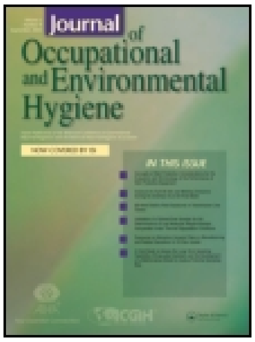

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Case Study

Erythema and Conjunctivitis: Investigation of an Outbreak in a School Gymnasium Caused by Unintentional Exposure to Ultraviolet Radiation from Metal Halide Lamps

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BACKGROUND AND INTRODUCTION

Ultraviolet (UV) light exposure can cause both erythema and conjunctivitis.[1] High intensity discharge (HID) lamps (e.g., those used in industrial lighting) can emit UV radiation if the envelope surrounding the bulb is damaged or absent. These lamps can continue to function despite this damage, creating the potential for uncommon routes of exposure to actinic UV radiation (UV-B and UV-C).[2,3]

Food and Drug Administration (FDA) regulations require that mercury vapor and metal halide lamps contain labeling that alerts consumers to possible "serious skin burn and eye inflammation from shortwave UV radiation if the outer envelope of the lamp is broken or punctured."[4, p. 658] Although non-self-extinguishing lamps (Type R lamps) were involved in these incidents, self-extinguishing lamps (Type T lamps) are also available. FDA regulations require that these lamps extinguish within 15 min after the outer envelope is broken or punctured.[4] Regulations also require that all incidents involving injury associated with the use of metal halide or mercury bulbs be reported to the light bulb manufacturer, who is obligated to report to the FDA. It is important to retain any broken bulb to identify bulb type and manufacturer.

This investigation followed the occurrence of adverse health events during an indoor gymnasium sporting event. Results from the environmental investigations, the case-patient questionnaires, and the medical literature support the hypothesis that the majority of health symptoms reported by persons in attendance at the sporting event were a result of overexposure to UV radiation from damaged metal halide lamps.

Multiple incidents of unintentional human exposure to UV light from damaged mercury vapor lamps and germicidal light bulbs have been reported.[5–8] However, previous reports lacked quantitative UV measurements that could be used to directly calculate a dose-response relationship. In this case study we present an incident of erythema and conjunctivitis in a school setting resulting from damaged metal halide lamps emitting UV light.

On February 1 and 2, 2002, the Occupational and Environmental Epidemiology Branch at the North Carolina Division of Public Health received multiple reports of skin and eye burns from 13 persons who had attended or participated in a basketball tournament held in a school gymnasium. School maintenance staff reported a broken bulb, which raised suspicion regarding possible UV radiation exposure as the cause of the symptoms.

METHODS

On February 6, 2002, an environmental investigation of exposures in the school gymnasium was conducted, including measurements of UV exposure from light fixtures. Using a radiometer (model 1400A; International Light, Newburyport, Mass.) with actinic detector (SEL240/T2ACT5), 100 UV radiation measurements were taken under each of the 28 lamps (including those with damaged bulbs), on bleachers on both sides of the gym, on the balcony near the locker rooms, and outside the facility. Following the environmental investigation, questionnaires were sent to 13 basketball tournament attendees and participants who reported symptoms consistent with exposure to a broken metal halide lamp. The questionnaires were used to document symptoms, seating location in the gym, and length of time at the tournament.

RESULTS

An environmental investigation revealed that there were two damaged light bulbs in the 28 metal halide lamps in the gymnasium (Figure 1). The outer glass envelopes on these lamps were broken and partially missing. These were Type R lamps, which are not self-extinguishing and will continue to operate with a broken or missing outer glass envelope. The light fixtures were located approximately 19–25 ft from the gymnasium floor and 17–19 ft from the bleachers.

Measured values using the radiometer with actinic detector ranged from the limit of detection (0.01 microwatts per square centimeter [μW/cm^2]) to 8.1 μW/cm^2. The highest values, $\geq$6.0 μW/cm^2, were detected in the vicinity of the broken lamp adjacent to the team bench. The highest measured value (8.1 μW/cm^2) was detected on the second level of the bleachers near the broken lamp.

