

# **Health Consultation**

## **Air Quality in Paulsboro, New Jersey Following a Train Derailment and Vinyl Chloride Gas Release**

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# Summary

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## Introduction

At approximately 7:00 am on November 30, 2012, several chemical tank cars derailed on a railroad bridge over the Mantua Creek at Paulsboro, NJ. Four cars ended up in the creek. One of these cars, which contained 24,000 gallons of vinyl chloride, ruptured and released the hazardous chemical into the air.

There was widespread concern about the public health impact of the event. In response, the New Jersey Department of Health (NJDOH) and the U.S. Centers for Disease Control and Prevention (CDC)—including the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH)—began assessing the public health implications of the event.

This Health Consultation summarizes the impact of the derailment and vinyl chloride gas leak on the air quality in Paulsboro, specifically the concentrations of vinyl chloride in the air over time following the leak. The purpose is to understand the magnitude and duration of exposures and the potential short-term and long-term health risks experienced by community residents.

*NJDOH has reached the following conclusions based on the information presented in this Health Consultation report:*

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## Conclusion 1

*Based on visual and photographic evidence, air monitoring, and air dispersion models, Paulsboro residents were exposed to varying levels of vinyl chloride as a result of the train derailment and gas leak.*

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## Basis for Conclusion 1

The train derailment in Paulsboro at 7:00 a.m. on November 30, 2012 caused a leak of vinyl chloride from a ruptured tank car. It is likely that most of the vinyl chloride was released in the first minutes to one hour following the breach, with the highest air concentrations and highest exposures occurring in the first hour after the derailment.

Air concentrations also likely varied across the town, with highest exposure occurring closer to the derailment site, though the

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dispersion was affected by topography, wind speed and direction, and other factors.

Air dispersion models indicated that peak levels in the first hour after the derailment could have been in the thousands of parts per million (ppm) within 0.2 miles of the site, and 250 ppm as far as 0.8 miles from the site. Between 8:30 and 8:40 a.m., personnel of the Paulsboro Refining Company recorded peak VOC levels over 700 ppm near the derailment site (corresponding to vinyl chloride concentrations over 1,400 ppm).

Subsequent air monitoring indicated lower levels as the released gas dispersed over the following few hours on November 30. There were occasional detections of elevated concentrations, particularly on December 3 and 4, until the breached tank was removed on December 5.

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**Conclusion 2**

*Exposures to vinyl chloride were likely to have been sufficiently high through much of the town of Paulsboro in the first hours after the derailment to cause reversible, short-term harmful health effects such as eye and nasal irritation or headache. Closer to the derailment site, exposures were potentially high enough to reach U.S. Environmental Protection Agency Acute Exposure Guidance Levels (AEGLs) for disabling and life-threatening effects.*

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Basis for  
Conclusion 2

Health surveys among emergency responders and Paulsboro residents showed that a high proportion of those responding to the surveys reported experiencing symptoms consistent with exposure to vinyl chloride. Based on modeled estimates and monitoring, peak air concentrations were far in excess of the ATSDR's acute-duration Minimal Risk Level (MRL) for vinyl chloride in air of 0.5 ppm, and in parts of the town exceeded the U.S. Environmental Protection Agency's Acute Exposure Guidance Levels (AEGL) for 1 hour exposure that are associated with reversible health effects (250 ppm), and possibly to disabling effects (1,200 ppm) or life-threatening effects (4,800 ppm). Beyond the first several hours after the derailment, air concentrations most likely did not reach or exceed these AEGLs in residential areas that had not been evacuated.

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**Conclusion 3**

*There were missed opportunities to reduce exposure to vinyl chloride in the immediate aftermath of the derailment and chemical release. The failure to use self-contained breathing apparatus led to preventable exposure to emergency response personnel. Lockdown of school buildings caused increased exposure in some school children who were turned away and sent home.*

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**Basis for  
Conclusion 3**

If personal protective equipment had been used, as required by OSHA regulations, and as recommended in the DOT Emergency Response Guidebook, exposure to vinyl chloride would have been reduced among the emergency responders. Establishment of the initial incident command post close to the derailment scene, without the use of personal protective equipment, led to preventable exposures to emergency responders who assembled there. Just after the incident command post was moved to the church at about 8:30 a.m. (about 100 yards away from the original location), high VOC concentrations were measured close by. However, emergency response personnel at this incident command post location still did not use personal protective equipment.

The school system's implementation of lockdown procedures in response to the incident resulted in children being turned away from school and sent back home through the cloud of vinyl chloride.

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**Recommended  
Next Steps**

**Employers of emergency responders, and incident commanders, should follow established regulations and guidance regarding the use of personal protective equipment (such as self-contained breathing apparatus).**

**Schools should ensure that emergency response plans are designed to protect children and staff from chemical exposures.**

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**Conclusion 4**

*Residents within approximately one-half mile of the derailment scene should have been evacuated as soon as it was feasible. Since resident evacuations did not start until the late afternoon of November 30, there was a missed opportunity to reduce the amount and duration of exposure to residents.*

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Basis for  
Conclusion 4

The U.S. Department of Transportation's Emergency Response Guidebook recommends an initial evacuation zone of one-half mile downwind of a large spill of vinyl chloride. Resident evacuation was initiated within about 15 minutes of the derailment, but this was halted shortly thereafter and residents were advised to shelter in place beginning around 7:30 a.m. Air monitoring by the Paulsboro Refining Company recorded VOC levels near the derailment site corresponding to over 1,400 ppm of vinyl chloride between 8:30 and 8:40 a.m., with levels diminishing through the morning hours.

Evacuation of approximately 45 residents closest to the derailment site was not ordered until about 4:00 p.m. and expanded to include an additional 500 residents at 5:00 p.m. Meanwhile, as noted above, the incident command post had been relocated to the Borough Hall at around 10:45 a.m. and was moved to Clarksboro around 2:00 p.m.

Incident commanders have to balance competing public safety considerations when deciding whether or when to evacuate. It should have been feasible to resume evacuating residents sooner than the late afternoon.

