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# Ototoxic Occupational Exposures for a Stock Car Racing Team: II. Chemical Surveys

Kristin K. Gwin,<sup>1</sup> Kenneth M. Wallingford,<sup>1</sup> Thais C. Morata,<sup>2</sup>  
Luann E. Van Campen,<sup>2,\*</sup> Jacques Dallaire,<sup>3</sup> and Frank J. Alvarez<sup>3</sup>

<sup>1</sup>Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies, National Institute for Occupational Safety and Health, Cincinnati, Ohio

<sup>2</sup>Hearing Loss Prevention Section, Division of Applied Research and Technology, National Institute for Occupational Safety and Health, Cincinnati, Ohio

<sup>3</sup>Human Performance International, Inc., Charlotte, North Carolina

\*Currently at Eli Lilly and Company, Indianapolis, Indiana

*The National Institute for Occupational Safety and Health (NIOSH) conducted a series of surveys to evaluate occupational exposure to noise and potentially ototoxic chemical agents among members of a professional stock car racing team. Exposure assessments included site visits to the team's race shop and a worst-case scenario racetrack. During site visits to the race team's shop, area samples were collected to measure exposures to potentially ototoxic chemicals, including, organic compounds (typical of solvents), metals, and carbon monoxide (CO). Exposures to these chemicals were all below their corresponding Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs), NIOSH recommended exposure limits (RELs), and American Conference of Governmental Industrial Hygienists (ACGIH<sup>®</sup>) threshold limit values (TLVs<sup>®</sup>). During site visits to the racetrack, area and personal samples were collected for organic compounds, lead, and CO in and around the "pit" area where the cars undergo race preparation and service during the race. Exposures to organic compounds and lead were either nondetectable or too low to quantify. Twenty-five percent of the CO time-weighted average concentrations exceeded the OSHA PEL, NIOSH REL, and ACGIH TLV after being adjusted for a 10-hour workday. Peak CO measurements exceeded the NIOSH recommended ceiling limit of 200 ppm. Based on these data, exposures to potentially ototoxic chemicals are probably not high enough to produce an adverse effect greater than that produced by the high sound pressure levels alone. However, carbon monoxide levels occasionally exceeded all evaluation criteria at the racetrack.*

**Keywords** automobile racing, professional stock car racing, race shop, racetrack, carbon monoxide, CO, lead, organic compounds, solvents

Address correspondence to Kristin K. Gwin, U.S. Department of Agriculture, Food Safety and Inspection Service, Environmental Health and Safety Branch, 5601 Sunnyside Avenue, Beltsville, MD; e-mail: kristin.gwin@fsis.usda.gov

## INTRODUCTION

The high-performance automobile racing industry encompasses a large occupational workforce. It is composed of five individual racing organizations, each of which can include one or more different racing series in which race teams compete. The National Association of Stock Car Automobile Racing (NASCAR) consists of three different racing series: Nextel Cup (formerly Winston Cup), Busch, and Craftsman Truck Series. The Nextel Cup and Busch Series each consist of approximately 43 racing teams and compete in 41 and 33 races, respectively, at approximately 23 different racetracks throughout the United States from February through November of each year. Formula One consists of approximately 20 race teams, Championship Auto Racing Teams (CART) has approximately 25 race teams, and the Indy Racing League (IRL) consists of approximately 38 race teams. The National Hot Rod Association (NHRA) has five different racing series, each consisting of a varying number of race teams. An individual race team may consist of as many as 15 to 20 people, thereby demonstrating a significant number of individuals within this working population. In addition, professional automobile racing has become a popular and fast-growing sport. However, this occupation has received very little, if any, investigation into the occupational exposures that the individuals working in this sport may encounter.

Although high-performance automobile racing has a strong record of safety innovations and practices, hazardous noise and chemical exposures have not been empirically studied. Moreover, the effects of these agents on hearing, communication, and job performance are unknown. Symptoms potentially related to chemical exposure, including fatigue, nausea, headache, and weakness, have also been reported by professional racing drivers after completing a race. In addition, one

Winston Cup driver was diagnosed with carbon monoxide (CO) poisoning, which caused him to stop racing.<sup>(1)</sup>

There are virtually no published data regarding the potentially ototoxic chemical exposures such as organic compounds (typically found in solvents), lead and other metals, and CO, during the building and racing of high-performance automobiles. However, reports in the published literature for these potentially ototoxic chemicals in other working populations have indicated these exposures are associated with neurobehavioral disorders and visual and auditory dysfunction.<sup>(2–5)</sup>

Because of unanswered questions regarding the health, safety, and performance effects of mixed (i.e., noise and chemicals) exposures in the automobile racing industry, the National Institute for Occupational Safety and Health (NIOSH) partnered with a professional stock car racing team to evaluate occupational exposures to these agents. The purpose of these surveys was to assess the level of exposures to potentially ototoxic chemicals. Exposure assessments included two site visits to the race team's shop located in Charlotte, North Carolina, and two site visits to Bristol Motor Speedway located in Bristol, Tennessee. This racetrack was chosen because members of the stock car racing team felt that Bristol Motor Speedway represented a worst-case exposure scenario for noise and CO due to its small size, steep banking, and high grandstand configuration that creates a semienclosed bowl-like configuration. This article reports exposure levels for potentially ototoxic chemicals, while the companion article reports exposure levels for noise.

