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MANAGING HAZARDOUS MATERIAL INCIDENTS: INSIGHTS FROM THE AMMONIA SPILL

POSTUPANJE U INCIDENTIMA SA IZLIVANJEM OPASNIH MATERIJA PRIKAZ SITUACIJE IZLIVANJA AMONIJAKA IZ CISTERNE

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Summary: In December 2022, a significant train derailment incident occurred near Pirot, Serbia, involving a 20-car freight train en route from Bulgaria, which resulted in a substantial ammonia release. This event resulted in over 50 cases of ammonia poisoning, with seven individuals needing hospital care and two fatalities. Furthermore, the released ammonia formed a dense ammonia vapor cloud upon interaction with environmental water, triggering a collision on a nearby highway. Follow-up environmental assessments revealed no residual ammonia in the air or in nearby water sources. This case exemplifies the potential risk of transporting hazardous materials and underscores the importance of adequate management and response mechanisms in such incidents, as detailed in the case analysis and management proposal based on current recommendations and guidelines

Key words: ammonia, accident, intoxication, emergency medicine

INTRODUCTION

Annually, over 1.5 million tons of ammonia are transported by rail across Europe, including approximately 250,000 tons within Southeast Europe alone. Despite improvements, the rail transport infrastructure in this region remains varied and continues to pose significant risks for accidents [1].

On December 25, 2022, a significant incident occurred near Pirot, Serbia, when a 20-car freight train traveling from Bulgaria derailed, resulting in a major ammonia release. Out of the 800 tons of ammonia being transported, only 20 tons were released due to damage to one cistern, narrowly avoiding a more extensive ecological and humanitarian disaster [2]. Pirot is a city in southeastern Serbia, located in the Nišava valley, with an urban population of around 35,000. The Nišava River, which flows through this region, serves as a crucial water source for more than 350,000 people in South and Southeast Serbia. Parallel to the river run an international highway and a railway line, both critical for transportation and commerce [3].

The proximity of these infrastructures poses a significant risk in the event of a train derailment incidents, which could lead to severe contamination of the river and endanger the lives and health of the local population.

AIMS

This aims to delve into the nuances of ammonia poisoning, focusing on the protocols and management strategies critical for addressing such incidents effectively. By examining this incident, this work seeks to underscore the importance of proper emergency preparedness and response mechanisms. To introduce the fundamental chemical properties of ammonia, the potential risks associated with its exposure, and the urgent need for accurate, swift responses during such emergencies. Through this exploration, the paper endeavors to contribute valuable insights into optimizing management strategies for hazardous material incidents, particularly those involving ammonia.

MATERIAL AND METHODS

Case Analysis

This study investigates the incident of the train derailment near Pirot, Serbia, which resulted in a significant ammonia release. The methodology encompasses the following key components:

Incident Documentation and Data Collection:

- **Primary Data:** Data was collected from incident reports, emergency response logs, and hospital records to understand the extent of ammonia exposure and the immediate health effects on the affected population.
- **Secondary Data:** Secondary data sources include publications from the Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH), and the Agency for Toxic Substances and Disease Registry (ATSDR). These sources provide context on ammonia toxicity and emergency response protocols.

DISCUSSION:

On December 25, 2022, at approximately 17:30 CET, a freight train carrying ammonia derailed near Staničenje, close to Pirot, Serbia. The derailment caused four wagons to overturn, releasing around 20 tons of ammonia. The release of pressurized ammonia reacted with air and water, forming a dense vapor cloud. This reaction severely reduced visibility on the nearby highway to less than 10 meters, leading to multiple vehicle collisions.

Emergency Response

Local units from Pirot and Bela Palanka were the first to arrive at the scene. Niš units were dispatched promptly once the scale of the incident was understood. The Pirot Fire Brigade and EMS arrived within 20 minutes of the derailment report, while units from Bela Palanka and Niš arrived within 40-60 minutes due to distance and road conditions. A 72-hour state of emergency was declared, prompting immediate advisories for residents to stay indoors and secure their homes against ammonia exposure. The A4 highway section

between Pirot and Bela Palanka was closed until December 28 due to potential contamination.