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Recommended  
Next Steps

**Incident commanders should follow guidance regarding the evacuation of residential areas as early in the response as possible.**

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**Conclusion 5**

*The prospect of long-term, non-cancer harmful health effects from the acute-duration exposure to vinyl chloride that occurred in Paulsboro cannot be determined.*

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Basis for  
Conclusion 5

There is insufficient toxicological and epidemiologic knowledge to assess whether there is a risk of long-term health effects due to the acute-duration exposures to vinyl chloride in Paulsboro. Medical management guidelines from ATSDR indicate that such effects are unlikely in persons who have recovered from the effects of acute exposure.



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**Conclusion 6**

*While cancer risk estimates for the short-term exposures experienced because of the train derailment are very uncertain, the long-term risk of cancer from the acute-duration exposures to vinyl chloride may have exceeded 1 additional case of cancer in 10,000 persons exposed, based on risk estimates by the National Research Council. This is a low increase in cancer risk in comparison to the background risk of cancer.*

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Basis for  
Conclusion 6

Vinyl chloride is known to be a human carcinogen when there is exposure through inhalation. This determination was based on finding an increased risk of a rare type of liver cancer (angiosarcoma) in occupational settings with chronic or long-term exposure to high levels of the chemical. Risk estimates for acute-duration exposure to vinyl chloride have been made based on findings from these chronic exposures, though there is a lack of consensus on the validity of this approach.

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**Conclusion 7**

*There is no specific medical monitoring or testing that is suggested by what is known about the long-term effects of acute-duration exposures. There is no screening method available for early detection of liver cancers.*

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Basis for  
Conclusion 7

Routine blood tests that check for liver function may show signs of many kinds of liver diseases, but such tests would not be specific indicators of damage from vinyl chloride exposure. Although there are screening tests for liver cancer, these are not recommended unless an individual is at high risk due to other medical conditions such as chronic cirrhosis or hepatitis B virus infection.

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Recommended  
Next Steps

**In the absence of specific testing recommendations, NJDOH recommends that Paulsboro residents seek routine, age-appropriate health care.**

**Consideration should be given to convening a group of community members and experts to explore potential long-term public health actions. Some options for such actions could include community health surveillance, epidemiologic research,**

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**establishment of an exposure registry, and communication of health risk information.**

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**For More Information**

Copies of this report will be provided to interested residents through the local library and the NJDOH web site. NJDOH will notify area residents that this report is available and will provide a paper copy upon request.

Questions about this report should be directed to the Environmental and Occupational Health Surveillance Program, New Jersey Department of Health, (609) 826-4984.

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## 1. Statement of Purpose

At approximately 7:00 am on November 30, 2012, several chemical tank cars derailed on a railroad bridge over the Mantua Creek at Paulsboro, NJ. Four cars ended up in the creek. One of these cars, which contained 24,000 gallons of vinyl chloride, ruptured and released the hazardous chemical into the air (NJOEM 2012a; NTSB 2013a).

There was widespread public concern about the public health impact of the event. In response, the New Jersey Department of Health (NJDOH) requested assistance from the U.S. Centers for Disease Control and Prevention (CDC), including the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH). These agencies responded by sending a field team to provide epidemiological assistance through an “Epi-Aid.” One of the objectives of this Epi-Aid assistance was to characterize exposure to those impacted by the vinyl chloride release.

*This Health Consultation summarizes the impact of the derailment and vinyl chloride gas leak on the air quality in Paulsboro, specifically the concentrations of vinyl chloride in the air over time following the leak. The purpose is to understand the magnitude and duration of exposures and the potential short-term and long-term health risks experienced by community residents and emergency responders.* This information will also be useful to provide a basis for interpreting the results of health surveys also conducted under the Epi-Aid investigations. The results of these surveys of emergency responders and residents (NIOSH 2013; NJDOH 2014), and a review of hospital emergency department medical records (ATSDR in preparation), are reported separately.

## 2. Background

The Conrail train that derailed consisted of two engines and 82 cars, 55 of which were carrying hazardous materials (NTSB 2013a).<sup>1</sup> Seven of the train cars derailed, four of which ended up partially in the Mantua Creek. Three of these carried vinyl chloride, and one contained ethanol. One of the vinyl chloride-containing cars was punctured as a result of the derailment; this car was carrying approximately 24,000 gallons of liquid vinyl chloride under pressure. Figure 1 is a map of the derailment location and surrounding areas.

Once the rupture occurred, pressure caused the vinyl chloride to be released from the tank, most likely as a liquid, aerosol (mist), and gas (vapor). Ground-level photographs taken close to the scene between ten and fifty minutes after the derailment show a dense fog

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<sup>1</sup> Among the 55 train cars carrying hazardous materials, four cars contained chlorine, a chemical that is categorized as a “Toxic Inhalation Hazard” (DOT 2012) because of its severe, immediate health effects when breathed in.

blanketing the Mantua Creek (Figures 2–5). An eyewitness reported that there was no fog prior to the derailment, indicating that the fog formed in response to the release of the vinyl chloride gas (NTSB 2013b). Accounts by police responding to the scene describe the movement of the fog into and spreading through an adjacent residential area of Paulsboro (NTSB 2013c-d).

Within minutes of the train derailment, police and fire personnel began arriving at the scene. An incident command was established at the scene by Paulsboro Fire Department officials. At about 7:15 a.m., Paulsboro police began knocking on doors to advise the nearest residents to evacuate the area. However, by about 7:30 a.m., police stopped advising evacuation and began instructing residents to stay home with windows closed (NTSB 2013 a).

The Fire Chief, who had assumed command of the emergency response, was informed by a Conrail representative that a half-mile evacuation radius was required (NTSB 2013a). The U.S. Department of Transportation’s (DOT) 2012 Emergency Response Guidebook (DOT 2012) states that, for a large spill of vinyl chloride, “Consider initial downwind evacuation for at least 800 meters (1/2 mile).”

Between about 7:25 a.m. and 7:40 a.m., Paulsboro schools were notified of the emergency situation and told to close (NTSB 2013a). In response, schools went into “lockdown” in which no one was allowed into or out of the school buildings. Approximately 150 students (out of a K-12 enrollment of about 1,100 children (NJDOE 2013) were already inside at one of the three public schools at the time of lockdown, and remained indoors at the schools until released later in the morning. Students who were on their way to school were turned back and sent home, in some cases through the fog (South Jersey Times 2012; Laday 2012; Forand 2013).

