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Exposures and symptoms among workers after an offsite train derailment and vinyl chloride release

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Abstract

Objective—In 2012 in New Jersey, a train derailment resulted in the puncture of a tanker car carrying liquid vinyl chloride under pressure, and a resulting airborne vinyl chloride plume drifted onto the grounds of a nearby refinery. This report details the investigation of exposures and symptoms among refinery workers.

Design and setting—The investigation team met with refinery workers to discuss their experience after the derailment and provided workers a self-administered survey to document symptoms and worker responses during the incident. Associations among categorical variables and experiencing symptoms were evaluated using Fisher’s exact test.

Participants—Twenty-six of 155 (17 percent) workers present at the refinery or driving on the access road the date the spill occurred completed the survey.

Main outcome measure(s)—Any self-reported symptom following exposure from the vinyl chloride release.

Results—Fifteen workers (58 percent) reported ≥1 symptom, most commonly headache (12, 46 percent). Three (12 percent) reported using respiratory protection. No differences in reporting symptoms were observed by location during the incident or by the building in which workers sheltered. Workers who moved from one shelter to another during the incident (ie, broke shelter) were more likely to report symptoms (Fisher's exact test, p = 0.03); however, there are only limited data regarding vinyl chloride concentrations in shelters versus outside.

Conclusions—Breaking shelter might result in greater exposures and managers and health and safety officers of vulnerable facilities with limited physical access should consider developing robust shelter-in-place plans and alternate emergency egress plans. Workers should consider using respiratory protection if exiting a shelter is necessary during a chemical incident.

Keywords

chemical hazard release; vinyl chloride; workplace

Introduction

At 6:59 AM on November 30, 2012, seven freight train tanker cars derailed when a bridge in a borough in New Jersey failed. One tanker car carrying liquid vinyl chloride under pressure was breached, releasing approximately 20,000 gallons of vinyl chloride as a vapor, mist, and liquid.[1,2] At approximately 7:15 AM, local police began advising residents door-to-door within 0.5 mile from the site to evacuate or shelter in place (SIP).[1,2] By 5:00 PM, evacuation orders were issued to include approximately 550 borough residents, and over the next 3 days, SIP were issued and lifted as airborne vinyl chloride concentrations fluctuated; on December 4, evacuation orders were issued to an additional 300–400 borough residents.[2]

Vinyl chloride is the product of chlorination of ethylene and is used in the production of polyvinyl chloride. Vinyl chloride is a colorless gas denser than air with a characteristic sweet odor[3,4] that is transported liquefied and under pressure. The US Environmental Protection Agency (USEPA) estimated a median annual ambient vinyl chloride concentration of 3.34×10^{-3} μg/m^3 (0.001 parts per million [ppm]) for the state of New Jersey in 1996.[5]

Acute health effects of vinyl chloride exposure include headache, difficulty in breathing, dizziness, drowsiness, and at extremely high concentrations, loss of consciousness and death.[1] Airborne acute exposure guideline levels (AEGLs) established for the National Research Council and the USEPA are as follows: AEGL-1 (reversible, nondisabling), 1 hour at 250 ppm-4 hours at 140 ppm; AEGL-2 (potentially irreversible, impairing ability to escape), 1 hour at 1,200 ppm-4 hours at 820 ppm; and AEGL-3 (potentially lethal), 1 hour at 4,800 ppm-4 hours at 3,400 ppm.[4] The odor threshold for vinyl chloride is dependent on the individual with a reported range from 10 to 3,000 ppin,[3,4] thus making odor an inadequate warning indicator.

In response to a request from the New Jersey Department of Health (NJDOH), the Centers for Disease Control and Prevention (CDC) and Agency for Toxic Substances and Disease Registry (ATSDR) assembled an assessment of chemical exposures (ACE) team, consisting of epidemiologists, toxicologists, and environmental health scientists to investigate health statuses after the vinyl chloride release among emergency responders[6] and residents (manuscript in preparation). Seventeen days after the derailment, the investigation team was contacted by an employee representative of an asphalt refinery located approximately 0.5 mile from the derailment site, who was concerned about workers' chemical exposures. The next day, the investigation team held meetings with refinery workers, the health and safety officer, and the environmental officer to discuss the workers' experiences and health concerns. This report describes the investigation of vinyl chloride exposures and symptoms experienced among workers at the refinery.

