

Health Consultation

**INVESTIGATION OF CARBON MONOXIDE EXPOSURE FROM
RECREATIONAL WATERCRAFT**

**LAKE PLEASANT REGIONAL PARK
MARICOPA COUNTY, ARIZONA**

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**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
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INTRODUCTION

The Arizona Department of Health Services (ADHS) conducted a carbon monoxide exposure survey among recreational boaters at the Maricopa County Lake Pleasant Regional Park during the 2003 Labor Day weekend. To investigate the extent that recreational boaters are exposed to carbon monoxide from a variety of watercraft, ADHS measured exhaled carbon monoxide to determine the amount of carboxyhemoglobin (COHb) present in their blood.

To determine whether a widespread public health hazard exists because of carbon monoxide exposure from watercraft, the ADHS health consultation, *Investigation of Carbon Monoxide Exposure, Rotary Beach at the London Bridge, Lake Havasu, Arizona, May 25-26, 2003*, recommended conducting further biomonitoring studies at other recreational lakes in Arizona.

ADHS asked the Agency for Toxic Substances and Disease Registry (ATSDR), under its Cooperative Agreement Program with ADHS, to interpret data from the Lake Pleasant survey and to determine whether carbon monoxide exposure is a public health hazard among recreational boaters at Lake Pleasant.

BACKGROUND

Carbon monoxide (CO) is an odorless, colorless gas that results from incomplete combustion of carbon compounds. Until recently, CO poisonings were thought to occur only indoors in enclosed, poorly ventilated areas. However, open-air cases of poisoning have been documented that include exposures to exhaust from various kinds of watercraft such as houseboats, cabin cruisers, and ski boats. Unlike automobiles, boat engines currently do not have mechanisms to reduce CO emissions.

Previous studies at Lake Havasu and Lake Powell, combined with other national data indicate that CO poisoning from recreational watercraft presents a substantial health hazard. The United States Coast Guard identified 493 CO poisonings between 1990 and 2000. Of these, 214 (43%) fatal and non-fatal poisonings occurred on boats other than houseboats. Lake Powell, located in Arizona and Utah, accounted for 165 (33%) of these poisonings. The United States Coast Guard has issued warnings to all boat owners concerning the potential for CO exposure and the risk of severe injury and death.¹

Lake Pleasant Regional Park

Lake Pleasant Regional Park is located 30 miles northwest of the Phoenix metropolitan area. The lake has 114 miles of shoreline for recreation uses. Recreational facilities are concentrated primarily on the western shore of the lake. The most popular activities at Lake Pleasant include boating, water skiing, camping, picnicking, hiking, and fishing. Daytime temperatures during the summer may range from 110° to 115° Fahrenheit.²

According to the park police, Humbug Cove, at the far northern end of the lake, is a popular congregating area for boaters. Because the shoreline at Humbug Cove is inaccessible to boaters,

large numbers of boats congregate in the water. The cove is also not accessible to motorized vehicles.

METHODS

ADHS staff examined the concentration of CO in the exhaled air of 90 persons who participated in water activities at the lake on August 30, 2003. Exhaled CO was used as a measure of the amount of carboxyhemoglobin (COHb) in the participant’s blood.

Volunteers provided samples by blowing exhaled air into a single-use mouthpiece. The mouthpiece was discarded after each individual use. A Scott/Bacharach Instrument Carbon Monoxide Sniffer with a Breath Analysis Module and Bedfont ToxCO CO monitor was used to analyze exhaled air samples. The module included an internal mechanism to ensure that ethanol did not interfere with the analytic results. Ambient air readings for CO were taken with a BW Technologies Multi-Gas Defender Detector.

ADHS staff also administered a short questionnaire as part of the survey. Participants were asked whether they smoked, what types of activities they had been participating in, and how long they had been at the lake. Personal identifiers were not recorded.