Police and fire department personnel and other emergency responders did not wear personal protective equipment, such as self-contained breathing apparatus, at the scene (NTSB 2013a). This is inconsistent with U.S. Occupational Safety and Health Administration (OSHA) regulations<sup>2</sup> and guidance in the Emergency Response Guidebook (DOT 2012). It should be noted that New Jersey is an approved OSHA state for public employers and employees and as such adopts OSHA regulations by reference.

Just before 8:30 a.m., the incident command post was moved to St. James Church, about 100 yards from the original site. Around this time, a team from Paulsboro Refining Company began monitoring the air near the derailment scene with photoionization detectors

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<sup>2</sup> 29 CFR 1910.120(q)(3). Occupational Safety and Health Standard for Hazardous Waste Operations and Emergency Response: Procedures for Handling Emergency Response. Accessed at: [https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9765](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9765).

29 CFR 1910.1017. Occupational Safety and Health Standard for Vinyl Chloride (including Appendix A). Accessed at: [https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10021](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10021), and [https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10022](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10022).

(PIDs) and found levels indicating high concentrations of vinyl chloride (NTSB 2013e). At about 10:45 a.m., at the urging of state environmental and emergency management officials, the incident command post was moved to Borough Hall (1211 N. Delaware St.). Early in the afternoon, a Unified Command was established, consisting of the U.S. Coast Guard, the New Jersey Department of Environmental Protection (NJDEP), the State of New Jersey Office of Emergency Management (NJOEM), Conrail, and the Paulsboro Fire Department (NJOEM 2012a; NTSB 2013a). The Unified Command was initially established at Borough Hall but moved around 2:00 p.m. to the Gloucester County Fire Academy in Clarksboro.

Prompted by air monitoring readings in the late afternoon, the Unified Command issued an evacuation order for about 45 residents nearest to the derailment site at about 4:00 p.m., then expanded the order to include approximately 500 more residents at about 5:00 p.m. (NJOEM 2012a). The rest of Paulsboro remained under instructions to shelter in place. Over the next three days, shelter-in-place orders were periodically lifted and reinstated; on December 4, the evacuation area was further expanded to include 300 to 400 additional residents (NJOEM 2012b).

### **3. Air Quality Information**

#### **3.1. Air Quality Monitoring**

##### Measurements Taken Shortly After the Derailment

About 90 minutes after the derailment, personnel from the Paulsboro Refining Company (PRC) began using hand-held photoionization detector (PID) instruments with data recorders to take measurements of volatile organic chemical (VOC) vapors in the air. (Note that VOC readings are not specific to vinyl chloride, and may reflect the presence of other chemicals from other sources in the area.) PRC technicians began taking readings at the corner of North Commerce St. and East Jefferson St., about one-tenth of a mile from the derailment site, registering maximum readings of over 700 parts per million (ppm) between 8:33 and about 8:40 a.m. (Table 1) (Paulsboro Refining Company 2012; NTSB 2013e). Based on the instrument's chemical-specific response factor (1.9), the VOC readings correspond to maximum concentrations of vinyl chloride of over 1,400 ppm during this window of time at that location. By about this time, the dense fog in the immediate vicinity of the derailment had begun to dissipate (Figure 6).

After moving about two blocks further from the derailment scene (to the corner of North Delaware St. and Billings Ave.) and recalibrating instruments, PRC personnel obtained peak PID readings of 108 to 193 ppm (200 to 370 ppm vinyl chloride) between about 8:44 and 8:48 a.m. (Table 1) (Paulsboro Refining Company 2012). Representatives of OxyVinyls, Inc. began air monitoring with PID instruments at the derailment scene at approximately 9:41 a.m.

Readings fluctuated, peaking at about 60 ppm (corresponding to a vinyl chloride concentration of 110 ppm) at 9:49 a.m. A photograph taken less than a half hour before this showed that the air had substantially cleared of a visible ground-level cloud (Figure 7). Peak readings as high as 31 ppm (60 ppm vinyl chloride) occurred as late as 3:15 p.m. (NTSB 2013f-i).

Hand-held PID readings taken by NJDEP during the morning were reported to be “high” over a half-mile away from the derailment scene, although specific values and times of the readings were not noted (EPA 2012a). In contrast, other PID readings taken by a contractor to the U.S. Environmental Protection Agency (EPA) did not record positive PID readings in various areas of the community during the morning hours (EPA 2012b).

### Establishment of Systematic Air Quality Monitoring

By the early afternoon of November 30, more systematic air monitoring was established around the community. A contractor to Conrail (Center for Toxicology and Environmental Health, or CTEH), began air monitoring using manually logged, handheld devices (MultiRAE PID units and colorimetric detector tubes specific to vinyl chloride) by approximately 1:30 p.m. Several of these devices were employed at fixed locations while other devices were portable and were used at various locations. At the request of NJDEP, the EPA also deployed its mobile laboratory called the Trace Atmospheric Gas Analyzer (TAGA) by about 1:30 p.m. The TAGA mobile laboratory made real-time measurements of vinyl chloride using gas chromatography. CTEH set up four stationary PID measurement devices (AreaRAE units) by approximately 4:30 p.m. (CTEH 2012a). CTEH also established seven fixed “analytical stations” which drew air samples daily; these samples were analyzed in a laboratory for vinyl chloride using EPA Method TO-15.

VOCs were detected periodically in the community by CTEH using hand-held, manually logged PIDs (Table 2). While levels were relatively low from mid-afternoon on November 30 until the end of the day on December 2, VOC detections were most frequent and reached their highest levels in the community on December 3 and December 4. Similarly, Table 3 shows that vinyl chloride levels measured with colorimetric detectors also peaked on December 3 and December 4; the highest colorimetric detector measurement of vinyl chloride concentration was 9.4 ppm on December 4. Vinyl chloride was removed from the leaking tank car on December 5. From December 5 on, there were few VOC detections with the hand-held PID instruments (CTEH 2012a-g).

VOC readings were also taken by CTEH using AreaRAE PIDs, at two fixed locations about 0.2 miles from the derailment site (Table 4). At Unit 1, located along the creek to the south-southwest, readings peaked on December 3 and 4, with the highest value exceeding 250 ppm (480 ppm vinyl chloride). At Unit 2, located to the west-northwest of the site, peak readings also occurred on those days, at approximately 11 ppm (20 ppm vinyl chloride).

