# Research and Discussion on the Handling Methods for Ammonia and Vinyl Chloride Leakage Accidents

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**Abstract.** Vinyl chloride and ammonia, as indispensable basic raw materials in the chemical industry, occupy a significant position in modern industrial production and are widely and extensively utilized in the manufacturing processes of various chemical products. From large-scale chemical synthesis to the production of fine chemical products, they play a pivotal role and are critical factors in driving the development of the chemical industry. However, in the daily operations of factories, the storage and transportation of vinyl chloride and ammonia face many challenges. Due to their special chemical properties and the complex factors that may exist during storage and transportation, such as equipment aging, improper operation, and environmental changes, leakage accidents of vinyl chloride and ammonia occur from time to time [1,2]. Leakage accidents of vinyl chloride and ammonia in chemical plants are extremely dangerous. They can cause fires, explosions, environmental pollution, and harm human health. This paper introduces the correct handling methods for these two gases and the severe consequences of incorrect handling. Vinyl chloride, being toxic and flammable, should be managed through controlled combustion or direct discharge. Ammonia, highly soluble and corrosive, is treated with water absorption or chemical neutralization. Using the wrong method can lead to ineffective pollution control, health risks, explosions, uncontrolled reactions, toxic gas release, and environmental pollution. Proper worker training is crucial to prevent accidents and minimize impacts.

**Keywords:** Vinyl chloride, Ammonia, Environmental pollution.

## 1. Introduction

In the field of industrial safety, the proper handling of hazardous gases is of utmost importance. Vinyl chloride and ammonia gas are two such substances that pose significant risks if not managed correctly. Vinyl chloride, a toxic and flammable gas, is commonly used in the production of polyvinyl chloride (PVC) plastics [3]. Its handling requires meticulous attention due to its potential to cause acute health issues and environmental damage. Similarly, ammonia, a highly soluble and corrosive gas, is widely used in agricultural and industrial processes. Its handling demands careful consideration to prevent accidents and environmental harm on November 28, 2015, a liquid ammonia leak occurred at Longgang Chemical Co., Ltd. in Handan, resulting in 3 deaths, 8 injuries, and direct economic losses of approximately 3.9 million yuan. On August 31, 2013, an ammonia leak at Shanghai Weng Refrigeration Co., Ltd. caused 15 deaths, 7 serious injuries, 18 minor injuries, and direct economic losses of about 25.1 million yuan. In February 2023, a vinyl chloride leak occurred in Ohio, USA, with about 300 tons of vinyl chloride leaked[4].Local emergency departments carried out a "controlled burn" operation, releasing the vinyl chloride from the tank into a pre-dug trench and igniting it in an attempt to prevent the toxic gas from being released into the atmosphere. On the afternoon of July 10, 2007, an ammonia gas leak occurred at a food company in Shandong, causing 25 employees to suffer from varying degrees of frostbite, with 6 employees severely affected. At 02:34 on April 24, 2019, vinyl chloride leaked from a gas holder at Inner Mongolia Yidong Group Dongxing Chemical Co., Ltd. in Xiqiaoying Industrial Park, Zhuozhou County, Wulanchabu, and spread to the electric stone cooling workshop. It ignited upon contact with a fire source, causing 4 deaths, 3 serious injuries, 33 minor injuries, and direct economic losses exceeding 41.54 million yuan [5]. The ammonia leak started at around 4:30 am on January 1 at a warehouse owned by FPL Foods in Augusta, Georgia [6]; At 00:40:55 on November 28, 2018, vinyl chloride leaked from China National Chemical Corporation's Hebei Shenghua Chemical Co., Ltd., located in the Wangshan

Circular Economy Demonstration Park in Zhangjiakou, Hebei. The leaked gas spread outside the factory area and encountered a source of ignition, causing an explosion and fire. The accident resulted in 24 deaths (including 1 person who later died due to ineffective treatment), 21 injuries (with 4 lightly injured individuals discharged after recovery), and the destruction of 38 large trucks and 12 small vehicles. As of December 24, 2018, the direct economic loss amounted to 41.488606 million yuan. [7,8].

