CDC Workplace Safety and Health™

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2002-0014-2958
U.S. Department of Transportation
St. Lawrence Seaway Development Corporation
Massena, New York

March 2005

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

PREFACE

The Hazard Evaluation 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 employers 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 Jeffrey Nemhauser, MD, and Lynda Ewers, PhD, CIH, of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Brian Curwin, Bradley King, Ann Krake, and Ashok Nimgade. Analytical support was provided by Ardith A. Grote and Daniel Lewis of NIOSH and DataChem Laboratories. Desktop publishing was performed by Ellen Blythe and Robin Smith. Editorial assistance was provided by Ellen Galloway.

Copies of this report have been sent to employee and management representatives at the St. Lawrence Seaway Development Corporation (SLSDC) and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed from the following internet address: www.cdc.gov/niosh/hhe/hhesearch.html. Single copies of this report will be available for a period of 3 years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

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For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Airborne Exposures and Health Effects Among Lock Maintenance Workers

In October 2001 the National Institute for Occupational Safety and Health (NIOSH) received a joint labor/management request for a health hazard evaluation (HHE) at the Eisenhower and Snell Locks on the St. Lawrence Seaway, Massena, New York. The request described “flu-like symptoms” and “general ill health” among workers exposed to stagnant water and decaying marine life during the annual winter inspection, cleaning, and repairs of the locks.

What NIOSH Did

- We looked at maintenance and repair activities in the Snell and Eisenhower Locks.
- We took air samples for endotoxins, hydrogen sulfide (H_2S), carbon monoxide (CO), and volatile organic compounds (VOCs). All of these were possible causes of some of the respiratory symptoms in the lock workers.
- We interviewed 27 lock maintenance workers and asked them about their health. We also looked at medical records of some workers.

What NIOSH Found

- Lock maintenance workers are potentially exposed to endotoxins, H_2S, and VOCs. However, short-term respiratory illness due to these exposures is unlikely. Concentrations of CO were low.
- NIOSH considers the locks to be confined spaces when maintenance work is done.
- Most of the 27 workers described a respiratory illness, including bronchitis, pneumonia, or an aggravation of their asthma. However, since so few workers participated, we cannot draw conclusions whether there is a relationship between winter work activities and the risk of developing short-term respiratory illnesses.

What St. Lawrence Seaway Development Corporation Managers Can Do

- Continue to check for H_2S during lock maintenance, especially where there are barriers to the free flow of air and during concrete chipping activities.
- Increase general ventilation in the locks to further reduce H_2S concentrations.
- Winter work employees should receive medical clearance before returning to work following a hospitalization, a severe respiratory illness, or while taking prescription medications.
- Develop a confined space entry plan following NIOSH recommendations.

What the St. Lawrence Seaway Development Corporation Employees Can Do

- Tell your supervisor if you have been ill or have had a medical procedure before you return to maintenance or repair work in the locks.

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 #2002-0014-2958

Health Hazard Evaluation Report 2002-0014-2958
U.S. Department of Transportation
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SUMMARY

In October 2001, the National Institute for Occupational Safety and Health (NIOSH) received a joint labor/management request to conduct a health hazard evaluation (HHE) at the Dwight D. Eisenhower and Bertrand H. Snell Locks on the St. Lawrence Seaway, near Massena, New York. The request described "flu-like symptoms" and "general ill health" as concerns among workers exposed to stagnant water and decaying marine life during the annual winter inspection, cleaning, and repairs of the locks. Another impetus for the request was the collapse of one worker at the bottom of a lock during the previous winter.

During site visits in 2002 and 2003, NIOSH investigators collected personal breathing zone (PBZ) and area air samples for endotoxins, hydrogen sulfide (H_2S), carbon monoxide (CO), crystalline silica, and volatile organic compounds (VOCs). Endotoxin concentrations above relative limit values were measured on two workers. However, because these employees (both painters) left the worksite while wearing the monitoring equipment during part of their work shift, the exposures cannot be said to be work related. Peak PBZ H_2S concentrations up to 87 parts per million (ppm) were measured while workers used pneumatic drills and jack hammers to remove deteriorating concrete from lock walls; the NIOSH recommended ceiling value is 10 ppm. Concentrations of CO, crystalline silica, and VOCs were below applicable NIOSH and OSHA occupational exposure limits. NIOSH investigators also concluded that the locks are confined spaces.

NIOSH investigators identified 71 employees as having regular or intermittent exposure to the locks during winter work; 27 were interviewed or had information in their medical records that could be abstracted to identify disease trends or patterns. Most of the 27 workers reported a history of respiratory illness including bronchitis, pneumonia, or an aggravation of their asthma while working on the locks. Although several workers provided a history of seeing their health care provider for a winter illness, only two provided a history of having been hospitalized. Given the small percentage of workers who participated in this study, we cannot draw conclusions about the relationship between winter work activities and the risk of developing acute respiratory illnesses.

NIOSH investigators conclude that some employees conducting winter work at the Dwight D. Eisenhower and Bertrand H. Snell Locks on the St. Lawrence Seaway are exposed to endotoxins, H_2S, and VOCs. Acute respiratory illness due to H_2S or VOC exposures at the levels measured during the NIOSH evaluation is unlikely. Recommendations are provided to consider the locks as confined spaces and to increase the ventilation inside the locks while winter work activities are conducted.

Keywords: SIC 4432 (Freight Transportation on the Great Lakes-St. Lawrence Seaway), seaway locks, construction, confined space, maintenance, endotoxins, hydrogen sulfide, carbon monoxide, crystalline silica

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INTRODUCTION

On October 5, 2001, the National Institute for Occupational Safety and Health (NIOSH) received a joint labor/management request to conduct a health hazard evaluation (HHE) at the Dwight D. Eisenhower and Bertrand H. Snell Locks on the St. Lawrence Seaway, near Massena, New York. The request described “flu-like symptoms” and “general ill health” as concerns among workers exposed to stagnant water and decaying marine life during the annual winter inspection, cleaning, and repair of these locks. During initial discussions with the requestors, NIOSH investigators learned that employees had experienced these adverse health effects for years prior to the submission of this HHE request. Subsequent discussions revealed that the main impetus for submitting this HHE request was the collapse of one worker at the bottom of a lock while participating in the previous year’s winter maintenance.

Maintenance work on the locks occurs each year from December until late March or early April. During this time, the Seaway is closed to nautical traffic. From January 16–17, 2002, NIOSH industrial hygienists and medical officers visited the Snell Lock and conducted voluntary health surveys with available employees. NIOSH investigators returned to the Snell Lock on February 25–28, 2002, to carry out an industrial hygiene survey, during which time they collected personal breathing zone (PBZ) and general area air samples over one 8-hour shift. NIOSH investigators screened for the presence of (and worker exposure to) airborne endotoxins and volatile organic compounds (VOCs), compounds that could cause the reported “flu-like symptoms” or “general ill health.” Endotoxins, substances released from a type of bacteria, are expected to be present in environments containing rotting organic matter; VOCs are released from oil-fueled furnaces or from the by-products of various maintenance activities such as welding and painting. Both are known to cause adverse respiratory effects in humans.