## METHODS

Area samples for organic compounds (typically found in solvents) were collected on either thermal desorption or charcoal tubes. Samples collected on the thermal desorption tubes were used as a qualitative screen to identify the most abundant organic compounds present. Samples collected on the charcoal tubes were analyzed quantitatively for specific organic compounds that were previously identified from the qualitative screen. Air samples collected on thermal desorption tubes using battery-powered sampling pumps calibrated at flow rates of either 0.05 or 0.10 L/min, were thermally desorbed in a PerkinElmer ATD 400 automatic thermal desorption system (PerkinElmer, Boston, Mass.). The thermal unit was directly interfaced to an HP6890A gas chromatograph (Hewlett-Packard, Avondale, Pa.) with an HP5973 mass selective detector (TD-GC-MSD) for analysis using *NIOSH Manual of Analytical Methods* (NMAM) 2549, with modifications.<sup>(6)</sup> Air samples collected on coconut shell charcoal tubes used battery-powered sampling pumps calibrated at flow rates of 0.01, 0.05, or 0.20 L/min. To avoid breakthrough, the charcoal tubes were routinely changed throughout the work shift before the maximum recommended air sample volumes were reached. The charcoal tubes were desorbed with 1.0 mL of carbon disulfide and analyzed using a gas chromatograph (GC) equipped with a flame ionization detector. Depending on the job being performed during the sampling period, the charcoal

tube air samples were quantitatively analyzed for one or more of the following organic compounds: acetone (minimum quantifiable concentration [MQC] 0.07 parts per million [ppm]), n-butyl acetate (MQC 0.007 ppm), epichlorohydrin (MQC 0.02 ppm), ethyl benzene (MQC 0.007 ppm), n-hexane (MQC 0.01 ppm), methylene chloride (MQC 0.18 ppm), naphthas (MQC 0.06 ppm), perchloroethylene (MQC 0.03–0.16 ppm), styrene (MQC 0.10–0.47 ppm), toluene (MQC 0.01 ppm), 1,1,1-trichloroethane (MQC 0.02 ppm), trichloroethylene (MQC 0.01–0.02 ppm), xylenes (MQC 0.03 ppm), and total hydrocarbons (MQC 0.08 ppm). (Total hydrocarbons were quantified using a heptane standard.) No analytical method is available for the analysis of these analytes on the same sorbent. Therefore, these analyses were performed using a combination of conditions from methods NMAM 1003, 1022, 1300, 1450, 1457, 1500, 1501, and 1550, with modifications.<sup>(7–14)</sup>

Direct-reading measurements were taken for airborne toluene using Dräger detector tubes. Ten hand pump strokes were used for a detection range of 5 to 80 ppm toluene.

An area sample was collected for metals and other elements on a 0.80  $\mu\text{m}$  pore size, 37 mm diameter, cellulose ester membrane (CEM) filter, using a battery-powered sampling pump calibrated at a flow rate of 1.0 L/min. Analysis was performed as described in NMAM 7300 using inductively coupled plasma emission spectrometry (MQC 0.001–1.1  $\text{mg}/\text{m}^3$ ).<sup>(15)</sup>

Area samples were collected for lead (stock cars use 110 octane leaded gasoline for fuel) on 0.80  $\mu\text{m}$  pore size, 37 mm diameter, CEM filters, using battery-powered sampling pumps calibrated at a flow rate of 3.0 L/min. This flow rate was chosen to ensure the minimum volume as specified in NMAM 7802 (200 L at 0.05  $\text{mg}/\text{m}^3$ ) was captured during the short duration of the race. The air samples were analyzed as described in NMAM 7082 (MQC 0.02  $\text{mg}/\text{m}^3$ ) and 7105 (MQC 0.0005  $\text{mg}/\text{m}^3$ ) using flame atomic absorption spectroscopy and graphite furnace atomic absorption spectroscopy, respectively.<sup>(16,17)</sup> (The latter is the more sensitive analytical procedure and is used when no lead is detected on the sample analyzed using flame atomic absorption spectroscopy.)