Of the 13 persons who reported symptoms most consistent with exposure to a broken metal halide lamp, the most commonly reported symptoms were eye irritation (92%), eye itching (92%), and eye burning (77%) (Table I). These 13 individuals sat in the bleachers closest to the broken lamp adjacent to the team bench. There was one person who attended only on Friday and two people who attended only on Saturday; the remaining 10 attended part of the tournament both days.

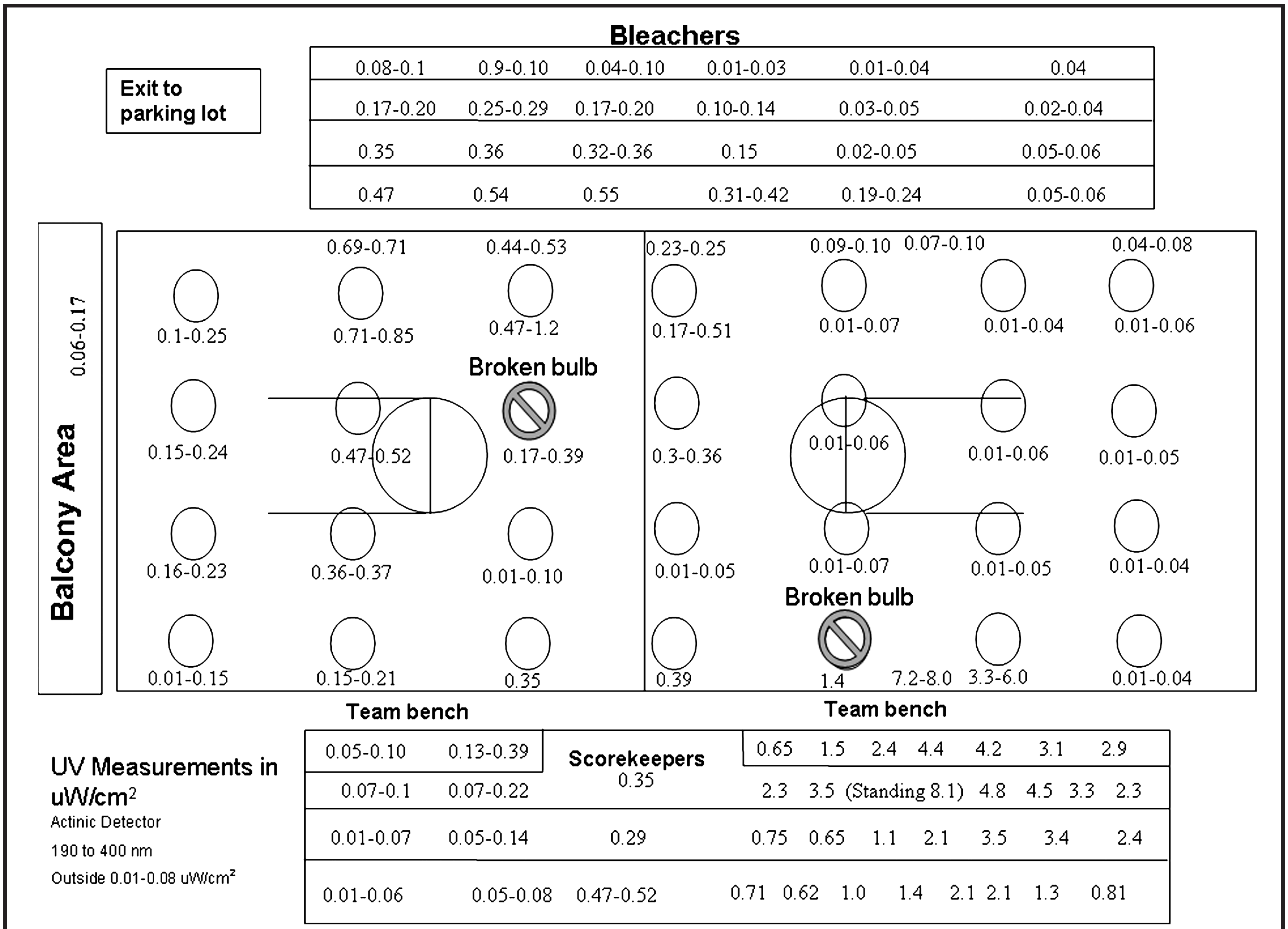

FIGURE 1. Basketball tournament gymnasium layout with ultraviolet radiation measurements

TABLE I. Symptoms Reported from Attendees (n = 13)

Symptoms	Attendees (%)
Eye burning	76.9
Eye itching	69.2
Eye irritation	92.3
Eye dryness	46.2
Swelling around eyes	38.5
Foreign body sensation in eye	46.2
Blurred vision	46.2
Sensitivity to light	53.8
Facial flushing	61.5
Facial burning	53.8
Facial rash	38.5
Itching	46.2
Runny nose	23.1
Headache	23.1
Skin rash on exposed skin other than face (e.g., scalp and arms)	30.8
Sore throat	30.8
Cough	15.4
Fever	7.7
Abdominal pain	15.4
Metallic taste in mouth	7.7
Chest pain	7.7
Thirst	7.7
Nausea	23.1
Diarrhea	7.7
Joint pains	0.0
Vomiting	0.0
Asthma	0.0
Tingling around mouth	30.8
Chapped lips	76.9

The average time spent in the gymnasium was 8.9 hours (range: 2.0–18.5 hours; median = 8 hours). The average time spent in the bleachers adjacent to the team bench was 8.5 hours (range: 2.0–18.5 hours; median = 6 hours).

The survey was completed by the 13 participants on average 13.3 days after the tournament (range: 11–17 days; median = 12 days). Twelve of the participants were spectators (one was a scorekeeper) and one was a player.

DISCUSSION

