Abatement of Toxic Levels of Carbon Monoxide in Seattle Ice-Skating Rinks

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Excessive levels of carbon monoxide were found in ice-skating arenas where ice-resurfacing machines were used. Efforts to overcome the problem are described.

Introduction

In November, 1971, complaints were received by the Seattle-King County Health Department calling attention to the illness of 15 children who had been skating at a local ice-skating arena. All of the children had headaches, four of them had become nauseated, and two had vomited. The symptoms had appeared before they left the rink, and most of the children recovered within 24 hr.

Investigation

The children were first thought to have some type of food-borne illness. However, an investigation of the food concession of the ice arena failed to show any evidence that food served there was the cause of the illness. A report that "gassy odors" had been present prompted an inspection of the rest of the premises. During this inspection, it was noted that there was a large ice-resurfacing machine at the rink, powered by a propane-fueled engine. Ventilation at the rink was inadequate. Questioning of the staff and some of the regular patrons of the rink disclosed that many other persons in prior months had suffered headaches. The premises were then monitored to determine the levels of carbon monoxide during the hours in which the ice-resurfacing machine was in use. The levels of carbon monoxide measured in the ice arena are shown in Table 1.

Results

Carbon monoxide levels were found to be as high as 304 parts per million. This level is far in excess of that required to produce symptoms. An evaluation of some of the maximum allowable concentrations of carbon monoxide showed some of these standards to be too high for the general public (Table 2). Children have a higher rate of metabolism than do adults and so have a higher uptake of carbon monoxide. In addition, the activity of skating may increase respiratory volume by as much as 10 times that required for sedentary activity. These factors would also contribute to a greater exposure potential for a child. In addition, one should be concerned about possible developmental effects on those children who regularly spend a considerable amount of time at a rink in concentrations of carbon monoxide such as these. For these reasons, it was felt that the Environmental Protection Agency standards were most reasonable.

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TABLE 1—Concentrations of Carbon Monoxide Recorded in Ice-Skating Arena during Operation of Propane-Powered Ice-Resurfacing Machine*

Time	CO Level (Avg)
p.m.	ppm
4–5	214
5–6	304
6–7	224
7–8	225
8–9	186
9–10	157
10–11	261
11–12	219

* The machine was operated for about 10 min every 1 or 2 hr. CO levels were measured at bench level between two adjacent rinks with a Mine Safety Appliance portable model D CO instrument.

TABLE 2—Maximum Allowable Concentrations of Carbon Monoxide

Standard	Length of Exposure	Maximum Allowable Concentration
	hr	ppm
Environmental Protection Agency[1]	1	35 (40 mg/m^3)
	8	9 (10 mg/m^3)
National Primary Ambient Air Quality Standards (proposed)	1	13
	8	9
American Conference of Governmental Industrial Hygienists Threshold Limit Value[2]		50
Washington State Department of Labor and industries	8	50

Survey of Arenas

The observation of high levels of carbon monoxide in one skating rink prompted us to do a survey of other skating rinks in the county, yielding the results shown in Table 3. All of the rinks except one which does not permit public skating were found to have excessive levels of carbon monoxide. None of these had adequate ventilation.

As noted in the remarks, some of the operators were unwilling to duplicate usual operating conditions. In some cases all of the outside doors were opened; in other cases the ice-resurfacing machines were operated for a shorter time than usual. It seems probable that patrons of these arenas were usually exposed to higher levels of CO than were recorded here.

The rate with which carbon monoxide levels rise in the air in an ice-skating arena is shown in Table 4. In this arena, measurements were made at 2- to 5-min intervals during the operation of a gasoline-powered Zamboni ice-resurfacing machine. Carbon monoxide levels rose to a level of 175 parts per million in 17 min. Although the machine was then stopped, the level still remained at 170 parts per million 32 min after the beginning of operation.

TABLE 3—Results of Initial Survey of Carbon Monoxide Levels in Ice-Skating Arenas in King County, Washington

Ice-Skating Arena	CO Level (Maximum)*	No. of Inspections	Remarks
	ppm		
Highland	250	4	Now open doors to augment ventilation
Ballard	45	1	Prior to the test all doors were opened by the owner (this is not normally done)
Bellevue	75	1	Owner ran machine only 7 min; machine normally runs 10 to 15 min
Burien	100	1	
Crossroads	175	1	
Coliseum	12	1	No public skating

* Measured by a Dräger gas detector, model 19/31.

