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Atmospheric hazards associated with ice-skating rinks

1. Introduction

Unfortunately, ice-skating rinks have been in the news quite a bit recently. A series of widely reported incidents of player and audience exposure to toxic contaminants from ice-resurfacing equipment exhaust has led several states to enact strict regulations.

2. Background

Many ice-skating rinks use a gasoline or propane powered resurfacing machine to periodically smooth or groom the ice. If ventilation is inadequate, toxic contaminants from the resurfacing equipment exhaust may reach dangerous concentrations. Numerous incidents involving the illness of drivers, hockey players, spectators and children have been linked to exposure to resurfacing equipment exhaust. As a consequence, a number of state and federal regulatory agencies are in the process of studying, developing, and implementing standards that will require rink operators to monitor for the two most common toxic contaminants in resurfacing equipment exhaust, carbon monoxide (CO) and nitrogen dioxide (NO_2).

The state of Massachusetts has been at the forefront of these regulatory efforts. In October 1996 Massachusetts enacted some of the strictest monitoring requirements in the country for these hazards. Several other states are looking to Massachusetts to provide guidance for their own pending regulations. In the case of ice-skating rinks in Massachusetts, failure to monitor and document exposure levels can lead to stiff fines, or even to the rink losing its license to operate. An explanatory memo from the State of Massachusetts Bureau of Environmental Health and Assessment cited a number of local incidents as illustration why the state has taken this action. The number of people involved can be surprisingly large. In Rockland, MA in 1991 and Hamilton, MA in 1993, exposure of players and audience members to ice-resurfacing equipment exhaust resulted in over 110 individuals being transported to area hospitals. Of course, incidents of this kind are not restricted to the Northeast. On March 18, 1996, 70 people were evacuated from an indoor ice-rink in Shoreline, Washington, due to a malfunctioning ice resurfacer. Several states besides Massachusetts (such as Rhode Island and Minnesota) are also poised to take regulatory action.

3. Theory

The engines of most ice-smoothing machines are powered by gasoline or propane. Various toxic gases are produced as unintended by-products of the combustion of these fuels. The most important are carbon monoxide and a family of contaminants known collectively as "oxides of nitrogen".

Carbon monoxide is a colorless, odorless toxic gas which readily bonds to the hemoglobin molecules in red blood cells. Contaminated red blood cells are unable to transport oxygen. Although high concentrations of carbon monoxide may be acutely toxic, and lead to immediate respiratory arrest or death, chronic exposure at even low concentrations may also cause serious illness. Although exposure levels may be too low to produce immediate symptoms, small repeated doses can reduce the oxygen carrying capacity of the blood over time to dangerously low levels. For that reason prudent monitoring programs have long targeted carbon monoxide as the leading contaminant of concern when workers are exposed to internal combustion engine exhaust.

CO is the leading cause of accidental poisoning in America! CO causes more accidental poisonings than any other chemical substance. According to the Journal of the American Medical

Association (JAMA) at least 1,500 persons are killed per year, and 10,000 more forced to seek medical attention as a function of exposure to this dangerous contaminant.

"Oxides of nitrogen" are compounds which consist of oxygen and nitrogen atoms bound together in various numerical combinations. Some of the more common of these "NOx" compounds include nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), and di-nitrogen tetroxide (N_2O_4), but other combinations are also possible.

Oxides of nitrogen tend to be very reactive. The most stable or persistent of these NOx compounds tends to be nitrogen dioxide (NO_2). For that reason monitoring programs usually focus on this contaminant.

At high concentrations nitrogen dioxide is a reddish brown gas. At the concentrations normally seen in engine exhaust it is usually invisible. Nitrogen dioxide has a pungent, acrid odor. Since NO_2 reacts with moisture to form nitric acid, it tends to cause a stinging sensation or produce tearing in the eyes of exposed workers. Nitrogen dioxide is a respiratory irritant. Exposure to nitrogen dioxide can be particularly harmful to individuals skating or engaging in other strenuous activities. Chronic exposure to nitrogen dioxide at levels as low as 0.4 - 2.7 PPM (parts-per-million) have been associated with the development of bronchitis and other cardiovascular problems. Other symptoms of NO_2 exposure include eye irritation, coughing, chest pain, pulmonary edema, respiratory arrest, and death.

4. Relationship between the concentration of CO and NO 2 in engine exhaust

CO and NO_2 are not usually both present when concentrations are dangerously high. When the concentration of one contaminant is high, the concentration of the other tends to be relatively low. Which gas is predominantly present is a function of the temperature of the engine.

When an engine is first started it will run at a lower temperature than is ideal. Until the engine has fully warmed up there is a tendency for the engine to run "lean". When an engine is running lean the fuel to air ratio is too low to provide optimal combustion. This results in increased carbon monoxide production.

Studies of enclosed ice-rink atmosphere report the highest carbon monoxide concentrations around the times ice smoothing machines are first started for the day. In some cases the general ice-rink concentration has been shown to exceed 125 PPM; over 5 times the ACGIH (American Conference of Governmental Industrial Hygienists) recommended TLV (threshold limit value) of 25 PPM for carbon monoxide. The concentrations experienced by resurfacing equipment operators and players on the ice are probably much higher.

As the ice-smoothing machine fully warms up and reaches its optimal operating temperature carbon monoxide production drops. As the machine continues to be used over the course of a hockey match or skating event it may begin to run hot or overheat. As the engine overheats it begins to produce increased amounts of nitric oxide (NO). Most of this nitric oxide quickly reacts with oxygen present in the atmosphere to produce nitrogen dioxide (NO_2). It is not uncommon for nitrogen dioxide concentrations to remain well above the ACGIH TLV of 3.0 PPM for the entire course of a hockey game!