Evacuation and Public Safety Measures

Immediate evacuations were carried out, removing 56 individuals from the affected area. Air quality monitoring was initiated with two mobile stations deployed in Pirot on December 26. Elevated ammonia levels were detected initially but decreased over time. Although the levels remained below critical limits, strong ammonia odors persisted throughout the city. Water contamination was monitored in the Nišava River. Initial water samples collected on December 26 showed serious pollution, with ammonia concentrations reaching the category V (1.95 mg/l) by December 27 near Prosek village. Residents were advised to avoid using well water for drinking and irrigation. By December 28, ammonia levels had dropped, allowing partial lifting of water restrictions.

Medical Response

Over 50 individuals presented with symptoms related to ammonia exposure. At Niš Clinical Center (UKC Niš), 15 patients were admitted; 11 were discharged after treatment, and 4 remained under observation. Pirot General Hospital (OB Pirot) treated 51 individuals, all of whom were discharged after treatment. Most patients experienced respiratory issues, eye irritation, and skin burns. Four patients at Niš had severe symptoms requiring prolonged observation. Tragically, two fatalities occurred due to high ammonia inhalation among individuals trapped in the vapor cloud on the highway, confirmed by autopsies as severe respiratory damage.

Environmental and Public Health Impact

The ammonia spill contaminated local water sources, including the Nišava River. Elevated concentrations of ammonia caused strong odors throughout the city, leading to health advisories for residents to stay indoors. Schools and kindergartens were closed to protect children from exposure.

Economic Impact

The state of emergency and necessary evacuations caused significant disruptions to local businesses and key transport routes, impacting logistics and supply chains. Substantial resources were required for emergency response, cleanup operations, and environmental remediation. The incident highlighted the need for better infrastructure maintenance and safety protocols for handling hazardous materials.

Initial response - positive aspects

1. Quick Response of Emergency Services: Firefighters, police, and medical teams were immediately dispatched to the scene in order to assess and control the situation. Firefighters, EMS and police from Pirot and Nis were dispatched to the site.
2. Evacuation of Residents: Emergency services successfully evacuated residents from the immediate vicinity of the accident, reducing the number of potentially affected people.

Initial response - negative aspects

1. Poor Coordination and Communication: There was a lack of effective communication and coordination between different emergency response units, leading to delays in response and ineffective crisis management.
2. Lack of Adequate Training and Protective Equipment: Some responders like EMS did not have adequate protective equipment for working with hazardous materials, which compromised their safety and the efficiency of the intervention. It is even noted that two firefighters needed medical help.
3. Insufficient Hazardous Material Training: The most of the responding teams were not adequately trained in handling hazardous material incidents of this magnitude. There was a noticeable uncertainty in executing the containment and decontamination procedures, which are critical in ammonia exposure scenarios.
4. Absence of a Unified Emergency Number: The lack of a unified emergency number (such as 112) hindered the quick and coordinated action of all relevant services in the emergency situation.

5. In the Ministry of Internal Affairs' Disaster Risk Assessment, it is stated that analyses and detailed investigations of chemical accidents have shown that the population and state authorities are partially prepared for such incidents.

What is ammonia?

Ammonia (NH₃) is a simple, stable compound of nitrogen and hydrogen. It is produced via the Haber-Bosch process, which combines these two elements, under high pressure and temperature.

As a colorless gas, it is notable for its strong, pungent odor and is lighter than air, dissolving easily in water. Primarily, ammonia is crucial in the production of fertilizers, which consume about 80% of its output. It also serves as a precursor for various commercially important nitrogen compounds, including explosives, synthetic fibers, and plastics. Beyond its industrial applications, ammonia acts as a refrigerant in cooling systems and plays a significant role in water purification and as a corrosion inhibitor. It is also a key component in many household cleaning products and is used across diverse industries, from pharmaceuticals to food and beverage [4].