TABLE 4—Carbon Monoxide Levels Recorded in an Ice-Skating Arena during Operation of a Gasoline-Powered Zamboni Ice-Resurfacing Machine

Time	Comments	CO Level*
		ppm
7:53	Zamboni ice-resurfacing machine started	
7:55	1st test	75–80
8:00	2nd test	101
8:05	3rd test	110
8:10	4th test; machine stopped	175
8:25	5th test	170

* Measured by a Dräger gas detector, model 19/31.

Health Department Action

As a result of this survey, a program was initiated to monitor carbon monoxide levels in all of the ice-skating arenas. Efforts were made to educate management personnel of these arenas about the hazards of carbon monoxide. An attempt was made to persuade them to increase ventilation in the arenas, to operate the machines less often and for shorter periods, and to purchase their own carbon monoxide-monitoring devices. As a result of these efforts, significant improvements were noted on a second survey of carbon monoxide levels (Table 5).

It became apparent that the 9 parts per million maximum level of concentration for an 8-hr exposure, as permitted by the Environmental Protection Agency, would not be practical, at least for the first year of this new program. It was therefore decided that we would permit a level of 25 parts per million for the first year.

Some of the operators attempted to meet standards by making use of catalytic mufflers. These devices appeared to be effective, at least for engines that were properly tuned and were operated on propane or lead-free gasoline (Table 6).

TABLE 5—Results of Second Survey of Carbon Monoxide Levels in Ice-Skating Arenas in King County, Washington

Arena	Machine	Length of Operation	CO Levels at Minute Intervals*						
			0–10	10–20	20–30	30–40	40–50	50–60	60–70
		min	ppm						
Burien	Zamboni	7	60		29				
Crossroads	Zamboni	13	30	30	105		45	40	33
Ballard	Jeep	10	40	25	20				
Highland	Zamboni	7	0						
Bellevue	Zamboni	7	45–50		29				

* All tests were made 42 inches above ice at edge of rink using a Mine Safety Appliance portable model D CO instrument 96300 or a Dräger gas detector, model 19/31. Most machines are operated for about 10 min every 1 or 2 hr when the arena is undergoing heavy use.

TABLE 6—Levels of Carbon Monoxide and Carbon Dioxide Recorded in the Exhaust of a Gasoline-Powered Engine and in the Skating Arena before and after Use of a Catalytic Muffler*

	Before Muffler		After Muffler	
	CO	CO_2	CO	CO_2
	ppm			
Engine exhaust gas	10,400	23,400	115	11,400
Skating arena	20	690	8	1,050

* Englehart exhaust gas purifier PTX-4, Series 360910.

TABLE 7—Consecutive Levels of Carbon Monoxide Recorded in an Ice Arena during Use of a Gasoline-Powered Ice-Resurfacing Machine Equipped with a Catalytic Muffler

Time	Engine Time	CO Level	Remarks
	min	ppm	
9:20 a.m.	0	4	Skating arena background
9:25 a.m.	5	110	Engine exhaust
9:35 a.m.	10	4	Skating arena after resurfacing
12:30 p.m.	25	8	Skating arena after resurfacing
2:15 p.m.	15	6	Skating arena after resurfacing
4:30 p.m.	18	8	Skating arena after resurfacing
8:00 p.m.	15	10	Skating arena after resurfacing
10:15 p.m.	14	15	Edging machine was used before resurfacing

Oxides of nitrogen have also been reported to be a problem associated with propane- and gasoline-powered engines used in ice-skating arenas. The catalytic mufflers apparently cannot eliminate this problem. In this investigation, no measurements were made of oxides of nitrogen. The American Conference of Governmental Industrial Hygienist's standards suggest that nitrogen dioxide tolerance levels should be 10 times lower than those for carbon monoxide. The presence of oxides of nitrogen is suggested by a yellowish brown haze in the air.[3]

Consecutive measurements of carbon monoxide levels in an ice arena during use of a gasoline-powered ice-resurfacing machine equipped with a catalytic muffler showed that these devices are able to prevent a buildup of carbon monoxide (Table 7).