Methods

CDC/ATSDR and the NJDOH determined that this investigation was public health practice (ie, non-research).

Meeting with refinery workers and survey design and administration

A subset of the investigation team interviewed the refinery safety officer and environmental officer, and met with approximately 20 workers (recruited by word-of-mouth) the day after the team was first approached by a refinery worker representative. Workers shared their experiences the day of the derailment and concerns about possible health effects associated with vinyl chloride exposure. These meetings informed the design of a cross-sectional voluntary survey of all refinery workers (including contractors) using a questionnaire adapted from the ATSDR ACE toolkit (http://www.atsdr.cdc.gov/ntsip/ace_toolkit.html). The questionnaire included questions detailing where they were during the incident, what they observed, where, if anywhere, they sheltered, and about any symptoms experienced and healthcare received following the vinyl chloride release (see Appendix 1). Three days after the investigation team visited the refinery, survey copies and return envelopes were provided to the refinery's health and safety officer, environmental officer, and employee representative for distribution to all workers the next week; during the next 3 weeks, the health and safety officer and environmental officer provided follow-up reminders. Participants had the option of mailing their survey to NJDOH or providing it to the refinery health and safety officer for batch-mailing to NJDOH. NJDOH completed survey data entry and provided the data to CDC/ATSDR investigators with identifiers removed. The findings of the investigation were provided to the refinery environmental officer.

Data analysis

Symptoms were grouped according to clinical presentation, including dizziness, weakness, and loss of balance (neurologic); runny nose, burning sensation in the nose or throat, and hoarseness (upper respiratory); and shortness of breath, chest tightness, wheezing, and burning sensation in the lungs (lower respiratory).[6] Coughing and increased congestion or increased phlegm were included separately because their cause might be upper or lower respiratory in nature. Associations among self-reported worker characteristics or activities

and experiencing any symptoms were assessed by either Fisher's exact test for dichotomous exposure categories or Cochrane-Armitage trend test for ordinal exposure categories, with $p < 0.05$ considered statistically significant. Statistical analyses were performed using SAS® 9.3 (SAS Institute Inc., Cary, NC).

Results

The refinery is located on a peninsula accessible by only one road, which is crossed by the railroad tracks. The bridge failure occurred immediately before shift change, and approximately 0.5 mile from the railroad crossing, resulting in the access road being blocked. Consequently, 155 workers were unable to leave the refinery or were blocked on the access road and unable to enter the refinery.

Refinery personnel used handheld photoionization detectors (PIDs; Industrial Scientific MX6) calibrated with isobutylene (which can be used to estimate vinyl chloride concentrations by multiplying the measured concentration by 1.9) and identified elevated levels of an unknown volatile organic compound (VOC) out-doors within the refinery property ≤40 minutes after the derailment. Workers reported witnessing a vapor cloud that rose above the railcars and spread to the refinery and access road. An hour after the derailment, the refinery environmental officer learned from the New Jersey Department of Environmental Protection that a SIP order had been given for nearby residents, and from local emergency response radio that the vapor cloud was moving toward the refinery. Refinery management communicated by refinery intercom, loudspeakers, and radio an order to SIP in the nearest building for all workers and activated the incident command. Workers sheltered in 10 refinery property buildings.

Approximately 30 minutes after the train derailed, law enforcement officers began telling workers on the access road to leave the area and, within 2 hours after the derailment, the traffic backup on the access road had dispersed. The train was cleared from the road approximately 4 hours after the derailment, and all nonessential workers were released from the refinery.

During the incident, field portable and stationary PID VOC readings at multiple refinery locations rose from 0 to >200 ppm. Therefore, vinyl chloride concentrations on the refinery grounds that exceeded the 1-hour AEGL-1 after the derailment were likely. The refinery health and safety officer and environmental officer both reported difficulty in obtaining information from the incident command at the derailment site and the subsequent incident unified command.

Exposure and symptom survey

Thirty workers completed the survey; of these 30, four reported not working the day of the incident and were excluded from further analysis. Characteristics of the 26 workers are provided (Table 1). Twenty (77 percent) were men; 14 (54 percent) were refinery employees, and 12 (46 percent) were contractors. Fourteen (54 percent) reported having received hazardous material (HAZMAT) training; 5 (of 25, 20 percent) reported firefighting

training; and 5 (of 24, 19 percent) reported being a member of the refinery's incident command.