Direct-reading CO measurements were made using Toxi Ultra Atmospheric Monitors (Biosystems, Middletown, Conn.) equipped with CO sensors as described in NMAM 6604.<sup>(18)</sup> The Toxi Ultra monitors were placed next to the other area samples during each sampling period. These monitors have a nominal range of 0 to 500 ppm with the highest accurate instantaneous reading of 1000 ppm. The instruments were operated in the passive diffusion mode and were programmed to record concentrations averaged over each minute. The peak CO measurements reported in these surveys are the highest 1-min average values within each specified time period. Data were stored in an internal data logger and later downloaded to a personal computer for data handling.

All battery-powered sampling pumps were calibrated before and after use with a primary standard calibration device. The detector tube hand pump was leak tested and calibrated before and after use with a primary standard calibration device. Calibration of the Toxi Ultra CO monitors was performed

**TABLE I. Area Air Sample Results at Race Shop: Initial Site Visit, Charlotte, North Carolina**

Compound	Airborne Concentration (ppm)					OSHA PEL <sup>F</sup> (ppm)	NIOSH REL <sup>G</sup> (ppm)	ACGIH TLV <sup>F</sup> (ppm)
	Gear Room (8-Hour TWA) <sup>A</sup>	Fabrication Area (8-Hour TWA) <sup>B</sup>	Fabrication Area (8-Hour TWA) <sup>C</sup>	Fabrication Area (5-Hour TWA) <sup>D</sup>	Fabrication Area (5-Hour TWA) <sup>E</sup>			
Acetone	0.07	0.08	0.08	<0.07 <sup>H</sup>	<0.07 <sup>H</sup>	1000	250	500
Carbon monoxide	0.50/6.0 <sup>I</sup>	3.8/105 <sup>I</sup>	3.6/91 <sup>I</sup>	4.0/84 <sup>I</sup>	5.6/117 <sup>I</sup>	50	35/200 <sup>J</sup>	25
n-Hexane	0.19	0.32	0.32	0.27	0.22	500	50	50
Hydrocarbons (total) <sup>K</sup>	4.4	2.8	2.8	4.2	3.9	500	85	400
Perchloroethylene	<0.10 <sup>H</sup>	<0.10 <sup>H</sup>	<0.10 <sup>H</sup>	<0.16 <sup>H</sup>	<0.16 <sup>H</sup>	100	Ca <sup>L</sup>	25
Styrene	<0.10 <sup>H</sup>	<0.10 <sup>H</sup>	<0.10 <sup>H</sup>	<0.15 <sup>H</sup>	<0.15 <sup>H</sup>	100	50	20
Toluene	1.4	1.1	1.1	1.6	1.6	200	100	50
Trichloroethylene	0.09	0.01	0.01	0.02	0.02	100	25	50
Xylenes (total)	0.09	0.05	0.06	0.08	0.08	100	100	100

<sup>A</sup> Sample located in the gear/suspension room by a Safety Kleen parts-cleaning station.

<sup>B</sup> Sample located in the fabrication area near a TIG welding station.

<sup>C</sup> Sample located in the fabrication area adjacent to the painting booth.

<sup>D</sup> Sample located in the fabrication area adjacent to the body shop.

<sup>E</sup> Sample located in the fabrication area near the engine testing station.

<sup>F</sup> 8-Hour time-weighted average.

<sup>G</sup> 10-Hour time-weighted average.

<sup>H</sup> Result = less than the minimum quantifiable concentration.

<sup>I</sup> TWA concentration/peak concentration.

<sup>J</sup> NIOSH REL/ceiling (not to be exceeded).

<sup>K</sup> Hydrocarbons (total) is the sum of all detected compounds minus acetone, n-hexane, perchloroethylene, styrene, toluene, trichloroethylene, and xylenes (total).

<sup>L</sup> Ca = potential occupational carcinogen; NIOSH recommends that the airborne concentration be reduced to the lowest feasible level.

before and after use with a span gas according to the manufacturer's instructions. Analytical quality assurance for the organic compounds and metals air samples included the use of field blanks and media blanks, which were forwarded to the analytical laboratory with the air samples and analyzed at the same time. All reported airborne concentrations have been blank-corrected if necessary. The MQC was calculated for each nondetectable analyte according to the laboratory determined limit of quantitation and are reported in Tables I and II for the appropriate analytes.

### Race Shop Chemical Exposure Assessment

The race team's shop is a large, one-story building with approximately 1390 square meters of indoor floor space divided into two main areas: set up and fabrication. The set-up area consists of a gear/suspension room and a large open space where the mechanics install the suspension, engine, and driveline in the cars. The fabrication area is a large room in the rear of the building consisting of a paint/body shop with an enclosed paint booth, a machine shop, a metal working area that includes metal inert gas (MIG) and tungsten inert gas (TIG) welding stations, and a storage area. Most of the race shop workers perform a variety of tasks during their typical 10-hour work shift.