These consecutive accidents not only caused severe economic losses but also resulted in a large number of casualties. This paper aims to provide a comprehensive overview of the correct handling methods for vinyl chloride and ammonia gas. It will also explore the severe consequences of incorrectly mixing their treatment approaches. For instance, applying water absorption or chemical neutralization methods, which are effective for ammonia, to vinyl chloride leaks can lead to ineffective pollution control, increased health risks, and potential explosions. Conversely, using controlled combustion or direct discharge methods, suitable for vinyl chloride, on ammonia leaks can result in uncontrolled chemical reactions, the release of toxic gases, and significant environmental pollution.

The importance of proper training for workers cannot be overstated. Ensuring that personnel are well-informed about the correct handling methods for each gas is crucial in preventing accidents and minimizing environmental and health impacts. This paper underscores the need for robust safety protocols and emphasizes the role of education in maintaining a safe working environment.

## 2. Comparison of ammonia and vinyl chloride treatment methods

### 2.1. Overview of gas properties

#### 2.1.1 Vinyl chloride:

Easily liquefied, colorless, and smelling like ether, vinyl chloride (C2H3Cl) has a boiling point of -13.9 °C (at ambient temperature) and a flash point of -78 °C, making it highly flammable. When combined with air, it can create an explosive mixture; its volume ratio explosion limit is 3.6% to 31.0%; and exposure to heat sources and open flames increases the risk of combustion and explosion [9,10]. After leaking, it gathers in low-lying areas and can spread to a substantial distance at a lower spot. It has a density ratio of 2.15:1, making it heavier than air. When exposed to the fire source, it will catch fire and re-ignite. When burned or in the absence of inhibitors, intense polymerization can happen. Vinyl chloride dissolves in most organic solvents, including ethanol, ether, and acetone, but it is insoluble in water. Vinyl chloride may be absorbed through the skin or enter the body through the respiratory system. Anesthesia is a symptom of acute poisoning, while mild poisoning causes drowsiness, dizziness, chest tightness, and a staggering gait; Coma, seizures, circulatory and respiratory collapse, and even death can result from severe poisoning. Vinyl chloride fluid contact might result in necrosis, edema, or erythema. Neurasthenic syndrome, hepatomegaly, hepatic dysfunction, digestive dysfunction, Raynaud's phenomenon, and acral osteolysis are all signs of chronic poisoning. It could be scaly, dry, chapped, eczema, etc. It can result in hepatic angiosarcoma and is a member of a class of carcinogens that the World Health Organization has identified. Avoid coming into contact with or becoming contaminated with vinyl chloride. The remaining basic properties [11]are shown in Table 1.

**Table 1** Vinyl chloride basic properties

| name | Basic properties |
|---|---|
| Appearance | Colorless, ether-like odorous gas |
| Melting point | - 153. 8 ℃ |
| Boiling point | - 13. 9 ℃ |
| Water-soluble | Slightly soluble |
| Explosion limit | Explosion Cap (V/V): 33%<br>Lower explosion limit (V/V): 3.6% |

