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Research Safety

Tetramethylammonium Hydroxide (TMAH) Fact Sheet

- TMAH can cause severe skin burns and has severe toxicity; these effects occur within minutes
  - *Any exposure must be washed in a safety shower immediately for 15 minutes, after which personnel should immediately seek medical attention*
- TMAH is a chemical commonly used in device fabrication
- Exposures to concentrations of TMAH as low as 2.38% have resulted in potentially fatal symptoms within one hour; concentrations of 25% have resulted in several deaths
- TMAH can be used safely with proper precautions, many of which are already standard in labs

Tetramethylammonium hydroxide (TMAH) is a potentially lethal chemical that is commonly used in device research as an etchant for silicon and developer for photopatterning[1]. It is also used for thermochemolysis[2], and cleaning DNA microarrays[3]. It is often used in aqueous solution, but is also occasionally used as a solution in methanol. TMAH supplanted the once-commonly used bases in electronics fabrication, like NaOH and KOH, because these alkali metals reduced device reliability. This fact sheet will cover hazards, best practices, and emergency guidance.

Hazards

TMAH has two prominent hazards: corrosivity and dermal toxicity. During skin exposure to TMAH, the hydroxide ion damages the skin and allows the highly toxic tetramethylammonium ion to quickly enter the bloodstream[4]. These burns can be painful, but there are reports of pain not developing for 15 minutes or more[5].

The key factor that makes TMAH particularly hazardous is how quickly it acts. Life-threatening symptoms can develop within 20 minutes, unconsciousness within 30, and, in the worst cases, death can occur within an hour[1,5,6]. These symptoms can occur even after exposure to low concentrations (as in a case of a worker who were exposed to 2.38% TMAH on 28% of their body) or exposure to relatively small body surface area (as in the cases where workers were exposed to 25% TMAH on 8% of their bodies)[1].

The key factors affecting the severity of symptoms are concentration, body surface area that was exposed, and the duration of the exposure[6,7,8]. Severity of symptoms increase with increases in these three factors. It is important to remember, however, that life-threatening symptoms may occur with concentrations as low as 2%[4].

Additionally, TMAH can cause severe eye damage, and is toxic by inhalation[7]. While TMAH is not volatile, anecdotal evidence exists that even small amounts of aerosolization in routine lab tasks such as pouring can cause feelings of illness.

Symptoms

- Symptoms have a rapid onset (<1 hour in all reported cases, often <15 minutes).
- TMAH can cause severe skin burns. In some cases, pain was reported to be immediate and intense, in others it was reported to be significantly delayed. Do not rely on pain as a sign of exposure. In less severe cases, skin rash may develop.

- Toxicity symptoms are similar to nicotinic/muscarinic mimics[7] and include:
    a. Difficulty breathing (up to and including respiratory paralysis in severe cases)
    b. Cardiac abnormalities (up to and including cardiac arrest in severe cases)
    c. Muscle weakness
    d. In some cases, central nervous system symptoms such as increased salivation, headache, dizziness, and difficulty keeping eyes open were reported
- In some cases, severe symptoms have still developed after rinsing in a safety shower[1]. If you believe you received *any* exposure or experience any of the above symptoms, seek medical assistance immediately after using the safety shower.
- In severe cases, TMAH exposure may result in death. In case studies of four exposures[1] to 25% TMAH, three victims died despite medical intervention. At least two were dead upon arrival at a hospital. In a circumstance of significant (>20% body surface area exposure) to 8% TMAH, the victim did not remove contaminated clothing and begin showering until ~30 minutes post-exposure and was subsequently found dead within 60 minutes[5]. In one instance, a victim received significant (28% body surface area exposure) to 2.38% TMAH. Despite rinsing in a safety shower, all vital signs ceased within 60 minutes, though they were successfully resuscitated at the hospital[1]. Toxicological animal studies indicate that the severity and rapidity of symptoms is highly dependent on concentration[6], but the case studies above demonstrate that significant individual variability is possible and immediate medical attention is necessary.

How Can I Protect Myself?

Engineering Controls

- All concentrations and quantities of TMAH must be used inside a certified chemical fume hood. Work with the sash as low as reasonably practical. Close the fume hood sash when not actively working with equipment/chemicals.
    - Note that TMAH has no odor, so smell will not be a reliable warning property.
- Ensure the nearest emergency safety shower / eyewash is accessible and has been tested in the last month.
- Ensure laboratory fume hood has been certified within the last 12 months and is functioning properly (check sticker on fume hood and inward airflow monitor).

