)pyrene under the OSHA 29 CFR 1910.1029 coke oven emissions standard, but was not adopted. A special NIOSH hazard review of chrysene recommended that it be controlled as an occupational carcinogen. Also, ACGIH includes chrysene and benzo(a)pyrene in its list of industrial substances suspected of having carcinogenic potential in man. The carcinogenic potential of other PNAs (benzo(a)anthracene, anthracene, pyrene, and fluoranthene) has also been documented.[16]

## Formaldehyde

Formaldehyde is a colorless gas with a strong odor. Exposure can occur through inhalation and skin absorption. The acute effects associated with formaldehyde are irritation of the eyes and respiratory tract and sensitization of the skin. The first symptoms associated with formaldehyde exposure, at concentrations ranging from 0.1 to 5 (ppm), are burning of the eyes, tearing, and general irritation of the upper respiratory tract. There is variation among individuals, in terms of their tolerance and susceptibility to acute exposures of the compound.[19]

In two separate studies, formaldehyde has induced a rare form of nasal cancer in rodents. Formaldehyde exposure has been identified as a possible causative factor in cancer of the upper respiratory tract in a proportionate mortality study of workers in the garment industry.[20] NIOSH has identified formaldehyde as a suspected human carcinogen and recommends that exposures be reduced to the lowest feasible concentration. The OSHA PEL is 0.75 ppm as an 8-hour TWA and 2 ppm as a STEL.[21] ACGIH has designated formaldehyde to be a suspected human carcinogen and therefore, recommends that worker exposure by all routes should be carefully controlled to levels "as low as reasonably achievable" below the TLV.[1] ACGIH has set a ceiling limit of 0.3 ppm.

*Note: NIOSH testimony to DOL on May 5, 1986, stated the following: "Since NIOSH is not aware of any data that describe a safe exposure concentration to a carcinogen NIOSH recommends that occupational exposure to formaldehyde be controlled to the lowest feasible concentration; 0.1 ppm in air by collection of an air sample for any 15-minute period as described in NIOSH analytical method 3500 which is the lowest reliably quantifiable concentration at the present time." NIOSH also lists an REL for formaldehyde of 0.016 ppm for up to a 10-hour TWA exposure (again using NIOSH analytical method 3500) and indicates that this is the lowest reliably quantifiable concentration at the present time. Investigators should be aware that formaldehyde levels can currently be measured below 0.016 ppm. It may be appropriate to refrain from using numerical limits and instead state that concentrations should be the lowest feasible (in some situations, this may be limited by the ambient background concentration).*

# RESULTS

## Initial Survey

On the first day of sampling in April 1999, eight foresters were exposed to 8-hr TWA concentrations of CO ranging from 8 to 31 ppm, with a mean of 20 ppm (Table 1). Four exposures were above the ACGIH TLV of 25 ppm. Maximum 15-minute exposure concentrations ranged from 40 to 170 ppm, with a mean of 100 ppm. No STEL has been developed for CO. Maximum peak (ceiling) exposure concentrations ranged from 150 to 1100 ppm with a mean of 500 ppm. Seven exposures were above the NIOSH ceiling exposure limit of 200 ppm.

On the second day of sampling, the work schedule was altered slightly by replacing the two 15-minute rest breaks with four 10-minute rest breaks. Seven foresters were exposed to 8-hr TWA CO concentrations ranging from 10 to 31 ppm, with a mean of 18 ppm (Table 1). Two exposures were above the ACGIH TLV. Maximum 15-minute exposure concentrations ranged from 45 to 110 ppm, with a mean of 69 ppm. Maximum peak exposures ranged from 290 to 770 ppm, with a mean of 460 ppm.

On the first day of sampling, mid-shift estimated COHb concentrations in non-smoking workers ranged from 0.7 to 4.9%, with a mean of 2.3% (Table 1). Post-shift estimated COHb concentrations in non-smokers ranged from 0.5 to 4.7%, with a mean of 2.1%. On the second day, mid-shift estimated COHb concentrations in non-smoking workers ranged from 0.5 to 3.9%, with a mean of 1.9%, and the post-shift estimated COHb concentrations in non-smokers ranged from 0.5 to 3.7%, with a mean of 2.1%. A total of five estimated COHb concentrations in non-smokers were above the ACGIH recommended biological exposure index (BEI) of 3.5% during the two days of sampling. The mean pre-shift (mid-week) estimated COHb concentration in non-smoking workers was 1.3%. Background levels of COHb in the general population of non-smokers are 0.5 to 1.5%.[1]

Foresters reported that the CO alarms most frequently sounded as they were kneeling or bending and cutting the stumps of larger trees. Figure I displays a forester's exposure to CO during the second day of sampling. The full-shift TWA exposure is 19 ppm and there were eight peak exposures above 200 ppm that occurred during the cutting of larger trees. Light winds ranging up to seven miles per hour (mph) occurred during both days of sampling.