Chemical Behavior of Ammonia in Environmental Incidents

When ammonia is pressurized and released into the atmosphere, it rapidly expands and cools, transforming into a dense, white cloud of fine liquid ammonia droplets. This visible manifestation occurs due to the high concentration of droplets.

Upon contact with water, ammonia undergoes an exothermic reaction, forming ammonium (NH₄⁺) and hydroxide (OH⁻) ions, commonly known as ammonium hydroxide (NH₄OH). This heat-releasing reaction can cause the water to evaporate, contributing to the development of a vapor cloud. Additionally, when ammonia gas interacts with air, it reacts to form nitrogen monoxide and water vapor. The water vapor may condense around air particles, further leading to cloud formation.

The generation of a dense vapor cloud is a critical concern, as it can disperse ammonia

across a broader area, significantly increasing the risk of exposure. Understanding these reactions is crucial for emergency response and mitigation strategies in ammonia release incidents [5].

Global Ammonia Demand and Production Forecast

Currently, global production of ammonia stands at approximately 180 million metric tons annually, primarily driven by its critical role in the fertilizer industry. This demand is projected to rise by 10 million metric tons each year, fueled by its expanding use in the hydrogen economy alongside traditional applications. By 2050, it is expected that the global production rate of ammonia will escalate to about 500 million metric tons—nearly tripling today's figures. This significant increase underscores the challenges ahead, emphasizing the urgent need for continued research and the implementation of lessons learned from past incidents to enhance safety measures and prevent future accidents [6].

Most Common Sources of Ammonia Exposure to Large Quantities and High Concentrations Transportation Incidents:

Transportation and storage of ammonia are the most common sources for exposure to large quantities and high concentrations. These activities pose significant risks due to potential spills or leaks during handling, transit, and storage. Emergency responders often face these dangers during incidents involving the transportation of ammonia.

Industrial Settings:

Industrial facilities involved in chemical manufacturing, refrigeration, and fertilizer production also present substantial risks. Workers may encounter high concentrations of ammonia during accidental releases or through maintenance activities where ammonia is prevalent. (A notable example is the largest ammonia-related incident in Dakar, Senegal, in 1992, the worst ammonia industrial catastrophe ever. High pressure inside the tank led to releasing 22 metric tons of pressurized ammonia. This incident claimed 129 lives and

injured over 1000 workers and citizens. For comparison, that is equivalent of only one cistern involved in Pirot accident [7].

Routes of Ammonia Exposure and Associated Health Risks: [8-10]

Ammonia exposure can occur through various routes, each presenting unique health implications:

Inhalation: The primary exposure route for the general population. Inhalation of ammonia can cause severe respiratory effects including nasopharyngeal and tracheal burns, bronchiolar and alveolar edema, and potential airway destruction. This may lead to respiratory distress or failure, with symptoms such as a burning sensation in the throat, coughing, difficulty breathing, chest tightness, altered mental state, a runny nose, and eye irritation. The severity of these effects varies with the ammonia concentration, exposure duration, and depth of inhalation.

Oral Exposure: Though less common, ingestion typically occurs through contaminated drinking water. Ammonia ingestion generally results in rapid conversion to urea, minimizing harm, but high levels can irritate the mouth, throat, and stomach, causing pain, excessive salivation, and potentially severe alkali burns to the aerodigestive tract.

Dermal Exposure: Contact with ammonia through skin exposure to cleaning products can vary in severity. Depending on the ammonia concentration, it can cause skin irritation, redness, swelling, or more severe reactions such as burns, blisters, or dry, flaking skin that may crack.

Ocular Exposure: Direct contact with ammonia can irritate or burn the eyes. Severe exposures may lead to temporary or permanent vision loss, underscoring the need for protective eyewear when handling ammonia.

SIGNS AND SYMPTOMS OF ACUTE AMMONIA EXPOSURE:

Acute exposure to ammonia can lead to a range of immediate and severe symptoms affecting various body systems:

Rapid Onset of Burning Sensation: A primary indicator of ammonia exposure is an intense burning sensation affecting the eyes, nose, throat, and respiratory tract. This irritation can cause significant discomfort and distress.