One year later (February 3–6, 2003) NIOSH investigators returned to Massena to conduct an industrial hygiene evaluation at the Eisenhower Lock. Area and PBZ endotoxin samples were collected. Investigators measured “real time” levels of hydrogen sulfide (H_2S) and carbon monoxide (CO); exposure to sufficiently high levels of either of these gases can result in a worker’s collapse. In response to a supplementary management request, NIOSH investigators measured exposure to crystalline silica among workers using pneumatic drills and jack hammers to remove deteriorating concrete from lock walls. NIOSH investigators also collected area and PBZ air samples for VOCs.

BACKGROUND

St. Lawrence Seaway

Eight locks exist between Lake Ontario (to the west) and the Gulf of St. Lawrence (to the east), where the St. Lawrence River flows into the Atlantic Ocean. Six of these eight locks are owned and operated by the Canadian government. Two locks, the Dwight D. Eisenhower and the Bertrand H. Snell, are owned, operated, and maintained by the St. Lawrence Seaway Development Corporation (SLSDC), which is subject to the policy direction and supervision of the United States Department of Transportation (DOT). These two locks are the focus of this investigation.

Each of the U.S. owned locks measures approximately 900 feet (ft) in length (L), 50 ft in width (W), and 110 ft in depth (D). Water levels within the lock are regulated by two sets of valves. Refilling a lock after the normal operation of lowering a vessel requires 20 million gallons of water and takes approximately 9 minutes to complete. Water turbulence associated with this rate of flow is reduced by channeling the water through 12 ft (D) by 14 ft (W) culverts that run alongside the locks. Water enters the main chamber of the lock through ports spaced intermittently along common walls shared by the culverts and the lock.

Lock Inspection and Repair

During most of the year, SLSDC employees operate the locks. From mid- to late December until the end of March, when the Seaway is closed to traffic, about 70 – 80 of the SLSDC workers inspect, clean, and repair the locks, generally working a single 8-hour shift (0730 – 1600), 5 days a week. Workers are permitted two 15-minute breaks per shift plus a 5-minute wash period before each break. They leave the job site to take showers at 1530. Although a second shift may be added to complete specific time-dependent tasks, work was confined to the first shift only during the NIOSH site visits. SLSDC management schedules extensive repair projects to occur in only one lock in any given year. Any worker may be called upon to perform a variety of tasks and most workers can rotate jobs as necessary. Skilled trades represented on the job site include millwrights (who maintain and troubleshoot machinery), carpenters, electricians, pipe-fitters, and painters.

In preparation for winter work, the locks are first dewatered and then partially enclosed with plastic sheeting and plywood barriers and covered with corrugated sheet metal. Two 1.5 million British Thermal Unit (BTU) furnaces fueled by #8 fuel oil provide heat for the general lock area; furnace stacks extend through the sheet metal roofs covering the locks. Propane heaters provide supplemental heat in some of the more remote areas of the locks. Direct-reading CO monitors are installed throughout the work environment.

A major task of winter work involves dislodging zebra mussels (*Dreissena polymorpha*) from all structures within the lock that are under water during the open season. Zebra mussels, an opportunistic species of freshwater bivalve mollusk native to Eastern Europe, are believed to have been introduced into the Great Lakes in the mid- to late 1980s. Shortly thereafter, they were found at Snell Lock on the St. Lawrence Seaway,[1] within locks in the greater Niagara region including Black Rock Lock in Buffalo, New York,[2] and in the upper Mississippi River at Lock and Dam 6 in Trempealeau, Wisconsin.[3] By the winter of 1990 – 1991, Snell Lock was reported to be infested by zebra mussels.[1] By 1992, nearly all underwater structures within Black Rock Lock, including those made of concrete, steel, granite, oak, and polyvinyl chloride pipe were infested by the same species. Layers of mussels as much as 4 inches thick were recorded at Black Rock Lock.[2] In 1993, following dewatering and during completion of routine maintenance, personnel at Black Rock Lock noticed that areas not cleaned by the sweep of the gates had a 3- to 4-inch coating of live and dead mussels; behind the lock gates, zebra mussel debris measured 10 to 12 inches deep.

By the winter of 1991 – 1992, numbers of zebra mussels at Snell Lock had reportedly decreased while at Eisenhower Lock, located approximately 3 miles upstream from Snell Lock, the numbers had increased significantly.[1] As was the case at Black Rock Lock, zebra mussels found at Eisenhower Lock covered the walls, floor, sills, miter gates, and cables. Workers most commonly found colonies of mussels on damaged concrete, but intact concrete, wood, and painted metal surfaces were also infested with mussels either in clusters of 50 – 150, or singly.[1] Despite the large numbers of zebra mussels present within the locks on the St. Lawrence Seaway, workers reportedly found no interference with the proper operation of gates, with water flow or pressure, or with water-level sensing equipment.[1]

While the population explosion of zebra mussels has caused extensive "biofouling" of the water-intensive industries throughout the Great Lakes region, during the second NIOSH site visit investigators observed noticeably fewer mollusks within the locks. According to management, indigenous fish had learned to eat zebra mollusks and this predation had apparently greatly reduced the numbers of mussels.

Workers usually clean the locks and the lock gates with brushes or scraping tools without using any chemical cleaning agents. In addition to zebra mussel removal, lock maintenance involves repairing metal and concrete structures within the locks. Structural repair to the metal components of the locks involves cutting, burning, and welding (both Metal Inert Gas [MIG] welding and Tungsten Inert Gas [TIG] welding). Incomplete clearing of zebra mussels can result in their incineration during burning and welding.

Repairing the concrete walls of the lock and culverts often requires use of pneumatic drills and jack hammers to remove spalling and deteriorating concrete, a task performed by "chippers." Once crumbling concrete is removed, plywood forms are installed, and ready-mix cement is used to fill the repairs. The Eisenhower Lock, made of locally acquired natural Portland cement, is structurally less sound and requires more frequent and extensive concrete repair than the Snell Lock, which is made of manufactured Portland cement.

SLSDC management had already identified worker exposure to crystalline silica from concrete as a potential health problem. In response, they initiated employee training and the use of personal protective equipment (PPE) to minimize silica exposures. The PPE used by employees during winter work includes powered air purifying respirators (PAPRs) with high efficiency filters, elastomeric half-mask respirators, or welding hoods, depending on the nature of the work being done. Other protective equipment used by SLSDC employees includes eyewear, gloves, coveralls, and galoshes.

