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Case Studies

Ozone Exposure at a Construction Site

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Introduction

On October 1, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) at a pulp and paper plant in Minnesota. The request concerned worker exposures during the construction of a new boiler, primarily, to emissions generated from three adjacent operating boilers. The reported health effects were headache and respiratory effects, such as asthma. The construction on the new boiler began in 1996 and the number of construction workers at the site varied between 400 and 450.

In response to the request, NIOSH investigators conducted an environmental and medical evaluation of the new boiler at the construction site on November 19–21, 1997. Given the specific concerns of the workers and the possibility for stack emissions (from adjacent operating boilers) to migrate through the construction area, the sampling efforts during the NIOSH evaluation were focused on worker exposures incurred from the nearby operating boilers.

Background

At the time of the NIOSH site visit, the facility was constructing a new recovery boiler (Boiler #10) as part of the plant's modernization program. Workers belonging to various trade unions have been employed by contractors working in the construction of the new boiler. Some of the trades represented at the construction site include carpenters, electricians, cement masons, boiler makers, ironworkers, welders, insulators, plumbers, steam fitters, laborers, and other related construction trades. The construction of the new boiler house (Boiler #10) was scheduled for completion in April 1998.

The new recovery boiler (Boiler #10) was located close to three other operating boilers (Boilers #7, #8, and #9). Boiler #7 was a power boiler which burned primarily bark (from logs used in the pulp manufacturing process) and primary wastewater sludge. Boiler #9 was also a power boiler which burned primarily bark and sludge, and Boiler #8 was the current recovery boiler which burned mainly black liquor from the pulp manufacturing process. Boiler #7 and Boiler #9 were also used to combust noncondensable gases from the pulping process. Boiler #10 was being constructed to replace Boiler #8. The vent stacks from Boilers #7 and #8 were approximately 253 feet in elevation, and the elevation of the vent stack from Boiler #9 was approximately 278 feet.

During April 1997, when the construction on the new boiler was approximately 198 feet in elevation, workers reported various symptoms such as headaches, eye and throat irritation, nasal congestion, chest discomfort, cough, dizziness, difficulty breathing, and a metallic taste in the mouth. These symptoms were reported when emissions from the adjacent operating boilers migrated through the construction area. This migration occurred when the wind was blowing from a north to northeast direction. During the time of the NIOSH site visit, construction on the new boiler was occurring at an elevation of approximately 270 feet (from ground level). Air samples were collected on November 20, 1997, when the wind was blowing from a northeast direction.

Since April 1997, the company and company-contracted environmental consultants had sampled for more than 100 different chemical compounds at the construction site in an effort to identify the etiological agent responsible for the workers' symptoms. Some of the sampled compounds included contaminates that may be present from the paper manufacturing process (e.g., SO_2, NO_2, NO, dimethyl sulfide, hydrogen sulfide, and mercaptans). Sampling for various other chemical compounds was performed in an effort to identify unknown contaminants at the construction site. The majority of the collected samples showed nondetectable concentrations. Some chemical compounds which have the potential to cause irritation of the respiratory system were detected at low concentrations (i.e., SO_2 and NO_2). Air samples for formaldehyde revealed concentrations up to 0.137 parts of formaldehyde per million (ppm) parts of air.

The company has contracted an environmental consultant to perform daily environmental monitoring at the construction site with real-time instruments for carbon monoxide (CO), chlorine dioxide, hydrogen sulfide, methane, lower explosive limits, SO_2, and formaldehyde. The environmental consultant had been given the authority to shut down construction operations if any high levels (levels that exceed the Minnesota Occupational Safety and Health Administration [OSHA] permissible exposure limits [PEL]) of these compounds were detected.