### 2.1.2 Ammonia:

At room temperature and pressure, ammonia (NH3) is a colorless, odorous, and unpleasant gas that is extremely poisonous and has the potential to ignite and explode in the atmosphere. It is alkaline and corrosive, and under normal circumstances, 700 volumes of water may dissolve 700 volumes of ammonia (saturated concentration of 35.28%). Its relative density is lower than that of air. Ammonia is a common ingredient in fertilizers, explosives, nitric acid, and other nitrogenous products. It is also used as a refrigerant. During manufacturing, storage, and transit, pressured liquefaction of liquid ammonia (20 °C, 891 kPa) is frequently used. Ammonia is one of the most important nitrogen-hydrogen compounds in nature, derived from the decomposition of nitrogen-containing organic matter. It is a colorless gas with an extremely pungent odor that causes tearing and choking. Ammonia gas is lighter than air and easily liquefied. It is highly soluble in water, freezes at –77.7°C, and boils below –33.3°C. Ammonia is highly flammable with an ignition limit of approximately 15.4 - 33.6% by volume in air. It decomposes into hydrogen gas at temperatures above 400°C. Ammonia irritates the respiratory tract, skin, and eyes, and exposure to large amounts of the gas can damage the lungs, leading to death [12,13,14]. Ammonia is a useful chemical raw material that is easy to transport and store. It can be liquefied by cooling or pressurization to form liquid ammonia, also known as anhydrous ammonia, and is typically kept in steel tanks or pressure-resistant cylinders. Chemical fertilizers, medications, and pesticides, as well as sterilizing, cooling, and refrigeration, are among its many applications. Because of its caustic and volatile nature, liquid ammonia has an extremely high accident rate—second only to chlorine leakage—due to the chemical industry's rapid growth and the ongoing expansion of its use in manufacturing, storage, and transportation. The American Conference of Governmental Industrial Hygienists has stated that the permissible time - weighted average and short - term exposure limits for ammonia are 25 ppm and 35 ppm respectively. Additionally, there is no established 50% lethal dose (LD50) for ammonia exposure in humans. The LD50 and 50% lethal concentration (LC50) values, which have been determined for rats, are 350 mg/kg and 2000 ppm (4 hours) [15]. Ammonia gas is both toxic and flammable, and its hazards can be significantly increased in the presence of other flammable substances, such as petroleum-based gases, or oxidizing agents like oxygen, or highly reactive compounds such as chlorine, bromine, and iodine. Even at low concentrations, ammonia gas poses a serious risk. Inhaling it or coming into contact with it on the skin can cause severe burning and may even lead to death [16,17]. The remaining basic properties are shown in Table 2.

**Table 2** Ammonia basic properties

| name | Basic properties |
| --- | --- |
| Appearance | Colorless, with a strong irritating odor. |
| Melting point | -77.75℃ |
| Boiling point | -33.3℃ |
| Water-soluble | Easily soluble in water. |
| Explosion limit | Explosion Cap (V/V): 30.2%<br>Lower explosion limit (V/V): 15% |

## 2.2. Accident handling methods

### 2.2.1 Vinyl chloride

Controlled Combustion Method

The leaked vinyl chloride is directed to a pre-dug trench or a designated combustion area. By controlling the combustion conditions, it is fully combusted in an oxygen-rich environment, transforming into relatively stable substances such as hydrogen chloride, carbon dioxide, and water. This reduces its dispersion and harm in the atmosphere. The controlled combustion method is an effective way to deal with large-scale vinyl chloride leaks. By directing the leaked vinyl chloride to a designated area for combustion, the dispersion of vinyl chloride in the atmosphere can be significantly reduced, lowering its impact on the environment and human health. For example, in the vinyl chloride leak incident in Ohio, USA, the controlled combustion method was used to handle the leaked vinyl chloride [4], effectively controlling the spread of pollutants. This method can transform vinyl chloride into relatively stable substances such as hydrogen chloride, carbon dioxide, and water, reducing the emission of toxic gases.

Although controlled combustion can effectively deal with large-scale vinyl chloride leaks, some harmful by-products may be generated during the combustion process. For example, incomplete combustion can produce carbon monoxide, a toxic gas that is harmful to both human health and the environment. In addition, highly toxic substances such as phosgene and dioxins may be generated. The production of these substances can exacerbate environmental pollution and cause long-term negative impacts on ecosystems and human health.