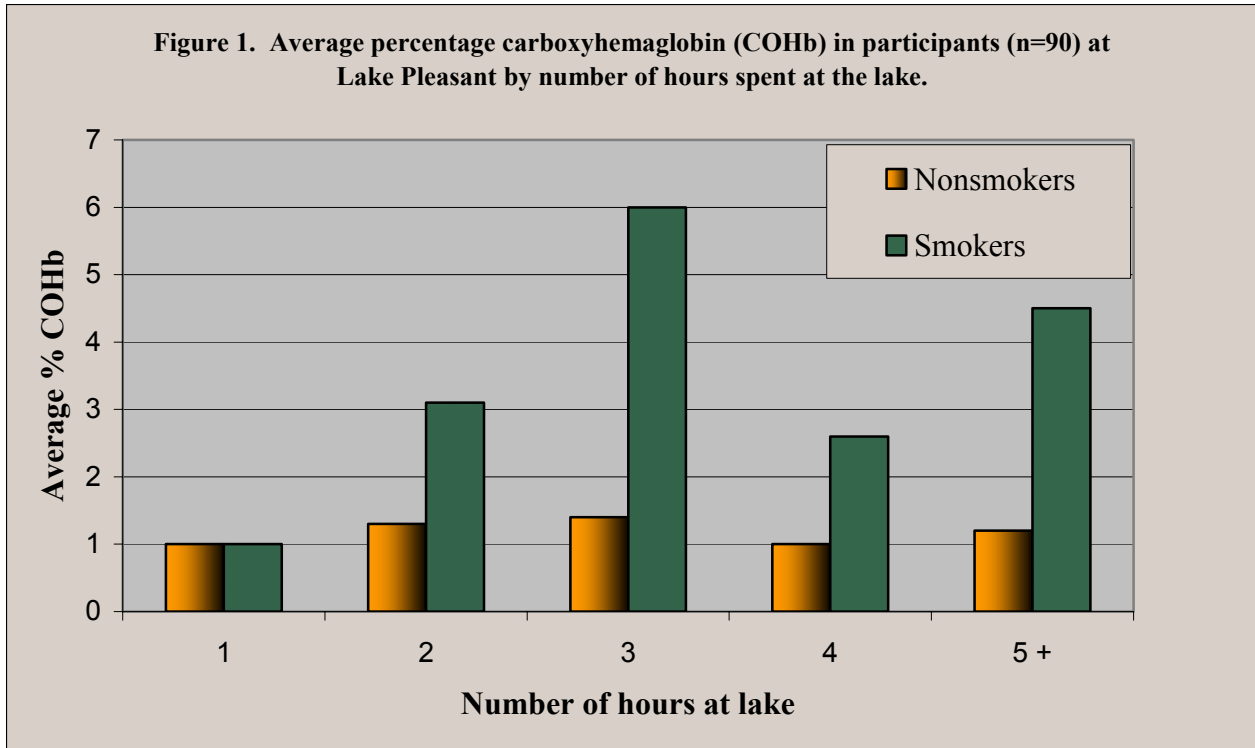
The time of day, general weather conditions, concentration of CO in the exhaled air of each participant, and the CO levels in ambient air were all recorded. Exhaled CO levels were converted to % COHb using a standardized conversion chart. Microsoft Excel® was used for data analysis.

RESULTS

Results of the analysis suggest that low levels of CO exposure occurred among participants during the survey. Results are presented in Table 1. The maximum COHb level observed for nonsmokers was 4.4 % COHb, and the maximum for smokers was 6.6 %.

Table 1. Percentage of carboxyhemoglobin (COHb) measured in participants at Lake Pleasant, AZ, Regional Park, August 30, 2003

Number of hours spent in recreation at time of sampling	Average % COHb, non-smokers	Number of non-smoking participants (n=67)	Average % COHb, smokers	Number of smoking participants (n=23)
1	1.0	16	1	3
2	1.3	3	3.1	3
3	1.4	7	6	1
4	1.0	8	2.6	5
>5	1.2	33	4.5	11



The average percentage COHb in the 67 non-smoking participants was low (1.1% COHb) and was less than 2 %, regardless of the time spent at the lake. These levels are below the threshold for adverse health effects.

The average percentage COHb in the 23 smoking participants was 3.5 %. These levels were below the threshold for adverse health effects except for one individual who had been at the lake for 3 hours and had smoked several cigarettes. Seven participants who smoked exceeded the threshold for mild adverse health effects, with individual percentages COHb ranging from 5.1% to 6.6 %.

Ambient air measurements of CO were non-detectable except when the Sea Arc workboat used by ADHS staff was nearby with the engines idling. The Sea Ark is a 43-foot, flat-bottom work boat operated by the Lake Pleasant Maintenance Department. It is capable of running in less than 6 inches of water and thus can run directly onto the shoreline. Any measurable levels of CO were attributed to idling engines on the Sea Ark.

DISCUSSION

Carbon Monoxide

Incomplete burning of gasoline produces CO, which is a colorless, odorless, tasteless gas. CO may overcome an exposed person without warning. Initial symptoms of CO poisoning may include headache, dizziness, drowsiness, or nausea. Symptoms may advance to vomiting, loss of consciousness, and collapse from prolonged or high exposure. Coma or death may occur if high

exposures continue.⁽³⁻⁹⁾ Symptoms vary widely among individuals and may occur sooner in sensitive persons such as the young or elderly, persons with preexisting lung or heart disease, or those who live at high altitudes. Health effects from CO exposure are listed in Table 2.

