Exposure to Nitrogen Dioxide in an Indoor Ice Arena — New Hampshire, 2011

In January 2011, the New Hampshire Department of Health and Human Services (NHDHHS) investigated acute respiratory symptoms in a group of ice hockey players. The symptoms, which included cough, shortness of breath, hemoptysis, and chest pain or tightness, were consistent with exposure to nitrogen dioxide gas (NO₂), a byproduct of combustion. Environmental and epidemiologic investigations were begun to determine the source of the exposure and identify potentially exposed persons. This report summarizes the results of those investigations, which implicated a local indoor ice arena that had hosted two hockey practice sessions during a 24-hour period when the arena ventilation system was not functioning.

A total of 43 exposed persons were interviewed, of whom 31 (72.1%) reported symptoms consistent with NO₂ exposure. The highest attack rate was among the hockey players (87.9%). After repair of the ventilation system, no additional cases were identified. To prevent similar episodes, ice arena operators should ensure ventilation systems and alarms are operating properly and that levels of NO₂ and carbon monoxide (CO) are monitored continuously for early detection of increased gas levels.

On January 4, 2011, NHDHHS was notified that a previously healthy male aged 19 years was hospitalized for sudden onset of cough, shortness of breath, and hemoptysis shortly after a team ice hockey practice. His physical examination was notable for crackles heard in both lung bases, and his oxygen saturation was decreased to 88%–91% on room air (normal: >95%). Bilateral infiltrates and nodules were observed on chest computed tomography. Investigation revealed that other members of his team (team A) and at least one player from another team (team B) were experiencing similar symptoms and had independently been directed to local emergency departments. Both teams had practiced in the same ice arena that had hosted two hockey practice sessions during a 24-hour period when the arena ventilation system was not functioning. A total of 43 exposed persons were interviewed, of whom 31 (72.1%) reported symptoms consistent with NO₂ exposure. The highest attack rate was among the hockey players (87.9%). After repair of the ventilation system, no additional cases were identified. To prevent similar episodes, ice arena operators should ensure ventilation systems and alarms are operating properly and that levels of NO₂ and carbon monoxide (CO) are monitored continuously for early detection of increased gas levels.

On January 4, 2011, NHDHHS staff members began interviewing all 33 players and five coaches who were present at practices on January 3. From these initial interviews, case finding was expanded to include four practice spectators and the two arena workers who operated the resurfacing equipment, for a total of 44 exposed persons. Questionnaires that assessed symptoms, exposures, and environmental observations were administered by NHDHHS staff members in person or by telephone. All but one of the 44 exposed persons completed the questionnaire.

A case was defined as the onset of cough, hemoptysis, chest pain, chest tightening, shortness of breath, headache, dizziness, nausea, or vomiting within 48 hours of being in the ice arena from 11:00 a.m. on Monday, January 3, to 9:00 a.m. on Tuesday, January 4. Illnesses with symptoms consistent with the common cold (e.g., runny nose, fever, and head congestion) were not counted as cases. Using this definition, 31 cases were identified among the 43 persons interviewed: 29 among the 33 players (87.9%) and two among the five coaches (40%). None of the four spectators had illness consistent with the case definition, nor did the one arena worker who completed the questionnaire. Most patients (90.3%) had two or more symptoms (Table 1). Although 10 nonplayers (coaches, spectators, and arena personnel) were exposed, players were nearly four times as likely to become ill (87.9% versus 20.0%, risk ratio [RR] = 4.39, 95% confidence interval [CI] = 1.26–15.28). Compared with nonplayers, players also were more likely to have spent more time on the ice (defined as >1 hour versus ≤1 hour) (84.8% versus 40.0%, RR = 2.12, CI = 0.98–4.59). As time spent on the ice increased, so did the attack rate and amount of hemoptysis (Figure).

On January 5, the New Hampshire Department of Environmental Services (NHDES) and the New Hampshire State Fire Marshal’s Office (NHFMO) inspected the ice arena. Measurements for CO and NO₂ were taken before running the resurfacing equipment (baseline conditions) and while operating the equipment, and recorded at breathing zone (where persons on the ice would be exposed) as well as adjacent to the equipment exhaust pipe. Air sampling was performed for NO₂ using a Gastec piston hand pump equipped with Sensidyne.
The use of propane-powered ice-resurfacing equipment for 60–90 minutes in an indoor ice arena without an operating ventilation system caused symptoms of NO2 intoxication in 31 of 43 exposed persons, including 31 of 42 persons who first entered the arena more than 6 hours after the ice resurfacing had been completed.

