



National Institute for Occupational Safety & Health

Denver Field Office

**Denver Federal Center
PO Box 25226
Denver, CO 80225-0226
(303) 236-6032
(303) 236-6072 FAX**

HETA 2000-0400

June 4, 2001

US National Park Service
ATTN: William Dickenson, Park Superintendent
Lake Mead National Recreational Area
601 Nevada Highway
Boulder City, Nevada 89005

Dear Mr. Dickenson:

On January 23-25, 2001, the National Institute for Occupational Safety and Health (NIOSH) and the Department of Interior (DOI) reviewed National Park Service (NPS) law enforcement and fatality records at Lake Mead National Recreational Area. The purpose of this review was to duplicate and expand upon an investigation that was begun in September 2000 at Glen Canyon National Recreation Area. At both National Parks, a thorough, organized search of fatality investigative records and Emergency Medical Service (EMS) activity records (run sheets) was conducted to identify fatal and non-fatal boat-related carbon monoxide (CO) poisonings. Our methods, findings, and conclusions are contained within the enclosed report.

Briefly stated, this review of records resulted in the identification of 1 fatal boat-related CO poisoning in a 10-year period (1990-2000) and at least 8 non-fatal boat-related CO poisonings in a 5-year period (1995-2000). Five of the 8 non-fatal poisonings occurred on houseboats. An additional houseboat CO poisoning incident was referred to in a Fire Department investigative report, but no related EMS records were found.

If you have questions or concerns about anything in this report, please contact Jane McCammon at the NIOSH office listed on the letterhead.

Sincerely,

Jane McCammon, CIH
Director, NIOSH Denver

Tim Radtke, CIH
US Dept. of Interior

Dr. Robert Baron
Medical Contractor, DOI
Medical Director, Prehospital Care
NPS Glen Canyon Nat=l Rec. Area

**Review of National Park Service Emergency Medical Service Records
to Identify Carbon Monoxide Poisonings at
Lake Mead National Recreation Area
NIOSH HETA 2000-0400**

Background

In recent months, NPS, DOI, and NIOSH identified 111 boat-related CO poisonings that occurred at Lake Powell in the Glen Canyon National Recreation Area from 1990 through 2000. Nine of these poisonings resulted in fatalities, and 7 of the 9 fatalities were related to houseboats of a specific design. These poisonings were identified through a search of the following records: all fatality records regardless of designated cause of death; all EMS runs sheets for which CO poisoning was the listed nature of incident, all EMS run sheets for which the listed symptoms were consistent with CO poisoning, regardless of the listed nature of incident. Information related to the Lake Powell CO poisonings can be found at the following website:

<http://safetynet.smis.doi.gov/COhouseboats.htm>

Attachment 1 lists the health effects related to CO exposure. Similar information and other educational materials can be found at the above website.

Three things were striking about the CO poisonings identified at Lake Powell. First, classification of the poisonings was possible because Glen Canyon NPS EMS personnel listed not only symptoms but also circumstances that were in place when the patient had symptom onset (i.e., generator was operating, patient was on the stern deck, etc.) Second, the total number of poisonings was of great concern. And finally, the fact that a large number of poisonings (7 of the fatal poisonings, and 28 of the non-fatal poisonings) occurred outdoors near the stern deck of multiowner non-rental houseboats. Six of the 7 fatal houseboat-related poisonings occurred as a result of the victim entering the airspace beneath the extended stern deck of boats with an on-board generator with a rear-directed exhaust terminus. The seventh death was also associated with a boat of that design. This drowning was unwitnessed, thus there is no documentation available as to the exact activities of the person while at the back of the boat. The body was found in the water at the stern of the boat, and death was confirmed as CO-related based upon a very high carboxyhemoglobin (COHb) concentration measured during autopsy.

These outdoor poisonings and deaths represent a newly recognized and previously unreported circumstance of poisoning, and raised concerns that many poisonings may have understandably gone unrecognized on other lakes in the United States. CO is not routinely tested by medical examiners unless specifically requested as part of an autopsy. In addition, the symptoms of CO poisoning mirror those of many other conditions and illnesses. As a result, many unexplained drownings may involve CO exposure that was unreported. All of these factors combined undoubtedly leads to under-reporting and under-recognition of CO related poisonings and drowning fatalities.

To address concerns about poisonings on other lakes, and to determine if records from lakes other

than Lake Powell would be useful in a retrospective analysis of poisonings, DOI, NPS, and NIOSH continued their investigation by examining records at Lake Mead National Recreation Area. Coincident to the review of law enforcement and fatality records summarized here, NIOSH also measured CO concentrations on a number of houseboats on Lake Mead in response to requests of two boat manufacturers with houseboats located there. Results of these evaluations will be reported separately, as the requests were submitted independently.