Direct Discharge Method

In open outdoor spaces, natural conditions such as air movement and sunlight are utilized to naturally dilute and decompose vinyl chloride in the atmosphere. Air movement can disperse vinyl chloride over a wider area, reducing its concentration in localized regions. Sunlight exposure can promote photochemical reactions of vinyl chloride, causing it to decompose into harmless or low-toxicity substances. The direct discharge method is simple and easy to implement, making it suitable for small-scale vinyl chloride leaks. It does not require complex equipment or substantial resource investment, and the cost is relatively low. In well-ventilated areas, it can quickly reduce the concentration of vinyl chloride and minimize its impact on the surrounding environment. For example, in some small-scale leakage incidents, the direct discharge method can rapidly lower the concentration of vinyl chloride to protect the safety of nearby residents and the environment.

Although the direct discharge method is simple to operate, it poses certain safety hazards and environmental issues. First, vinyl chloride is a flammable and explosive gas with an explosive limit of 3.6%–33%. During the discharge process, if it encounters an open flame or high-temperature object, it can easily trigger an explosion, posing a serious threat to personnel and equipment. Second, the decomposition rate of vinyl chloride in the natural environment is relatively slow, and its decomposition products, such as hydrogen chloride, can still cause environmental pollution. Hydrogen chloride, when combined with water vapor in the air, forms acid rain, which can corrode and damage soil, water bodies, and buildings, affecting ecological balance and human production and living.

### 2.2.2 Ammonia:

Dilution Method

The dilution method involves using water sprays or air movement to disperse leaked ammonia gas in the atmosphere, reducing its concentration and thereby minimizing its impact on the environment and human health. Water sprays can absorb some of the ammonia gas, dissolving it in water and thus lowering the concentration of ammonia in the air.

The dilution method is simple and easy to implement, making it suitable for ammonia gas leaks of various scales. By diluting the gas, the concentration of ammonia in the affected area can be quickly reduced, lessening its impact on the surrounding environment and people. For example, in some ammonia gas leakage accidents, firefighters have used water sprays to dilute the affected area, effectively controlling the spread of ammonia gas.

During the dilution process, a large amount of wastewater may be generated, which needs to be properly treated to avoid polluting water bodies. Additionally, the effectiveness of dilution is highly dependent on meteorological conditions. For instance, under calm wind or temperature inversion conditions, the dilution effect may not be ideal.

Adsorption Method

Adsorption materials such as activated carbon and sand can be used to adsorb leaked ammonia gas, reducing its dispersion in the air. These materials can physically adsorb ammonia molecules, fixing them on the surface of the adsorbent and thereby lowering the concentration of ammonia in the air.

The adsorption method can effectively reduce the amount of ammonia leakage and minimize its environmental pollution. Adsorbents can also be reused, which makes this method economically viable. For example, in some small-scale ammonia leakage incidents, using sand and other adsorbents can quickly control the leakage and reduce its impact on the surrounding environment.

The selection and use of adsorbents need to consider their adsorption capacity and rate. If the adsorbent is insufficient or its adsorption effect is poor, it may not effectively control the leakage. In addition, the adsorbed materials need to be properly disposed of to avoid secondary pollution.

Chemical Neutralization Method

Chemical neutralization involves spraying acidic solutions (such as dilute hydrochloric acid or dilute sulfuric acid) into the leaked ammonia gas to cause a neutralization reaction. This reaction produces harmless or low-toxicity salts and water. For example, ammonia reacts with hydrochloric acid to form ammonium chloride and with sulfuric acid to form ammonium sulfate. This method can quickly and effectively remove leaked ammonia gas, reducing its impact on the environment and human health. The salts and water produced in the neutralization reaction are relatively stable and do not cause secondary pollution to the environment. Moreover, this method is suitable for large-scale ammonia gas leakage accidents, as it can rapidly control the source of the leak and prevent further dispersion of ammonia gas. The chemical neutralization method requires precise control of the amount and application range of the acidic solution to avoid new environmental pollution caused by excess acid. Additionally, the neutralization reaction may generate a large amount of heat, and it is necessary to be cautious of other safety issues that may arise due to heat accumulation.