## Follow-up Survey

In May 2000, six foresters were exposed to full-shift TWA CO concentrations ranging from 5 to 23 ppm, with a mean of 11 ppm during two days of sampling (Table 2). Maximum 15-minute exposure concentrations ranged from 0 to 9.0 ppm, with a mean of 2.7 ppm. Maximum peak exposures ranged from 90 to 530 ppm, with a mean of 260 ppm. Mid-shift estimated COHb concentrations in non-smokers ranged from 0.9 to 1.9%, with a mean of 1.4%. Post-shift estimated COHb concentrations in non-smokers ranged from 0.5 to 4.5%, with a mean of 1.7%. One non-smoker and two smokers had estimated COHb concentrations above the ACGIH BEI of 3.5%. The mean Monday morning pre-shift estimated COHb concentration in non-smoking workers was 0.65%. The mean Tuesday morning pre-shift estimated COHb concentration in non-smokers was 1.7%.

Winds were slightly stronger during the follow-up survey with velocities ranging up to 9 mph on the first day and 11 mph during the afternoon of the second day. Also, foresters reported that they were working in an area that had smaller trees than the area being thinned during the initial NIOSH survey.

The chainsaw fuel contained 1.6 % benzene. Full-shift TWA air exposure to benzene ranged from 0.03 to 0.1 ppm, with a mean of 0.05 ppm (Table 3). Full-shift exposure to total airborne hydrocarbons ranged from 3.8 to 17 mg/m$^3$, with a mean of 8.2 mg/m$^3$. The NIOSH REL for total hydrocarbons is 350 mg/m$^3$.

Full-shift TWA exposure to formaldehyde ranged from 0.013 to 0.029 ppm, with a mean of 0.018 ppm (Table 3). Full-shift TWA exposure to acetaldehyde ranged from 0.008 to 0.02 ppm, with a mean of 0.01 ppm. NIOSH considers both formaldehyde and acetaldehyde to be potential occupational carcinogens. Exposure should be reduced as low as possible. Full-shift TWA exposure to benzaldehyde ranged from non-detectable (<0.0002 ppm) to 0.002 ppm. Exposure limits have not been established for benzaldehyde.

Of the 16 PNAs that were analyzed, 8 of the lower molecular weight PNAs up through chrysene were detected (Table 4). Naphthalene and acenaphthene were detected in the highest concentrations. Exposure to naphthalene ranged from 6.3 to 12 micrograms per cubic meter (ug/m$^3$), and exposure to acenaphthene ranged from 7.7 to 17 ug/m$^3$. Five of the detected PNAs are known to have carcinogenic potential. These are anthracene, fluoranthene, pyrene, benzo(a)anthracene, and chrysene.[16]

## Employee Interviews

The NIOSH investigator interviewed five men and two women ranging in age from 27 to 50 years, with a mean age of 37 years. All of the foresters are certified wildland firefighters who are annually required to pass physical fitness requirements. Two of the interviewed workers are light smokers (two or three cigarettes/day). The health effects reported by the interviewed foresters consisted of recurring musculoskeletal symptoms. All seven (100%) reported having at least one symptom and four (57%) had multiple symptoms. Four (57%) reported sore or stiff finger joints, primarily in the morning. Two (29%) reported sore or fatigued lower backs, and one (14%) had soreness in the upper back. Two (29%)

had sore elbows of the dominant arm, and one (14%) reported that both elbows became sore. One (14%) had a sore wrist of the dominant arm, and one (14%) reported soreness in both wrists. One (14%) experienced soreness of the dominant shoulder, and one (14%) reported a sore neck.

There have been no accidents resulting in lost-time injuries associated with tree cutting at TNWR, however, foresters reported that there have been some "close calls," such as chainsaws accidently cutting through clothing or workers nearly being struck when cutting through spring poles (a tree under tension from the weight of another tree).

