



Atmospheric Effects in the Entertainment Industry: Constituents, Exposures, and Health Effects

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Summary of Results

Why did we do this study?

In 1999, SHAPE (a tripartite organization to promote Safety and Health in Arts, Production, and Entertainment) asked the University of British Columbia to help investigate several questions related to the safety of theatrical smokes and fogs. These questions were:

- What products and equipment are being used in the BC entertainment industry, what chemicals do these products actually contain, and do these chemicals change when the products are heated during use?
- What measuring equipment can be used for on-site monitoring by production staff, to measure the levels of smokes and fogs chemicals in the air at entertainment industry worksites?
- What levels of smokes and fogs chemicals are actually present in the air? What are the sizes of the airborne fog droplets? How much are BC entertainment industry employees exposed to during their work? What factors at the worksite contribute to more or less exposure?
- Are BC entertainment industry employees suffering ill health effects as a result of exposure to theatrical smokes and fogs? If so, is it possible to link the ill effects to any particular chemical or type of work?

The study plan was endorsed by the Board of SHAPE, IATSE Local 891, the Canadian Film and Television Production Association, the Directors Guild of Canada, the Alliance of Motion Picture and Television Producers, and the Vancouver Musicians' Association. Funding for the study came from the BC Workers' Compensation Board, the BC Lung Association, SHAPE, and UBC.

What did we do? What did we find out?

Survey of special effects technicians

We interviewed 23 members of IATSE Local 891 about their jobs. Most worked mainly in television and movie production, and consequently worked long shifts, averaging over 12 hours. About half owned their own fog machines, but most used other equipment as well. Glycol-using machines (i.e., those that use heat to generate fog) were usually used with fluids supplied by the manufacturer, but this was not so for other machine types. Nearly half the technicians sometimes formulated their own fluids. Many machines could be used to create diverse effects, including source smoke, large volume smoke, smoldering, atmospheric haze, low lying fog, and steam effects. Mineral oil-based machines were limited to a more circumscribed set of effects, as were "crackers", "bee-smokers" and "steamers." Only smoke cookies were used to create coloured smoke.

Analysis of chemicals used

We collected bulk samples of 15 glycol-based fluids from the technicians: two 'home brews'; 13 commercially available fluids, five from LeMaitre, two each from Rosco and CITI, and one each from Antari, Atmospheres, MBT, and MDG. We found that most of the fluids had the same proportions of specific glycols as reported on their Material Safety Data Sheets.

Because glycol-based fluids are heated to produce fogs, we heated samples of the 15 bulk fluids in environmental chambers in the laboratory to the highest temperature normally expected in fog machines,

to determine if the heating could cause the production of additional contaminants. Except for one “homebrew” sample, there were no increases in concentrations of typical combustion gases such as carbon dioxide (CO₂) or carbon monoxide (CO), nor declines in the oxygen concentration, indicating that breakdown of the glycol fluids did not occur at this temperature.

We also measured potential breakdown products directly. We detected aldehydes in most samples, and certain polycyclic aromatic hydrocarbons in a small number of samples. The study design was unable to distinguish whether they were contaminants present in the unheated fluids or products of the heating process. The concentrations were extremely low, similar to background levels in air.

Simple monitoring method for use in the industry

To identify techniques for measuring theatrical fogs that could be used by industry personnel to rapidly assess levels of exposure, we evaluated three commercially available real-time direct-reading monitors: the M903 nephelometer, the DataRAM personal aerosol monitor, and the APC-100 laser single-particle counter. We assessed these by comparing their measurements to personal exposures monitored using standard measurement techniques.

The DataRAM and the nephelometer were best able to predict personal exposures. The DataRAM, although expensive (\$8,000), is easy to use, small enough to wear as a personal monitor and silent, therefore it was selected as the preferred method of those tested. Similar instruments are available and should perform equally well.

Levels of exposure

We studied the exposures of 111 entertainment industry personnel working in 19 locations in the TV and movie sector, live theatre, music concerts, and a video arcade. Some sites were visited more than once, for a total of 32 sampling days. On about half the days, glycols fogs were used, to produce many types of fog effects, and on the other half, mineral oils were used, to produce atmospheric haze effects only.