Both Lake Powell and Lake Mead are contained within parks operated by NPS, and have similar EMS programs. In both parks, emergency medical services are provided by National Park Service Rangers who are responsible for a wide variety of other activities as well. EMS activities are routed through, and logged by, the NPS dispatch center. The lakes differ, however, in topographical characteristics and user demographics.

Although more than 2,600,000 people visit Lake Powell annually, it is very isolated. There is only one town and one primary care hospital adjacent to the lake. Lake Powell is over 275 miles away from the nearest major metropolitan area (i.e., Phoenix or Las Vegas) and has only 4 points of motor vehicle access. The lake is 186 miles long, but has 1920 miles of convoluted shoreline. The many isolated coves of Lake Powell provide shelter from the wind, and make it ideal for houseboating.

According to data collected by NPS at Glen Canyon National Recreation Area, in April 2001, there were 216 houseboats of the design of concern available for use on Lake Powell in 2001. Although no data were collected regarding the total number of houseboats on the lake, NPS estimated that the number is greater than 2,000. No data were available on actual use (hours/days/months per year) of the houseboats, nor on the proportion of rental to private owner boats. However, professionally-managed shared-ownership private houseboats are common on Lake Powell, and this managed shared-ownership results in steady use of these boats during the boating season. All of these facts are important to consider in regard to the database that was being used to access case reports. If a visitor experiences a life-threatening medical event on this lake, it can take hours to get to medical help if they try to transport themselves by boat to the launch ramp where their car is located. NPS, however, can shorten that time substantially, by bringing the medical help to the visitor, and then facilitating helicopter transport if needed. As a result, visitors on this lake are very likely to access NPS EMS services in an emergency.

Lake Mead National Recreation Area hosts more than 9,000,000 visitors per year, due in part to the close proximity of Las Vegas, Nevada (25 miles). This proximity to a major metropolitan area also means that there are many hospitals of varying levels of care near the lake. The Recreation Area encompasses Lake Mead and Lake Mohave, a geographic area of 1.5 million acres including a combined shoreline of nearly 1,000 miles. The footprint of Lake Mead is very different than that of Lake Powell, with many more large open areas and few coves providing protection from the considerable wind of the area.

In January 2001, there were 592 rental and privately-owned houseboats at the seven marinas on Lake Mead. Of these, 104 had extended rear decks with an airspace beneath into which the generator exhaust was directed. Lake Mead NPS allows shared ownership of houseboats occupying boat slips on the lake, but does not allow professional management of those boats. Again, as at Lake Powell, there were no data available on the actual use of the houseboats present on Lake Mead, but the absence of professional management may result in reduced use of privately-owned boats.

Lake Mead is much easier to access by paved roads than Lake Powell. This facilitates easy motor vehicle access to the lake along the shore. In addition, there are at least 15 designated motor vehicle access points around the perimeter of the lake and seven major marinas. Simply put, it is much easier for visitors on this lake to transport themselves to a wide range of medical care in the event of an emergency compared to Lake Powell. This investigation involved review of NPS EMS records only, and no attempts were made to identify self-transportations at hospitals around Lake Mead. In addition, there were fewer houseboats in total, and fewer with the design of most concern.

Methods

The initial review of records at Lake Mead was conducted by NIOSH (Jane McCammon) and DOI (Tim Radtke). During this review, records were conservatively selected for medical review by Dr. Robert Baron (Medical Director for Prehospital Care, Glen Canyon National Recreation Area, contracted by DOI for this record review). The CO poisoning case definition developed for the Lake Powell investigation (see Attachment 2) was used in the final epidemiologic review (Ms. McCammon and Dr. Baron) for case classification.

Lake Mead NPS provided requested hard-copy listings of fatalities that had occurred within Lake Mead National Recreation Area from 1991 through 2000, and with logs of law enforcement dispatches from 1995 through 2000. Both sets of records included land- and lake-based incidents.

There were approximately 3,000 entries per year in the dispatch logs. These entries reflect a portion of the wide spectrum of responsibilities of the approximately thirty park rangers employed by NPS in this park. NIOSH and DOI extracted lists of approximately 250 EMS incidents per year that appeared to be lake-related based upon the location listed in the log. NPS dispatch personnel (who were more familiar with the locations in the log) reviewed the lists and deleted incidents that were not lake-related. Hard copy records for the remaining incidents were retrieved from NPS files and reviewed.