# DISCUSSION

Much of the CO exposure among foresters occurs during very brief (<1 minute) periods when CO levels frequently exceed the NIOSH ceiling limit of 200 ppm. It would be impossible to work with chainsaws and stay below the ceiling limit when cutting larger trees. Realistically, peak CO exposures among TNWR foresters are too brief to be considered immediately hazardous. Even a CO exposure of 1000 ppm during a moderate work load (alveolar ventilation rate of 20 liters per minute) requires eight minutes to reach 3.5% COHb in an average-sized adult.[1,22] Furthermore, TNWR foresters were found to have peak CO exposures exceeding 200 ppm up to eight times per shift without exceeding a full-shift TWA exposure of 25 ppm, or an estimated COHb concentration of 3.5%.

Probably the most useful measures of exposure to CO among foresters at TNWR are the full-shift TWAs along with mid-shift and post-shift COHb estimates. Although no foresters were exposed to full-shift TWA CO levels above the NIOSH REL and none of their estimated COHbs exceeded the NIOSH recommendation, exposures did exceed the more protective ACGIH TLV of 25 ppm. Also, the foresters' estimated COHb levels exceeded the ACGIH BEI of 3.5%. ACGIH lists the following reasons for their more conservative recommendations:[1] (1) minimize decrements in psychomotor function that may increase the potential for accidents, (2) maintain cardiovascular work and exercise capacities, and (3) provide a greater margin of safety for people more susceptible to the effects of CO, such as pregnant workers and their fetuses, people with chronic heart and respiratory disease, and smokers who already have elevated COHb levels. People who smoke one pack of cigarettes per day have COHb levels of 5% to 6%, and heavy smokers may have COHb levels up to 20%.[23]

It could be argued that the superior physical fitness of TNWR foresters combined with their good safety record provide reasons for not needing to follow the more protective ACGIH TLV for CO. However, chainsaws are potentially dangerous tools and tree cutting is physically demanding work that requires optimum mental alertness. Therefore, it would be prudent to reduce CO exposure in accordance with the ACGIH TLV and BEI to minimize decrements in psychomotor function that may increase the potential for serious accidents.[1]

Environmental monitoring indicated that exposure to chainsaw exhaust was higher during the initial survey. This was most likely due to a combination of the larger trees being cut and the lower wind velocities that occurred at that time. During the follow-up survey, all of the full-shift TWA exposures were below 25 ppm, however, three of the foresters had mid- or post-shift estimated COHb levels above 3.5 %. The correlation between environmental CO exposure and COHb levels can vary considerably due to body size and work load.[22] Also, two of the workers with elevated COHb concentrations were light smokers who had one or two cigarettes during the shift.

There are few options for reducing exposure to chainsaw exhaust. Studies have found no difference in emissions between differing brands of saws, and worn-out chainsaws do not emit higher levels of contaminants than new saws.[24] There have been no recent technical improvements to reduce exhaust emissions in 2-stroke engines which are particularly troublesome because up to 30% of their fuel is unburned and emitted as part of the exhaust.[25] A leaner fuel-air mixture can reduce emissions of CO and most hydrocarbons, however, this increases the emission of aldehydes.[24] Previous studies of exposure to chainsaw emissions among logging workers have produced the following recommendations: (1) reduce the amount of chainsaw use during the work shift, (2) avoid working during conditions of low wind speed,[24,25] and (3) avoid working in deep snow or in thick timber stands.[24] Only the first of these recommendations appears to be a feasible option at TNWR. Avoiding work on days with light wind could greatly reduce the number of tree-cutting opportunities, considering that tree-cutting is also avoided for safety reasons on days when wind velocities exceeds 15 mph. Deep snow is rarely a problem at TNWR and avoiding thick timber stands is not an option because that is the primary purpose for cutting trees at TNWR.

The increased rest breaks that were recommended during the initial survey could have helped reduce full-shift exposure to chainsaw exhaust in addition to relieving some of the musculoskeletal symptoms. However, the additional breaks were discontinued after the first NIOSH visit because most of the foresters did not like them. They reported that each time they rested for more than a few minutes their muscles became stiff, and two additional rest breaks just meant two more times they had to get "limbered up" and get moving again. This seemed to make the work day last longer. A better option that could have a dual effect on reducing exposure would be to sharpen saws more frequently. Sharper saws cut through trees faster and shorten the duration of peak exposures, especially when cutting larger trees. Also, each 10 minutes taken to sharpen the saws reduces overall chainsaw use during the shift while improving the forester's efficiency.