Eighteen workers (69 percent) reported being at the refinery during the incident and sheltering-in-place, and 8 (31 percent) reported being blocked on the access road; of the eight workers blocked on the access road, two reported first learning about the derailment and vinyl chloride release from a coworker or supervisor. Ten workers at the refinery (56 percent) reported moving from one shelter to another (ie, breaking shelter) during the incident at the direction of supervisors or refinery emergency communications, either in response to rising VOC measurements or to congregate at other predetermined shelters. Three workers at the refinery (17 percent) reported wearing a respirator at some point during the incident. Although not specifically asked in the questionnaire, one respondent noted that concentrations were, at one point, higher in their shelter than outside.

Fifteen of 26 (58 percent) reported experiencing ≥1 symptom (Table 2), most commonly headache, which was also the most common symptom reported by first responders.[6] None reported seeking medical care following the incident. Seventeen (65 percent) reported an unusual odor or taste after the incident, 10 (59 percent) of whom described it as sweet; an unusual or a sweet odor or taste was not associated with experiencing symptoms.

One worker's duties included searching the grounds for other workers and escorting them to shelter; this worker reported wearing a self-contained breathing apparatus (SCBA) and was excluded from the following analyses. Workers at the refinery who reported breaking shelter were more likely to report having a symptom (9/10 vs 2/7; Fisher's exact $p = 0.03$). Furthermore, 5/6 (83 percent) who broke shelter one time (ie, sheltered in two locations) reported symptoms, and 4/4 (100 percent) who broke shelter two times (ie, sheltered in three locations) reported symptoms (Cochrane-Armitage exact $p = 0.02$). Sex, employer, having received firefighter or FIAZMAT training, being part of the incident command, location at time of incident (at refinery vs on access road), and the building where the worker sheltered were not associated with reporting symptoms.

Workers also expressed multiple concerns in qualitative responses, including lack of communication with outside agencies after the derailment (n = 5); emergency responders not being able to reach the refinery if the entrance was blocked by a train (n = 3); and workers sheltering in locations with detectable, elevated VOCs (n = 3). One noted that no SCBAs were located in their shelter, and one noted that the incident might have been worse if the released chemical had been chlorine or hydrogen fluoride.

Discussion

Evacuating and sheltering-in-place are protective actions against chemical releases.[7] Evacuating is less expedient and can result in higher acute exposures but can be the better response when prolonged exposure is likely. Sheltering-in-place involves staying indoors, protected from a hazardous airborne chemical outside. Even in leaky buildings, limited air exchange can greatly reduce exposures during an outdoor chemical incident, provided the air-handling system is shutdown; we do not know whether air-handlers in the refinery

buildings designated as shelters were shut down in response to this incident. However, continuing to SIP after a chemical plume has passed might result in additional exposure because the indoor chemical concentrations might equilibrate with high levels in outside air. Comparisons between the two options are limited; however, Kinra et al.[8] reported greater odds of experiencing symptoms among evacuees versus persons who sheltered-in-place after a chemical fire at a plastics factory.

In the incident described in this report, refinery workers were unable to evacuate the facility, but some broke shelter and might have been acutely exposed. Although sheltering in any given building or set of buildings was not associated with reporting symptoms, those workers who broke shelter by moving from one building to another were more likely to report symptoms. However, those workers might have broken shelter after observing rising VOC concentrations in their shelter; this possibility cannot be addressed because of the limited sample size and lack of monitoring data, but one worker indicated that at one point during the incident, VOC concentrations were greater inside the shelter than outside.

This analysis has certain limitations, including a relatively low participation rate (26 of 155) and possible selection bias for workers who were more likely to have experienced symptoms. The lack of association between noting an unusual odor and experiencing a symptom might reflect the broad odor threshold for vinyl chloride and underscores its inadequate odor-warning properties. We have only limited access to documented VOC measurements at the time of the incident and given the size of the refinery and nature of the incident (a chemical plume crossing a facility with multiple buildings), we cannot estimate vinyl chloride concentrations in shelters versus outside. The limited sample size of this analysis also limits its statistical power and prevents concluding that proximity to the incident or sheltering-in-place in any given location was associated with symptoms. We did not gather information on symptom duration or intensity; however, none of the workers reported seeking a medical evaluation for their symptoms. The survey was made available to refinery workers 21 days after the incident, which might have limited the potential for recall bias.