Two site visits were made to the race team's shop; a 2-day visit and a follow-up 1-day visit 3 weeks later. During the initial

2-day site visit, area samples were collected at five locations for organic compounds and CO to measure the potential chemical exposures of workers in the gear/suspension and fabrication areas. During the follow-up 1-day site visit, area samples were collected at four locations for organic compounds to measure potential exposures to workers in the paint booth/body shop (individual organic compound analytes were chosen based on a chemical inventory of the paint booth/body shop since this was not in operation during the initial site visit). Additionally, an area sample was collected at one location for metals and other elements to measure potential exposures during operation of the TIG welding machine in the fabrication area.

### Racetrack Chemical Exposure Assessment

Bristol Motor Speedway is a 0.533-mile (0.858-kilometer) oval track with 36° banking and seating capacity for 135,000 spectators. Grandstand seating extends upward around the track, creating a bowl-like configuration. All the race car haulers are parked in the infield area of the speedway. Teams are given limited space in front of the haulers to arrange their equipment and tools, which are used to tune the race cars in the pit area prior to the race. The pit area has marked positions for each of the race cars and is separated from the infield by a low concrete wall. During practice and the race, race cars cycle through the pit area for tuning adjustments, fuel, and tire changes.

**TABLE II. Area Air Sample Results at Race Shop: Follow-Up Site Visit, Charlotte, North Carolina**

Compound	Airborne Concentration (ppm)				OSHA PEL <sup>D</sup> (ppm)	NIOSH REL <sup>E</sup> (ppm)	ACGIH TLV <sup>D</sup> (ppm)
	Paint Booth <sup>A</sup>	Paint Booth <sup>B</sup>	Paint Mixing <sup>C</sup>	Body Shop			
Acetone	0.96	3.8	4.7	0.98	1000	250	500
n-Butyl acetate	0.15	0.06	0.29	0.05	150	150	150
Epichlorohydrin	<0.02 <sup>F</sup>	<0.02 <sup>F</sup>	<0.02 <sup>F</sup>	<0.02 <sup>F</sup>	5.0	Ca <sup>G</sup>	0.50
Ethyl benzene	0.20	0.03	<0.007 <sup>F</sup>	0.02	100	100	100
Methylene chloride	<0.18 <sup>F</sup>	<0.18 <sup>F</sup>	<0.18	<0.18 <sup>F</sup>	25	Ca <sup>G</sup>	50
Naphthas	3.2	2.6	7.6	2.7	100	100	—
Perchloroethylene	<0.03 <sup>F</sup>	<0.03 <sup>F</sup>	<0.03 <sup>F</sup>	<0.03 <sup>F</sup>	100	Ca <sup>G</sup>	25
Styrene	<0.47 <sup>F</sup>	<0.47 <sup>F</sup>	<0.47 <sup>F</sup>	<0.47 <sup>F</sup>	100	50	20
Toluene	0.72	0.74	3.0	0.66	200	100	50
1,1,1-Trichloroethane	0.04	0.03	0.07	0.02	350	350	350
Xylenes (total)	0.50	0.11	0.33	0.07	100	100	100

<sup>A</sup> Inside paint booth.

<sup>B</sup> Outside paint booth.

<sup>C</sup> Paint storage and mixing area.

<sup>D</sup> 8-hour time-weighted average.

<sup>E</sup> 10-hour time-weighted average.

<sup>F</sup> Result = less than minimum quantifiable concentration.

<sup>G</sup> Ca = potential occupational carcinogen; NIOSH recommends that the airborne concentration be reduced to the lowest feasible level.

During the initial site visit to the track, racing events took place over 2 days. The practice period and first round of qualifying took place the day before the race. There were 10 to 12 cars on the track during practice at any given time. On the day of the race, a total of 43 cars (positioned according to the driver's qualifying time) were in the starting lineup for the afternoon race. During the second site visit to the track 5 months later, all of the racing events were combined into 1 day due to the evening race time. In addition, a different racing series organization had a practice period during the same day, before the race. As with the first race, a total of 43 cars started this race.

During the first site visit to the racetrack, area samples were collected for organic compounds, lead and CO at two sites within the pit, and on the team's race car hauler behind the pit during the 1 hour and 48-min afternoon professional stock car race. During the second site visit, area samples were collected for CO at three locations within the pit and on the team's race car hauler behind the pit at the racetrack during practice, qualifying, and the night-time professional stock car race. Two NIOSH researchers also wore CO monitors at the racetrack throughout the entire day. In addition, a CO monitor was placed inside the race car near the driver's head during practice.