There were 317 deaths recorded in the park fatality logs. Again, deaths that appeared to be lake-related and listed as CO poisonings or natural cause fatalities were extracted from the logs by NIOSH and DOI. NPS staff retrieved hard-copy records related to these fatalities for review.

Results

Fatality Review

A total of 182 records of NPS investigations of drowning or natural cause fatalities was selected for initial review. Reviewers selected thirteen records from the 182 records for further medical review.

One of these records detailed a CO poisoning incident that occurred on a cabin cruiser. Exposure to CO in this instance resulted in one fatal and one non-fatal poisoning. The source of CO in this incident was an on-board gasoline-powered generator. The boat occupants were poisoned while they slept inside the boat cabin. This was classified as a definite CO poisoning based upon the case definition for this review.

The remaining twelve natural-cause and drowning fatality records were selected for further review because the DOI and NIOSH reviewers had questions about the medical information contained in the record. None of these records contained autopsy results, references to autopsy results, or death certificates. As such, the initial EMS assessment was the only information available about cause of death.

The medical review of these 12 records resulted in classification of 11 of the deaths as non-cases based upon comparison with the case definition. This classification was based upon the fact that clinical information in the record was consistent with the assessed cause of death, and that the circumstances of death were either not fully described, or were not consistent with CO exposure (i.e., several instances where a person with relevant previous medical history died inside a houseboat where no other people in the boat were symptomatic, a man was thought to have had a heart attack while docking a boat in high winds, etc.).

The circumstances of the remaining death left unanswered questions for all reviewers, but was also classified as a non-case. In this instance, witnesses on a houseboat stated that a companion swimming alone near the rear deck in the early morning hours swam under the houseboat. There was no information available in the record as to whether the generator was operating, if he entered the airspace beneath the stern deck, or how long he swam near the rear of the boat. An autopsy was referred to in the record, but no COHb analysis measuring CO in blood was mentioned. The circumstances of this death were similar to CO-related drownings on Lake Powell, but it was not possible to determine if CO exposure had actually occurred.

Non-fatal CO Poisonings

Eight records of known non-fatal CO poisonings were identified through the review of EMS records from 1995-2000. All of these cases met the definition of definite cases. One of the poisonings occurred on a personal water craft. One poisoning record refers to an inboard engine but no boat type. One occurred on a cabin cruiser (this was the incident for which there was also a fatality) and was related to generator operation.

Five poisonings occurred on houseboats. Three of these poisonings occurred on rental houseboats when the person was outdoors exposed as follows:

- In a small rubber raft on the starboard side of a houseboat when he inhaled the exhaust fumes from the houseboat generator for about 5 minutes
- Playing around a generator for about 10 minutes when she fell into the water and lost consciousness
- Working on a houseboat that had a rope around the propeller with his head close to the exhaust terminus of the generator that was operating when he lost consciousness

One of the houseboat-related poisonings occurred in the cabin of a privately-owned boat. In this instance, the boat occupants were awakened when the CO alarm sounded. The boat was checked and found:

".....to have a proper ventilation system. The vessel did have a separate vessel side tied to the starboard side of it toward the rear. That vessel was also running its generator and was tied near the air intake for the houseboat."

The circumstances of exposure for the remaining houseboat-related poisoning was listed as follows:

- Exposure in a "confined space" for approximately 7 hours

In addition to these houseboat-related CO poisonings documented in EMS records, one additional poisoning incident (unknown number of people poisoned) was documented in a report from the local Fire Department. This report referred to a reported CO poisoning incident that occurred in the rear sleeping compartment of a rental houseboat. The poisoning was thought to have been caused by the boat's generator's exhaust that was close to that sleeping area. No record of this incident was found in the search of law enforcement EMS records, and the poisoning/s referred to are not included in the totals listed in this report.

Other EMS Hard-Copy Records Reviewed

Forty-one records of non-fatal EMS incidents (1995-2000) were selected by DOI and NIOSH for further medical review. These records were not designated by EMS personnel as CO-related, but contained medical information that was unclear to the initial reviewers, or had circumstances or information in the record that caused the reviewers to have further questions.

The medical review resulted in elimination of 4 of the 41 records (classified as non-cases) because medical information in the record was consistent with the listed diagnosis and inconsistent with CO poisoning.

Four of the 41 records were pulled from the total because further followup through a review of medical records at the hospital that received the patient was needed.