Conclusions

Although SIP is considered an effective method for reducing acute chemical exposures, transit from one shelter to another might not be advisable because workers can be exposed to high-contaminant concentrations; opening the doors at the new shelter can allow intrusion of the chemical(s), thereby increasing indoor concentrations and increasing exposure of those already in the shelter; and workers can be exposed to secondary contamination because of off-gassing from clothing or gear. Although this refinery activated an emergency response for chemical exposures including an SIP order, workers were still exposed to vinyl chloride and experienced symptoms. Development and refinement of robust SIP protocols for vulnerable facilities (such as this physically isolated refinery) to protect against chemical exposures could include several aspects. Being able to monitor contaminant concentrations both inside and outside helps inform decisions to break shelter or discontinue the SIP order. Buildings that are designated as shelters need the ability to control outdoor air exchange; they should have a quick and well-understood protocol for shutdown of the air-handling

system to reduce the potential for chemical intrusion indoors. And after a chemical plume has passed, air-handlers need to be able to be restarted quickly to flush intruded chemicals. In the case that exiting a shelter during a chemical incident becomes necessary, workers can use respiratory protection (eg, SCBA) to reduce acute exposures. SIP protocols should also include a communication strategy (eg, text messaging or phone call) to warn offsite workers of a chemical incident. Managers and safety officers of facilities with limited physical access and the possibility of toxic exposures should consider alternate emergency egress plans and ensure that their facilities be integrated into local emergency response plans and drills.

Acknowledgments

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Appendix 1

TRAIN DERAILMENT INCIDENT: HEALTH SURVEY FOR EMPLOYEES OF _____

This questionnaire is about the train derailment incident. It asks about:

- What symptoms you may have felt after the derailment and chemical release
- What medical care you may have received
- How you heard about the incident and what to do about it

Completing the survey is voluntary. All information you write down will be kept private. Your names will not be used in any report. Please answer the questions based on what you know or remember. If you do not want to answer a question, just leave it blank.

If you have any questions about filling out this questionnaire, please call the New Jersey Department of Health at (609) 826-4920, and we will call you back as soon as we can.

We think it will take you about 15-30 minutes to fill out this questionnaire.

PLEASE COMPLETE THIS QUESTIONNAIRE AND RETURN IT TO THE NEW JERSEY DEPARTMENT OF HEALTH BEFORE **JANUARY 20, 2013**. PLEASE USE THE POSTAGE-PAID ENVELOPE TO RETURN THE QUESTIONNAIRE TO:

New Jersey Department of Health
Environmental and Occupational Health Surveillance Program
P.O. Box 369
Trenton, NJ 08625-0369

Thank you for participating in this survey. Your answers will help state and federal health agencies to better understand the public health impact of the train derailment incident.

THE QUESTIONNAIRE BEGINS ON THE BACK OF THIS PAGE

#1. What is your name and mailing address? Write your answer in the table below:

Name
Street address
Apartment or unit number
City/town
State
Zip code

#2. We may want to contact you to follow up on your answers. What is the best contact information for you? Write your answer in the table below:

Home telephone number
Mobile/cell number
E-mail address

#1. Which of the following statements describes your experience at _____ on November 30, 2012, between 7 AM and 12 noon? Please check one box:

- ☐ I was at work
- ☐ I was not scheduled to be at work
- ☐ I was scheduled to be at work but called in sick
- ☐ I attempted to reach work but was unable because the road was blocked (please answer question #1a, 1b, and 1c)
- ☐ Other: _____

Please answer questions 1a, 1b, and 1c if you checked the fourth (4th) box above:

#1a. Approximately how long did you wait at the blocked road before leaving? _____

#1b. Did you wait inside a vehicle, outside, or both? _____

#1c. Why did you leave? _____

#2. Are you a first responder (emergency worker) who worked at the scene of the train derailment? Please check the Yes or No box.

- ☐ Yes
  - What was your job?
  - ☐ Firefighter
  - ☐ Police officer
  - ☐ Emergency medical services (EMS) responder
  - ☐ Other (please specify): _____
- ☐ No

#3. After the train derailment, did you smell or taste any unusual odors that you think were related to the incident? Check one box below:

☐ Yes ☐ No

If Yes, please describe that unusual smell or taste:

_____

_____

#4. Now we want to know if you felt any **new symptom**, or had **any symptom that got worse**, after the train derailment.