It should be noted that exposure to hydrocarbons and aldehydes were measured during the cutting of smaller trees and stronger wind conditions. Exposure to these compounds would be higher during more adverse conditions, such as those that occurred during the first NIOSH visit. Assuming no change in the chainsaw fuel-air mixture, exposure to these contaminants directly correlate with exposure to CO. Therefore, exposure to hydrocarbons and aldehydes could be up to 60 % higher when cutting larger trees during light wind conditions.

It is interesting to note the difference in health effects reported by European studies of loggers exposed to chainsaw exhaust. Headache, fatigue, cough, and irritation of the eyes, nose, and throat were the primary symptoms reported by loggers.[24,26] Minor pulmonary function changes were also detected.[26] The level of full-shift TWA exposure to potential irritants, such as formaldehyde and total hydrocarbons were similar to the levels that likely occur at TNWR during adverse conditions. However, foresters at TNWR did not report any irritative symptoms. Full-shift exposure to formaldehyde among both occupations was below 0.1 ppm, which usually is not high enough to cause irritative symptoms. The major difference between the work done by TNWR foresters and loggers is probably the size of the trees being felled. Cutting larger trees likely results in higher short term exposure to aldehydes and other irritants.

# CONCLUSIONS

Environmental monitoring indicated that TNWR foresters were exposed to increased health and safety risks due to overexposure to CO, according to the most protective evaluation criteria. Reducing the potential CO hazard would also reduce the possible health risks posed by exposure to several confirmed and suspected occupational carcinogens found in chainsaw emissions.

# RECOMMENDATIONS

1. Foresters should reduce daily exposure to chainsaw exhaust by replacing some of the time spent on chainsaw work with other duties during the shift. This could also help reduce musculoskeletal problems.

2. Saws should be kept as sharp as possible, and should be operated, adjusted, and maintained according to the manufacturer's instructions.

3. Ensure that new employees are thoroughly trained in proper felling techniques and safe work practices.

4. Foresters at TNWR are also wildland firefighters who take care to maintain top physical condition. However, during tree-cutting they should avoid excessive muscle fatigue which may increase the possibility of accidents and musculoskeletal problems.

5. Follow safety procedures applicable to the felling of larger trees in accordance with OSHA 29 CFR 1910.266,[27] such as: (a) The distance between adjacent occupied work areas must be at least two tree lengths of the trees being felled. (b) If a tree is lodged against another tree, remove it before any further work begins in the area by using mechanical means or other techniques that minimize worker exposure. (c) When cutting a spring pole or other tree under stress, permit no one but the feller to be closer than two tree lengths when the stress is released.

# REFERENCES

1. ACGIH [2001]. Documentation of threshold limit values and biological exposure indices for chemical substances and physical agents.

Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. NIOSH [1994]. NIOSH manual of analytical methods. 4th ed. Cincinnati, OH. DHHS (NIOSH) Publication No. 94-113.

3. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

4. ACGIH [2001]. 2001 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

5. CFR [1997]. 29 CFR 1910.1000. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

6. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to carbon monoxide. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11000.

7. CDC [1988]. NIOSH recommendations for occupational safety and health standards 1988. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control; National Institute for Occupational Safety and Health. MMWR 37 (supp. S-7).

8. NRC [1985]. Emergency and continuous exposure guidance levels for selected contaminants. Washington, DC: National Research Council. National Academy Press.

9. ENVIRON Corporation [1990]. Summary report on individual and population exposures to gasoline. Arlington, VA: ENVIRON Corporation. November 28.

10. NIOSH [1992]. Health hazard evaluation report: American Petroleum Institute, Washington, D.C. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Report No. 88-304-2326.

11. NIOSH [1974]. Criteria for a recommended standard: occupational exposure to benzene. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 74-137.

12. Proctor NH, Hughes JP, Fischman ML [1988]. Chemical hazards of the workplace. Philadelphia, PA: J.B. Lippincott Company.

13. WHO [1989]. IARC monographs on the evaluation of carcinogenic risks to humans: occupational exposures to the petroleum refining; crude oil and major petroleum fuels. World Health Organization *45*: 159-201. 1-8 March 1988.

14. NTP [1991]. Sixth annual report on carcinogens: 1991 summary. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Toxicology Program.