### Evaluation Criteria

Although there are many potentially ototoxic chemicals present in the stock car racing work environment, five from this pilot study have known ototoxic properties: CO, lead, styrene, toluene, and xylene. Carbon monoxide and lead were expected to be found in highest concentrations at the racetrack due to the use of gasoline-powered generators, the large amount of vehicle exhaust present, and the use of leaded gasoline in

the race cars. The highest concentrations of styrene, toluene, and xylene were expected at the race shop in the paint/body shop area because a chemical inventory revealed they were repeatedly found in the paints and products used in this area. The evaluation criteria for these potentially ototoxic chemicals were not established with regard to ototoxicity. These criteria are provided with the results in Tables I–IV.

## RESULTS

### Race Shop

During the initial 2-day visit to the race shop, multiple organic compounds typical of solvents were detected on the thermal desorption tubes used for qualitative screening. The most abundant compounds identified were C<sub>7</sub> alkanes and toluene. Other organic compounds identified included acetone, perchloroethylene, xylenes, trichloroethylene, hexane, and styrene. The quantitative 8-hour full-shift area samples collected the first day, and the 5-hour half-shift area samples collected on the second day, indicated concentrations of acetone, n-hexane, perchloroethylene, styrene, toluene, trichloroethylene, total hydrocarbons, and total xylenes that were either not detected, or were detected in extremely low levels, well below any applicable occupational exposure criteria as shown in Table I.

The time-weighted average (TWA) CO concentrations for both the 8-hour and 5-hour area samples collected during the initial site visit were well below the OSHA PEL of 50 ppm, the NIOSH REL of 35 ppm, and the ACGIH TLV of 25 ppm.<sup>(19–21)</sup> Peak CO concentrations on both days within the fabrication area did not exceed the NIOSH recommended ceiling limit of 200 ppm (Table I).<sup>(20)</sup>

During the follow-up site visit, the 10-hour full-shift area samples indicated concentrations of acetone, methylene chloride, naphthas, ethyl benzene, epichlorohydrin, perchloroethylene, total xylenes, styrene, toluene, 1,1,1-trichloroethane, and n-butyl acetate that were either not detected, or were detected in extremely low levels, well below any applicable occupational exposure criteria as shown in Table II.

Direct-reading measurements for toluene indicated airborne concentrations ranging from 6 to 20 ppm. Xylene and benzene were not detected on the detector tubes. Measurements were taken during the mixing of primer and paint, while a sealant coat was being applied to the race car's hood, and while the Safety Kleen lacquer thinner bath was running for approximately 30 sec while the paint gun was being cleaned. The highest measurement (20 ppm) was detected while the Safety Kleen bath was running (the local exhaust ventilation system mounted at the top of the bath was not operational). The direct-reading toluene measurements were all below the OSHA PEL of 200 ppm, the NIOSH REL of 100 ppm, and the ACGIH TLV of 50 ppm.<sup>(19-21)</sup> (This sample data is not shown in the tables.)

The short-term area sample collected for metals and other elements near a TIG welding station in the fabrication shop revealed no detectable concentrations, with the exception of manganese. However, the detected concentration of manganese (0.012 mg/m<sup>3</sup>) was less than the NIOSH recommended short-term exposure limit (STEL) of 3.0 mg/m<sup>3</sup>.<sup>(20)</sup> (This sample data is not shown in the tables.)

### Racetrack

During the first 2-day site visit to the racetrack, qualitative analysis of three area samples collected on thermal desorption tubes identified multiple organic compounds typical of solvents. The most abundant compounds identified were isopentane, C<sub>8</sub> alkanes (isooctane, dimethylhexanes, trimethylpentanes), and toluene. Other compounds identified included various C<sub>4</sub>-C<sub>9</sub> alkanes, benzene, perchloroethylene, xylene, butyl cellosolve, alkyl benzenes, naphthalene, and limonene. However, the amounts of even the most abundant compounds

identified were too low to quantify. (This sample data is not shown in the tables.)

The three lead area samples revealed non-detectable concentrations after the initial analysis was performed using flame atomic absorption spectroscopy. The more sensitive method of analysis (graphite furnace atomic absorption spectroscopy), performed subsequently, determined the highest concentration of lead to be 5.0 μg/m<sup>3</sup>, below the OSHA PEL of 50 μg/m<sup>3</sup>, the NIOSH REL of 100 μg/m<sup>3</sup>, and the ACGIH TLV of 50 μg/m<sup>3</sup>.<sup>19-21</sup> (This sample data is not shown in the tables.)