The company and the environmental consultants, however, did not sample for ozone at the construction site. Ozone is generated from oxygen in the vicinity of electrical sources.[1] Ozone can be produced industrially from oxygen by means of ultraviolet generators or by passing air through a high-voltage, alternating-current electrical

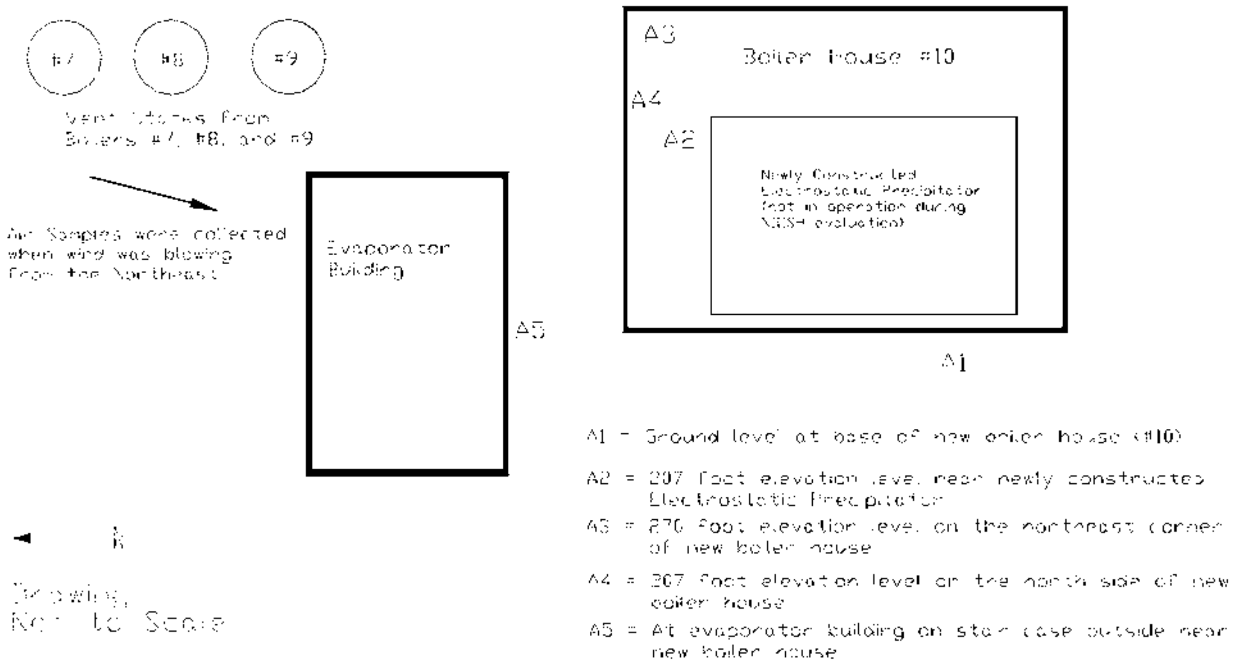

FIGURE 1
Area sample locations (Elevations are from ground level).

discharge.[1] Electrostatic precipitators have the capability to produce ozone. A NIOSH study at a cement company found ozone concentrations approaching 5 ppm when an operating electrostatic precipitator back-drafted into a kiln.[2] Ozone may also be generated during inert-gas-shielded arc welding where, depending on the gas flow, ozone concentrations may be as high as 6–9 ppm.[1] These studies suggest that it was plausible for ozone production to occur as a result of the large electrostatic precipitators located on each of the operating boiler stacks adjacent to the construction area and/or during welding operations at the construction site.

Methods

Industrial Hygiene

A walk-through inspection of the new boiler construction site was conducted on November 19, 1997, to familiarize NIOSH personnel with the construction activities and work areas where smoke emissions have the potential to migrate. On November 20, 1997, full-shift area samples for VOCs, NO, NO_2, SO_2, and inorganic acids were collected at five area locations (see Figure 1 for area sample locations): (1) ground level at the base of the new boiler house on the west side of the construction area (location A1); (2) at the 207-foot elevation level near the newly constructed electrostatic precipitator (location A2); (3) at the 270-foot elevation level in the northeast corner of the new boiler construction area (location A3); (4) at the 207-foot elevation level on the north side of the new boiler house (location A4); and (5) outside the evaporator building on a staircase near the new boiler house (location A5).