## 2.3. The Hazards of Combining Methods

### 2.3.1 Vinyl chloride treated with ammonia gas methods

Common methods for treating ammonia gas are water absorption and chemical neutralization. However, applying these methods to vinyl chloride leaks can have very serious consequences.

Water Absorption Method: Ammonia gas is highly soluble in water and can be effectively absorbed by spraying water, reducing its concentration in the air. However, vinyl chloride is only slightly soluble in water, and spraying water will not effectively absorb the leaked vinyl chloride gas. The leaked vinyl chloride will still remain in the air in large quantities, failing to achieve the goal of controlling pollution and reducing harm. Moreover, if vinyl chloride accumulates to a certain concentration in a confined or poorly ventilated environment, it can easily ignite or explode upon contact with a flame or high temperature, causing casualties and property damage.

Chemical Neutralization Method: Using acidic substances to neutralize ammonia gas is an effective method for treating ammonia leaks. However, vinyl chloride is an unsaturated hydrocarbon, and its reaction with acidic substances requires specific conditions and catalysts. Without these conditions, forcibly using acidic substances to react with vinyl chloride will not only fail to effectively remove vinyl chloride but may also produce new toxic and harmful substances, further exacerbating environmental pollution and health risks.

### 2.3.2 Ammonia treated with vinyl chloride methods

Common methods for treating vinyl chloride are controlled combustion and direct discharge. Applying these methods to ammonia leaks can also have very serious consequences.

Controlled combustion method: Vinyl chloride can be completely burned under controlled conditions using the controlled combustion method, reducing its dispersion and explosion risk. However, ammonia gas is highly flammable and explosive, and using the controlled combustion method to treat ammonia leaks requires precise control of combustion conditions. Otherwise, it can easily cause a violent explosion. In addition, the combustion of ammonia gas produces toxic and harmful gases such as nitrogen oxides, which can cause serious harm to the environment and human health. For example, nitrogen oxides are important precursors in the formation of acid rain and photochemical smog, causing long-term pollution to the atmospheric environment.

Direct discharge method: In open outdoor spaces, direct discharge of vinyl chloride can utilize air movement and sunlight to naturally dilute and decompose it. However, ammonia gas has strong irritant and corrosive properties. Direct discharge will cause ammonia gas to rapidly disperse in the atmosphere, causing serious impacts on the surrounding environment and people. High concentrations of ammonia gas can not only irritate the respiratory tract and eyes but may also cause coughing, asthma, and other respiratory diseases, and even lead to suffocation and death. Moreover, when ammonia gas enters water bodies, it can react with nitrites in the water to form toxic nitrogen oxides, which are fatal to aquatic life.

## 3. Conclusion

Mixing the treatment methods for vinyl chloride and ammonia gas leaks can lead to a variety of serious consequences, including increased chemical reaction risks, higher explosion risks, exacerbated environmental pollution, and greater difficulty in emergency response. In actual handling processes, it is essential to strictly distinguish between the two types of leaks and apply targeted treatment methods to avoid mixing, in order to minimize the harm and losses caused by accidents. Therefore, factories must strengthen the training of workers to ensure they understand the correct treatment methods and emergency measures. The training content should include:

Safety Operating Procedures: Workers should be familiar with the physical and chemical properties of vinyl chloride and ammonia gas, and understand the correct methods for handling leaks. For example, in the case of a vinyl chloride leak, personnel in the contaminated area should be quickly evacuated to the upwind direction, and the area should be isolated with strict restrictions on entry and exit. In the case of an ammonia gas leak, on-site personnel should be quickly evacuated to avoid inhaling vapors. At the same time, more advanced gas leak detection methods, such as Gaussian leak location methods for ammonia, should be used.