The TWA and peak CO concentrations collected at three locations during the first race are shown in Table III. The 1-hour, 48-min TWA CO concentrations (12 to 14 ppm) were well below the OSHA PEL of 50 ppm, the NIOSH REL of 35 ppm, and the ACGIH TLV of 25 ppm.<sup>(19-21)</sup> However, these occupational evaluation criteria are 8- and 10-hour TWAs and therefore the TWA CO concentrations cannot be directly compared to these exposure standards. The peak concentrations measured during the race (31 to 55 ppm) did not exceed the NIOSH recommended ceiling limit of 200 ppm.<sup>(20)</sup>

During the second site visit to Bristol Motor Speedway 5 months later, the TWA and peak CO concentrations on top of the race car hauler, and on both the left and right sides of the toolbox located in the pit area were measured during the practice period (10:30 a.m. to 12:30 p.m.), qualifying (3:35 p.m. to 4:40 p.m.), and the professional stock car race (7:04 p.m. to 8:53 p.m.) (Table IV). Two additional CO monitors were placed on a speaker post by the pit and in the race car during the practice period. Peak CO concentrations exceeded the NIOSH recommended ceiling limit of 200 ppm in three of five locations during the practice period (202, 235, and 458 ppm).<sup>(20)</sup> Peak CO concentrations recorded during qualifying and the race did not exceed the NIOSH recommended ceiling limit of 200 ppm (range of 19 to 118 ppm).<sup>(20)</sup>

Table IV also shows the TWA and peak CO concentrations for these same locations for the entire day (approximately 10 hours and 23 min; 10:30 a.m. to 8:53 p.m.). Peak concentrations in two of the three locations (on the toolbox in the pit) exceeded 200 ppm (235 and 835 ppm). The greatest peak concentration

**TABLE III. Carbon Monoxide Air Sample Results: Initial Site Visit, Bristol Motor Speedway, Bristol, Tennessee**

Sample Location	Carbon Monoxide Concentration (ppm)					
	TWA <sup>A</sup>	Peak	OSHA PEL: <sup>B</sup> 50	NIOSH REL: <sup>C</sup> 35/C: <sup>D</sup> 200	ACGIH TLV: <sup>B</sup> 25	IDLH: <sup>E</sup> 1200
Pit toolbox (left side)	14	55				
Pit toolbox (right side)	12	31				
Top of race car hauler	13	52				
Carbon monoxide evaluation criteria (ppm)						

<sup>A</sup>TWA concentration during the 1-hour, 48-min stock car race.

<sup>B</sup>8-hour time-weighted average.

<sup>C</sup>10-hour time-weighted average.

<sup>D</sup>C = ceiling concentration not to be exceeded.

<sup>E</sup>IDLH = immediately dangerous to life and health.

**TABLE IV. Carbon Monoxide Air Sample Results: Follow-Up Site Visit, Bristol Motor Speedway, Bristol, Tennessee**

Sample Location	Carbon Monoxide Concentration (ppm)							
	Practice (2 hours)		Qualifying (1 hour, 5 min)		Race (1 hour, 49 min)		Full Day (10 hours, 23 min)	
	TWA	Peak	TWA	Peak	TWA	Peak	TWA	Peak
Top of race car hauler	14	33	16	32	11	24	15	40
Pit toolbox (left side)	157	458	10	41	5.2/5.7/5.7 <sup>A</sup>	26/19/40 <sup>A</sup>	86	835
Pit toolbox (right side)	76	235	11	118	5.8/7.7 <sup>A</sup>	27/33 <sup>A</sup>	35	235
Pit speaker post	32	126	—	—	—	—	—	—
Race car interior	36	202	—	—	—	—	—	—
Personal 1	20	151	15	42	12	41	14 <sup>B</sup>	151
Personal 2	6.8	30	4.4	19	7.6	25	5.7 <sup>B</sup>	40
Carbon monoxide evaluation criteria (ppm)	OSHA PEL: <sup>C</sup> 50		NIOSH REL: <sup>D</sup> 35/ <sup>C</sup> : <sup>E</sup> 200		ACGIH TLV: <sup>C</sup> 25		IDLH: <sup>F</sup> 1200	

<sup>A</sup> Sequential averages.

<sup>B</sup> 11-hour, 23-min TWA concentration.

<sup>C</sup> 8-hour time-weighted average.

<sup>D</sup> 10-hour time-weighted average.

<sup>E</sup> C = ceiling concentration not to be exceeded.

<sup>F</sup> IDLH = immediately dangerous to life and health.

(835 ppm) occurred during the other racing series practice period (12:45 p.m. to 3:15 p.m.) and was measured on the monitor located in the pit on the left side of the toolbox.