The EPA TAGA mobile laboratory measured vinyl chloride concentrations for several hours each day beginning in the afternoon of November 30 (Table 5). As with CTEH's PID measurements, vinyl chloride levels reached their highest on December 3 and December 4. A maximum value of 41 ppm was recorded on December 3, representing an average over approximately 45 minutes around 5:30 p.m. Vinyl chloride concentrations averaged over the monitored hours were approximately 0.06 ppm in the afternoon and evening hours of November 30, 0.03 ppm on December 1 and 2, 0.4 ppm on December 3, 0.2 ppm on December 4, and less than 0.01 ppm on the next two days (EPA 2012c).

Average daily vinyl chloride concentrations were measured by CTEH at five fixed stations in Paulsboro in or near populated areas (Table 6). Beginning on the afternoon and evening of November 30, daily average vinyl chloride concentrations ranged from 0.87 ppm at Station 2 along the Mantua Creek (co-located with AreaRAE Unit 1 discussed above) to less than 0.005 ppm at two of the stations farther from the derailment site. Average levels increased slightly or stayed approximately the same over the next two days, then spiked on December 3, ranging as high as 35 ppm at Station 2 (CTEH 2012h).

### Summary of Air Monitoring Data

The first available air monitoring data was from close to the scene of the derailment about 90 minutes after the incident. By that time, an extensive cloud of vinyl chloride gas had been released and had begun dispersing into the community. Vinyl chloride concentrations from these first measurements near the scene were as high as about 1,400 ppm. Over the next couple of hours, vinyl chloride concentrations fluctuated near the scene, ranging from tens to hundreds of ppm. By the afternoon of November 30, and continuing over the next two days, vinyl chloride concentrations appear to have been much lower than in the hours shortly after the derailment. However, on December 3 and 4, vinyl chloride concentrations began to increase again; for example, the EPA TAGA laboratory readings reached as high as 41 ppm in the early evening of December 3.

### **3.2. Air Dispersion Modeling**

About 90 minutes elapsed between the vinyl chloride release at about 7:00 a.m. and the time that hand-held PID readings were first recorded by emergency response personnel from PRC. Until systematic monitoring began in the early afternoon, few data were collected to assess the potential for exposure to vinyl chloride in the community.

Air dispersion models may be used in this circumstance to provide estimates of the range of vinyl chloride concentrations that could have been in the air in the first hour after the vinyl chloride leak began. The National Oceanographic and Atmospheric Administration (NOAA) and EPA developed the Areal Locations of Hazardous Atmospheres (ALOHA) model as a tool for emergency responders and planners to estimate how chemicals may be dispersed in

the air following a release (NOAA 2011). As part of the response to the train derailment in Paulsboro, the NOAA Office of Response and Restoration coordinated the development of a series of ALOHA models to assist emergency responders in the evaluation of the threat posed by the vinyl chloride release.

Based on characteristics of the chemical, the release source, and weather conditions, the ALOHA models estimate the distance to which hazardous air concentrations of a chemical may extend. Models do not necessarily show the actual concentrations of chemicals in the air, which are likely dispersed in more complex patterns determined by local topography and air movement. Models developed for the Paulsboro train derailment indicated that much of the vinyl chloride would have escaped from the tank within the first hour (NOAA 2012; IMAAC 2012). The models also estimated that outdoor air concentrations within the first hour could have exceeded 4,800 ppm as far out as 0.2 miles in the direction of the wind, 1,200 ppm as far out as 0.4 miles, and 250 ppm as far out as 0.8 miles (NOAA 2012). Much of the area of Paulsboro is within 0.8 miles of the train derailment.

## **4. Discussion**

To assess whether a health hazard exists to a community, it is necessary to determine whether there is a completed exposure pathway from a contaminant source to a receptor population, and whether exposures to contamination are high enough to be a health concern.

### **4.1. Exposure Pathways**

An exposure pathway is a series of steps starting with the release of a contaminant into environmental media (such as air, water or soil) and ending at the interface with the human body. A completed exposure pathway consists of: a source of contamination; environmental media and transport mechanisms; a point of exposure; a route of exposure; and a receptor population. Exposure pathways are used to evaluate specific ways in which people were, are, or will be exposed to environmental contamination.

In Paulsboro, there was a *completed exposure pathway* to vinyl chloride in the hours and days following the train derailment, tank car breach and release of gas on November 30, 2012. The source of exposure was the leaking tank car. Vinyl chloride gas escaped and vaporized into the air. Residents and emergency responders were exposed to vinyl chloride at various locations via inhalation of the gas.

Emergency responders were variably exposed to vinyl chloride, depending on the amount of time and timing of activities near the derailment site. Exposure to emergency responders could have been lower had OSHA regulations and DOT Emergency Response Guidebook recommendations been followed (29 CFR 1910.120(q)(3) and 29 CFR 1910.1017;



DOT 2012). The siting of the incident command post close to the derailment scene during the first few hours, without the use of personal protective equipment, resulted in preventable exposure to emergency responders.

Paulsboro residents, particularly those closer to the derailment scene, were exposed in their homes and neighborhoods as the vinyl chloride vapors dispersed through the town. School children who were on their way to school after the incident were exposed; those who were turned away to return home could have been exposed further. Exposure to nearby residents could have been reduced had the evacuation that was initiated around 7:15 a.m. been continued. However, a decision during an emergency response to evacuate or to order sheltering in place is a complex one, and incident commanders may have to balance competing public safety considerations.

Estimating with confidence the vinyl chloride concentrations to which people were exposed is complicated by temporal and geographic gaps in available monitoring data, differences in methods employed to measure vinyl chloride levels, differences in averaging times of measurements, and the variability introduced by topography and wind direction. Most residents are likely to have spent most of their time indoors, especially on the day of November 30, but air concentrations of vinyl chloride within residences were not measured.

Nonetheless, based on available monitoring data from the first few hours after the derailment and the modeled concentrations of vinyl chloride within the first hour, it is likely that emergency responders as well as residents living close to the derailment site were exposed for an hour or more on November 30 to vinyl chloride concentrations as high as 1,200 ppm or greater, followed by lower concentrations on subsequent hours and days. Many of the residents living farther from the scene could have been exposed to vinyl chloride concentrations at least as high as 250 ppm in the first hours.