It was felt that the operators of the ice-skating arenas were more likely to take precautions to maintain good ventilation and to limit the emission of carbon monoxide if the premises were monitored at intervals by environmental health personnel of the Health Department. Measurements were usually taken at the rink by a Dräger gas detector, model 19/31, or by the expensive but more accurate Mine Safety Appliance portable model D CO instrument. Individual conferences were held with operators of the rinks and advice was given as to how carbon monoxide emissions might be reduced. In addition, a meeting was held by the Health Department for operators of all of the ice-skating arenas. Experts from the Washington State University College of Medicine and from other agencies were invited to discuss the hazards of carbon monoxide poisoning and to suggest ways in which the hazard of carbon monoxide could be reduced.

News releases were prepared and distributed to inform the public about the hazards of CO in the arenas. The result of this program has been to achieve the compliance of all of the ice-skating arenas with Environmental Protection Agency standards, with one exception. The owner of one arena did not cooperate until recently. If this one recalcitrant owner had not complied with the Environmental Protection Agency standards the Health Department would have sought an injunction against operation of the ice-resurfacing machine. The department has not received any more complaints from the public about illness in the rinks.

Conclusions

There are an estimated 600 to 700 ice-skating arenas in the United States, as well as large numbers in Canada and in Europe. Most of these use ice-resurfacing machines that

produce considerable amounts of CO. Arenas using these machines should be checked to evaluate the hazard to the public from carbon monoxide poisoning. Nitrogen dioxide levels should also be determined. Adequate ventilation is probably a better solution than the catalytic mufflers, especially where NO_2 emissions are also a problem. The best solution to this problem of CO and NO_2 emissions is probably the use of the electrically powered ice-resurfacing machine.

REFERENCES

1. Environmental Protection Agency. National Primary and Secondary Ambient Air Quality Standards. Federal Register, Vol. 36, No. 21, Part II, Jan. 30, 1971.
2. ACGIH Committee on Threshold Values. Threshold Limit Values for 1970. American Conference of Governmental Industrial Hygienists, P.O. box 1937, Cincinnati, OH 45201.
3. Anderson, D. E. Problems Created for Ice Arenas by Engine Exhaust. Am. Ind. Hyg. Assoc. J. 32:790–801, 1971.

CHECK YOUR RECORDS NOW

You should check now to make sure your youngsters have been immunized against the following dangerous childhood diseases:

POLIO
MEASLES
MUMPS
RUBELLA (German Measles)
DIPHTHERIA
TETANUS (Lockjaw)
PERTUSSIS (Whooping cough)

Why should you check? Because many pre-school children have missed one or more of their immunizations against childhood diseases. These children face a needless risk of serious illness and devastating, perhaps fatal, complications.

THE DANGER

In recent years, the percentage of children immunized against childhood diseases has been declining. As a result, polio, measles and other preventable diseases continue to strike.

Worse still, health experts warn that unless more young children are immunized, widespread epidemics could take place once again, spreading particularly among pre-school children.

A CALL TO ACTION

Anyone who remembers the polio epidemics of the 1950s, when many children died and thousands more were seriously crippled, understands the importance of immunization. More recently, measles and rubella were brought under control. Before vaccines were available, measles complications claimed hundreds of young lives each year. The last rubella epidemic took place in 1964-65 and resulted in the birth of 20,000 deformed babies and 30,000 miscarriages.

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IMMUNIZATION
ACTION MONTH

Epidemics must not be allowed to strike again. Parents are urged to check their records to make sure their children have received all their immunizations. Unimmunized children should be taken to their doctor without delay. Remaining unimmunized for childhood diseases is a risk no child should face.

DON'T PUT IT OFF

Many children are not immunized until they approach school age. This leaves them susceptible to disease at a time when they are most vulnerable – most of the diseases are likely to strike young children and the consequences are often most severe in this age group. If an epidemic started, it could spread quickly among these unimmunized pre-school children. That is why it is essential that children be immunized early in life.

WHEN SHOULD CHILDREN BE VACCINATED?

Polio
The oral polio vaccine begins early in life – at about 2 months of age. Three doses are given during the first six months to one year. A booster dose is sometimes given at 15 to 18 months of age. Another dose is recommended at school entry.

Measles, Mumps, Rubella
Each of these diseases requires only one immunization. In fact, combination vaccines are available that make it possible for one injection to provide immunization for all three diseases. The immunization is recommended shortly after the child's first birthday.

Diphtheria-Tetanus-Pertussis
The combination DTP vaccine is given in four doses, beginning at about 2 months of age. A booster dose is given at school entry.