If you felt no new or worsening symptoms, check the box in the first row ("No symptoms").

No symptoms	
Irritation/pain/burning of eyes	
Increased eye tearing	
Blurred or double vision	
Headache	
Dizziness or lightheadedness	
Sleepiness	
Confusion	
Loss of balance	
Generalized weakness	
Numbness or tingling in the arms or legs	
Nausea	
Vomiting	
Ringing of the ears	
Runny nose	
Nose bleed	
Irritation of nose or throat	
Irritation of lungs	
Chest tightness	
Difficulty breathing/feeling out of breath	
Coughing	
Increased congestion or phlegm	
Wheezing in chest	
Palpitations or fast heart rate	
Any other symptoms? If yes, list them:	
1.	
2.	
3.	
4.	

#5. Were you provided with medical care by an EMT (emergency medical technician) or paramedic because of the train derailment incident? Check Yes or No:

☐ Yes ☐ No

#6. Were you provided with care at a hospital? Check Yes or No:

☐ Yes ☐ No

If Yes, what is the name of the hospital(s)?

_____

#7. Other than at a hospital or by an EMT or paramedic, were you seen by a doctor or other medical professional because of symptoms related to the train derailment incident? Check Yes or No

☐ Yes ☐ No

If Yes, please explain:

_____

_____

#8. Before the train derailment incident, did you have any of the following health-related conditions? *Your answers to this question will help us understand the symptoms you may have felt.*

Asthma	
Chronic obstructive pulmonary disease (COPD) or emphysema	
Current smoker	
Used to smoke but quit	

#9. What is your sex?

☐ Male ☐ Female (please answer questions #9a and #9b)
☐ Decline to answer

#9a. **Answer only if you are female:** Are you currently pregnant? Check Yes or No
☐ Yes ☐ No

#9b. **Answer only if you are female:** Are you currently breastfeeding? Check Yes or No
☐ Yes ☐ No

#10. Did you receive instructions to shelter in place?
☐ Yes (if yes, please complete question 10a) ☐ No

#10a. Please describe how you received instructions to shelter in place:

_____
_____
_____
_____
_____
_____
_____
_____

#11. Did you shelter in place?
☐ Yes (please answer question #11a) ☐ No

#11a. Where did you shelter in place? (If you sheltered in place in more than one location, please check all locations that apply and answer question #11b)
☐ Security building
☐ Palmer modified asphalt
☐ Laboratory
☐ Maintenance shop
☐ Change house
☐ Warehouse/office
☐ Training center
☐ Control room
☐ Administration building
☐ Personal vehicle
☐ Other (please specify): _____

#11b. Please describe where you first sheltered and how you went to the next shelter.
_____
_____
_____

#12. On what floor did you shelter in place?
☐ The building only had one floor
☐ The building had more than one floor, and I sheltered in place on the first floor
☐ The building had more than one floor, and I sheltered in place on the second floor
☐ I shelter in place, but not in a building
☐ I did not shelter in place
☐ Not applicable OR I did not attempt to go to work that day

#13. Are you trained as a firefighter?
☐ Yes ☐ No

#14. Are you HAZMAT trained?
☐ Yes ☐ No

#15. Are you a _____ employee or a contractor?
☐ Employee ☐ Contractor ☐ Other: _____

#16. What is your job title? _____

#17. Are you part of _____ incident command structure?
☐ Yes (please answer question #17a) ☐ No ☐ Don't know

#17a. What is your role in incident command?
_____
_____
_____
_____

#18. Did you wear a respirator during the incident?
☐ Yes (please answer question #18a and 18b) ☐ No

#18a. What type of respirator did you wear (check all that apply)?
☐ N95 mask
☐ Half face respirator
☐ Full face respirator
☐ PAPR
☐ SCBA
☐ Other _____