Lacrimation (Excessive Tearing): Ammonia vapor stimulates the lacrimal glands, resulting in excessive tearing. High exposure levels can lead to profuse tearing, blurred vision, and increased eye irritation, intensifying ocular discomfort.

Upper Airway Swelling: Inhalation can irritate and inflame the upper airway mucosa, causing swelling in the throat, larynx, and pharynx. Symptoms may include difficulty swallowing, hoarseness, and stridor. The presence of throat tightness or constriction signals a significant airway compromise that requires immediate medical attention.

Respiratory Symptoms: Beyond affecting the upper airway, ammonia can provoke other respiratory symptoms such as coughing, wheezing, and shortness of breath. These symptoms can escalate quickly, especially in individuals with existing respiratory issues or impaired lung function. Severe cases may require supplemental oxygen and mechanical ventilation to ensure adequate breathing.

Olfactory Disturbances: Even at low concentrations, ammonia's pungent odor can disrupt normal olfactory function, leading to a temporary loss of smell or altered odor perception, adding to the discomfort of exposure.

Nausea and Vomiting: Exposure can also activate the chemoreceptor trigger zone in the brain, causing nausea and vomiting. This can exacerbate issues like dehydration and electrolyte imbalances, particularly when combined with excessive tearing and respiratory difficulties.

Altered Mental Status: In severe exposure scenarios, systemic absorption of ammonia may result in neurological symptoms, including confusion, agitation, and seizures. These symptoms develop quickly and are indicative of significant toxicity, necessitating urgent medical evaluation and intervention.

Exposure (ppm)	Signs and Symptoms
50	Irritation to eyes, nose and throat (2 hours' exposure)
100	Rapid eye and respiratory tract irritation
250	Tolerable by most people (30–60 minutes' exposure)
700	Immediately irritating to eyes and throat
>1,500	Pulmonary oedema, coughing, laryngospasm
2,500–4,500	Fatal (30 minutes' exposure)
5,000–10,000	Rapidly fatal due to airway obstruction

Table 1: Summary of toxic effects following acute exposure to ammonia by inhalation (Public Health England. (2015). Ammonia: Toxicological overview. Public Health England. https://assets.publishing.service.gov.uk/media/5a81a887e5274a2e8ab552a6/Ammonia_TO_PHE_240815.pdf)

KINETICS AND METABOLISM OF AMMONIA [8,9,11,12]

Absorption and Distribution: Ammonia is highly soluble in water and rapidly dissolves in the mucus of the respiratory system, forming ammonium hydroxide. Upon short-term inhalation, a significant amount of ammonia is retained in the upper nasal mucosa. At higher concentrations, it can overwhelm the mucosal barrier and enter systemic circulation through the lungs. Although ammonia quickly contacts the eyes, systemic absorption from ocular exposure is minimal. Similarly, acute skin exposure typically results in limited systemic absorption, whereas absorption through mucous membranes and the gastrointestinal tract is more substantial. Once in the system, ammonia reacts with hydrogen ions to form ammonium ions, which are largely confined within body compartments due to their charged nature.

Toxicokinetic: Ammonia's pungent odor is detectable at concentrations as low as 5 ppm, making unaware exposure rare. Tolerable ambient levels can reach up to 100 ppm without adverse effects, but exposure to 1700 ppm can cause symptoms like coughing, laryngospasm, and glottic edema. Fatalities have occurred at concentrations between 2500 and 4500 ppm within 30 minutes, and exposures above 5000 ppm often result in rapid respiratory failure.

NIOSH stipulates a maximum time-weighted average (TWA) exposure limit of 25 ppm during an 8-hour workday, with a short-term exposure limit (STEL) of 35 ppm. The immediate danger to life and health (IDLH) threshold is set at 300 ppm.