Ozone samples were collected in two separate areas at the new boiler construction site. The first monitoring site was located on the north side of the new boiler house at area location A2 (see Figure 1). The electrostatic precipitator located on the new boiler (Boiler #10) was still under construction and was not yet operational. The second monitoring site was on a stairwell at area sample location A3 (see Figure 1). These two area locations were selected based on the drifting of smoke (from the operational boiler stacks adjacent to the construction site) through the construction area. Chlorine samples were also collected at location A3. In addition to area samples, PBZ samples for elements were collected on five workers who performed welding operations at the construction site.

Ozone

Ozone samples were collected using a Metrosonics pm-7700 toxic gas monitor equipped with a gs-7709 ozone sensor (Metrosonics Inc., Rochester, New York). The pm-7700 toxic gas monitor is a direct-reading instrument with data-logging capabilities. This monitor collects four samples per second and reports the measured ozone minimum, average, and maximum concentration every minute. The monitor also reports peak concentrations and the time-weighted average (TWA) concentration over the entire sample period. The ozone concentrations recorded by the monitor were downloaded to a personal computer for evaluation.

Medical Evaluation

The NIOSH physician interviewed 15 employees who presented themselves for interviews. Her availability was made

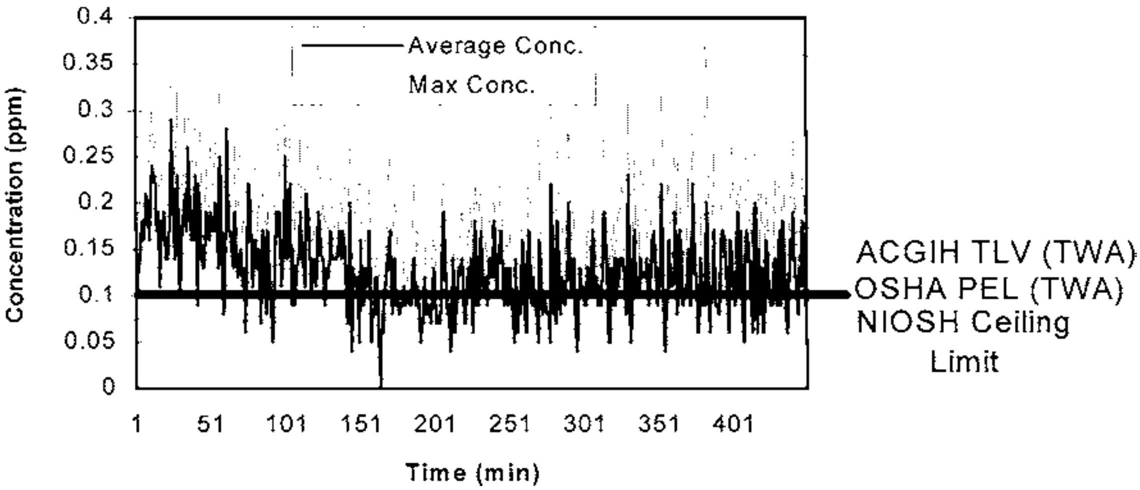

FIGURE 2
Ozone average and maximum concentrations plotted each minute during the sampling period at area sample location A2 (207-foot elevation).

known to them by both management and their unions. All were asked to provide medical records if they had seen a physician. Two of the interviewed employees released medical records for review, and the company provided medical records for two employees who were no longer working at the facility.