The full-shift TWA concentration measured on the left side of the toolbox in the pit (86 ppm) exceeded the OSHA PEL, NIOSH REL, and ACGIH TLV of 40, 35, and 20 ppm, respectively, after the exposure criteria were adjusted for a 10-hour work shift. The 10-hour, 23-min TWA concentration measured on the right side of the toolbox (35 ppm) exceeded the adjusted ACGIH TLV of 20 ppm.<sup>(21)</sup>

In addition, Table IV gives the personal breathing zone CO sampling results collected on the two NIOSH researchers during the second site visit to the racetrack. Time-weighted average and peak CO concentrations are given for the practice period, qualifying, the professional stock car series race, and the entire day from arrival at the track's infield through the end of the race (11 hours, 23 mins; 9:30 a.m. to 8:53 p.m.). The full-shift TWA concentrations (5.7 and 14 ppm) did not exceed the OSHA PEL, NIOSH REL, and ACGIH TLV of 35, 30, and 18 ppm, respectively, after they were adjusted for an 11½-hour workday.<sup>(19-21)</sup> None of the peak concentrations exceeded the NIOSH recommended ceiling limit of 200 ppm (40 and 151 ppm).<sup>(20)</sup>

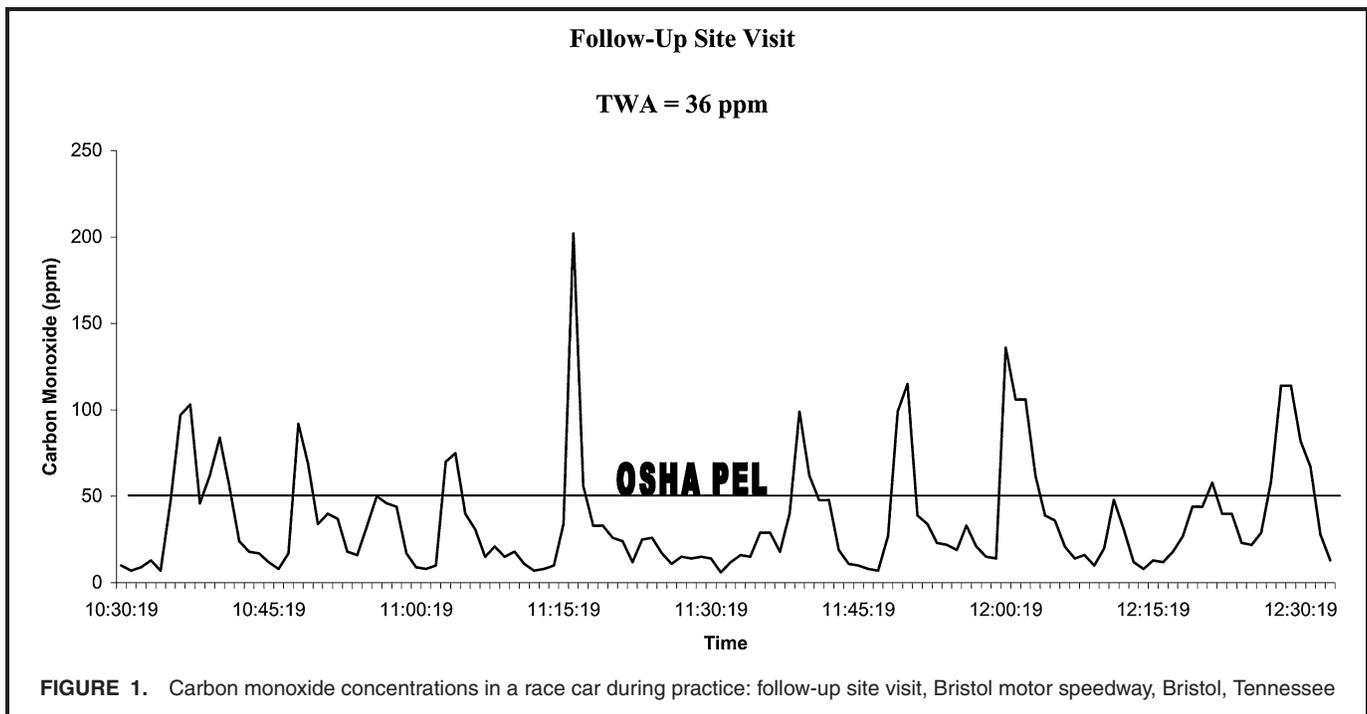
Table IV and Figure 1 show the CO measurements from inside the race car during the practice period (10:30 a.m. to 12:30 p.m.). The 2-hour TWA CO concentration was 36 ppm and the highest peak concentration was 202 ppm, exceeding the NIOSH recommended ceiling limit of 200 ppm.<sup>(20)</sup> The CO measurements shown in Figure 1 are the average concentrations measured over 1-min intervals.

## DISCUSSION

Air sampling at the racing team's race shop and the race-track revealed that organic compound concentrations and levels of lead and other metals were either not detected or were extremely low, and well below any occupational exposure criteria. Carbon monoxide levels never exceeded the 8-hour TWA exposure criteria, or the NIOSH recommended ceiling limit at the race shop.