Although CO and NO_2 will rarely both be present in hazardous concentrations at the same time, the gases should still be monitored simultaneously since it is difficult to be certain whether an engine is burning rich or lean at any particular moment. The relationship between CO and NO2 generation and engine temperature is illustrated in Figure 1.

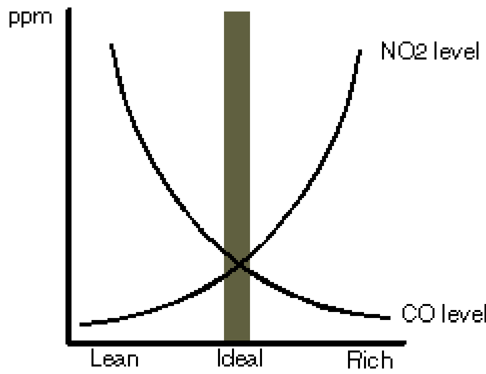

Figure 1: CO and NO_2 generation as a function of engine temperature

5. What do Massachusetts regulations require

Effective October, 1996, regulations contained in Chapter XI of the Commonwealth of Massachusetts State Sanitary Code, 105 CMR 675. 006:

"Air Sampling Requirements" requires that operators of indoor ice-skating rinks take and record air measurements for both carbon monoxide *and* nitrogen dioxide within their skating rinks at least twice a week at a minimum, and at least once during weekend operations. Samples must be taken immediately after resurfacing is completed, then again 20-minutes after resurfacing is completed. The sampling must occur at least two hours before the time the rink closes for the day; and air samples must be taken either at center-ice or the perimeter of the ice-surface at the center ice line. The operator must keep an "Air Quality Recordkeeping Log", where air sampling results as well as other information specified by 105 CMR 675 are recorded. The 2-samples that are taken for each contaminant in a sampling sequence are averaged to provide the reading that is logged and used to determine compliance with the "air action levels" which are listed in Table 1. "Correction" level action must be taken any time the concentration of either hazard (based on the air-sampling sequence discussed above) is found to exceed 30 PPM CO, or 0.5 PPM NO_2. Any single instance where air measurement readings exceed the "Correction" level requires the ice-rink operator to take action to reduce air levels of CO and NO_2.

Any time the concentration of CO is found to exceed 60 PPM on the basis of a single air-sampling sequence, or 30 PPM on the basis of 6 consecutive samples; the ice-rink operator must notify the local fire department, the local Board of Health, and the Massachusetts Bureau of Environmental Health and Assessment within 24 hours of the reading. A single reading of 1.0 PPM, or 6 consecutive readings of 0.5 PPM NO_2 triggers similar notification requirements.

Any time the concentration of CO is found to exceed 125 PPM, or NO_2 is found to exceed 2 PPM on the basis of a single sampling sequence, the icerink operator must immediately evacuate all people from the interior of the ice-skating rink., contact the local fire department and Board of Health upon completion of the evacuation, and contact the Bureau of Environmental Health and Assessment within 2-hours of the incident.

Action level	CO	NO_2
Correction	Single reading of 30 PPM	Single reading of 0.5 PPM
Notification	Single reading of 60 PPM, or 6 consecutive readings of 30 PPM	Single reading of 1.0 PPM, or 6 consecutive readings of0.5 PPM
Evacuation	Single reading of 125 PPM	Single reading of 2.0 PPM

Table 1: Massachusetts air action levels

6. Biosystems makes ice-rink monitoring easy

Biosystems offers a range of products which are ideal for ice-skating rink monitoring applications.

The PhD Ultra and PhD5 are a multi-sensor gas detectors that utilize from one to four sensors; oxygen, combustible gas, and up to two toxic gas sensors. These monitors can easily be configured with substance specific electrochemical sensors for the direct detection of CO and NO_2.

The instrument may or may not need to be set up to include combustible gas (LEL) and oxygen sensors. (If the instrument is to be used for confined space entry as well as CO / NO_2 detection; O_2 and LEL sensors should always be included.)

The flexibility of the PhD design makes it *the* cost effective approach for most ice-rink operators. As an added bonus, the PhD Ultra and PhD5 automatically record measurement data whenever the instrument is turned on. This recorded information can be reviewed directly through the instrument, or downloaded to a personal computer or printer to automatically generate reports, tables or graphs of monitoring results. Another approach is to use single-sensor gas detectors to monitor for specific toxic hazards. Biosystems' Toxi Ultra and Toxi Vision datalogging gas detectors are ideal for use in single-contaminant monitoring applications. This may be an especially attractive approach in states such as Rhode Island and Minnesota where the emphasis (so far) is on carbon monoxide only, rather than the simultaneous measurement of both hazards.

7. Summation

Ice-skating rink operators all over the country are increasingly concerned with the quality of the air in their facilities. In several states it is now mandatory to monitor to ensure that contaminants do not exceed the "action levels" for a listed hazard. In most other states it's simply a matter of time. In addition, although this Application Note focuses on engine exhaust in ice-rinks, the fact is that any time gasoline or propane fueled engines are used within an enclosed structure, similar concerns and hazards will be found to exist.

Engine exhaust in an enclosed structure is always a potential danger. The key is recognizing the danger, and taking the appropriate steps to monitor for the presence of these dangerous contaminants. Biosystems instruments are ideal for this purpose.