

**HEALTH EFFECTS  
EVALUATION OF THEATRICAL  
SMOKE, HAZE, AND PYROTECHNICS**

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## **EXECUTIVE SUMMARY**

### **A. Introduction**

At the request of Actors' Equity Association (AEA) and the League of American Theaters and Producers (LATP), investigators from the Mount Sinai School of Medicine and ENVIRON Corporation conducted a study to determine whether the use of smoke, haze, and pyrotechnics special effects in theatrical musical productions is associated with a negative health impact in Actors. This effort was initiated in response to ongoing concerns by Actors that the use of these theatrical effects may have a deleterious impact on their health.

### **B. Previous Work**

Previous studies of possible health effects associated with the use of theatrical effects have been conducted at the request of AEA and LATP. The National Institute for Occupational Safety and Health (NIOSH) conducted Health Assessments of theatrical effects in 1990-91 and 1993, but these studies were limited in their scope. In the 1990-91 study, Actors in three musical productions using theatrical effects were compared to Actors in three dramatic productions that did not use any of these effects. While increased rates of occupational asthma were noted in the initial study, the follow-up study in 1993 of a subgroup of the performers failed to find an increase in asthma. Symptoms associated with irritative effects of the respiratory tract were noted.

A subsequent investigation was conducted by Consultech Engineering Company at the request of AEA. Consultech conducted a survey of Actors and a review of medical utilization through insurance records. A questionnaire inquiring about health effects as a result of exposure to theatrical effects was placed in the AEA's monthly newsletter, but was only completed by a small number of Actors. The low response rate for the questionnaire limits the applicability of its results. The insurance data review indicated that there might be greater use of medical resources among Actors in productions using these effects.

Because of limitations in these prior investigations, the question of whether these substances present a health hazard to theatrical performers remained.

### **C. Study Methodology**

The goal of this study was to determine whether associations exist between exposure to theatrical effects (i.e., smoke, haze, and pyrotechnics) and health effects, taking into account the specific work environment and activities involved in a professional theatrical musical production. Based on a review of the toxicological literature on the components of these effects and previous information regarding theatrical exposure levels, it was determined that the likelihood that systemic toxicity could occur from exposure to any of these substances was extremely low. Therefore, considering symptoms previously reported by Actors and the results

of the toxicological review, the health endpoints selected for investigation in this study were those related to local irritant effects of the respiratory tract and eyes.

The study is comprised of two primary components – an epidemiologic assessment and an exposure assessment (Figure ES-1). The epidemiologic assessment included the collection of data from Actors regarding the symptoms they reported experiencing and background information (e.g., demographics, performance schedule, and other activities). The epidemiologic assessment also included a medical evaluation to collect clinical data on a subgroup of Actors before and after a performance. The data for the epidemiologic assessment was collected in three phases:

- In Phase 1, baseline questionnaires were distributed to all Actors and Stage Managers in a current Broadway musical. The questionnaire responses were used to collect background, symptom, and medical information from the participants, as well as information on their activities onstage and their theatrical experience.
- Phase 2 was designed to collect longitudinal data on daily symptoms over the course of the study. Actors were asked to complete daily checklists describing their activities and symptoms for three one-month periods.
- Phase 3 of the study involved a medical evaluation, which consisted of vocal quality assessments, pulmonary function tests, and direct visualization of the vocal cords. The evaluation was performed before and after a matinee performance. The medical evaluation is a unique aspect of this study in that it allows for a direct comparison of the upper airway, voice, and respiratory tract in the same person before and after a performance.

The second component of the study was a detailed exposure assessment, which was conducted to characterize potential exposures to Actors in the theatrical environment. A sampling strategy was developed to collect sufficient data to evaluate both time-integrated exposures (over the course of an entire performance) and potential peak levels of exposure (the maximum levels of exposure an individual may experience during a performance). Potential exposures were estimated by collecting personal breathing zone and general air samples from various locations in the theaters in both live performance and rehearsal settings. These air sampling data were combined with time and motion information (e.g., time on stage, inhalation rates associated with on-stage activities) developed for the productions to determine potential exposure to individual Actors. Two types of exposure estimates were developed:

- A “preliminary exposure matrix” was developed using time and activity data from the baseline questionnaires and stage-wide average concentration data. The purpose of this exposure matrix was to provide preliminary estimates of exposure so that initial analyses of all 439 of the Actors participating in the study could be conducted.
- A “detailed exposure matrix” was developed to provide a more accurate characterization of exposure on a subset of 218 Actors for the epidemiological analysis. Use of the

detailed exposure matrix provided the ability to distinguish between integrated and peak exposures.