Safe Work Practices

- Substitute TMAH for a lower hazard chemical wherever possible.
- Work with the minimum quantity and lowest concentration necessary. If the solution must be heated, do so slowly and to the lowest required temperature.
- Develop an SOP for procedures involving TMAH. EH&S is available for consultation.
- Establish a designated area for TMAH use and post sign "Tetramethylammonium Hydroxide Use Area." Also post a sign on lab door when in use.
- Always have a buddy in the room who has appropriate PPE for TMAH.
    - Symptoms of exposure can be debilitating and a person exposed to TMAH will likely need assistance getting to medical treatment.
- Ensure secondary containment and segregation of incompatible compatible chemicals; see SU Compatible Storage Group Classification System.
- Store TMAH solutions below eye level.

- Have a copy of the safety data sheet for TMAH and this fact sheet printed out and readily available in case of emergency. Bringing these to the hospital can assist doctors in determining treatment. Other important information to share includes:
    - Summary of any first aid given, including safety shower use
    - What body parts were exposed, when the exposure occurred, and the duration of the exposure
    - The concentration of the TMAH solution

Personal Protective Equipment

- It is essential that NO skin be exposed.
- Eye/face: always wear goggles and a face shield with chin protection
- Body: lab-appropriate attire (long pants or equivalent, closed-toe shoes covering the entire foot), lab coat, and chemical resistant apron; for large quantities (>1 L) consider Tyvek coveralls with a chemical resistant apron on top
    - It is important to note that TMAH can readily penetrate clothing, so while lab-appropriate attire is important it should not be relied on
- Hands: nitrile gloves that reach the elbow

Health and Safety Training

Lab personnel must receive:

- General safety training, which includes General Safety & Emergency Preparedness (EHS-4200) and Chemical Safety for Laboratories (EHS-1900).
- Lab-specific training, which includes reviewing the hazards of TMAH, safety precautions, and emergency procedures. The SOP, Safety Data Sheet (SDS), and this fact sheet can be used for such training.
- Keep training records for at least one year.

Emergency Response

Skin Exposure

- For exposures to >1% TMAH solutions on any body part except the eyes, **immediately** wash skin for 15 minutes and call 911.
    - Minutes matter. Stay calm but act quickly.
- For exposures to <1% TMAH solutions, significant body exposures (e.g., an entire forearm) may still require medical care. When in doubt, call 911 or go to the Stanford Hospital Emergency Department.
- Report the exposure to Stanford EHS by calling 650-725-9999. This may be done by the affected person after they have been stabilized, or by another person once the affected person is receiving treatment.

Eye Exposure

- Use the emergency eye wash (not the sink) for 15 minutes and call 911.
- Report the exposure to Stanford EHS by calling 650-725-9999. This may be done by the affected person after they have been stabilized, or by another person once the affected person is receiving treatment.

Inhalation Exposure[9]

- Move to fresh air and then seek medical attention.
- Report the exposure to Stanford EHS by calling 650-725-9999. This may be done by the affected person after they have been stabilized, or by another person once the affected person is receiving treatment.

Ingestion Exposure[9]

- Do **not** induce vomiting. Rinse the mouth with water and seek medical attention.
- Report the exposure to Stanford EHS by calling 650-725-9999. This may be done by the affected person after they have been stabilized, or by another person once the affected person is receiving treatment.

Spills

In the event of a spill or release:

- Do **not** attempt to clean the spill yourself without EH&S consultation.
- Notify Stanford Responders: Call (650) 725-9999 (24 hours/day, 7days/week).
- Provide local notifications to your supervisor and any people nearby.

Incident Reporting/Follow-up

- Laboratory personnel are to report all occupational injuries or illnesses to laboratory supervisor as soon as practical. They must also fill out an SU-17.
    - Laboratory personnel are encouraged to report "near-misses" as they are considered a precursor to more serious incidents.
- The Principal Investigator / Laboratory Supervisor should conduct (or coordinate) an investigation of all incidents and "near misses." The goal of the investigation is to identify and address any deficiencies that may have contributed to the incident. EH&S is available for consultation.

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