Emergency Response Skills: Workers should master basic emergency response skills, such as the correct use of protective equipment, blocking the source of the leak, and cleaning up the leaked material. For example, during an ammonia gas leak, response personnel should wear respirators and use inert materials to absorb the leaked substance.

Factories should develop comprehensive emergency response plans, clarifying the procedures for handling leaks and the persons responsible. For example, in the case of a vinyl chloride leak, the emergency response plan should be immediately activated, and emergency rescue teams and environmental protection departments should be notified. In the case of an ammonia gas leak, the source of the accident should be quickly controlled, and the nature and hazard area of the dangerous chemicals should be determined. In addition, factories should regularly organize emergency drills to improve workers' emergency response capabilities and teamwork.

## References

[1] Jafari, M.J.; Bahmani, R.; Poyakian, M.; Behzadi, Y.K.; Khodakrim, S. Modeling the consequence of vinyl chloride accidental release from tanks in a petrochemical plant. Occup. Hyg. Health Promot. 2021, 4, 301–314.

[2] Suciu, I.; Prodan, L.; Ilea, E.; Păduraru, A.; Pascu, L. Clinical manifestations in vinyl chloride poisoning. Ann. N. Y. Acad. Sci. 2010, 246, 53–69.

[3] U.S. Pats. 2,188,396 (Jan. 30, 1940) and 1,929,453 (Oct. 10, 1933), W. L. Semon (to the B. F. Goodrich Co.).

[4] Chen Jiantuo. (2024). Research and Discussion on the Treatment Methods of the Vinyl Chloride Leakage Accident in the United States. Sichuan Chemical Engineering, 27(3), 57-60.

[5] The "April 24" Major Production Safety Accident in Inner Mongolia [J]. China Work Safety,2020, 15(06):50-51.

[6] "Ammonia leak prompts warnings to local residents." 2005. *World Pumps*. ISSN 1350-4789. February 2005.

[7] Investigation Report on the "November 28" Major Explosion and Fire Accident at Shenghua Chemical Company, China National Chemical Corporation, Zhangjiakou, Hebei [Z].

[8] Analysis and Research on the Rescue of Vinyl Chloride Leakage and Explosion Accident [A].

[9] Zhao, E.K.; Ji, D.F. Petrochemical equipment maintenance process safety management. Chem. Eng. Des. Commun. 2018, 133.

[10] Chen, W.; Zhang, X.; Management, D.O. Excavation of key risk factors based on apriori algorithm for fire and explosion in storage and transportation of hazardous chemicals. Fire Saf. Sci. 2017, 26, 133–139.

[11] Wang Junjun, Ruan Zhen, Yang Guoqiang, et al. Analysis and Research on the Rescue of Vinyl Chloride Leakage and Explosion Accidents [J]. Today's Fire Control, 2021, 6(10): 1-4.

[12] Whitburn S, Van Damme M, Kaiser JW, et al Ammonia emissions in tropical biomass burning regions: Comparison between satellite-derived emissions and bottom-up fire inventories Atmos Environ. 2015;121:42–54

[13] Zhou W, Zhu B, Li Q, Ma T, Hu S, Griffy-Brown C. CO2 emissions and mitigation potential in China’s ammonia industry Energy Policy. 2010;38:3701–3709

[14] Jafari MJ, Matin AH, Rahmati A, et al Experimental optimization of a spray tower for ammonia removal Atmos Pollut Res. 2018;9:783–790

[15] ACGIH, TLVs and BEIs based on the documentation of the threshold limit values for chemical substances and physical agents & biological exposure indices ACGIH. 2019

[16] Duijm NJ, Markert F, Paulsen JL Safety assessment of ammonia as a transport fuel. 2005 Roskilde, Denmark Risø National Laboratory

[17] Anjana NS, Amarnath A, Harindranathan Nair MV. Toxic hazards of ammonia release and population vulnerability assessment using geographical information system J Environ Manage. 2018;210:201–209