The results of the epidemiologic and exposure assessments were combined in developing conclusions regarding associations between exposures to theatrical effects and health effects in performers.

## **D. Results and Discussion**

This study was conducted in 1997-99 with 439 adult Actors performing in 16 Broadway musicals. No significant acute change in voice quality, pulmonary function, or vocal cord appearance was found among Actors exposed to theatrical smoke, haze, or pyrotechnic agents. However, Actors with exposures to elevated or peak levels of glycols reported more symptoms than Actors with less exposure. In addition, some mild chronic effects in Actors with greater exposure to peak levels of glycols and mineral oil were observed. These findings may reflect a negative health impact of exposure to theatrical agents or other factors (e.g., physical demand).

### **1. Phase 1 – Baseline Questionnaires**

**Glycols.** There are associations between symptoms reported in the baseline questionnaires and increasing glycol exposure levels, based on the preliminary exposure estimates developed for all 439 study participants. To examine the nature of these associations, symptom reporting was evaluated in the subset of 218 Actors for whom detailed integrated dose and peak exposure estimates were measured (using time exposed to two times and five times the Broadway average exposure level as a measure of peak exposure). Based on this analysis, symptom reporting – in particular respiratory, throat, and nasal symptoms – was found to be associated with peak exposures and not integrated dose.

Peak levels of glycol exposure are associated with reported symptoms of mucus membrane irritation. This is consistent with the chemical and physical properties of glycols, since they have irritative and drying properties at high doses. There are consistent, statistically significant associations between an overall increase in throat symptoms with increasing glycol exposure. Similarly, symptoms such as coated vocal cords, hoarseness, and voice change were associated with increasing glycol exposure, as were symptoms of nasal irritation.

**Mineral Oil.** As opposed to glycols, which are generally used to generate localized effects, mineral oil is usually used to produce a uniform, low level haze effect across the stage. Thus, the distribution of mineral oil is similar for all Actors on stage regardless of their locations, with no exposure to short bursts of high concentration. Two shows (Cats and Sound of Music), however, utilized mineral oil in a peak concentration during one scene. In this study, exposure to mineral oil was not associated with increased respiratory or nasal symptom reporting, as glycol exposure was. There was, however, a statistically significant increase in irritated throat symptoms among those Actors with the

highest mineral oil exposures in the detailed exposure analysis (those with more than 10 minutes at peak mineral oil exposure, principally Actors from Rent).

**Pyrotechnics.** Overall, there were no significant or consistent associations observed between symptoms and pyrotechnics use. This may reflect the relatively low current use of pyrotechnics on Broadway, both in the number of shows utilizing pyrotechnics and the magnitude of the exposure, or that under the conditions of use in participating shows, no adverse effects occur. An increase in nose and sinus symptoms was noted for the preliminary pyrotechnics exposure assessment, which is consistent with irritative effects of particulates. However, there was no association with the detailed measurements.

**Multiple Effects.** We also investigated whether Actors exposed to more than one theatrical effect had increased rates of symptoms compared to Actors exposed to a single special effect. There was no evidence of an additive or multiplicative effect from exposure to more than one agent.

## **2. Phase 2 – Daily Checklists**

Symptoms reported frequently in Phase 1 were also commonly reported on the Daily Checklists during Phase 2. Interestingly, there was no variation in symptom frequency by month of the year or season, making heating or air conditioning in the theaters less likely factors in symptom frequency in Phase 2. This suggests that integrated exposure levels, which are dependent on ventilation in the theater, are not associated with symptom frequency (as opposed to peak concentrations, which are generally independent of ventilation). No consistent statistically significant associations were found between occurrence of symptoms and exposure to glycol, mineral oil, or pyrotechnics, although a positive association between glycol use and most of the symptoms was noted. The strongest predictors of daily symptoms in Phase 2 were the number of performances, performances on a weekend, physical demand of the role(s) played, and perceived levels of stress at work and away from work. These associations were much stronger than any contribution to symptom occurrence from theatrical effects.

The finding of strong associations between weekend performances (i.e., Friday through Sunday) and daily symptoms may be due to several factors. Typically, most Actors perform five shows over these three days; thus, the weekend is the most demanding part of their workweek. Increased numbers of performances also place greater physical and vocal demands on Actors. For example, Actors in Rent, a show with high vocal and physical demand, have the highest rate of reported symptoms. Stress level, another significant factor in Phase 2 symptom rates, is also very high among Actors in Rent. Conversely, Actors in Smokey Joe's Café, the show with the highest vocal demand but average physical demand and the lowest stress level at work, report low rates of symptoms for Phase 2.