Metabolic Pathways: Inhalation exposures under 120 seconds cause minimal systemic absorption, whereas prolonged exposure enhances systemic uptake. About 70% to 80% of the inhaled ammonia is absorbed by the upper respiratory tract mucus and later exhaled. Oral ingestion leads to rapid absorption and significant hepatic processing; in rodents, most ingested ammonia is converted to glutamate and urea within half an hour. Nearly all orally administered ammonia is metabolized in the liver to urea, which is then excreted in the urine. About 25% is eliminated within six hours, and 72% within three days. Oral ingestion typically does not lead to systemic toxicity due to the insufficient elevation of blood ammonia levels. Currently, there is no evidence to suggest that dermal exposure to ammonia results in systemic absorption.

MECHANISM OF AMMONIA TOXICITY [8,9,12]

The toxic effects of ammonia are primarily attributed to its ability to disrupt cellular homeostasis and induce oxidative stress. Upon

exposure, ammonia diffuses rapidly across biological membranes, including the respiratory epithelium, gaining entry into the systemic circulation where it causes several harmful effects:

Respiratory Irritation: Ammonia vapor irritates the respiratory mucosa, leading to symptoms such as coughing, dyspnea (shortness of breath), and bronchospasm. High concentrations can cause chemical burns to both upper and lower airways, significantly worsening respiratory conditions.

Disruption of Acid-Base Balance: Ammonia reacts with water to produce ammonium hydroxide, a strong base, which can lead to systemic alkalosis. This condition results from the accumulation of ammonium ions in the bloodstream, disrupting the body's normal acid-base balance and affecting essential physiological functions.

Neurological Effects: Ammonia can cross the blood-brain barrier and accumulate in the central nervous system, where it disrupts normal neurotransmission. This interference is particularly detrimental to the glutamatergic system, leading to neurotoxic effects such as confusion, lethargy, seizures, and in severe cases, coma. These symptoms are typical of hepatic encephalopathy, which can develop with high levels of ammonia.

Hepatotoxicity: Within the liver, ammonia is processed through the urea cycle. Excessive levels of ammonia can overwhelm this pathway, leading to hepatic dysfunction and reduced efficiency in ammonia clearance. This can cause hepatocellular injury and hepatic encephalopathy, compounding the systemic toxicity.

GUIDELINES AND RECOMMENDATIONS FOR MANAGING AMMONIA DISASTERS [9-11]

Initial Response: The initial response to an ammonia disaster involves a critical and immediate assessment of the scene by first responders. Key actions include identifying the source and extent of the ammonia release. To protect against the corrosive and caustic nature of ammonia, which can cause severe irritation

and chemical burns to the eyes, skin, respiratory tract, and alimentary canal, responders must wear appropriate personal protective equipment (PPE). Essential PPE includes:

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is essential when dealing with potentially unsafe levels of ammonia to prevent inhalation of harmful gases.

Chemical-Resistant Clothing and Eye Protection: To safeguard the skin and eyes from ammonia burns and irritation, the use of chemical-protective clothing and eye protection is mandatory.

The effective use of PPE, coupled with ensuring adequate ventilation, forms the cornerstone of safety measures in ammonia disaster scenarios. Immediate decontamination procedures are crucial to minimize the risk of ammonia exposure. Emergency medical responses should prioritize rapid decontamination and provide symptomatic treatment to address both immediate and potential long-term health effects of ammonia exposure. These steps are vital for mitigating the impact on affected individuals and ensuring the safety of emergency response personnel.

Creation of Zones: To manage the disaster effectively, the area should be divided into three primary zones: Hot Zone, Decontamination Zone, and Support Zone.

Hot Zone (Exclusion Zone): The Hot Zone is the area immediately surrounding the ammonia release, where the concentration of ammonia poses direct and significant health risks. Only personnel with appropriate PPE and specific training should enter this zone. Their main tasks include stopping the source of the leak (if possible) and beginning the evacuation of any victims.