Confined Space Entry

In addition to the potential hazards identified by management and labor representatives in their HHE request, NIOSH investigators identified both the Snell and Eisenhower Locks as confined spaces. At first, the locks did not appear to meet the definition of a typical confined space. For example, when dewatered, most working areas are very large and employees engage in their normal activities unhindered and unencumbered. Nevertheless, entry into and egress from the locks is via temporary scaffolding descending over 100 feet, and even the largest areas are not designed for continuous human occupancy, thus satisfying two important NIOSH criteria in the definition of a confined space.[4]

Worker-Reported Health Effects

According to the HHE requestors, workers begin to experience "flu-like symptoms" and "general ill health" approximately 1 month after the onset of winter work, a pattern that has been observed over many years. The requestors stated that worker health typically worsens during the season and then gradually improves following the reopening of the Seaway. Although the requestors reported to NIOSH investigators that employees had been diagnosed with occupational asthma, the percentage of workers affected was not known since employees are seen by their private physicians. Management and employee representatives both suggested to NIOSH investigators that exposure to rotting and decaying marine life at the bottom of the locks following drainage is a possible cause of worker symptoms. Because zebra mussels are so numerous, and the odor from their decay so noticeable, much attention has been focused on them by management and employees as an explanation for the workers' illness.

METHODS

Industrial Hygiene

Endotoxins

Samples were collected on tared 5.0 micrometer (µm) pore size, 37 millimeter (mm) polyvinyl chloride filters using a calibrated flow rate of 2 liters per minute (L/min). The filters were subsequently analyzed for endotoxin content using the Kinetic-QCL Limulus Amebocyte Lysate (LAL) assay kit (BioWhittaker, Walkerville, Maryland) according to the manufacturer's recommended procedures. For these analyses, 10 endotoxin units (EU) are equivalent to 1 nanogram of endotoxin.

In 2002, NIOSH investigators measured levels of exposure to endotoxins among SLSDC employees in the Snell Lock by collecting seven full-shift PBZ air samples from five welders and two painters. Ten area air samples were obtained and, for comparison, five background air samples were also collected.

In 2003, NIOSH investigators collected full-shift PBZ air samples from two painters, three chippers, one pipe-fitter, and two fender pit maintenance workers in the Eisenhower Lock. Three area air samples were collected. For comparison, four background air samples were obtained and analyzed.

Hydrogen Sulfide and Carbon Monoxide

The Toxi Ultra single sensor gas detector (Biosystems Inc.) provides real time monitoring for the presence of H_2S and CO in the environment. As with most direct reading instruments, however, the possibility exists for compounds in the environment to interfere with the Toxi Ultra's electrochemical sensors, resulting in erroneously high or low readings. Two gases reported by the instrument manufacturer to have such an effect on H_2S measurements are nitrogen dioxide and chlorine, both of which can reduce the H_2Ssignal by about 20%.[5] CO concentration signals may be increased by the presence of H_2S, sulfur dioxide, nitrous oxide, chlorine gas, hydrogen gas, hydrogen cyanide, and hydrogen chloride.

In 2003 at the Eisenhower Lock, NIOSH investigators collected PBZ samples for H_2S from three chippers, one painter (sampled on 2 days), and a fender pit maintenance worker. Two area air samples for H_2S were also collected. Samples for CO were collected from two painters and a pipe-fitter, in addition to one area sample.

Crystalline Silica

Samples of crystalline silica were collected on 37-mm polyvinyl chloride filters using a 10-mm nylon cyclone pump calibrated at 1.7 L/min flow rate. Sample analysis was performed using x-ray diffraction with a Siemens Model D5000 Diffractometer. Samples were analyzed using the NIOSH Manual of Analytical Methods (NMAM) Method 7500 with modifications.[6] Analytical method modifications were as follows: 1) filters were dissolved in tetrahydrofuran rather than by furnace ashing, and 2) standards and samples were run concurrently and an external calibration curve was prepared using peak heights rather than the suggested normalization procedure.

Crystalline silica PBZ air samples were collected in 2003 from three workers who used pneumatic drills and jack hammers to remove deteriorating concrete from the Eisenhower Lock walls. In addition, two area samples for crystalline silica were collected within the area where chipping took place.

Volatile Organic Compounds

For qualitative VOC sample collection, NIOSH investigators routinely use stainless steel thermal desorption (TD) tubes that contain three beds of sorbent material (designated as "type I" tubes in this report). For this HHE, however, a second type of thermal desorption tube ("type II" tube) was also used to collect VOC samples. Type II tubes more accurately measure reactive compounds such as sulfur compounds and possibly amines, both of which are expected to be produced by decomposing mollusks.

Each TD tube was attached to a sampling train and pump calibrated at a flow rate of 50 milliliters per minute (mL/min). Type I tubes were stainless steel with three compartments containing Carbopack™ Y, Carbopack™ B and Carboxen™ 1003 sorbents. Type II tubes were Sulfinert™-coated stainless steel tubes, which contain only two beds of sorbent material, a front bed of Tenax™ TA sorbent, and a back bed of Spherocarb™. All TD tube samples were desorbed in a Perkin-Elmer® ATD 400 system at 300 degrees Celsius (˚C). The thermal unit was interfaced directly to an HP5890A gas chromatograph with a HP5970 mass selective detector. A 30 meter DB-1 fused silica capillary column was used for analyses.

During general area air sampling conducted in 2002 at the Snell Lock, NIOSH investigators collected qualitative side-by-side VOC samples using both of the above-described TD tubes. Samples were then analyzed to identify the major VOC species present in the lock. In 2003, quantitative sampling for VOCs within the Eisenhower Lock was performed using charcoal tubes to measure the major VOC species identified by the qualitative TD screening conducted the previous year. Samples collected from three painters and one pipe-fitter were analyzed for toluene, methyl isobutyl ketone (MIBK), propylene glycol monomethyl ether acetate (PGMEA), and xylenes. All samples were analyzed using NIOSH Methods 1501, 1550, and the OSHA Chemical Information Manual modified by using gas chromatography with a capillary column and oven conditions and carrier gas flow rates varied to achieve separation of compounds.[6]

Medical

Employee Interviews

During the first site visit to Massena, two NIOSH medical officers conducted confidential employee interviews with available workers who volunteered to participate in this survey. Interview questions included the employee's age, the number of years the employee had worked at the lock doing winter work, and the symptoms, if any, the employee experienced during the winter.

Medical Record Review

In addition to conducting confidential employee interviews, the principal NIOSH medical officer also obtained written consent from employees to request medical records from their individual health care providers. The NIOSH medical officer specifically requested records relating to the diagnosis, treatment, and follow-up of respiratory diseases (including bronchitis, pneumonia, and asthma) or any "flu-like illnesses" acquired by the employee in January, February, or March. Any records of these illnesses, regardless of the year of diagnosis, were requested.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use environmental evaluation criteria to assess 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 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 increase 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),[7] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[8] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[9] Employers are encouraged to follow the NIOSH RELs, the ACGIH TLVs, the OSHA limits, or whichever is 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)]. Employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). However, 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.