15. Harrison's Principles of Internal Medicine [1980]. Ninth Edition. New York, NY: McGraw-Hill Book Company, pp 255-262.

16. NIOSH [1978]. Criteria for a recommended standard: occupational exposure to coal-tar products. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78-107.

17. Herwin RL, Effect EA [1976]. Health Hazard Evaluation Report No. 75-194-324. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease

Control, National Institute for Occupational Safety and Health.

18. Gorman RW, Liss GM [1981]. Health Hazard Evaluation Report No. 80-206-1164. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health.

19. NIOSH [1977]. Criteria for a recommended standard: occupational exposure to formaldehyde. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-126.

20. Stayner L, Smith AB, Reeve G, Blade L, Keenlyside R, Halperin W [1985]. Proportionate mortality study of workers exposed to formaldehyde. Am J Ind Med 7:229-40.

21. OSHA [1992]. Occupational exposures to formaldehyde: final rule. Occupational Safety and Health Administration, Washington, DC: Federal Register 57(102)22289-22328. U.S. Government Printing Office.

22. Coburn RF, Forster RE, Kane PB [1965]. Considerations of the physiological variables that determine the blood carboxyhemoglobin concentration in man. J. Clin. Invest. 44(1):1899-1910.

23. Stewart RD, Baretta ED, Platte LR, [1974]. Carboxyhemoglobin levels in American blood donors. JAMA 229(9):1187-1195.

24. Nilsson CA, Lindahl R, Norstrom A [1987]. Occupational exposure to chainsaw exhausts in logging operations. AIHAJ 48(2):99-105.

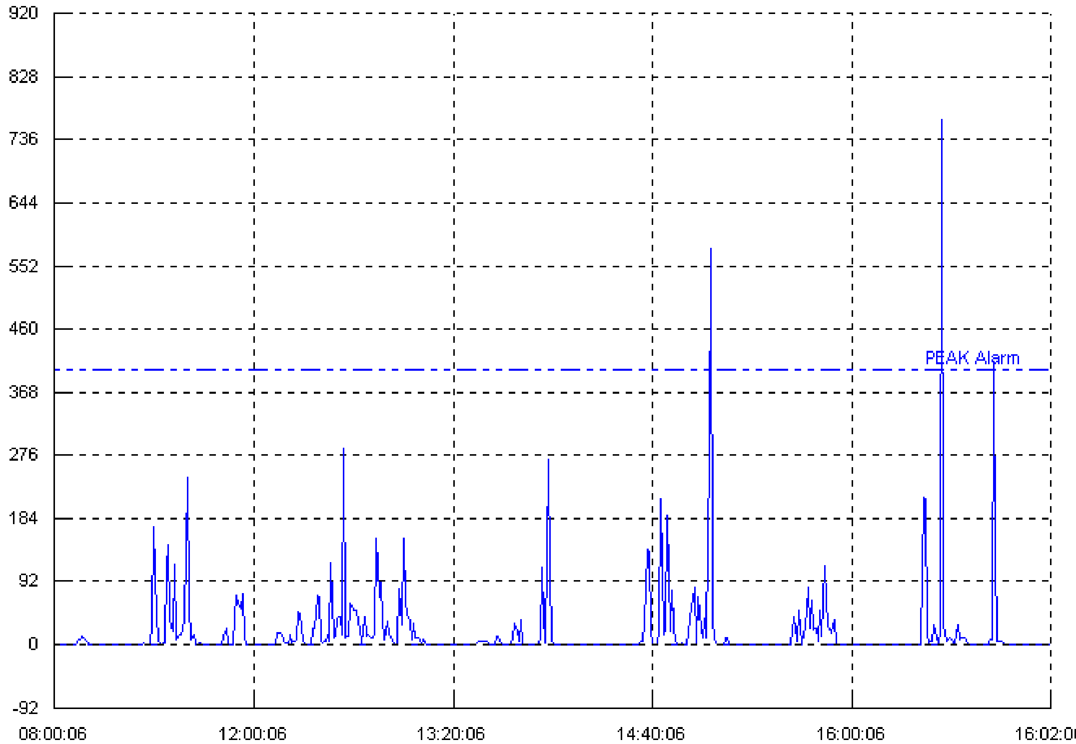
25. Bunger J, Bombosch F, Mesecke U, Hallier E [1997]. Monitoring and analysis of occupational exposure to chainsaw exhausts. AIHAJ 58:747-751.