#### **4.2. Public Health Implications**

This section evaluates the public health implications of varied levels of exposure to vinyl chloride in Paulsboro, including both the short-term and long-term health risks posed by this exposure.

##### Short-Term Health Effects of Acute-Duration Vinyl Chloride Exposure

Exposure to high concentrations of vinyl chloride may cause dizziness or lightheadedness, dulling of sight and hearing, nausea, headache and irritation of the eyes, nose and throat, liver toxicity, tingling in the arms and legs, and heart palpitations (National Research Council 2012; ATSDR 2006a; ATSDR 2006b). With exposures lasting hours to days, it is appropriate to compare environmental concentrations to acute-duration guidelines. For vinyl chloride, ATSDR has established an Acute (1 to 14 days) Minimal Risk Level (Acute

MRL)<sup>3</sup> of 0.5 ppm, representing an air concentration that *is not expected* to result in adverse non-carcinogenic health effects (ATSDR 2006b). The Acute MRL is intended to be protective against the potential for adverse fetal developmental effects observed in experimental animals. In the experiment, the fetuses of pregnant mice exposed to air with 500 ppm of vinyl chloride for 7 hours per day for 5 to 16 days showed delayed bone development; significant toxic effects were also observed in the pregnant mice at this dose. No effects were seen in the fetal mice at 50 ppm. The MRL is based on this no-observed-adverse-effect-level (NOAEL) of 50 ppm, after adjusting the dose for experimental conditions and dividing by safety factors (ATSDR 2006b).

Other health-based comparison values may be used to assess the likelihood of health effects. The EPA has established Acute Exposure Guideline Levels (AEGLs) designed to help emergency responders evaluate hazards when members of the public are exposed during a hazardous substance release incident (EPA 2012d). AEGLs are concentrations of a chemical in air at which most people—including potentially more sensitive individuals such as the sick, elderly or very young—*would be expected* to begin experiencing symptoms. AEGLs are developed for three tiers of health effect severity, and for several exposure durations. The AEGLs for vinyl chloride for 60-minute and 8-hour exposure periods are shown in the table below.

**Table A. Acute Exposure Guideline Levels (AEGLs) for Vinyl Chloride, in parts per million (ppm) in air.**

Severity Tier	Vinyl Chloride Air Concentration (ppm)		Definition
	Exposure for 60 minutes	Exposure for 8 hours	
AEGL-1	<b>250</b>	<b>70</b>	<i>The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals...</i>
AEGL-2	<b>1,200</b>	<b>820</b>	<i>...could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.</i>
AEGL-3	<b>4,800</b>	<b>3,400</b>	<i>...could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.</i>

Sources: EPA 2012e and EPA 2012d

<sup>3</sup> An MRL may be based on toxicological studies in animals or on reports of effects from human occupational exposures. MRLs are usually extrapolated doses from observed effect levels in animal toxicological studies or occupational studies, and are adjusted by a series of uncertainty (or safety) factors or through the use of statistical models. Observed effect levels may be a “no-observed-adverse-effect level” (NOAEL), which is the highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals, or a “lowest-observed-adverse-effect level” (LOAEL), which is the lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

For vinyl chloride, the AEGL-1 is based on a study in humans in which headaches were experienced following inhalation exposure. The AEGL-2 is based on a study in humans in which severe dizziness was experienced after brief exposure, indicating the potential for an impaired ability to escape. The AEGL-3 is based on cardiac sensitization to adrenaline in experimental animals, potentially leading to heart arrhythmia and death (National Research Council 2012).

Responders or residents exposed to vinyl chloride exceeding 1,200 ppm for an hour or more could have experienced acute symptoms (severe dizziness) potentially impairing their abilities to escape the scene. Responders or residents exposed to more than 250 ppm for an hour or more could have experienced reversible symptoms (AEGL-1, Table A) such as eye and nasal irritation or headache. Health surveys showed that a high proportion of survey respondents reported experiencing these symptoms (NIOSH 2013; NJDOH 2014). Symptoms may appear immediately upon exposure, or may be delayed up to 48 hours following acute-duration exposure (ATSDR undated; Table A).

### Long-term Health Risks from Acute-Duration Exposure

#### *Non-Cancer Effects*

There is little or no toxicological information in the literature relevant to long-term, non-cancer effects from non-occupational acute-duration exposures in community settings. In the absence of experimental and occupational studies reflecting the type of exposure experienced in this community, available studies with dissimilar exposure scenarios are reviewed to assess the potential for non-cancer health effects.

ATSDR's Medical Management Guidelines indicate that acute-duration exposures from which an exposed person recovers are unlikely to experience long term effects (ATSDR undated). For those with long-term, repeated exposure to vinyl chloride in the workplace, medical surveillance should include annual blood tests for liver function or liver damage (29 CFR 1910.1017). These tests are general indicators of how well the liver is performing or whether there are responses to damage, and are not specific to vinyl chloride exposure.

For fetal impact, ATSDR's acute-duration MRL of 0.5 ppm is based on protection against a developmental endpoint (delayed bone growth) occurring after repeated maternal exposure to 500 ppm vinyl chloride in air (ATSDR 2006b). The repeated exposure scenario in the experimental conditions is dissimilar to the acute-duration conditions in this incident, so the relevance of ATSDR's acute-duration MRL is not clear.

## *Cancer Risk*

Vinyl chloride is classified by the EPA as a known human carcinogen by the inhalation route of exposure (EPA 2012f; ATSDR 2006b). This classification is based on human epidemiologic evidence of a causal association between occupational exposure to vinyl chloride by inhalation and the development of angiosarcoma, a very rare tumor of the liver. Vinyl chloride exposure may also be linked to other forms of liver cancer. While there have been studies that suggest a link to other cancers, including brain cancer and lung cancer, the evidence is considered weak. There is evidence of carcinogenicity in experimental animals (rats, mice, and hamsters), and vinyl chloride has been shown to be mutagenic.