Endotoxins

Gram negative bacteria (GNB), the source of endotoxins, are found everywhere in the environment. Endotoxins, lipopolysaccharide compounds found within the outer cell wall of GNB, are released from the cell wall when the bacteria die.[10,11] In experimental studies, human volunteers inhaling high concentrations of endotoxins experienced airway and alveolar inflammation as well as chest tightness, fever, and malaise, and had acute reductions in lung function, as measured by the forced expiratory volume in 1 second (FEV_1).[12,13] Airborne endotoxin exposures between 45 – 400 endotoxin units per cubic meter of air (EU/m^3) are associated with acute airflow obstruction, mucous membrane irritation, chest tightness, cough, shortness of breath, fever, and wheezing.[11,14,15,16] Chronic health effects associated with airborne endotoxin exposure include chronic bronchitis, bronchial hyper-reactivity, chronic airway obstruction, hypersensitivity pneumonitis, and emphysema. Permanent decreases in pulmonary function, along with respiratory symptoms, have been reported in several cross-sectional epidemiological studies.

Although endotoxins have come to be accepted as a cause of adverse human health effects, no dose-response relationship has yet been established due to problems with analytical methods. Until the problems are resolved, comparison of samples collected at different times or analyzed by different laboratories is not considered valid. For these reasons, ACGIH has proposed using relative limit values (RLVs), rather than the more usual TLVs as evaluation criteria for concentrations of endotoxins in the environment.

To measure RLVs, air samples must be collected from the area of interest and from an area representative of background levels of endotoxins in the local environment. These samples are then analyzed at the same time. The RLV is expressed as a comparison (or ratio) between the endotoxin level measured in the area of interest and the background endotoxin level. ACGIH has proposed that if the level of endotoxin exposure within the area of interest exceeds the level of endotoxin measured in the background by a factor of 10 (and if there are health effects consistent with endotoxin exposure) then the RLV action level has been exceeded. When exposures exceed the RLV action level, actions to remediate endotoxins are recommended. It is important to note that the nature of the relationship between the RLV and adverse human health effects has not been elucidated at the time of writing this report.

Hydrogen Sulfide

Hydrogen sulfide (H_2S), also called swamp gas or sewer gas, is highly flammable and a dangerous fire hazard. It is the leading cause of sudden death in the workplace.[17,18] A naturally occurring gas released by volcanoes and hot springs, H_2S is also formed by bacteria, fungi, and other microorganisms that live on decaying organic matter.[19] Entering confined spaces where decaying organic matter is abundant (e.g., a dewatered lock) without proper monitoring equipment or respiratory protection is potentially dangerous.

People are generally exposed to H_2S through the air that they breathe, and it may also be absorbed through the skin; oral exposures are not an important route of intoxication.[17,19] H_2S is colorless and has the odor of rotten eggs. Because of its characteristic odor, people are usually able to smell this gas at low concentrations in the air ranging from 0.0005 to 0.3 parts per million (ppm).[19] In urban areas, the concentration of H_2S derived from natural sources that can be measured in the air is generally less than 1 part per billion (ppb; one one-thousandth of a ppm).[19] In communities situated near natural or industrial sources of hydrogen sulfide, however, air levels of 90 ppb or greater have been measured.[19] Although H_2S can be detected by its smell at 90 ppb, at this concentration it is still several orders of magnitude below the level reported to cause adverse health effects.

At concentrations of 100 – 150 ppm (and above) H_2S rapidly damages the nasal cells responsible for the sense of smell and people lose their ability to smell the characteristic odor of this toxic gas.[8,19] Moreover, it is at these higher concentrations that H_2S becomes a recognized human health hazard. And, since damage to the cells of the nose occurs very quickly, the inability to detect the odor of H_2S at high concentrations makes exposure to this gas dangerous. Human data indicate that the organs most sensitive to the effects of H_2S at higher levels of exposure are the nervous system, the respiratory tract, and the eyes.[8,17,18,19]

Acute exposures to H_2S concentrations of greater than 500 ppm (lasting for less than 1 hour) cause unconsciousness followed by apparent recovery.[19] H_2S causes serious acute damage to the human respiratory tract, especially at very high concentrations of exposure. At lower concentrations, H_2S acts as an irritant to the respiratory tract. Low level exposures may be responsible for nasal irritation, sore throat, cough, shortness of breath, and increased visits to the hospital emergency room due to breathing problems (including asthma).[19] People with asthma may be more sensitive than others to the effects of H_2S; in studies of non-asthmatic workers exposed to H_2S, scientists found no changes in their lung function.[19]

Like the lungs and the brain, the eyes are also sensitive to the effects of H_2S exposure.[8,17,19] Conjunctivitis and keratitis (eye irritation and inflammation) have been reported to occur at air concentrations of H_2S ranging from 5 to 30 ppm.[8,18] A 1-hour exposure to concentrations of H_2S ranging between 50 and 100 ppm may produce worsening eye irritation with pain, tearing (lacrimation), and increasing sensitivity to light (photophobia).[8,18]

Chronic headaches, fatigue, dizziness, irritability, and loss of libido are all examples of health effects reportedly due to long-term, low-level H_2S exposure.[8] However, adequate studies have not been conducted to identify whether exposures to H_2S at concentrations less than 20 ppm may cause the reported adverse health effects.[8,18] Health effects attributed to long-term, low-level exposures could result instead from unmeasured peak high-level exposures in healthy persons.[8]

OSHA has established a legal airborne PEL ceiling value for H_2S of 20 ppm and a 10-minute maximum peak of 50 ppm.[9] The NIOSH REL is a ceiling value of 10 ppm, which should not be exceeded at any time.[18] The ACGIH TLV-TWA of 10 ppm and the TLV-STEL of 15 ppm are recommended for occupational exposure to hydrogen sulfide.[8]

Carbon Monoxide

CO is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials such as gasoline. It combines with hemoglobin in red blood cells to form carboxyhemoglobin (COHb), which prevents the transport of oxygen throughout the body. Symptoms of CO poisoning begin with headache, dizziness, drowsiness and nausea, and may progress to loss of consciousness and eventually death.[20] The NIOSH REL for CO is 35 ppm for an 8-hour TWA. NIOSH also recommends a 200 ppm ceiling which should not be exceeded and an immediately dangerous to life and health value (IDLH) of 1200 ppm.[20] The OSHA PEL is 50 ppm for an 8-hour TWA exposure.[9] The ACGIH recommends a TLV of 25 ppm 8-hour TWA.[8]