In the Hot Zone, where the concentration of hazardous substances like ammonia is the highest and the risk of exposure is greatest, the PPE requirements are much more stringent to ensure maximum protection for the responders. Here's a detailed overview of the appropriate PPE for personnel operating in the Hot Zone during an ammonia disaster:

PPE for the Hot Zone

1. Full Body Protection:

- **Encapsulating Chemical Protective Suit (Level A protection):** This suit provides the highest level of protection against vapors, gases, mists, and particles. It is completely sealed, encapsulating the wearer to prevent any contact with ammonia.

- **Chemical-Resistant Material:** The suit should be made of materials that resist the corrosive nature of ammonia, such as Teflon, Viton, or other specialized laminates.

2. Respiratory Protection:

- **Self-Contained Breathing Apparatus (SCBA):** This is essential in the Hot Zone as it provides the most reliable protection. SCBA units supply clean air from a compressed air tank, allowing responders to breathe safely in highly contaminated environments where ammonia levels may exceed the IDLH level of 300 ppm.

3. Gloves and Boots:

- **Double-Gloving:** Wearing two layers of gloves, usually with a highly chemical-resistant outer glove over a more dexterous inner glove, can provide both protection and dexterity.

- **Chemical-Resistant Boots:** These should be sturdy, providing not only chemical resistance but also adequate grip and comfort for potentially prolonged operations.

4. Eye and Face Protection:

- **Full Facepiece:** SCBA typically includes a full facepiece which provides eye and face protection from chemical splashes and harmful vapors.

- **Face Shield:** An additional face shield can be worn over the SCBA mask for extra protection against unexpected splashes.

ABC REMINDERS FOR INITIAL RESPONSE

1. **Airway:** Quickly assess and ensure that the patient has a patent airway. If trauma is suspected, take precautions to maintain cervical immobilization manually. Apply a cervical collar and use a backboard when feasible to prevent potential spinal injuries.

2. **Breathing:** Confirm that the patient has adequate respiration. Monitor breathing patterns and be prepared to assist ventilations if necessary.

3. **Circulation:** Check for a pulse and signs of effective circulation. Address any conditions like bleeding or shock that could compromise circulation.

Victim Removal Protocols

Ambulatory Victims: If victims are capable of walking, guide them immediately out of the Hot Zone to the Decontamination Zone. It's crucial to minimize their exposure time and begin decontamination procedures quickly.

Non-Ambulatory Victims: Victims unable to walk should be carefully removed using backboards or gurneys to ensure their stability and safety. If these are not available, it may be necessary to carry or drag them to a safer area. When moving victims, always prioritize spinal integrity, especially if trauma is suspected.

Medical practitioners usually do not enter the Hot Zone but must be prepared to provide remote guidance on first aid and emergency care to responders in this area via communication devices. They advise on the handling and triage of severely affected victims until they can be moved to a safer area for treatment.

Decontamination Zone (Warm Zone):

Positioned outside the Hot Zone, the Decontamination Zone is where individuals exposed to ammonia undergo decontamination to prevent further contamination and health issues. Decontamination procedures depend on the type of exposure but typically involve removing contaminated clothing and flushing exposed skin and eyes with copious amounts of water. This zone serves as a buffer to prevent any spread of contamination to cleaner areas. Decontamination procedures typically involve removing contaminated clothing and flushing the skin and eyes with water. Emergency medical treatment can also begin here for those showing symptoms of exposure. After decontamination, individuals move to the Support Zone for further care and evaluation.

Here, medical practitioners supervise the decontamination process. They provide specific instructions on decontamination procedures, ensuring that it is done thoroughly to prevent chemical burns and inhalation effects from

worsening. They also assess and prioritize victims for medical treatment based on the severity of their symptoms.

Decontamination Zone is where direct contact with ammonia-contaminated victims or materials is likely. The PPE requirements here are more stringent than in the Support Zone but may be less than those required in the Hot Zone if the ammonia concentration is confirmed to be low:

1. Protective Suits: Chemical-resistant suits (such as Level B or C protective clothing) should be worn to prevent any contact with ammonia liquid or contaminated water.