What are the implications for public health practice?
Because exposure to NO2 can occur more frequently than is recognized, public health agencies should consider educating ice arena operators about the importance of arena ventilation, air monitoring for combustion gases, and maintenance of propane-powered equipment; if use of electric ice resurfacing equipment is not feasible. Additionally, ice arena operators as well as ice hockey players and coaches who use indoor rinks should be familiar with the signs and symptoms of NO2 toxicity.

**TABLE 1. Number and percentage of persons with symptoms consistent with exposure to nitrogen dioxide gas (NO2) in an indoor ice arena (N = 31) — New Hampshire, January 3, 2011**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>No.</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>26</td>
<td>(83.9)</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>24</td>
<td>(77.4)</td>
</tr>
<tr>
<td>Chest tightness</td>
<td>20</td>
<td>(64.5)</td>
</tr>
<tr>
<td>Chest pain</td>
<td>14</td>
<td>(45.2)</td>
</tr>
<tr>
<td>Weakness</td>
<td>11</td>
<td>(35.5)</td>
</tr>
<tr>
<td>Sore throat</td>
<td>11</td>
<td>(35.5)</td>
</tr>
<tr>
<td>Nausea/Vomiting</td>
<td>10</td>
<td>(32.3)</td>
</tr>
<tr>
<td>Hemoptysis/Bloody sputum*</td>
<td>8</td>
<td>(25.8)</td>
</tr>
<tr>
<td>Throat irritation</td>
<td>8</td>
<td>(25.8)</td>
</tr>
<tr>
<td>Headache</td>
<td>8</td>
<td>(25.8)</td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>6</td>
<td>(19.4)</td>
</tr>
<tr>
<td>Eye irritation</td>
<td>5</td>
<td>(16.1)</td>
</tr>
<tr>
<td>Dizziness</td>
<td>1</td>
<td>(3.2)</td>
</tr>
<tr>
<td>Choking</td>
<td>1</td>
<td>(3.2)</td>
</tr>
</tbody>
</table>

* Includes two persons with late-onset hemoptysis reported at follow-up survey.

colorimetric gas detector tubes. A TSI Q-Trak indoor air quality monitor was used to obtain direct readings for CO. While the ice resurfacer was operating in the arena, the NO2 concentration in the breathing zone increased, reaching 0.5 parts per million, the level at which corrective action must be taken according to regulations in states that regulate indoor air quality in ice arenas (Table 2). These measurements did not simulate actual conditions in the arena on January 3 because the arena ventilation system had been fully functional for approximately 24 hours at the time of sampling.

Beginning January 20, a follow-up questionnaire was administered to exposed persons to assess late-onset and persistent symptoms. Thirty-nine (90.7%) of the original 43 persons interviewed responded to the follow-up questionnaire. No new cases were identified; however, two of the original patients reported late onset of hemoptysis (at 5 days and 21 days postexposure) and were advised to seek medical evaluation. Six patients (20%) reported persistent symptoms: shortness of breath on exertion (four cases), cough (two cases), and fatigue (one case).

NHDDHHS, in consultation with the Northern New England Poison Center, recommended that all exposed persons seek medical evaluation, even if asymptomatic, preferably at a designated occupational health clinic. Ultimately, 39 (90.6%) complied (30 of 31 [96.8%] patients and nine of 12 [75.0%] of persons without symptoms). After these initial medical evaluations, the need for follow-up was determined on a case-by-case basis, dependent on severity. NHDES and NHPMO recommended that the arena include an NO2 sensor in the air monitoring system, establish alarm set points for CO and NO2 in line with air action level recommendations (Table 2), and test this system at least monthly. The arena also was advised to conduct maintenance and tailpipe emissions testing on all ice resurfacing equipment at the beginning of the ice arena season and at least once during the season, and consider installing catalytic converters to reduce emissions. However, the most reliable way to prevent exposure in this setting is to replace propane-powered equipment with electric equipment, which should be considered as a long-term solution.