Crystalline Silica

Exposure to crystalline silica (quartz, cristobalite, and other forms) has been associated with silicosis, a fibrotic lung disease caused by the deposition of fine particles of crystalline silica within the lungs. Symptoms usually develop insidiously with cough, shortness of breath, chest pain, weakness, wheezing, and non-specific chest illnesses. Silicosis usually occurs after years of exposure but may appear in a shorter period of time if exposure concentrations are very high.[21]

The NIOSH REL for respirable crystalline silica is 50 micrograms per cubic meter of air (μg/m^3) as a TWA for up to 10 hours per day during a 40-hour work week.[21] The REL is intended to prevent silicosis although some evidence indicates that crystalline silica is also a potential occupational carcinogen.[22,23,24]

The ACGIH TLVs for respirable quartz and cristobalite are 100 and 50 μg/m^3, as 8-hour TWAs, respectively.[8] The OSHA PEL (8-hour TWA) for crystalline silica (as respirable quartz) varies based on the percentage of silica.[9]

Volatile Organic Compounds

VOCs describe a large class of chemicals which are organic (i.e., contain carbon) and have a sufficiently high vapor pressure to allow some of the compound to exist in a gaseous state at room temperature. Many of the paints used by SLSDC winter work employees are formulated with VOCs, including toluene, MIBK, PGMEA, and xylene. Routes of exposure to solvents include inhalation of the vapors (lungs), direct contact with the liquid (skin), and ingestion or swallowing (gastrointestinal tract). Because many organic solvents have relatively high vapor pressures and readily evaporate, inhalation of vapors is considered the primary route of exposure. Exposure to solvents may result in eye, nose, and throat irritation, central nervous system depression, headache, and nausea. Some solvents are also described in the medical literature to adversely affect the liver, the kidneys, and other organs.[25,26]

Table 1 presents the current recommendations and standards for the quantified VOCs. Evaluation criteria are not established for PGMEA in the United States.

Confined Space Entry

According to NIOSH, confined spaces meet the following criteria: 1) they have limited openings for entry and exit; 2) they have unfavorable natural ventilation which could contain or produce dangerous air contaminants; and 3) they are neither designed nor intended for continuous employee occupancy. Confined spaces include (but are not limited to) storage tanks, compartments of ships, process vessels, pits, silos, vats, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines. Within the larger category of confined space entry, NIOSH has further established three specific classes of confined space hazards. Designated A, B, and C, each confined space class is defined in the NIOSH *Criteria for a Recommended Standard*.[4]

A "Class A" designation indicates a confined space atmosphere that is immediately dangerous to life and health. NIOSH defines "Class B" as a confined space in which the atmosphere is dangerous, but not immediately life-threatening. The toxicity of a "Class B" confined space is defined as greater than the contamination level referenced in 29 CFR Part 1910 subpart Z, but less than the IDLH. A "Class C" designation indicates a confined space that is a potential hazard with a toxicity of less than the contamination level referenced in subpart Z. The OSHA definition of a permit required confined space (PRCS) does not include those spaces that fall under the NIOSH Class C confined space category. Thus, OSHA does not mandate any special procedures upon entry of a Class C confined space.

RESULTS

Industrial Hygiene

Endotoxins

Personal Breathing Zone Samples

Snell Lock: 2002

PBZ samples for endotoxin were collected from five welders and two painters (Table 2). Endotoxin concentrations for the welders ranged from less than detectable to 5.0 EU/m^3. The endotoxin concentrations measured for the two painters were 120 and 130 EU/m^3, respectively. However, these painters reported that they had left the worksite by driving to an off-site paint store while wearing the NIOSH sampling equipment.

Eisenhower Lock: 2003

NIOSH industrial hygienists repeated endotoxin sampling in 2003. Concentrations ranged from 1.2 – 8.9 EU/m^3 for workers involved with painting, chipping concrete, pipe-fitting, and fender pit maintenance (Table 2). By using a measured background level of 0.82 EU/m^3, any PBZ greater than 8.2 EU/m^3 resulted in a calculated RLV of greater than 10. Therefore, the exposure of the person performing maintenance in the fender pit area was higher than the ACGIH-recommended RLV.

Area Samples

Thirteen area samples for endotoxin concentrations were collected from various locations within each of the locks over the 2 years of sampling (Table 3). Nine samples collected from outside the locks were considered representative of background levels of endotoxins. The in-lock results ranged from 0.1 – 20 EU/m^3. The highest value, collected from the upstream fender recess, exceeded the RLV.

Hydrogen Sulfide

NIOSH investigators sampled for H_2S at the Eisenhower Lock on February 4–5, 2003. Concrete chipping took place between 10:00 a.m. and 12:00 p.m. During this time period, a general area air sample collected near the concrete chipping measured a maximum H_2S peak of 19 ppm. Sensors placed on each of the three workers using pneumatic drills and jack hammers to remove deteriorating concrete recorded maximum peak values of 18 ppm, 87 ppm, and 68 ppm, respectively. Also during this time period, the sensors recorded a broader series of peaks, several of which exceeded the NIOSH ceiling of 10 ppm and the OSHA ceiling of 20 ppm. One PBZ sample on a painter who was not working in or around the chipping area also had an H_2S exposure that exceeded the NIOSH ceiling value. The results of real time H_2S sampling are presented in Table 4.

Carbon Monoxide

The 2003 results of CO sampling are presented in Table 5. All measured CO concentrations were within the NIOSH and ACGIH recommendations, and the OSHA PEL.

Silica

All 5 PBZ air samples for respirable cristobalite were below the minimum detectable concentration (MDC) of 0.050 μg/m^3. Four of five samples for respirable crystalline quartz were below the MDC of 0.024 μg/m^3, and the one remaining sample had a trace amount (between 0.024 and 0.071 μg/m^3.) MDCs were calculated using a sample volume of 422 liters (the minimum volume of the air samples).

Volatile Organic Compounds

No sulfur or amine compounds were detected in any TD tube samples. Based on the TD results, the following VOCs were quantified using charcoal tubes: toluene, MIBK, PGMEA, and xylene. With the exception of PGMEA (for which neither a REL nor an OSHA PEL has been established), these results were below their respective NIOSH RELs (Table 6).

Confined Space Entry

The Snell and Eisenhower Locks meet the criteria used by NIOSH to define a "Class C" confined space. NIOSH investigators contacted the area director of OSHA in Syracuse, New York, to determine how their inspectors have categorized the locks in the past. In a letter dated December 3, 2002, the area director responded that neither the general lock spaces nor the cross-under for the locks (the stairwells and tunnel beneath the locks) are considered confined spaces. PRCSs within the Snell and Eisenhower Locks, according to OSHA, include the piston holes and inside the lock gates.