Ozone

Low concentrations of ozone (0.01 ppm to 0.05 ppm) may produce a sharp, irritating odor even during brief exposures.[(3)] Symptoms of ozone exposure include irritation of the eyes, dryness of the nose and throat, and cough. If ozone concentrations continue to rise, more severe symptoms may develop. These symptoms may include headache, pain or tightness in the chest, and shortness of breath or tiredness.[(3)] Short-term exposure (a few hours) to ozone concentrations on the order of 0.1 ppm has been shown to produce temporary decreases in measured lung volumes in humans.[(4)]

The NIOSH REL for ozone is 0.1 ppm and is to be measured as a ceiling limit.[(5)] A ceiling limit is a peak concentration that should not be exceeded at any time during the workday. NIOSH has also recommended an immediately dangerous to life and health (IDLH) limit of 5 ppm for ozone.[(6)] The current OSHA PEL for ozone is 0.1 ppm for an 8-hour (40-hour work week) TWA.[(7)] The current ACGIH® TLV® is based on the amount of physical exertion or workload required for the job being accomplished and is to be averaged over an 8-hour period. The TLV is 0.1 ppm for jobs requiring light physical exertion, for moderate physical exertion the TLV is lowered to 0.08 ppm, and for heavy physical exertion the TLV is lowered to 0.05 ppm.[(8)]

Results

Industrial Hygiene

Ozone. Figure 2 presents the average and maximum ozone concentrations collected each minute during the sampling period at location A2. The peak ozone concentration measured at this location was 0.37 ppm. This is nearly four times the NIOSH ceiling limit of 0.1 ppm. The TWA ozone concentration at this area location was 0.12 ppm. These values indicate that there is a potential to exceed the OSHA PEL (0.1 ppm) and the ACGIH TLV for light work (0.1 ppm), moderate work (0.08 ppm), and heavy work (0.05 ppm) at this area location.

The peak ozone concentration measured at location A3 was 0.1 ppm, which is at the NIOSH ceiling limit. The TWA ozone concentration at this area location was 0.04 ppm and is below OSHA and ACGIH exposure criteria. See Table I for a summary of ozone sampling results.

TABLE I
Summary of ozone sampling results

Location	Peak concentration (ppm)	TWA concentration (ppm)
Location A2 (207-foot elevation)	0.37	0.12
Location A3 (270-foot elevation)	0.1	0.04

Ozone evaluation criteria
NIOSH ceiling limit 0.1 ppm.
OSHA PEL 0.1 ppm
ACGIH TLV for light work (0.1 ppm), moderate work (0.08 ppm), and heavy work (0.05 ppm)

Samples collected for elements, NO, NO_2, SO_2, and inorganic acids all had concentrations less than the most stringent applicable exposure criteria.

Medical

The 15 employees who presented for interview represented three contractors, and several trades—boiler maker, sheet-metal, ironworker, electrician, and foreman. Their duration of employment at this job site ranged from approximately 1 month to 1 year, with the majority being 2–6 months. Six of the 15 interviewed employees (out of approximately 400 to 450 employees) reported intermittent symptoms temporally related to work, especially when a foul odor was present. These symptoms were eye irritation, cough, and sore throat. In September 1997, two other employees reported transient health effects consisting of hoarseness, eye irritation, lightheadedness, headache, and skin irritation after a release of unknown chemicals in a separate area of the plant, which was not related with the construction of the #10 boiler. The employees were treated at an emergency room and released. Neither had current health problems. Several employees reported self-limited gastrointestinal or respiratory illness. These were not temporally related to work, and resolved despite continued work at the facility. Of the two employees who were not interviewed and were no longer working on-site, but whose records were reviewed, one had been kept off work by his physician after a steam release inside the plant (not from the vent stacks) had caused him some respiratory difficulty. Two other employees were involved, but had not missed work. The other employee had been diagnosed with asthma that was exacerbated by exposure to irritants at the facility, and was currently working at another job.