For carcinogenic chemicals, AEGLs have been calculated to quantify potential long-term cancer risks from acute-duration exposures. However, the National Research Council committee that produced AEGLs indicates that there is considerable scientific uncertainty and lack of consensus on the validity and usefulness of these estimates (National Research Council 2001). For vinyl chloride, the AEGL for a 1-hour exposure that is associated with an added risk of 1 case in 10,000 exposed persons was calculated to be 350 ppm in the air (National Research Council 2012). This 1-hour concentration was likely to have been exceeded in parts of the town of Paulsboro within the first hour or hours after the vinyl chloride leak, so it is reasonable to estimate that the incremental addition to lifetime cancer risk from exposure to vinyl chloride from this incident may have exceeded 1 case in 10,000 people exposed. Based on the sharp drop-off in vinyl chloride concentrations from the initial modeled and monitored vinyl chloride levels, it is probable that most of the vinyl chloride exposure and risk would have been experienced in the first hour or two following the train derailment and gas leak.

To put this risk in perspective, it should be noted that the lifetime risk of being diagnosed with any invasive cancer in the U.S. is 44 per 100 individuals for males, and 38 per 100 for females. Lifetime risks of being diagnosed with the most common specific types of cancers are: 15 in 100 (prostate cancer in males); 12 in 100 (breast cancer in females); 8 in 100 (lung cancer in males); 6 in 100 (lung cancer in females); 5 in 100 (colorectal cancer in males); and 5 in 100 (colorectal cancer in females). The lifetime risk of any form of liver and bile duct cancer is about 1 in 100 in males and about 1 in 200 in females (American Cancer Society 2013a).

Screening for liver cancer may be done with an alpha-fetoprotein (AFP) test or by ultrasound. However, these screening tests are not recommended except for those at high risk due to long-term cirrhosis of the liver or chronic infection with the hepatitis B virus (American Cancer Society 2013b). The occurrence of cancer in the community of people exposed to vinyl chloride can be examined over time through periodic examination of the data collected by the New Jersey State Cancer Registry. However, the long latency of cancers (up to several decades) means that this activity may not be meaningful for a long time.

## 5. Conclusions and Recommendations

**Conclusion 1.** *Based on visual and photographic evidence, air monitoring, and air dispersion models, Paulsboro residents were exposed to varying levels of vinyl chloride as a result of the train derailment and gas leak.*

The train derailment in Paulsboro at 7:00 a.m. on November 30, 2012 caused a massive leak of vinyl chloride from a ruptured tank car. It is likely that most of the vinyl chloride was released in the first minutes to one hour following the breach, with the highest air concentrations and highest exposures occurring in the first hour after the derailment. Air concentrations also likely varied across the town, with highest exposure occurring closer to the derailment site, though the dispersion was affected by topography, wind speed and direction, and other factors.

In the first hour, air dispersion models indicated that peak levels could have been in the thousands of ppm within 0.2 miles of the site during the first hour, and 250 ppm as far as 0.8 miles from the site. Between 8:30 and 8:40 a.m., personnel of the Paulsboro Refining Company recorded peak VOC levels over 700 ppm near the derailment site (corresponding to vinyl chloride concentrations over 1,400 ppm). Subsequent air monitoring indicated lower levels as the released gas dispersed over the following few hours, though there were occasional detections of elevated concentrations particularly on December 3 and December 4.

**Conclusion 2.** *Exposures to vinyl chloride were likely to have been sufficiently high through much of the town of Paulsboro in the first hours after the derailment to cause reversible, short-term harmful health effects such as eye and nasal irritation or headache. Closer to the derailment site, exposures were potentially high enough to reach AEGLs for disabling and life-threatening effects.*

Health surveys showed that a high proportion of emergency responders and Paulsboro residents responding to the surveys reported experiencing symptoms consistent with exposure to vinyl chloride (NIOSH 2013; NJDOH 2014). Based on modeled estimates and monitoring, peak air concentrations were far in excess of the ATSDR's acute-duration Minimal Risk Level (MRL) for vinyl chloride in air of 0.5 ppm, and exceeded the EPA's Acute Exposure Guidance Levels (AEGL) for 1 hour exposure that are associated with reversible health effects (AEGL-1: 250 ppm), and possibly to disabling effects (AEGL-2: 1,200 ppm) or life-threatening effects (AEGL-3: 4,800 ppm). Beyond several hours after the incident, air concentrations most likely did not reach or exceed these AEGLs in residential areas that had not been evacuated.

**Conclusion 3.** *There were missed opportunities to reduce exposure to vinyl chloride in the immediate aftermath of the derailment and chemical release. The lack of use of self-contained breathing apparatus led to preventable exposure to emergency response personnel. Lockdown*

*of school buildings caused increased exposure in some school children who were turned away and sent home.*

If personal protective equipment had been used, as required by OSHA regulations, and as recommended in the DOT Emergency Response Guidebook, exposure to vinyl chloride would have been reduced among the emergency responders. Establishment of the initial incident command post close to the derailment scene, without the use of personal protective equipment, led to preventable exposures to emergency responders who assembled there. Just after the incident command post was moved to the church at about 8:30 a.m. (about 100 yards away from the original location), high VOC concentrations were measured close by. However, emergency response personnel at this incident command post location still did not use personal protective equipment.

The school system's implementation of lockdown procedures in response to the incident resulted in children being turned away from school and sent back home through the cloud of vinyl chloride.

**Recommendations.** Employers of emergency responders, and incident commanders should follow established regulations and guidance regarding the use of personal protective equipment (such as self-contained breathing apparatus). Schools should ensure that emergency response plans are designed to protect children and staff from chemical exposures.

**Conclusion 4.** *Residents within approximately one-half mile of the derailment scene should have been evacuated as soon as it was feasible. Since resident evacuations did not start until the late afternoon of November 30, there was a missed opportunity to reduce the amount and duration of exposure to residents.*

The U.S. DOT Emergency Response Guidebook recommends an initial evacuation zone of one-half mile downwind of a large spill of vinyl chloride. Resident evacuation was initiated within about 15 minutes of the derailment, but this was halted shortly thereafter and residents were advised to shelter in place beginning around 7:30 a.m. Air monitoring by the Paulsboro Refining Company recorded VOC levels corresponding to over 1,400 ppm of vinyl chloride between 8:30 and 8:40 a.m., with levels diminishing through the morning hours.

Evacuation of approximately 45 residents closest to the derailment site was not ordered until about 4:00 p.m. and expanded to include an additional 500 residents at 5:00 p.m. Meanwhile, as noted above, the incident command post had been relocated to the Borough Hall at around 10:45 a.m. and was moved to Clarksboro around 2:00 p.m.