2. Gloves and Boots: Chemical-resistant gloves and boots are essential to protect skin from chemical burns and exposure.

3. Respiratory Protection: At a minimum, a full-face air-purifying respirator with cartridges suitable for ammonia should be used. If the concentration of ammonia is unknown or if it is above the IDLH (Immediately Dangerous to Life or Health) level of 300 ppm, a more protective approach using a self-contained breathing apparatus (SCBA) is warranted.

4. Eye Protection: If not already integrated into the respiratory protection, tight-fitting chemical goggles should be worn to protect against splashes and vapors.

Exposure assessment and immediate actions:

- Victims exposed solely to ammonia gas without any signs of skin or eye irritation do not require decontamination and can be directly moved to the Support Zone.
- Those with any contamination or symptoms must undergo decontamination. If ammonia levels are under 20 ppm, decontamination can be performed by personnel in less protective gear than required in the Hot Zone.

ABC REMINDERS FOR EMERGENCY CARE:

- **Airway:** Quickly assess and secure a patent airway. Use a cervical collar and backboard if trauma is suspected.
- **Breathing:** Ensure adequate respiration and administer supplemental oxygen if needed.

Assist ventilation with a bag-valve-mask device as required.

- **Circulation:** Check pulse and address any circulation issues promptly.

Basic Decontamination Procedures:

- **Skin and Eye Decontamination:** Urgently remove contaminated clothing and flush exposed skin and eyes. Victims capable of assisting should do so under guidance.

- **Clothing:** Double-bag contaminated clothing and personal items to prevent secondary exposure.

- **Skin Washing:** Flush any liquid-exposed skin and hair with water for at least 5 minutes. If possible, wash thoroughly with soap and water, being mindful to prevent hypothermia, particularly in vulnerable populations like children or the elderly. Provide blankets for warmth if necessary.

- **Eye Irrigation:** Irrigate exposed or irritated eyes with water or saline for at least 15 minutes. Remove contact lenses if it can be done without causing additional trauma. Continue irrigation during transport to the Support Zone.

- **Ingestion:** Do not induce vomiting or perform gastric lavage. Do not administer activated charcoal. If the victim is conscious and able to swallow, provide 4 to 8 ounces of water or milk to dilute the ingested substance.

Transport to Support Zone:

- Once basic decontamination is complete, promptly transfer victims to the Support Zone for further medical evaluation and care.

Support Zone (Cold Zone):

The Support Zone is a safe area where operational support takes place. This zone hosts incident command, medical triage and treatment, and support services. It should be upwind and uphill from the disaster site to avoid contamination. All strategic decision-making, support, and media communication occur here to manage the incident effectively without compromising the safety of additional personnel.

This area serves as the primary base for medical triage, treatment, and coordination. Emergency medical practitioners set up triage stations to categorize victims based on the urgency of their medical needs. They manage resources such as

medical supplies, personnel, and patient transport vehicles. They also ensure that medical teams are well-equipped with appropriate PPE and are trained to handle the unique challenges of chemical exposure.

The Support Zone is generally considered a safe area where the risk of ammonia exposure is minimal. The PPE requirements here are primarily for precautionary measures and comfort:

1. Standard Precautions: Depending on proximity to the Decontamination and Hot Zones, basic PPE such as gloves and surgical masks might be advisable.

2. Protective Clothing: While full chemical suits are not necessary, wearing coveralls or other disposable garments can help prevent accidental contact with residues that might have been missed during decontamination.

3. Eye Protection: Safety glasses or face shields should be worn if there is any risk of encountering airborne irritants from nearby zones.

4. Respiratory Protection: Generally, respiratory protection is not required in the Support Zone. However, if there is any possibility of ammonia drift due to wind or other factors, a respirator may be appropriate.

SUPPORT ZONE PROTOCOLS

Victim Management:

Ensure that all victims have been properly decontaminated before entering the Support Zone. Victims who have been exposed only to ammonia vapor and have undergone necessary decontamination pose no significant risk of secondary contamination. Thus, Support Zone personnel generally do not require specialized protective gear in such cases.