Discussion

Studies suggest that it is plausible for ozone production to have occurred as a result of the large electrostatic precipitators located on each of the operating boiler stacks adjacent to the construction area and/or during welding operations at the construction site.[1,2] Smoke from the boiler vent stacks could migrate across the construction site when the wind was blowing from a north or northeast direction. During our evaluation, the wind was blowing from the northeast and some of the smoke from the adjacent stacks did migrate into the construction area. Ozone concentrations detected at the construction site indicate that workers have the potential to be overexposed to ozone.

Formaldehyde concentrations up to 0.137 ppm have been detected by environmental consultants at the construction site. Irritation symptoms (i.e., irritation of the eyes, throat, and nose) may occur in people exposed to formaldehyde at concentrations below 0.1 ppm, but more typically these symptoms begin at exposures of 1.0 ppm and greater.

Conclusion

Ozone samples collected at area sample location A2 indicate that there was a potential for workers to be exposed to ozone concentrations above established occupational exposure criteria. Many of the symptoms reported by the workers at the construction site (i.e., irritating odor, irritation of the eyes and throat, cough, headache, chest discomfort, difficulty breathing, and tiredness) were consistent with ozone exposure. One individual experienced an exacerbation of his asthma which may have been due to ozone exposure. Vent stack emissions may also contain low concentrations of other respiratory irritants (i.e., sulfur dioxide and nitrogen dioxide) which may have the potential to cause some of these symptoms. Formaldehyde may also have the potential to cause some of the reported symptoms at the construction site.

Recommendations

The following recommendations were addressed at the survey close-out meeting (November 21, 1997) and/or in an interim report sent to the company and the union December 16, 1997. These recommendations were reportedly implemented.[9] After implementation, reports of health effects from the construction workers have dramatically decreased.[10,11]

1. The risk of exposure to ozone and other respiratory irritants may be increased by emissions from the adjacent boiler stacks migrating into the construction area. To help reduce the migration of smoke emissions into the new boiler construction area, it was recommended that the siding on the north and east side of the new boiler house be completed first.

2. To target all sources of ozone emissions (boiler vent stacks and/or welding operations), it was recommended that additional ozone monitoring be conducted by the company. The company should identify any areas where ozone concentrations may exceed the established evaluation criteria (i.e., NIOSH REL, ACGIH TLVs, or OSHA PEL). Ozone samples should be collected during welding operations and environmental worst-case scenarios such as thermal inversions and wind blowing from the north that forces smoke emissions (from adjacent boiler vent stacks) toward the construction site. These samples should be collected in any areas where work activities are conducted. If samples indicate that exposure criteria may be exceeded, steps need to be taken by the company to reduce worker exposures.

3. Engineering controls should be used to reduce worker exposures wherever feasible. Administrative controls and personal protective equipment (PPE) (i.e., respirators) are designed to protect workers from airborne exposures when engineering controls are not feasible or not effective in reducing air contaminates to acceptable levels. Administrative controls were in place at the new boiler construction site. These controls included worker removal from elevated construction levels to ground level if a worker experiences any symptom of exposure. We recommend that these administrative controls be continued. Other administrative controls may include limiting the amount of time that workers are permitted to work in the construction area. This may reduce the TWA exposures. However, this practice may not be successful in reducing worker

exposures below exposure criteria ceiling limits.

4. The company had contracted an environmental consultant to perform daily environmental monitoring with direct reading of instruments for CO, hydrogen sulfide, methane, lower explosive limits, SO_2, and formaldehyde at the construction site. The environmental consultant had the authority to stop construction operations if any high levels of these compounds are detected. It was recommended that this practice continue until all construction activity on the new boiler was completed.

All persons with reported health effects should be evaluated by an occupational medicine physician, preferably the same one or group, so that trends or patterns can be observed and evaluated.

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EDITORIAL NOTE: Ronald M. Hall and Elena Page, M.D., are with the Hazard Evaluation and Technical Assistance Branch of NIOSH. More detailed information on this evaluation is contained in Health Hazard Evaluation Report No. 98-0003-2698, available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone: (800) 35-NIOSH; fax: (513) 533-8573.