Incident commanders have to balance competing public safety considerations when deciding whether or when to evacuate. It should have been feasible to resume evacuating residents sooner than the late afternoon.

**Recommendations.** Incident commanders should follow guidance regarding the evacuation of residential areas as early in the response as possible.

**Conclusion 5.** *The prospect of long-term, non-cancer harmful health effects from the acute-duration exposure to vinyl chloride that occurred in Paulsboro cannot be determined.*

There is insufficient toxicological and epidemiologic knowledge to assess whether there is a risk of long-term health effects due to the acute-duration exposures to vinyl chloride in Paulsboro. Medical management guidelines from ATSDR indicate that such effects are unlikely in persons who have recovered from the effects of acute exposure.

**Conclusion 6.** *While cancer risk estimates for the short-term exposures experienced because of the train derailment are very uncertain, the long-term risk of cancer from the acute-duration exposures to vinyl chloride may have exceeded 1 additional case of cancer in 10,000 persons exposed, based on risk estimates by the National Research Council. This is a low increase in cancer risk in comparison to the background risk of cancer.*

Vinyl chloride is known to be a human carcinogen when there is exposure through inhalation. This determination was based on finding an increased risk of a rare type of liver cancer (angiosarcoma) in occupational settings with chronic or long-term exposure to high levels of the chemical. Risk estimates for acute-duration exposure to vinyl chloride have been made based on findings from these chronic exposures, though there is a lack of consensus on the validity of this approach.

**Conclusion 7.** *There is no specific medical monitoring or testing that is suggested by what is known about the long-term effects of acute-duration exposures. There is no screening method available for early detection of liver cancers.*

Routine blood tests that check for liver function may show signs of many kinds of liver diseases, but such tests would not be specific indicators of damage from vinyl chloride exposure. Although there are screening tests for liver cancer, these are not recommended unless an individual is at high risk due to other medical conditions such as chronic cirrhosis or hepatitis B virus infection.

**Recommendations.** In the absence of specific testing recommendations, NJDOH recommends that Paulsboro residents seek routine, age-appropriate health care. Consideration should be given to convening a group of community members and experts to explore potential long-term public health actions. Some options for such

actions could include community health surveillance, epidemiologic research, establishment of an exposure registry, and communication of health risk information.

## **6. Public Health Action Plan**

The purpose of a Public Health Action Plan is to ensure that this Health Consultation not only identifies public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. Included is a commitment on the part of NJDOH to follow-up on this plan to ensure that it is implemented. The public health actions to be implemented by the NJDOH are as follows:

### ***Public Health Actions Taken***

NJDOH reviewed available information and relevant data to evaluate air concentrations of vinyl chloride and potential health implications of exposure following the train derailment that occurred in Paulsboro, NJ on November 30, 2012.

Federal and state public health agencies conducted health surveys and reviewed medical records to document and assess the health impact on residents and emergency responders. These surveys are documented separately (NIOSH 2013; NJDOH 2014; ATSDR in preparation).

### ***Public Health Actions Planned***

Copies of this Health Consultation will be made available to concerned residents through the borough libraries and the Internet. NJDOH may hold public meetings, if needed, to discuss the findings of this report and address additional community concerns.

NJDOH will consider forming a group of community residents, emergency responders, and medical experts. This group could discuss the need and feasibility of future public health activities, such as conducting community health surveillance or epidemiologic research, establishing an exposure registry, and communicating health risk information.



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## **Report Preparation**

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## **Tables and Figures**





Table 1. Summary of peak readings for volatile organic chemicals (VOCs) using photoionization detectors (PIDs), taken by the Paulsboro Refinery Hazardous Materials Response Team within the first hours after the train derailment and vinyl chloride gas leak on November 30, 2012. Data source: Paulsboro Refining Company 2012.

<b>Instrument</b>	<b>Monitoring Time Range</b>	<b>Peak Value in Interval (parts per million, or ppm)</b>
<b><i>Monitoring at N. Commerce and E. Jefferson Sts.</i></b>		
11075075-001	8:33 a.m. to 8:34 a.m.	631 ppm at 8:33 a.m.
110654S-001	8:33 a.m. to 8:40 a.m.	760 ppm at 8:37 a.m.
110620J-001	8:33 a.m. to 8:40 a.m.	694 ppm at 8:34 a.m.
<b><i>Monitoring at N. Delaware St. and Billings Ave., then at varied locations after about 8:55 a.m.</i></b>		
11075075-001	8:41 a.m. to 9:21 a.m.	108 ppm at 8:48 a.m.
110654S-001	8:41 a.m. to 3:33 p.m.	193 ppm at 8:44 a.m.
110620J-001	8:41 a.m. to 10:16 a.m.	234 ppm at 9:16 a.m.
110648T-001	8:41 a.m. to 10:21 a.m.	111 ppm at 8:48 a.m.
110620H-005	8:41 a.m. to 9:30 a.m.	108 ppm at 8:48 a.m.
110620H-004	8:33 a.m. to 10:53 a.m.	115 ppm at 8:48 a.m.

Note: VOC readings are not specific to vinyl chloride and may reflect the presence of other chemicals from other sources. Estimated maximum concentrations of vinyl chloride would be 1.9 times higher than the VOC readings indicated in the table, based on the PID instrument's chemical-specific response factor for vinyl chloride.

Table 2. Summary of hand-held, real-time air monitoring for volatile organic chemicals (VOC) using photoionization detectors (PID). Data source: CTEH 2012a-g.

Date (2012)	Time Range	Community Outside the Evacuated Area		Evacuated Area	
		# Detections of # Readings	Maximum VOC Concentration (ppm)	# Detections of # Readings	Maximum VOC Concentration (ppm)
Nov. 30	1:39 pm to 11:59 pm	8 of 85	0.5	5 of 25	4.5
Dec. 1	12:00 am to 11:59 pm	2 of 214	0.1	5 of 46	3.0
Dec. 2	12:00 am to 11:59 pm	3 of 274	1.6	9 of 76	6.9
Dec. 3	12:00 am to 11:59 pm	142 of 563	30	71 of 113	20.9
Dec. 4	12:00 am to 11:59 pm	83 of 402	6.8	45 of 188	868 *
Dec. 5	12:00 am to 11:59 pm	2 of 357	0.7	0 of 203	< 0.1
Dec. 6	12:00 am to 11:59 pm	2 of 317	0.1	2 of 192	0.6

\* In CTEH 2012e, a footnote for this result states: "This VOC reading was a peak and not sustained."