Medical

Prior to the initial site visit to Massena, SLSDC management provided NIOSH investigators with the names of 50 employees likely to be working in the locks during winter work. Subsequently, NIOSH investigators received an employee roster (dated October 30, 2001) listing 149 full-time, permanent employees of the SLSDC. This roster included the names of office and administrative staff and employees actively engaged in winter work.

Following completion of both site surveys, representatives from SLSDC helped classify the 149 employees that appeared on the roster as working either "regularly," "intermittently," "seldom," or "never" in the locks when winter work activities take place. Regular exposure was defined as working in the locks on a daily basis; intermittent exposure was defined as working in the locks at least once per week but not on an everyday basis. Employees classified as being seldom or never exposed to the lock environment were identified as working in the locks once per month or less. Seventy-one of 149 (48%) employees were identified by SLSDC representatives as having either regular or intermittent exposure to the locks during winter work. Of these 71 employees, 37 were among the 50 names originally provided to NIOSH in advance of the initial site visit.

Confidential Interviews and Medical Record Review

Of the 71 employees identified as having either regular or intermittent exposure to the lock environment during winter work, NIOSH investigators conducted confidential interviews with 22 who volunteered to be interviewed. Thirteen of the 71 employees identified as having regular or intermittent exposure provided medical records for review and participated in interviews, while nine were interviewed but did not provide medical records.

Twenty-six employees (of the 71 identified as having regular or intermittent exposure to the lock environment during winter work) provided medical records for review. This encompasses the 13 employees identified above. The other 13 employees who provided medical records were either unavailable to be interviewed or declined to be interviewed.

By combining data collected from confidential interviews and the medical record review, a total of 27 employees identified as having regular or intermittent exposure to the lock environment during winter work over the past several years had information that could be abstracted. Twenty of 27 employees had a history of some respiratory illness occurring in the past several years during the winter months of January, February, or March, while working at SLSDC. Specifically, 14/27 provided a history of ever having had an occurrence of bronchitis, 8/27 ever had a case of pneumonia, and 3/27 provided a history of ever having had an aggravation of their asthma during the winter months of January, February, or March in their time of employment over the past several years; some employees had more than one illness. One employee provided a history of occupational asthma most likely due to a chemical exposure in the remote past unrelated to winter work; he noted a worsening of his symptoms when entering fender pit areas.

Eighteen of 27 provided a history of having been seen by their health care provider for an illness during the months of January, February, or March during their time of employment over the past several years; two provided a history of having been hospitalized with a respiratory illness during these months. Six of 27 reported a history of tobacco use.

DISCUSSION/ CONCLUSIONS

Large numbers of zebra mussels within the locks on the St. Lawrence Seaway present at least two potential hazards for SLSDC employees actively engaged in performing winter work: 1) the possibility of exposure to toxins known to accumulate within the soft tissues of the mussels; and 2) exposure to the significant odor that results as these animals decay when the lock is dewatered. Zebra mussels filter water for food and oxygen and several studies have shown that high levels of metals such as cadmium, mercury, lead, and copper, and organic contaminants such as polychlorinated biphenyls (PCBs), pesticides, and petroleum hydrocarbons may become concentrated in their soft tissues.[27,28]
Subsequent studies (reported by the U.S. Army Engineer Waterways Experiment Station)

indicate that the shells of the zebra mussels act to dilute the overall concentration of contaminants within their soft tissues.[28] As the size of an individual mussel increases so does its overall shell mass. Thus, because contaminants are only associated with the soft tissues of these animals (rather than with their shells) contaminant concentrations decrease as the size of the shells increase. Additional research has identified that the concentrations of contaminants in whole zebra mussels (soft tissue and shells combined) are relatively low. When compared with the U.S. Environmental Protection Agency's (EPA) sediment guidelines, zebra mussel waste is considered "non-polluted."[28] Zebra mussels have, therefore, been determined to be non-hazardous.[28]

The second concern (as mentioned above) for SLSDC employees coming into regular contact with large numbers of dead and decaying zebra mussels is exposure to the foul odor.[27,29] Although thick layers of mussels are known to survive even in dewatered locks,[2] most zebra mussels will not survive out of water or in the extreme cold temperatures of the locks on the St. Lawrence Seaway. Since both the Snell and Eisenhower Locks are covered in the winter, it has been suggested that the resulting odor from dead zebra mussels cannot readily vent to the atmosphere and may be "particularly noticeable."[1]

Methane, organic sulfur compounds, and H_2S are three gases likely to be responsible for the odor associated with decaying zebra mussels.[27,29] These byproducts result from the bacterial decomposition of the zebra mussels under anaerobic conditions.[30] Methane and H_2S are toxic to humans; methane may displace oxygen from the environment and H_2S poisons the body by interfering with the proper use of oxygen by the body. In a confined space (such as a covered lock chamber) in the absence of adequate ventilation, the risk of toxicity to workers may be greater than in an open area. NIOSH investigators conducting this HHE conclude that the general lock area meets the definition of a NIOSH "Class C" confined space.

Using direct-reading instruments, NIOSH industrial hygienists measured elevated concentrations of H_2S, suggesting that exposure to elevated concentrations of this gas occurs episodically in areas near concrete chipping activities. Maximum instantaneous peaks for the three chippers exceeded both the NIOSH and OSHA ceiling values. In addition, one painter also had a maximum peak H_2S exposure that was higher than the NIOSH ceiling value.

Since other gases in the environment are known to interfere with direct-reading real time monitors, we recommend confirming the presence of H_2S by conducting additional sampling. The NIOSH Manual of Analytical Methods Number 6013 is one such confirmatory method.[6] It is important to note that the results of this test are purely confirmatory; they may be used only to exclude or confirm other gases as potential sources of interference with real time monitoring equipment. The results obtained from confirmatory testing (measured as a time-weighted average) cannot be used to establish whether or not H_2S exceeds the ceiling value recommended by the NIOSH criterion.

During the first NIOSH site visit (2002), sampling identified high concentrations of endotoxins in two painters. NIOSH investigators, however, are unable to fully account for the activities or location of these two employees during the interval while they were away from the locks. Thus, we cannot conclude that exposures within the lock environment were responsible for the elevated endotoxin sample concentrations. With the exception of these two very high readings, exposures to endotoxins among most SLSDC employees engaged in winter work were below the RLV recommended by ACGIH. Moreover, directed monitoring of painters for endotoxins during the second NIOSH site visit (2003) did not reveal similarly high concentrations. Ultimately, since only the samples collected from the two painters who left the worksite showed exposure to high concentrations of endotoxins, it is not possible to determine the significance of these findings. Area samples for endotoxins were slightly elevated in the upstream fender recess area of the Snell Lock.

Of the samples collected to measure concentrations of CO, crystalline silica, or VOCs, none exceeded any listed NIOSH or OSHA criteria. NIOSH industrial hygienists did find PGMEA at higher concentrations than the other VOCs in one PBZ sample collected from a single painter but this particular organic compound does not have established exposure criteria and the health effects at this concentration, if any, are not known.