26. Hagberg M, Kolmodin-Hedman B, Lindahl R, Nilsson CA, Norstrom A [1985]. Irritative complaints, carboxyhemoglobin increase and minor ventilatory function changes due to exposure to chain-saw exhaust. Eur. J. Respir. Dis. 66:240-247.

27. CFR [1997] 29 CFR 1910.266. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Figure 1
Typical Full-Shift CO Exposure During Tree Thinning
Turnbull National Wildlife Refuge
HETA 99-0173

CO
(ppm)




Time of
Day

Table 1
Exposure to CO (ppm) and Estimated COHb Concentrations (%)
Turrnbull National Wildlife Refuge
HETA 99-0173

| Job | Sample Duration (min.) | Full-Shift TWA CO Exposure | Maximum 15-minute TWA | Maximum Peak | Pre-Shift COHb | Mid-Shift COHb | Post-Shift COHb |
|---|---|---|---|---|---|---|---|
| April 27, 1999 | | | | | | | |
| Forester 1 | 465 | 8 | 40 | 150 | - | 4.9 | 1.1 |
| Forester 2 | 465 | 19 | 69 | 200 | - | 2.5 | 1.7 |
| Forester 3 | 470 | 31 | 170 | 590 | - | 3.1 | 4.7 |
| Forester 4 | 470 | 8 | 52 | 260 | - | 0.7 | 0.5 |
| Forester 5 | 465 | 26 | 110 | 760 | - | 1.3 | 0.5 |
| Forester 6 | 470 | 27 | 150 | 710 | - | 1.3 | 1.7 |
| Forester 7 | 470 | 13 | 72 | 290 | - | 2.5 | 3.1 |
| Forester 8 | 470 | 27 | 170 | 1100 | - | 2.5 | 1.9 |
| April 28, 1999 | | | | | | | |
| Forester 1 | 480 | 10 | 45 | 340 | 1.9 | 2.5 | 3.5 |
| Forester 2 | 465 | 15 | 49 | 340 | 2.5 | 3.9 | 1.9 |
| Forester 3 | 465 | 26 | 110 | 490 | 2.3 | 1.9 | 3.7 |
| Forester 4 | 480 | 19 | 90 | 770 | 0.1 | 0.5 | 0.5 |
| Forester 5 | 470 | 14 | 45 | 290 | 0.5 | 1.1 | 0.9 |
| Forester 6 | 490 | 31 | 92 | 550 | 0.7 | 1.7 | 1.9 |
| Forester 7 | 500 | 11 | 55 | 440 | 1.1 | 1.7 | 2.1 |
| Evaluation Criteria | | 25 | | 200 | | 3.5 | 3.5 |

| Table 2<br>Exposure to CO (ppm) and Estimated COHb Concentrations (%)<br>Turnbull National Wildlife Refuge<br>HETA 99-0173 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Job | Sample Duration (min.) | Full-Shift TWA CO Exposure | Maximum 15-minute TWA | Maximum Peak | Pre-Shift COHb | Mid-Shift COHb | Post-Shift COHb |
| May 2, 2000 | | | | | | | |
| Forester 1* | 350 | 5 | 0 | 90 | 1.1 | 1.9 | 3.1 |
| Forester 2 | 350 | 7 | 1 | 110 | 0.1 | 1.3 | 1.3 |
| Forester 3** | 355 | 11 | 3 | 200 | 1.7 | 2.1 | 3.7 |
| Forester 4 | 355 | 13 | 2 | 520 | 0.9 | 0.9 | 0.9 |
| Forester 5** | 360 | 9 | 4 | 220 | 1.5 | 3.7 | 3.1 |
| Forester 6 | 360 | 23 | 0 | - | 0.5 | 1.9 | 4.5 |
| May 3, 2000 | | | | | | | |
| Forester 1 | 320 | 14 | 4 | 300 | 3.5 | 0.9 | 0.9 |
| Forester 2 | 340 | 16 | 3 | 530 | 0.9 | 1.9 | 1.1 |
| Forester 3** | 345 | 8 | 0 | 210 | 1.9 | 2.3 | 0.9 |
| Forester 4 | 245 | 8 | 4 | 330 | 0.7 | 0.9 | 0.9 |
| Forester 5** | 315 | 10 | 9 | 220 | 2.1 | 0.9 | 1.5 |
| Forester 6 | 340 | 12 | 2 | 170 | 1.7 | 1.1 | 0.5 |
| Evaluation Criteria | | 25 | | 200 | | 3.5 | 3.5 |