**Reported by**

**Editorial Note**
Respiratory illness caused by NO2 in indoor hockey rinks has been documented infrequently in the literature. Hazardous levels of NO2 in ice arenas often result from malfunction of propane-fueled ice resurfacing equipment or arena ventilation systems (I–5).
Nitrogen dioxide is a yellow to reddish brown gas that irritates the upper and lower respiratory tracts and can cause short-term central nervous system symptoms \((5,6)\). Severity of symptoms is related to duration of \(\text{NO}_2\) exposure \((5,6)\), although exertion with increased frequency and depth of respiration might have made the hockey players more susceptible than the spectators or coaches to the effects of the gas. This has been reported during other exposures \((4)\). No specific antidote for \(\text{NO}_2\) toxicity exists, and therapy is focused on supportive care and prolonged monitoring \((6)\). The long-term consequences of acute \(\text{NO}_2\) exposure are not well understood, but in this instance, six of 31 persons had persistent symptoms up to 4 weeks postexposure. Other studies document self-reported symptoms several weeks after exposure \((4)\), 6 months postexposure \((1)\), and even 5 years postexposure \((7)\). However, tests of pulmonary function (e.g., spirometry and bronchoprovocation) at 10 days, 2 months, and 6 months postexposure have provided little objective evidence of compromised lung function \((1,4)\). The small but unpredictable potential for delayed development of life-threatening conditions such as bronchiolitis obliterans warrants follow-up of exposed persons \((6)\).

### TABLE 2. Air quality recommendations for ice arena owners and managers

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Description</th>
</tr>
</thead>
</table>
| Air quality in ice arenas: action steps* | • Educate workers on their role in indoor air quality and protecting occupants.  
• Establish a system of monitoring air quality  
• Establish procedures for responding to indoor air complaints and emergencies  
• Provide continuous ventilation whenever a rink is occupied  
• At a minimum, use ventilation requirements for sports arenas as described in the ASHRAE Ventilation for Acceptable Indoor Air Quality, Standard 62.1-2007 (or most recent edition)  
• Ensure that fresh air intake is not blocked and not located near the exhaust from loading docks and outside idling vehicles  
• Consider replacing older equipment that does not meet current Environmental Protection Agency emissions standards with newer compliant equipment or upgrade to most efficient burning fuel type and pollution control devices  
• Warm up resurfacing equipment in a well-ventilated room or a room equipped with a local exhaust  
• Use ice edgers only when the ventilation system can adequately exhaust the emissions. Keep arena gates open when resurfacing to allow for adequate ventilation of the ice area  
• Keep resurfacing equipment well maintained daily and serviced annually by a qualified technician  

**Air action levels†**  
• Immediate evacuation level: 85 ppm for CO or 2 ppm for \(\text{NO}_2\)  
• Corrective action level: 25 ppm for CO or 0.5 ppm for \(\text{NO}_2\)

**Abbreviations:** ASHRAE = American Society of Heating, Refrigeration and Air-conditioning Engineers; CO = carbon monoxide; NO\(_2\) = nitrogen oxide.


† No federal recommendations or regulations exist for air action levels in ice arenas. These recommendations are taken from Minnesota Department of Health Interim Regulations 4620 and Massachusetts Department of Public Health Regulation 105 CMR 675.000.

### FIGURE. Outcomes among persons exposed to nitrogen dioxide gas (\(\text{NO}_2\)) in an indoor ice arena (\(N = 43\)), by time spent on ice — New Hampshire, January 3, 2011*

Most ice arenas are designed to minimize natural ventilation in an effort to keep warm air away from the ice surface and the ice temperature near freezing. This can create a thermal inversion in which cold air and gases (especially \(\text{NO}_2\), which is denser than air) become trapped over the ice \((6)\). The protective glass between spectator stands and the ice rink creates an additional barrier to airflow. In this episode, exposure was made worse by prolonged use of propane-powered ice resurfacing while the ventilation system was off.
The findings in this report are subject to at least two limitations. First, a broad case definition was used to ensure complete case finding and appropriate follow-up; however, this might have led to inflation of the attack rate. Second, with the exception of the index case, symptom data were based on self-report, which also might have inflated the attack rate.

No federal regulations exist for indoor air quality in ice arenas, and only three states have enacted regulations (Minnesota, Rhode Island, and Massachusetts). Only Minnesota and Massachusetts specify limits for NO\textsubscript{2} levels. After this incident, NHFMO sent an informational bulletin to all indoor ice arenas in the state based, in part, on recommendations from the U.S. Environmental Protection Agency and the regulations existing in other states (Table 2). Without legislated regulations, however, direct education of the public about signs and symptoms of NO\textsubscript{2} exposure and education of arena staff about the risk of NO\textsubscript{2} toxicity is important for prevention.

Acknowledgments


References