### 3. Phase 3 – Medical Evaluations

The Phase 3 medical evaluations included examinations of vocal cord appearance and function, voice analysis, and pulmonary function. Each test was performed before and after a matinee performance. The comparison of each Actor before and after a show was designed to measure acute changes in these measurements due to exposure to theatrical effects. In addition, data from the pre-performance evaluations were analyzed independently to determine whether exposures were associated with signs of chronic irritation. Most Actors were evaluated on Wednesday, after one or two days off from performing on Broadway.

**Acute Effects.** No statistically significant acute changes after a performance were detected in vocal cord appearance and function, perceptual voice rating, or pulmonary function regardless of exposure to theatrical effects. The lack of acute change in exposed Actors in vocal cord appearance is consistent with no adverse effect from these exposures or may in part reflect the short-term humectant properties of glycols and mineral oil, which may inhibit acute irritant effects. Additionally, Actors performing on Broadway generally have tremendous vocal capacity, which may allow them to compensate for mild irritation and/or inflammation. Limited changes were observed from the comparison of the computerized voice analysis with peak glycol exposures, which suggests a potential minor impact on voice quality from these exposures.

**Chronic Effects.** In the analysis of Phase 3 data from the pre-performance examinations, Actors whose performance requires longer exposure to peak levels of glycols had a statistically significant increased rate of certain vocal cord appearance parameters (indicating inflammation of the throat or vocal cords). There was no adverse impact from mineral oil or pyrotechnics use. Rates of other vocal cord abnormalities (such as nodules or polyps) were not increased by exposure to any theatrical effect. There was no negative impact on vocal cord function associated with exposures to glycol, mineral oil, or pyrotechnics. Similar to the analysis of acute effects, minor impacts on vocal quality were associated with peak glycol exposures.

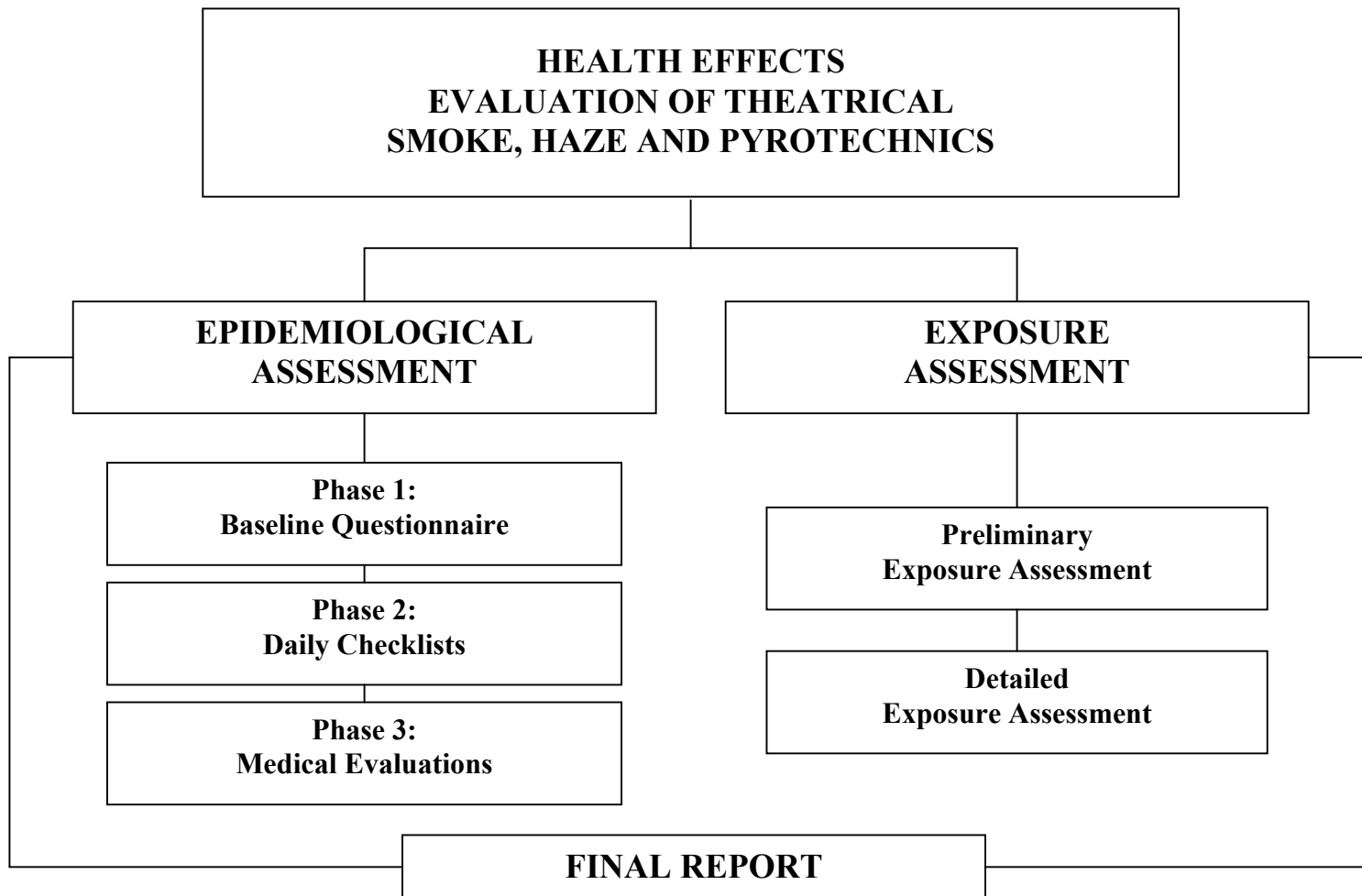
There was no clinically significant adverse impact on pulmonary function due to either acute or chronic use of glycol or pyrotechnics. This is consistent with the findings from the second NIOSH study, where there was no increase in rates of asthma or other pulmonary disorders in Actors in smoke shows compared to non-exposed Actors. It is also consistent with the chemical properties of glycol at the concentrations measured in the theaters, where these compounds can exert irritant effects on mucus membranes, but not on the lower respiratory tract. On the other hand, Actors with the highest exposure to mineral oil had a statistically significant decrease in one pulmonary function parameter – forced vital capacity. This finding was surprising, as decreases in forced vital capacity are usually associated with interstitial lung processes or with interference with taking a deep breath from external pressures, such as pleural thickening or obesity. While an effect was noted, it is important to note that the Actors still have pulmonary function within the normal range. As with glycol exposure, there was no evidence of airway obstruction.