The remaining 33 records required further information to assess possible CO-relatedness, but follow-up on the cases is not possible. These are records for which the patient had symptoms consistent with CO poisoning, but the EMS preliminary assessment listed another cause of illness (heat stress, dehydration, loss of consciousness, seizures of unexplained cause, etc.), and there

was limited information about the circumstances of illness (no mention of whether the generator was running, where the person was upon symptom onset, etc.) In several instances, listed symptoms were not consistent with the assessed nature of incident. For example, "heat stress" or "dehydration" assessments were sometimes inconsistent with the listed normal vital signs and history of taking in fluids during the day. Nonetheless, these 33 cases did not meet the case definition, and thus were classified as non-cases.

Discussion

The absence of the information needed to answer the questions raised during this review of records does not suggest error or poor performance by NPS Park Rangers at Lake Mead. As was pointed out earlier in this report, the outdoor acute fatal poisonings reported at Lake Powell represent a newly recognized finding that may have understandably gone unrecognized on many bodies of water. Detailed information in accident investigation records is critical to determine if CO poisonings occurred. On both Lake Mead and Lake Powell, EMS records accessed because the patient had symptoms consistent with CO poisoning sometimes contained few details to allow reviewers to determine if CO poisonings were possibly assessed as other conditions, such as heat stress, dehydration, loss of consciousness, or convulsions of unspecified cause. In our review of NPS records at Lake Powell, where years of conscious effort was placed on including detail about the circumstances of illness onset, there was a similar number of records (greater than 30 at Lake Powell, 37 at Lake Mead) lacking detail needed to document CO exposure (no mention of where the person was or what was operating on the boat, etc.). What was different at Lake Powell was that there were 111 records of CO poisonings with excellent detail, and 10 records with details confirming CO poisonings at Lake Mead.

The discrepancy between the number of poisonings identified at Lake Mead compared to Lake Powell may be related to a number of factors:

- There are currently twice as many boats of the design on which people died on Lake Powell than on Lake Mead. Presumably, the difference in numbers of boats remained constant over the period of the study.
- Windy weather, vast open areas on Lake Mead, and demographic characteristics of the users of that lake result in more speedboat use and relatively fewer houseboats and houseboat use on this lake than on Lake Powell.
- EMS and death records at Lake Mead were, with some exceptions, less complete than records at Lake Powell. As such, it was much more difficult to determine the final medical diagnosis for transported patients or cause of death for people who drowned. For example, death records at Lake Powell consistently included autopsy reports, or summaries of the autopsy results to confirm the actual cause of death. Records selected for review at Lake Mead seldom contained that information.
- The record review at Lake Mead did not cover as many years as the Lake Powell review.

- No effort was made to identify self-transports at Lake Mead because of the large number of hospitals that would have involved.
- According to NPS, houseboats on Lake Mead are typically owned by a single family or small groups of owners. This may reduce the overall use of each boat as compared to Lake Powell, where professional management of individual boats may encourage more constant use of each boat.
- All rental boats on both lakes are designed differently than the boats on which the deaths at Lake Powell occurred.

Conclusions

At least 8 boat-related CO poisonings, including 3 outdoor poisonings on houseboats, were identified through a search of records at Lake Mead. These poisonings, along with additional reports of outdoor poisonings from lakes across the United States,¹ indicate that such poisonings are not unique to Lake Powell.

Substantially fewer CO poisonings were identified at Lake Mead than at Lake Powell. This difference may be due to a number of factors discussed earlier in this report.

Historic EMS records from water bodies other than Lake Powell may be of limited use in identifying the full scope of the problem of CO poisonings, particularly those that occur outdoors. These limitations arise from at least three factors:

- 1) The geographic isolation of Lake Powell may have presented a unique opportunity for case identification as discussed earlier;
- 2) EMS personnel unaware of the potential problem may not have gathered sufficient information to connect exposure to symptoms;
- 3) CO poisonings occurring outdoors are likely to be diagnosed as other conditions in the absence of sufficient information.

Recommendations

1. Awareness among EMS personnel is critical to diagnosis and treatment of CO poisonings, and development of related records that will adequately document CO poisoning. NPS should encourage the use of a standard data collection form when boat occupants requesting assistance present with or report symptoms consistent with CO poisoning (i.e., headache, nausea, dizziness, loss of consciousness, convulsions, etc.). An example of this type of form for use by EMS or other park rangers investigating the incident can be found at the following Internet website address: <http://safety.net.smis.doi.gov/COhouseboats.htm>.

2. EMS personnel should ensure that the information collected above is transferred to the receiving medical facility to aid the treating physician in decisions regarding treatment and diagnosis. In addition, this information should be shared with coroners/medical examiners that

receive the bodies of drowning victims (particularly if the drowning was unwitnessed or nontraumatic in nature) or people who died of natural causes. The goal of this recommendation is to encourage the collection of blood and/or breath samples for COHb analysis at the hospital emergency department or other medical facility receiving the patient.