UV radiation is part of the electromagnetic spectrum between visible light (approximately 400 nm) and ionizing radiation (approximately 100 nm). The UV spectrum is divided into three bands: UV-A (315–400 nm), UV-B (280–315 nm), and UV-C (100-280 nm). Natural sunlight includes biologically significant amounts of UV-A and UV-B; UV-C is typically filtered out by the upper atmosphere. Because a limited amount of UV radiation can penetrate through the skin, the effects of exposure to UV radiation occur most often to the skin and eyes.

The typical effect of acute exposure is photokeratitis of the cornea, often called welder's flash, arc eye, or flash burn. From 2–24 hours after exposure, the exposed person can experience severe eye pain, redness, photophobia, and spasm of the eyelid. The condition usually clears within 1–5 days, depending on the severity of exposure. Healing is usually complete, without residual injury. UV radiation also can cause erythema of the skin (sunburn) and if the exposure is severe, blisters and edema. These symptoms can develop 2–10 hours after exposure. Persons vary in skin type and sensitivity to UV radiation; the U.S. Environmental Protection Agency has defined four skin types.[9] Some people rarely burn but instead show a rapid tanning response (Type 4), whereas others rarely tan but develop sunburns (Type 1). The intensity and duration of the burn depend on the dose and wavelength of UV radiation and on the person's skin pigmentation.[10]

Because the UV detectors for the measurement system used in this investigation are weighted to 274 nm, we assumed that the measurements taken at the gymnasium measured energy at 270 nm, the peak response with regard to biological effectiveness. According to guidelines of the American Conference of Governmental Industrial Hygienists (ACGIH®), the allowable dose (radiant exposure) at this wavelength is 0.003 Joules per square centimeter (J/cm^2). The allowable exposure duration (T_{max}) in seconds may be calculated by dividing this value by the measured irradiance (E_{eff}) in watts per square centimeter (W/cm^2):