ABC Reminders:

- **Airway:** Quickly assess and secure a patent airway. Apply a cervical collar and use a backboard if trauma is suspected.
- **Breathing:** Ensure that the victim has adequate respiration. Administer supplemental oxygen if needed.
- **Circulation:** Check pulse, establish intravenous access if necessary, and place the

victim on a cardiac monitor to continuously assess their condition.

Additional Decontamination:

- Continue rinsing exposed skin and eyes as needed. For cases of ingestion, do not induce vomiting or administer activated charcoal. Avoid neutralizing with weak acids. If the patient is conscious and able to swallow, give 4 to 8 ounces of water or milk to help dilute the ingested substances.

Advanced Treatment:

- **Respiratory Support:** For respiratory compromise, secure the airway with endotracheal intubation or perform a cricothyroidotomy if trained to do so.
- **Seizures and Hypotension:** Follow advanced life support (ALS) protocols for patients presenting with seizures, hypotension, or cardiac arrhythmias.
- **Bronchospasm:** Treat with aerosolized bronchodilators, carefully considering the use of cardiac sensitizing agents based on the patient's overall exposure and health status.
- **Pediatric Care:** For children with stridor, consider administering 0.25–0.75 mL of 2.25% racemic epinephrine solution in water, repeating every 20 minutes as needed, while monitoring for myocardial effects.

Monitoring and Support:

- **Monitor fluid and electrolyte balance,** especially in patients with pulmonary edema. Administer fluids cautiously, and adjust based on the patient's respiratory status.

Transport to Medical Facility:

- Ensure that only decontaminated patients, or those not requiring decontamination, are transported to medical facilities. Utilize body bags only when absolutely necessary to prevent contamination during transport.
- Report the patient's condition, treatments administered, and estimated time of arrival to the base station and receiving medical facility.
- Prepare for possible complications en route, such as vomiting from ingested ammonia. Equip ambulances with towels and plastic bags to safely manage and contain vomitus.

CONCLUSION

The Pirot derailment case serves as a critical learning point for emergency management and response teams. It underscores the necessity for rapid response capabilities, specialized training, and appropriate protective equipment to manage hazardous materials effectively. The delayed response time exacerbated the situation, allowing the ammonia gas to disperse further, increasing the risk and exposure to the surrounding communities. The lack of specialized protective gear and inadequate hazardous material training among the first responders hampered the containment efforts,

illustrating a clear gap in preparedness for chemical spill incidents.

By reflecting on this event and implementing the recommended changes, we can aim to mitigate the effects of similar incidents in the future, protecting both human lives and environmental health. This calls for a concerted effort to reforge the links in our emergency response chain, making them stronger, more flexible, and better equipped to handle the unexpected, yet inevitable challenges posed by hazardous material accidents.

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POSTUPANJE U INCIDENTIMA SA IZLIVANJEM OPASNIH MATERIJA PRIKAZ SITUACIJE IZLIVANJA AMONIJAKA IZ CISTERNE

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Sažetak: U decembru 2022. godine, u blizini Pirota u Srbiji dogodio se značajan incident sa iskliznućem voza, u kojem je učestvovao teretni voz od 20 vagona na putu iz Bugarske, što je rezultiralo značajnim ispuštanjem amonijaka. Ovaj događaj je rezultirao sa preko 50 slučajeva trovanja amonijakom, sa sedam osoba kojima je potrebna bolnička nega i dva smrtna slučaja. Osim toga, oslobođeni amonijak formirao gusti oblak pare amonijaka nakon interakcije sa vodom iz životne sredine, što je izazvalo sudar na obližnjem autoputu. Naknadne procene životne sredine otkrile su da nema zaostalog amonijaka u vazduhu ili u obližnjim izvorima vode. Ovaj slučaj ilustruje potencijalni rizik od transporta opasnih materija i naglašava važnost adekvatnih mehanizama upravljanja i reagovanja u takvim incidentima, kao što je detaljno opisano u analizi slučaja i predlogu upravljanja na osnovu aktuelnih preporuka i smernica

Ključne reči amonijak, nesreća, trovanje, urgentna medicina

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