The results of this study of the effects of theatrical smoke, haze, and pyrotechnics indicate that there are health effects associated with exposure of Actors to elevated or peak levels of glycol smoke and mineral oil. However, as long as peak exposures are avoided, Actors' health, vocal abilities, and careers should not be harmed. In order to minimize Actor exposures to peak glycol concentrations, the use of glycols should be such that an Actor's exposure does not exceed 40 mg/m<sup>3</sup>. Mineral oil, for the most part, does not appear to have significant effects on Actors, provided that the exposures are minimized and uniform, rather than in concentrated bursts. For chronic exposures to mineral oil, the existing standards established for oil mists (5 mg/m<sup>3</sup> as an eight-hour time-weighted average) should also be protective for Actors in theatrical productions. In addition, the use of mineral oil should be such that an Actor's exposure does not exceed a peak concentration of 25 mg/m<sup>3</sup>. Pyrotechnics as currently used on Broadway does not have a significant effect on Actors' health.

## **E. Conclusions**

The major findings of this study are summarized below:

- No evidence of serious health effects was found to be associated with exposure to any of the theatrical effects evaluated in this study.
- Peak exposures to elevated localized air concentrations following a release of glycol smoke are associated with increased reporting of respiratory, throat, and nasal symptoms, and findings of vocal cord inflammation.
- Elevated exposures to mineral oil haze are associated with increased reporting of throat symptoms.
- No health effects were associated with the current use of pyrotechnic effects in any of the productions included in the study.
- There was no evidence of an additive or multiplicative increase in effect from exposure to more than one of the types of theatrical effects evaluated in this study.
- Other factors besides theatrical effects were also found to be associated with increased symptom reporting. These factors include perceived levels of stress (at work and away from work), performance schedule, and physical demand of the role(s) played.
- Based on the observed association between increased signs and symptoms of respiratory irritant effects and exposure to elevated levels of glycols and mineral oil, it is recommended that exposures to these materials by Actors performing in musical productions not exceed peak or ceiling concentrations of 40 mg/m<sup>3</sup> for glycols and 25 mg/m<sup>3</sup> for mineral oil. Time-weighted average exposures to mineral oil should be kept below 5 mg/m<sup>3</sup>. Based on the results of this study, no change in the current use of pyrotechnics is necessary. As long as peak exposures are avoided, health, vocal abilities, and careers of Actors should not be harmed.



**Figure ES-1:** Flowchart of Health Effects Evaluation