We found that the fog aerosols were small enough that a large proportion of them could enter the smallest airways and air sacs of the lungs. These small aerosols can stay suspended in air for long periods, from hours to days. The average fog aerosol concentration measured in the breathing zones of the study subjects was 0.70 mg/m³ (range 0.05 to 17.1 mg/m³) with exposures to mineral oils, on average, about twice as high as exposures to glycols (0.94 vs. 0.49 mg/m³), and with exposures to movie and TV personnel more than twice as high as those in other productions (1.01 vs. 0.40 mg/m³).

The average personal mineral oil mist exposure in this study exceeded the proposed ACGIH TLV for all mineral oils (0.2 mg/m³), and the level (0.5 mg/m³) requiring an exposure control plan for severely refined oils (i.e., one-half the Exposure Limit of 1 mg/m³) according to the British Columbia WCB regulation. In movie and television productions, the average mineral oil exposure exceeded the WCB standard itself. None of the glycol samples exceeded the current 8-hour glycerin mist standard of 10 mg/m³. Note that WCB exposure limits are lower for personnel whose shifts are longer than 8 hours.

Exposures to aldehydes and polycyclic aromatic hydrocarbons were low, similar to background levels in air, and might be attributable to other sources, such as off-gassing building materials, vehicle exhaust or cigarette smoke.

The level of employee exposure to the fogs was higher for employees working close to the fog machine and spending a greater proportion of time in the visible fog, and at productions having a greater numbers of fog machines in use, regardless of the type of production or type of fog chemicals being used.

Health effects

We also studied the respiratory health of 101 of the 111 persons who participated in the exposure monitoring study. For each person, we measured his or her lung function (before and after a fog-exposure period) and conducted a standard interview about lung health and other factors that may contribute to lung health. We compared answers and test results to similar information from a ‘control group’ of BC Ferries employees.

Compared to the control group, the entertainment industry employees had lower average lung function test results and they reported more chronic respiratory symptoms: nasal symptoms, cough, phlegm, wheezing, chest tightness, shortness of breath on exertion, and current asthma symptoms, even after taking other factors into account such as age, smoking, and other lung diseases and allergic conditions. The entertainment industry employees also had increased rates of *work-related* phlegm, wheezing, chest tightness, and nasal symptoms.

Most of these symptoms and decreased lung function were associated with having been exposed to greater amounts of theatrical smoke and fog (higher levels and more days of exposure) over the previous two years. The individuals in the highest exposure categories where effects were observed were mainly employed in TV and movie production. Lower levels of lung function were also seen in employees who worked closest to the fog machine.

We also examined acute changes in symptoms and lung function in relation to exposures on the testing day. Increased nose, throat, and voice symptoms were associated with increased exposure levels overall. Increased dry cough or dry throat and increased headache, dizziness, and tiredness on the testing day were more common when glycol fogs were used. In contrast, a measurable drop in lung function (over the testing period of about 4 hours on average) was more often seen when mineral oil fogs were used.

Overall, the health study results suggest that exposure to theatrical smokes and fogs is provoking non-specific respiratory irritation and increasing the risk for chronic airflow obstruction among BC theatrical industry employees.

What do we recommend?

1. The industry should start working on exposure control plans for mineral oil in order to comply with regulations and to prevent the health effects observed in this study.
2. Although glycol levels were below regulatory limits, the findings suggest that exposure minimization would be a reasonable approach for glycol fluids as well.
3. Exposure reduction might be achieved by:
 - increased emphasis on other methods to create generalized atmospheric haze (e.g., filters, post-production computerized methods);
 - more conscious decision making in every production about the *necessity (or not)* of chemically generated special effects;
 - consideration of other products where feasible, e.g., fresh de-ionized water mists or steam for short-lived effects, use of liquid nitrogen;
 - maximizing the distance between employees and fog machines, minimizing the number of machines used, reducing the time fog machines are on, minimizing the time that employees spend in visible fog;
 - scheduling filming that uses fogs near the end of a production day so that the residual airborne mist is given time to settle when no one is on the set;
 - ventilating the sets with fresh air during and after fog use; and
 - training about potential exposures and health effects resulting from the use of smokes and fogs.
4. Where theatrical smokes and fogs continue to be used, exposures should be monitored to ensure that control methods are working.

Where can you get more information about the study?

A detailed technical report describing our results has been provided to SHAPE and the BC Workers' Compensation Board. It is also available for reading and downloading from our website at: <http://www.cher.ubc.ca/publications/theatricalfogs.asp>. We will be working with SHAPE and the WCB to discuss prevention strategies and prepare more information for the industry about recommendations to control exposures and reduce employee health risks. This information will also be posted on our website as it becomes available.