Table 2. Health effects from carbon monoxide exposure, by percentage of carboxyhemoglobin (COHb) in the blood

% COHb	Symptom
< 5	None
5-10	Slight headache, decreased exercise tolerance
10-20	Mild dyspnea on exertion, headache
20-30	Throbbing headache, mild nausea, some impaired judgment
30-40	Severe headache, nausea and vomiting, impaired judgment
40-50	Confusion and syncope
50-60	Syncope, coma, seizures
60-70	Coma, seizures, cardiorespiratory depression, death
>70	Failing hemodynamic status, death

By binding with hemoglobin to form carboxyhemoglobin, CO limits the ability of blood to carry oxygen to body tissues. Once exposed, the body compensates for the reduced blood-borne oxygen by increasing cardiac output, thereby increasing blood flow to specific oxygen-demanding organs such as the brain and heart. This action may be limited by preexisting heart or lung diseases that inhibit increased cardiac output.

Blood has an estimated 210-250 times greater affinity for CO than for oxygen. Once absorbed into the bloodstream, CO has a half-life ranging from 2 to 6.5 hours.¹⁰ When oxygen is administered to an exposed person, as happens in emergency treatment, the half-life is decreased by as much as 75% (to approximately 40 minutes). Hyperbaric treatment, which is the delivery of oxygen under pressure, reduces the half-life of CO to approximately 20 minutes.⁽³⁻⁹⁾

The smoking of cigarettes and other tobacco products increases COHb. The increase in COHb levels observed in this study among active smokers is likely due to the smoking of tobacco products. These persons may likely experience chronic mild symptoms of carbon monoxide exposure including headache or decreased exercise tolerance because of their active smoking.¹⁰

Comparison of Lake Pleasant and Lake Havasu studies

Participants at Lake Pleasant had much lower % COHb than did participants in an earlier study conducted by ADHS at Lake Havasu.¹¹ The Lake Havasu study identified a public health hazard based on data collected during the 2003 Memorial Day weekend.

The Lake Pleasant and Lake Havasu study areas differed in several ways. The Lake Pleasant Regional Park consists of large, wide-open areas that resulted in a much lower density of boats compared with Rotary Beach at Lake Havasu. Winds were relatively light during the Lake Pleasant study period. In addition, water levels at the lake were substantially below normal because of the ongoing severe drought in the southwestern United States. Water levels combined

with the greater than 100° Fahrenheit temperatures most likely limited the number of boaters using the lake during the Labor Day weekend.

Lake Pleasant is close to the Phoenix metropolitan area, and this allows many boaters to visit the lake for few hours and return home. The ambient air temperatures during the study period ranged from a sunny 104° to 107° Fahrenheit making it unlikely that boaters would spend very many hours out on the lake at one time.

Boaters at Lake Havasu tend to spend more consecutive hours in the channel by the bridge and do not usually dock and exit their boats as often as boaters at Lake Pleasant do. Boaters at Lake Pleasant frequently go on and off the water to swim off the beaches and seek shade and cover. Numerous accessible beaches and picnic areas are available for Lake Pleasant boaters to frequent, contrasted with the closed channel at Rotary Beach, Lake Havasu.

Alcohol consumption was not as common among participants at Lake Pleasant as it was among participants at Lake Havasu. Alcohol consumption and CO poisoning may cause similar symptoms including headache, impaired judgment, nausea, and vomiting. The combination of alcohol and CO exposure are likely to create a more significant health hazard. The majority of participants at Lake Pleasant were members of families who spent most of their boating time along the shorelines so their children could play in the water. Many of these families expressed concern for the safety of their children and said they were not aware of possible CO exposures resulting from the use of recreational watercraft.

Lake Pleasant Park Police expressed concern to ADHS about activities at Humbug Cove at the far northern end of the lake. These boaters were more likely to have high COHb levels because many boaters idle their engines in the cove to socialize with other boaters.

Boaters frequenting Humbug Cove likely had higher rates of alcohol consumption, but most of these boaters declined to participate in the survey and left the area when contacted by ADHS staff. Many boaters approached at the cove questioned the purpose of the survey and declined participation. ADHS staff did not enter the cove on the advice of park police but remained on the Sea Ark at the cove entrance. Boaters were contacted as they entered and left the cove.

CHILD HEALTH CONCERNS

ATSDR and ADHS recognize that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contaminants in air. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Children participating in recreational activities at times when CO levels are high are at risk of CO poisoning, which can result in death. Data collected by the United States Coast Guard has identified 493 CO poisonings between 1990 and 2000. Of these fatal and non-fatal poisonings, 214 (43%) involved children and occurred on boats other than houseboats.

CONCLUSIONS

Results of the analysis at Lake Pleasant suggested that no apparent health hazard existed at the time of the study. Seven participants who were actively smoking cigarettes slightly exceeded the threshold for mild adverse health effects.

RECOMMENDATIONS

ADHS will continue to conduct additional biomonitoring studies at Arizona's lakes in the spring and summer of 2004 to determine whether a widespread public health hazard exists because of CO exposure from motorized watercraft.

PUBLIC HEALTH ACTION PLAN

ADHS will continue working with other public agencies to help the public understand how to reduce exposure to CO from motorized watercraft.

ADHS will provide information about CO on the agency website and will make a brochure about CO poisoning available for download.

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