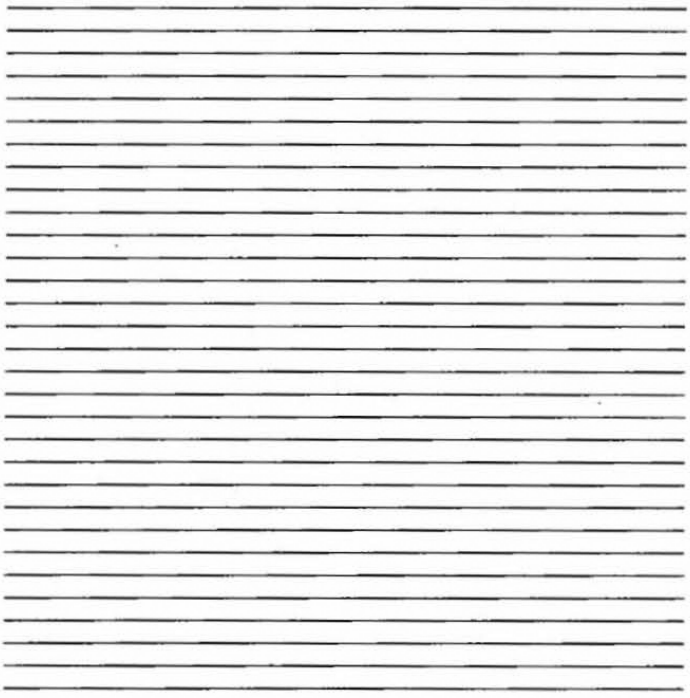
#18b. Are you fit tested for the respirator that you wore?
☐ Yes ☐ No ☐ Don't know

#19. After shelter in place was lifted, what did you do? Check one box below:
☐ I went home because the end of my shift had passed
☐ I was dismissed as nonemergency personnel
☐ I continued my shift as usual
☐ I remained on duty beyond my usual hours
☐ I was not told to shelter in place
☐ Not applicable OR I did not attempt to go to work that day
☐ Other: _____

#20. How did you first receive information that the train derailment and vinyl chloride leak had happened? Please check any box that applies:
☐ Directly from a public authority (police, firefighter)
☐ Communication from government agency (such as DEQ)
☐ Safety officer
☐ Supervisor
☐ Other coworker (please list their job title: _____)
☐ TV
☐ Radio
☐ Newspaper
☐ Relative, friend, neighbor
☐ Reverse 911 telephone call (recorded message)
☐ Text message on a cell phone
☐ E-mail
☐ Web site
☐ Other (please specify): _____

21. During the week following the train derailment incident, how did you continue to receive information about the incident and what you were supposed to do? Please check any box that applies:
☐ Directly from a public authority (police, firefighter)
☐ Communication from government agency (such as DEQ)
☐ Safety officer
☐ Supervisor
☐ Other coworker (please list their job title: _____)
☐ TV
☐ Radio
☐ Newspaper
☐ Relative, friend, neighbor
☐ Reverse 911 telephone call (recorded message)
☐ Text message on a cell phone
☐ E-mail
☐ Web site
☐ Other (please specify): _____

#22. Is there anything else you want to tell us about your health concerns related to the train derailment incident? Use back of page if necessary.



You have completed the survey. We would like to sincerely thank you for your time.

Table 1

Characteristics of workers who completed the survey*

Worker characteristic	No.	Percent
Sex		
Men	20	77
Women	6	23
Employer		
Refinery	14	54
Contractor	12	46
Training†		
Firefighter (n = 25)‡	5	20
Hazardous materials	14	54
Incident command member	5	19
Experience during incident		
At refinery	18	69
Unable to reach refinery because of blocked access road	8	31
Symptoms experienced†		
Headache	12	46
Upper respiratory symptoms	8	31
Neurological	8	31
Lower respiratory symptoms	7	27
Coughing	6	23
Irritation, pain, or burning sensation of eyes	6	23
Nausea or vomiting	5	19
Increased congestion or phlegm	3	12
Any symptom	15	58
Noticed unusual odor or taste	17	65
Sweet odor or taste (n = 17)	10	59

* n = 26, unless otherwise noted.

† Multiple answers allowed; totals may be greater than 100 percent.

‡ One worker did not answer this question.

Table 2

Characteristics of workers who were at the refinery during the incident*

Worker characteristic	No.	Percent
Experienced ≥1 symptom	11	65
Sheltered in one location at refinery	7	41
Experienced ≥1 symptom (n = 7)	2	29
Sheltered in two locations at refinery	6	35
Experienced ≥1 symptom (n = 6)	5	83
Sheltered in three locations at refinery	4	24
Experienced ≥1 symptom (n = 4)	4	100
Used a respirator at any time during incident	2	12

* n = 17 (one worker who wore a self-contained breathing apparatus and searched the refinery grounds for nonsheltering workers is excluded from this analysis).