Approximately one-third of employees identified as having regular or intermittent exposure to the lock environment during winter work were interviewed or provided medical record information. Of those employees who participated in the NIOSH survey, most provided a history of some type of respiratory illness occurring in the past several years during the winter months of January, February, or March, while working at SLSDC. Respiratory illnesses are commonly occurring conditions among the population, especially in the winter. Our review of medical records and interviews (combined with an examination of exposure data collected during the two NIOSH site visits) did not identify characteristics among SLSDC employees that would lead us to believe that the reported respiratory conditions were unusual in this working population over time.

As noted previously in this report, human volunteers who inhaled high concentrations of endotoxins experienced chest tightness, fever, and inflammation of the lungs. These health effects are seen when people are exposed to airborne endotoxin concentrations between 45 – 400 EU/m^3. In our survey, however, only two workers had endotoxin concentrations in this range, and both had left the worksite; drawing conclusions regarding these two workers cannot be done adequately. Personal breathing zone concentrations obtained for other employees (as well as area air monitoring results) were not sufficiently high to suggest that endotoxins represent a source of recurrent winter illnesses among exposed employees.

H_2S represents another potential source for recurrent respiratory illness among SLSDC winter work employees. Some personal breathing zone and area air monitoring results were at levels found in other studies to cause eye and upper airway irritation in exposed individuals. Employees interviewed as part of this NIOSH survey did not describe having these symptoms.

Based on our findings, NIOSH investigators do not believe that workplace exposures account for the "flu-like symptoms" and "general ill health" reported by SLSDC employees. However, this conclusion is based upon the airborne exposures measured on the days of our evaluation and on the medical survey, which was limited by the small numbers of workers who participated in the interviews or who provided medical records for review.

RECOMMENDATIONS

1. Perform real-time monitoring for H_2S in all areas within the locks, especially areas with barriers to the free flow of air and during concrete chipping activities.

2. Increase general area ventilation to further reduce H_2S concentrations (some of which exceeded the NIOSH ceiling of 10 ppm).

3. Begin a confined space entry plan following the guidelines detailed in Appendix A (the confined space entry procedures used by NIOSH investigators during the second year of this survey). At a minimum, NIOSH recommends the following before allowing workers to enter into a "Class C" confined space: (1) a permit system; (2) initial atmospheric testing for hazardous gases/vapors or lack of oxygen; (3) training; (4) labeling and posting; (5) entrance, communication, rescue, and work procedures; (6) provision of safety belts; and (7) rescue equipment.[4]

4. Continue to spray water on concrete surfaces while chipping to minimize the generation of airborne silica dust.

5. Start a medical surveillance program. We recommend consulting with a physician to conduct annual surveillance for acute respiratory illnesses among SLSDC winter work employees.

This physician should have experience in evaluating individuals with workplace exposures and should have a good understanding of conducting epidemiological studies. Comparison of rates of illness from year to year among those having regular exposure to the lock environment will help identify job assignments or work locations (if any) within the locks that may result in exposures most likely to cause respiratory illnesses. Annual surveillance may also serve as an effective means of minimizing concerns among employees about the likelihood of developing respiratory illnesses as a consequence of participating in winter work.

6. Provide all SLSDC winter work employees with medical clearance prior to returning to work following a hospitalization or medical procedure, a severe respiratory illness, or while taking medication(s) prescribed by a health care provider. Each of these conditions may compromise an individual's ability to safely use personal protective equipment or to work within a confined space.

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Table 1
Occupational Exposure Limits for Selected Volatile Organic Compounds
St. Lawrence Seaway, HETA 2002-0014-2958

	Toluene (ppm)	MIBK* (ppm)	PGMEA† (ppm)	Xylene (ppm)
NIOSH REL	TWA 100 ST 150 IDLH 500	TWA 50 ST 75 IDLH 500	None	TWA 100 ST 150 IDLH 900
OSHA PEL	TWA 200 C 300 500 10 min max peak	TWA 100	None	TWA 100
ACGIH TLV	TWA 50 skin	TWA 50 STEL 75	None	TWA 100 STEL 150

*MIBK = methyl isobutyl ketone
†PGMEA = 1-methoxy-2-propylacetate or methoxypropyl acetate
ppm = parts per million
REL = Recommended Exposure Limit
PEL = Permissible Exposure Limit
TLV = Threshold Limit Value
TWA = Time-Weighted Average
ST or STEL = Short Term Exposure Limit – a 15 minute exposure that should not be exceeded at any time during a workday
C = Ceiling concentration that should not be exceeded at any time
Skin = personal protective clothing is needed

Table 2
Personal Breathing Zone Endotoxin Concentrations
St. Lawrence Seaway, HETA 2002-0014-2958
2002 and 2003

Location	Job Title	Date	Sampling Time (minutes)	Air Concentration (EU/m^3)	Comparison to RLV**
Snell Lock	Welder 1	2/26/02	410	2.0	Less than
	Welder 2	2/26/02	414	ND*	Less than
	Welder 3	2/26/02	432	ND	Less than
	Welder 4	2/26/02	430	ND	Less than
	Welder 5	2/26/02	318	5.0	Less than
	Painter 1	2/27/02	363	130±	Greater than
	Painter 2	2/27/02	329	120.±	Greater than
Eisenhower Lock	Painter 3	2/4/03	430	1.2	Less than
	Painter 4	2/4/03	349	4.1	Less than
	Painter 4 (repeat)	2/5/03	393	6.9	Less than
	Chipper1	2/4/03	425	2.0	Less than
	Chipper 2	2/4/03	455	4.3	Less than
	Chipper 3	2/4/03	422	4.2	Less than
	Pipe-fitter 1	2/5/03	393	2.1	Less than
	Fender pit maintenance 1	2/5/03	100	8.6	Greater than
	Fender pit maintenance 2	2/5/03	139	1.9	Less than

[1] The minimum detectable concentration (MDC) was calculated to be 0.60 endotoxin units per cubic meter (EU/m^3) using a sample volume of 830 liters.

*ND = non-detectable, below the MDC.

**RLV = Relative Limit Value. The average (0.82 EU/m^3) of the background air samples collected outside the locks was used to calculate the RLV recommended by the American Conference of Governmental Industrial Hygienists (ACGIH).

±This value exceeds the ACGIH RLV calculated for this worksite (10 times the background level). However, since these employees left the work site while being sampled, we cannot conclude that their endotoxin exposures resulted from their work in the lock.