3. The Park Medical Director's tasks should include monitoring trends reflected in data from EMS records on a periodic basis. Frequency of this review of data should be based upon such things as size of the park, number of incidents, and available resources.

4. NPS should work with receiving medical facilities and medical examiners/coroners to increase awareness of CO exposure and poisonings on boats. The goal of this recommendation is to encourage improved identification of CO-related fatalities through regular measurement of COHb when victims die of unwitnessed non-traumatic drownings.

5. NPS and their concessionaires should educate all boat users about CO hazards (both symptoms of poisoning, and what circumstances will lead to poisoning). Examples of educational materials developed for this purpose can be found at the internet website address listed earlier in this report. NPS should ensure that this training and information is provided for all boat owners and users, regardless of the type of boat ownership or management.

6. NPS and other agencies responsible for responding to emergencies on waterbodies should work with the appropriate US Coast Guard, national NPS, and DOI staff to develop a systematic method of reporting and tracking severe medical events.

References

1. Radtke T, Baron RL, McCammon J [2001]. Letter of March 21, 2001 from T. Radtke, U.S. Department of Interior, R. Baron, U.S. Department of Interior and National Park Service, and J. McCammon, National Institute for Occupational Safety and Health, to P. Cappel, U.S. Coast Guard, Washington D.C. B listing updated on internet website <http://safetynet.smis.doi.gov/Cohouseboats.htm>

Attachment 1

Health Effects of Exposure to Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials such as gasoline or propane fuel. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, or nausea. Symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. If the exposure level is high, loss of consciousness may occur without other symptoms. Coma or death may occur if high exposures continue.⁽¹⁻⁶⁾ The display of symptoms varies widely from individual to individual, and may occur sooner in susceptible individuals such as young or aged people, people with preexisting lung or heart disease, or those living at high altitudes.

Exposure to CO limits the ability of the blood to carry oxygen to the tissues by binding with the hemoglobin to form carboxyhemoglobin (COHb). Blood has an estimated 210-250 times greater affinity for CO than oxygen, thus the presence of CO in the blood can interfere with oxygen uptake and delivery to the body. Once absorbed into the bloodstream, the half-life of bloodborne CO at sea level and standard pressure is approximately five hours. This means that an initial COHb level of 10% could be expected to drop to 5% in five hours, and then 2.5% in another five hours. If oxygen is administered to the exposed person, as happens in emergency treatment, the COHb concentration drops more quickly. Once exposed, the body compensates for the reduced bloodborne oxygen by increasing cardiac output, thereby increasing blood flow to specific oxygen-demanding organs such as the brain and heart. This ability may be limited by preexisting heart or lung diseases that inhibit increased cardiac output.

Altitude affects the toxicity of CO. With 50 ppm CO in the air, the COHb level in the blood is approximately 1% higher at an altitude of 4,000 feet than at sea level. This occurs because the partial pressure of oxygen (the gas pressure causing the oxygen to pass into the blood) at higher altitudes is less than the partial pressure of CO. Furthermore, the effects of CO poisoning at higher altitudes are more pronounced. For example, at an altitude of 14,000 feet, a 3% COHb level in the blood has the same effect as a 20% COHb at sea level.⁽⁷⁾

References

1. 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.
2. NIOSH [1977]. Occupational diseases: a guide to their recognition. Revised ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-181.
3. NIOSH [1979]. A guide to work-relatedness of disease. Revised ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 79-116.

4. Proctor NH, Hughes JP, Fischman ML [1988]. Chemical hazards of the workplace. Philadelphia, PA: J.B. Lippincott Company.
5. ACGIH [1996]. Documentation of threshold limit values and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
6. NIOSH [1999]. Pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-115.
7. American Gas Association [1988]. What you should know about carbon monoxide. American Gas Association 1985 Operating Section Proceedings. American Gas Association, Arlington, Virginia.

ATTACHMENT 2

Investigative Case Definition for Boat-Related CO Poisonings

A definite case was defined as a person on or near a boat the experienced:

Signs and symptoms consistent with CO poisoning (i.e., death, loss of consciousness, seizures, headache, nausea, confusion, weakness, and altered state of consciousness) with a laboratory-confirmed elevated carboxyhemoglobin level (>2% in children or nonsmoking adults and >9% in smoking adults or adults for whom smoking status is unknown); or known exposure to engine or generator exhaust and one of the following; 1) loss of consciousness with no other cause; 2) symptoms of CO poisoning (other than loss of consciousness) and association with a person who also experienced symptoms of CO poisoning; or 3) symptoms of CO poisoning that improved on removal from exposure.