Note: VOC readings are not specific to vinyl chloride and may reflect the presence of other chemicals from other sources. Estimated maximum concentrations of vinyl chloride would be 1.9 times higher than the VOC readings indicated in the table, based on the PID instrument's chemical-specific response factor for vinyl chloride.

Table 3. Summary of hand-held, real-time air monitoring for vinyl chloride using colorimetric detection tubes. Data source: CTEH 2012a-g.

Date (2012)	Time Range	Community Outside the Evacuated Area		Evacuated Area	
		# Detections of # Readings	Maximum Vinyl Chloride Concentration (ppm)	# Detections of # Readings	Maximum Vinyl Chloride Concentration (ppm)
Nov. 30	1:39 pm to 11:59 pm	12 of 15	1.2	7 of 8	3.0
Dec. 1	12:00 am to 11:59 pm	1 of 8	0.3	3 of 5	3.0
Dec. 2	12:00 am to 11:59 pm	0 of 12	< 0.02	2 of 4	1.8
Dec. 3	12:00 am to 11:59 pm	54 of 113	5.6	22 of 30	8.6
Dec. 4	12:00 am to 11:59 pm	68 of 82	9.4	29 of 41	8.6
Dec. 5	12:00 am to 11:59 pm	1 of 1	0.3	no readings	no readings
Dec. 6	12:00 am to 11:59 pm	0 of 4	< 0.02	no readings	no readings

Table 4. AreaRAE photoionization detector (PID) results for volatile organic chemicals (VOC), November 30 through December 6, 2012, at the two fixed monitoring locations near Paulsboro residential areas. Data from CTEH 2012a-g.

Date (2012)	Time Range	Unit 1 *		Unit 2 *	
		# Detections of # Readings	Maximum VOC Concentration (ppm)	# Detections of # Readings	Maximum VOC Concentration (ppm)
Nov. 30	4:46 pm to 11:59 pm	821 of 1,045	11.8	0 of 1,118	< 0.1
Dec. 1	12:00 am to 11:59 pm	605 of 1,720	4.2	1 of 1,616	0.1
Dec. 2	12:00 am to 11:59 pm	328 of 4,354	4.7	60 of 3,342	0.4
Dec. 3	12:00 am to 11:59 pm	1,202 of 4,832	147.2	1,483 of 4,817	11.3
Dec. 4	12:00 am to 11:59 pm	2,118 of 4,808	253.5	1,471 of 4,649	11.2
Dec. 5	12:00 am to 11:59 pm	33 of 3,840	3.9	224 of 3,804	0.1
Dec. 6	12:00 am to 11:59 pm	0 of 1,102	< 0.1	75 of 1,086	0.1

\* Unit 1: Stationed to the SSW of the derailment site, at the base of Washington St. near Mantua Creek.  
 Unit 2: Stationed to the WNW of the derailment site on North Commerce St. below 7<sup>th</sup> St.

Note: VOC readings are not specific to vinyl chloride and may reflect the presence of other chemicals from other sources. Estimated maximum concentrations of vinyl chloride would be 1.9 times higher than the VOC readings indicated in the table, based on the PID instrument's chemical-specific response factor for vinyl chloride.

Table 5. U.S. Environmental Protection Agency (EPA) Trace Atmospheric Gas Analyzer (TAGA) mobile laboratory monitoring summary. Vinyl chloride measurements made by gas chromatography. Derived from EPA 2012c.

Date (2012)	Total Hours of Monitoring Time	Vinyl Chloride Concentration (ppm)	
		Time-Weighted Average of Daily Runs	Maximum
Nov. 30	10.1	0.062	1.2
Dec. 1	9.6	0.033	0.19
Dec. 2	13.8	0.028	2.6
Dec. 3	9.2	0.41	41
Dec. 4	4.0	0.19	6.4
Dec. 5	3.9	0.003	0.16
Dec. 6	1.1	0.0008	0.005

Table 6. Vinyl chloride concentrations (ppm) at fixed “analytical stations” which drew air samples daily. Samples were analyzed in a laboratory for vinyl chloride using EPA Method TO-15. Data source: CTEH 2012h.

Date (2012)	Vinyl Chloride Concentration (ppm)				
	Station 1 *	Station 2 *	Station 5 *	Station 6 *	Station 7 *
Nov. 30	0.0078	0.87	< 0.005	0.02	< 0.005
Dec. 1	0.028	0.14	0.022	< 0.01	< 0.005
Dec. 2	0.5	2.3	0.19	< 0.005	0.038
Dec. 3	2.5	35	1.2	0.011	0.15
Dec. 4	0.025	0.029	0.009	0.009	0.014
Dec. 5	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dec. 6	0.0064	0.0081	< 0.005	< 0.005	< 0.005

- \* Station 1: Located to the WNW of the derailment site on North Commerce St. below 7<sup>th</sup> St.
- Station 2: Located to the SSW of the derailment site, at the base of Washington St. near Mantua Creek.
- Station 5: Located to the WNW of the derailment site near North Delaware St. and 7<sup>th</sup> St.
- Station 6: Located to the SSW of the derailment site near Swedesboro Ave. and Baird Ave.
- Station 7: Located to the NNW of the derailment site near Greenwich Ave. and 5<sup>th</sup> St.

# Paulsboro Train Derailment



Figure 1. Location of Conrail train derailment on November 30, 2012 in Paulsboro, New Jersey.



Figure 2. Witness photograph taken at 7:11 am on November 30, 2012.  
(Witness Photograph 2012a)



Figure 3. Witness photograph taken at 7:44 am on November 30, 2012.  
(Witness Photograph 2012b)





Figure 4. Witness photograph taken at 8:00 am on November 30, 2012.  
(Witness Photograph 2012c)



Figure 5. Witness photograph taken at 8:00 am on November 30, 2012.  
(Witness Photograph 2012d)



Figure 6. Witness photograph taken at 8:46 am on November 30, 2012.  
(Witness Photograph 2012e)



Figure 7. Witness photograph taken at 9:17 am on November 30, 2012.  
(Witness Photograph 2012f)