$$T_{\max} = 0.003(J/cm^2)/E_{\text{eff}} \times (W/cm^2) \qquad \textbf{(1)}$$

Using the highest measurement (8.1 μW/cm^2) taken during the evaluation, the maximum exposure duration before receiving the allowable dose would be 6.25 min, according to ACGIH guidelines. The implication is that with this dose rate, nonphotosensitive persons are at increased risk for developing erythema or sunburn and photokeratoconjunctivitis with just over 6 min of exposure. Persons who are genetically photosensitive or those taking photosensitive medications might react in shorter time. Based on the estimated time of exposure, we calculated that the dose of UV for case patients was on average 54.7 mJ, the median was 47.3 mJ, and the range was 0.4–105.8 mJ. Based on this dose, most individuals with skin Types 1, 2, or 3 will show evidence of burning, and even most persons with skin Type 4 would burn at a dose of 105.8 mJ.[9]

The investigation of the incident included measurements of UV radiation, which documented elevated levels near the broken lamps. These measurements suggest that persons closest to the lamp (horizontally or vertically) were at highest risk for exposure. The measurements also suggested that persons sitting on both sides of the lamp, not those sitting directly beneath the lamp, were at highest risk for exposure (assumed to be a result of the angle of the bulb within the lamp and the reflection from the metal envelope surrounding the bulb).

Limitations of the investigation include the inability to accurately assess the length of exposure to the broken bulbs.

RECOMMENDATIONS

To prevent injuries similar to those described in this investigation, the Lamp Section of the National Electrical Manufacturers Association (NEMA) has developed multiple recommendations for the care and maintenance of high-intensity metal halide and mercury lights in schools. These recommendations highlight ways to minimize UV radiation exposure from damaged bulbs.

- If the outer glass bulb breaks, which is obvious from falling glass or the presence of glass on the floor, immediately turn off the fixture. Do not turn it on again until the bulb is replaced by a competent maintenance person wearing suitable protective equipment (e.g., eye protection and work gloves).
- Lighting fixtures that fully enclose the bulbs and have a lens of glass or plastic material are recommended for any lighting installation that is at risk of damage from flying objects. These fixtures, in conjunction with regular bulbs, are the most efficient, and they cost less to maintain than using self-extinguishing bulbs.
- Wire guards on open fixtures or on fixtures with damaged lenses do not provide protection against UV radiation from a broken bulb.
- If an installation does not have fully enclosed fixtures, a self-extinguishing bulb can be ordered through electrical suppliers. These bulbs include the letter T in their model number. However, the bulbs are not available in all sizes, they provide less light, and they generally cost more than regular bulbs.
- The use of self-extinguishing bulbs does not prevent bulb breakage; the bulbs simply turn off automatically after the outer glass of the bulb is broken. School supervisors should ensure that persons responsible for the maintenance of these lighting systems fully understand the federally mandated and other caution notices that manufacturers print on lightbulb packages.

Additional guidance on the use of metal halide lighting systems is available on the National Electrical Manufacturers Association website at www.nema.org, which includes "The Best Practice for Metal Halide Systems, Plus Questions and Answers about Lamp Ruptures in Metal Halide Lighting Systems."

A 15-min window of exposure to a broken UV light should be recognized as potentially hazardous, and precaution should be taken even if damage occurs to self-extinguishing lamps, since these lamps may not immediately stop illuminating. In addition to switching from Type R to Type T lamps, UV-reducing diffusers are recommended to protect the bulb from damage and prevent broken glass from showering on the area below. Depending on the severity of their symptoms, some persons with injuries from UV radiation associated with damaged metal halide or mercury vapor lightbulbs might need health care services. Building owners and managers should report all incidents that involve injury from metal halide or mercury bulbs to the manufacturer, who in turn is obligated to report to the Food and Drug Administration.

The medical community should receive public health education concerning the potential harmful effects of the use of mercury vapor and metal halide lamps in public settings. When persons recognize that damaged mercury vapor and metal halide lamps can be a potential route for UV exposure, future exposures can be prevented.

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