* Forester # matches those in Tables 3 and 4.
** light smokers (2-3 cigarettes per day)

| Table 3<br>Exposure to Airborne Aldehydes and Other Hydrocarbons<br>Turnbull National Wildlife Refuge<br>HETA 99-0173 | | | | | | |
|---|---|---|---|---|---|---|
| Job | Sample Duration (min.) | Total Hydrocarbons ($mg/m^3$) | Benzene (ppm) | Formaldehyde (ppm) | Acetaldehyde (ppm) | Benzaldehyde (ppm) |
| May 2, 2000 | | | | | | |
| Forester 1* | 350 | 3.8 | 0.03 | - | - | - |
| Forester 2 | 350 | 5.8 | 0.03 | - | - | - |
| Forester 3 | 355 | 7.9 | 0.05 | 0.015 | 0.008 | ND** |
| Forester 4 | 355 | 11 | 0.07 | 0.013 | 0.007 | ND |
| Forester 5 | 360 | 17 | 0.1 | 0.015 | 0.009 | ND |
| Forester 6 | 360 | 5.7 | 0.03 | - | - | - |
| May 3, 2000 | | | | | | |
| Forester 1 | 320 | 4.4 | 0.03 | - | - | - |
| Forester 2 | 340 | 8.2 | 0.06 | - | - | - |
| Forester 3 | 345 | 8.9 | 0.06 | 0.014 | 0.008 | ND |
| Forester 4 | 245 | 5.8 | 0.04 | 0.022 | 0.01 | ND |
| Forester 5 | 315 | 10 | 0.05 | - | - | - |
| Forester 6 | 340 | 9.4 | 0.07 | 0.029 | 0.02 | 0.002 |
| Evaluation Criteria | | 350 | 0.1 | 0.016 | LFL | None |

- Forester # matches those in Tables 2 and 4.

** ND = below the sampling and analytical limit of detection (approx. 0.0002 ppm)

| Table 4<br>Exposure to Airborne PNAs (µg/m³)<br>Turnbull National Wildlife Refuge (HETA 99-0173) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Job | Sample Duration (min) | Naphthalene | Acenaphthylene | Acenaphthene | Fluorene | Phenanthrene | Anthracene | Fluoranthene | Pyrene | Benzo(a)anthracene | Chrysene | Benzo(b)fluoranthene | Benzo(k)fluoranthene | Benzo(a)pyrene | Indeno(1,2,3-cd)pyrene | Dibenz(a,h)anthracene | Benzo(ghi)perylen |
| **May 2, 2000** | | | | | | | | | | | | | | | | | |
| For 1* | 350 | 11 | ND** | 12 | 0.53 | 0.19 | (.06)+ | (.56) | (0.1) | ND | ND | ND | ND | ND | ND | ND | ND |
| For 2 | 350 | 12 | ND | 10 | 0.40 | ND | (.06) | (.42) | (0.2) | ND | ND | ND | ND | ND | ND | ND | ND |
| For 6 | 360 | 11 | 4.2 | 17 | 0.54 | ND | (.07) | 0.76 | 0.12 | (.04) | ND | ND | ND | ND | ND | ND | ND |
| **May 3, 2000** | | | | | | | | | | | | | | | | | |
| For 1 | 320 | 7.5 | ND | 7.7 | 0.44 | 0.30 | (.03) | ND | (.06) | ND | ND | ND | ND | ND | ND | ND | ND |
| For 2 | 340 | 6.9 | ND | 8.2 | 0.32 | ND | (.04) | ND | (.06) | ND | ND | ND | ND | ND | ND | ND | ND |
| For 5 | 315 | 6.3 | ND | 7.8 | 0.30 | ND | (.05) | (0.5) | ND | ND | (.06) | ND | ND | ND | ND | ND | ND |

* Forester # matches those in Tables 2 and 3.
** ND = below the sampling and analytical limit of detection
\+ = Values in parenthesis are above the limit of detection but below the limit of quantitation

**For Information on Other**
**Occupational Safety and Health Concerns**

**Call NIOSH at:**
**1–800–35–NIOSH (356–4674)**
**or visit the NIOSH Web site at:**
**www.cdc.gov/niosh**