Table 3
Area Endotoxin Concentrations
St. Lawrence Seaway, HETA 2002-0014-2958
2002 and 2003

Location	Sample Position	Date	Sample Duration (minutes)	Endotoxin Concentrations (EU/m^3)	Comparison to RLV**
Snell Lock	Lower part of sill	2/26/02	320	ND*	Less than
	Top of stairwell	2/26/02	317	1.0	Less than
	On sill	2/26/02	326	0.1	Less than
	Southside fender 1	2/26/02	271	0.7	Less than
	De-watering pump	2/26/02	329	1.0	Less than
	Meter end of northgate	2/26/02	318	ND	Less than
	Downstream Snell North	2/27/02	183	1.8	Less than
	Lower level upstream	2/27/02	355	3.2	Less than
	Fender recess upstream	2/27/02	355	20.	Greater than
	Upper levels upstream	2/27/02	356	1.2	Less than
Eisenhower Lock	Upstream sill	2/4/03	314	2.9	Less than
	Fender recess north #1	2/4/03	299	ND	Less than
	Upstream control house (indoors)	2/4/03	283	ND	Less than

[1]The minimum detectable concentration (MDC) was calculated to be 0.60 endotoxin units per cubic meter (EU/m^3) using a sample volume of 830 liters.
*ND = non-detectable, below the MDC.
**RLV = Relative Limit Value. The average (0.82 EU/m^3) of the background air samples collected outside the locks was used to calculate the RLV recommended by the American Conference of Governmental Industrial Hygienists (ACGIH).

Table 4
Area and Personal Breathing Zone Air Concentrations of Hydrogen Sulfide (H_2S)
St. Lawrence Seaway, HETA 2002-0014-2958
2003

Work Activity or Sample Location	Date	TWA* (ppm)§	STE± (ppm)	Maximum Recorded Peak (Instantaneous ppm)
Chipper 1	2/04/03	1	13	18**
Chipper 2	2/04/03	2	17	87**
Chipper 3	2/04/03	1	21	68**
Painter 3	2/04/03	0	1	5
Painter 3 (day 2)	2/05/03	0	7	11**
Fender Pit Maintenance Worker 1	2/05/03	0	1	2
Area Shed Near Chipping	2/05/03	0	2	3
Area Raft Near Chipping	2/05/03	1	10	19**

*TWA = Time-Weighted Average concentration adjusted for 8 hours
** = Exceeds NIOSH Ceiling of 10 ppm and/or the OSHA Ceiling of 20 ppm
§ ppm = parts per million
±STE = Short Term Exposure Limit (15 minute exposure)

Table 5
Area and Personal Breathing Zone Air Concentrations of Carbon Monoxide
St. Lawrence Seaway, HETA 2002-0014-2958
2003

Work Activity or Sample Location	Date	TWA* (ppm)§	STE± (ppm)	Maximum Recorded Peak (Instantaneous ppm)
Painter 4	2/05/03	0	5	19
Painter 5	2/05/03 (p.m. only)	1	3	8
Pipe-Fitter	2/05/03	1	3	21
Area Raft Near Chipping	2/05/03	2	33	58

*TWA = Time-Weighted Average exposures for up to a 10-hour workday
§ ppm = parts per million
±STE = Short Term Exposure–a 15 minute exposure

Table 6
TWA* Personal Breathing Zone Concentrations of Volatile Organic Hydrocarbons
St. Lawrence Seaway, HETA 2002-0014-2958
2003

Location	Job Title	Date	Sampling Time (minutes)	Toluene (ppm)§	MIBK (ppm)	PGMEA (ppm)	Xylene (ppm)
Eisenhower Lock	Painter 3	2/5/03	336	Trace	0.120	3.12	2.31
	Painter 4	2/5/03	394	0.015	0.017	15.0	0.662
	Painter 5	2/5/03	289	ND**	ND	ND	Traceº
	Pipe-fitter	2/5/03	393	ND	ND	0.033	0.050
	Minimum Detectable Concentration (MDC)			0.009	0.008	0.010	0.012
	Minimum Quantifiable Concentration (MQC)			0.032	0.021	0.029	0.036

*TWA = Time-Weighted Average
**ND = Non-detectable
ºTrace = Indicates a concentration below the MQC but above the MDC. The MDCs and MQCs were based on the minimum sample size of 58.13 L.
§ ppm = parts per million

APPENDIX A

Class C Confined Space Entry SOP for the General Lock Area

1. Permit. When each person enters he/she will sign a permit. This permit shall be kept at the job site for the duration of the job. If circumstances cause an interruption in the work or a change in the alarm conditions for which entry was approved, a new Confined Space Entry Permit must be completed. A written copy of St. Lawrence Seaway Development Corporation (SLSDC) rescue procedures shall be at the work site for the duration of the job.

2. Initial atmospheric testing. Before entering any area, the atmosphere within the space will be tested to determine whether dangerous air contamination and/or oxygen deficiency exists. A direct reading gas monitor shall be used. Testing shall be performed by the team leader. The parameters to be monitored are oxygen deficiency, carbon monoxide, lower explosive limit, and hydrogen sulfide concentration; these parameters will be tested for simultaneously. A written record of the pre-entry test results shall be made and kept at the work site for the duration of the job. The team leader will certify, in writing, based upon the results of the pre-entry testing, that all hazards have been eliminated. Affected employees shall be able to review the testing results. If there are no non-atmospheric hazards present and if the pre-entry tests show there is no dangerous air contamination and/or oxygen deficiency within the space and there is no reason to believe that any is likely to develop, entry into and work within may proceed.

3. Continuous testing of the atmosphere in the immediate vicinity of the workers within the space is not required in this situation. However, where the Seaway has established monitoring devices, the workers will immediately leave the permit space when any of these alarm set points are reached as defined. Workers will not return to the area until the team leader has used a direct reading gas detector to evaluate the situation and has determined that it is safe to enter.

4. Medical surveillance is not required in this situation. However, the surrounding area shall be surveyed by the standby person to avoid hazards such as drifting vapors from tanks, piping or sewers.

5. Training of personnel will be performed prior to going into the field.

6. Labeling and posting will be done.

7. Preparations; including isolation/lockout/tagout, purge and ventilate, cleaning processes; are not required.

8. One standby person will be stationed at the entrance to the locks at all times when any other employee is within the lock area. Communications will be established between personnel within the confined space and the standby person.

9. Safety equipment. Safety helmets, glasses, hand protection, and boots, will be worn. Rubber boots and gloves will be provided by the SLSDC. Safety harnesses will be worn by all workers.

10. Rescue. An approved hoist and crane must remain available at the site. If at any time there is any questionable action or non-movement by the worker inside, a verbal check will be made. If there is no response, the worker will be removed immediately. Exception: If the worker is disabled due to falling or impact, he/she shall not be removed from the confined space unless there is immediate danger to his/her life. Local fire department rescue personnel shall be notified immediately.

11. Rescue. Call the fire department services for rescue. Where immediate hazards to injured personnel are present, workers at the site shall implement emergency procedures to fit the situation.

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