Carbon monoxide measurements taken during the first race could not be compared with 8-hour TWA exposure criteria because the duration of the race was less than 2 hours. However, none of the peak CO measurements exceeded the NIOSH ceiling limit of 200 ppm.<sup>(20)</sup>

A trend was observed between peak CO concentrations and some of the laps that were run under caution. Laps run under caution during the middle of the race coincided with higher peak concentrations as compared with laps run under caution during the beginning or end of the race, or laps run under normal race conditions. During pit stops cars are refueled, tires are changed, and adjustments are made to the car. Generally, the majority of pit stops are taken during laps run under caution well into the race when fuel and/or new tires are needed. The timing of pit stops is strategically important in terms of the driver's track position. Because of this, cars generally pit together to either keep from losing positions, or to possibly gain positions. Thus, it is likely that an accumulation of CO generated from vehicle exhaust would be detected in higher concentrations in the pit area when a greater number of cars pit simultaneously. This generally occurs during the middle of the race.



This same trend was also observed during the second race. Two distinct CO peaks were recorded during the race at approximately 7:45 p.m. and 8:06 p.m. on all five monitors located on the toolbox in the pit area. The peaks recorded at 7:45 p.m. ranged from 18 ppm to 40 ppm, whereas the peaks recorded at approximately 8:06 p.m. ranged from 19 ppm to 31 ppm. These highest CO peaks observed during the race coincide with the evaluated team's pit stops. Some of the elevated peaks also corresponded to laps run under caution during the middle of the race.

Measurements taken throughout the entire day during the second visit to the racetrack revealed TWA and peak CO concentrations in the pit that exceeded the OSHA PEL, NIOSH REL, and ACGIH TLV (after adjustment for a 10-hour work day), and the NIOSH recommended ceiling limit.<sup>(19–21)</sup> The peak concentration for the full day (835 ppm) was the greatest CO concentration measured at the track. It was measured on the monitor located in the pit on the left side of the toolbox during the other racing series' practice period. When TWA and peak concentrations were analyzed for each individual event, the greatest concentrations occurred during the practice period. Peak CO concentrations recorded at both locations in the pit (235 ppm and 458 ppm) and in the race car (202 ppm) exceeded the NIOSH recommended ceiling limit.<sup>(20)</sup> The lowest levels occurred on top of the team's race car hauler, the farthest sampling location from the track and pit.

The main source of CO during the practice period appears to be the small gasoline-powered engines used by the racing teams to power electrical generators. Generators are used to power tools that are used to make adjustments to the race car. Generally, on practice days, the generators are turned

on when the team sets up at the track in the morning and run extensively throughout the day up until the race because adjustments are made on a continuous basis. This is corroborated by the location of the CO monitor that recorded the highest TWA and peak concentrations during both practice periods. This particular monitor was located in the pit on the left side of the toolbox, adjacent to the operating small gasoline-powered engine. The results from the personal CO samples followed the same trend observed in the area samples; the highest concentrations occurred during the practice period while the NIOSH investigator wearing the monitor was by the left side of the toolbox in the pit area checking the area monitors. Area samples cannot be considered representative of personal breathing zone samples. The trend only supports the speculation that the small gasoline-powered engines used to power the generators are the main source of CO exposure at the racetrack.

In addition, it was observed that there were fewer number of race cars (10 to 12) on the track at any given time during practice as compared with the number of cars on the track during the races (43 to start). However, the CO concentrations measured during the practice periods were substantially greater than those measured during the race. This supports the speculation that CO generated solely from vehicle exhaust does not have as great an effect on exposure as that generated by the small gasoline-powered engines.

Due to the large difference in CO concentrations observed during the practice period, as compared with the race when small gasoline-powered engines are not used, it appears that small gasoline-powered engines may be the greatest source of CO exposure at racing events.

## CONCLUSIONS

Based on the data collected during these surveys, exposures to potentially ototoxic chemicals are probably not high enough to produce an adverse effect on hearing greater than that produced by the high sound pressure levels alone as reported in the companion article.

The small gasoline-powered engines, which are used to power electrical generators, appear to be the greatest source of CO exposure at stock car racing events. This is illustrated when comparing TWA and peak CO concentrations measured during the second visit to the racetrack. The greatest concentrations were observed during the practice periods, a period during which all race teams require the use of small gasoline-powered engines to power the tools that are used to make adjustments to the race car. In comparison, the lowest concentrations were measured during the race, when the use of small gasoline-powered engines is not permitted.

In summary, CO generated solely from vehicle exhaust during the race does not appear to accumulate in a uniform manner and does not appear to have as great an effect on exposure as that generated by the small gasoline-powered engines used to power tools.

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