2022 ChemE Cube Safety Program

1.0 Program Overview

The objective of the ChemE Cube Safety Program is to ensure safety is considered during all phases of the competition, including prototype development (construction and testing) and the competition. The safety program consists of a compliance audit and competition safety rules. A review of the product design and a compliance evaluation will be conducted from the documentation provided by competing teams, and an onsite audit of the product by safety professionals.

2.0 Safety Review Process

Teams will design a cube that can purify challenge water to drinking water standards according to the 2022 Problem Statement. They will develop a working prototype of their design and describe the design in a document called an Engineering Documentation Package (EDP). The EDP contains information about the design, and includes a description of the process, technical data, chemical information, and information on hazards and safeguards.

Teams will be required to consider safety as they conceptualize the design. They will also be required to complete safety training prior to working in the lab or with a 3D printer or other fabrication tools to develop a prototype. When the team has completed a prototype (i.e., the cube mini-plant hardware that will be used in the competition) and an EDP (signed by a supervising faculty member), a team of safety professionals will review the design and conduct two compliance audits (online and onsite). Safety professionals will assess the design and the physical prototype for hazards, ensure that these hazards have been mitigated to the extent possible, and that adequate safeguards are present to protect participants and audience members during operation of the prototype on competition day.

The safety review process steps (for safety professionals):

1. Review the EDP documentation.
2. Complete a EDP Review form.
3. Return EDP Review forms to teams via RAPID staff to allow product revisions as needed.
4. Complete an onsite safety assessment of the prototype and EDP.

5. Attest by signature that each prototype is compliant with the safety rules for the competition, which permits teams to compete.

3.0 Compliance Audit

A compliance audit will occur in two stages:

- Online evaluation where teams will submit an Engineering Documentation Package (EDP) electronically and receive feedback. A RAPID staff member will communicate EDP instructions to all teams. **Failure to meet the posted deadline will result in exclusion from the competition.** The EDP template is available for download on the ChemE Cube Competition Website: www.aiche.org/chemecube
- Onsite evaluation on competition day where teams must bring a printed EDP, printed EDP reviewer feedback and a printed Management of Change (MOC) Form all in a folder or binder. Teams should be ready to answer questions from a compliance auditor during a live safety review of their product. Teams must pass both the online and onsite evaluations in order to compete.

3.1 Safety Audit: Online

An engineering documentation package (EDP) for your ChemE Cube must be completed and submitted by the posted deadline. A template is available here: www.aiche.org/chemecube. A complete EDP will include the following in the following order:

Section 1.0 Product description: Please describe the cube, include a description of the processes (filtration, disinfection, etc.) capabilities and limitations. This should be similar to your product pitch. Example: *"A modular cube of extruded aluminium frame and 3D printed internals designed to purify turbid water with simulated bacterial contaminants to drinking water standards through the use of a combination flocculation/filtration technique. Weighing only 20 pounds, this cube is capable of purifying 25L of water per day and can be stacked with up to 6 additional cubes to increase capacity…"*

Section 2.0 User Operating instructions: Include a paragraph explaining how the cube operates, and if maintenance is required, filter changing, waste disposal, etc. Be brief and limit technical jargon, this is for a potential future user, not for your use on competition day. Example: "*To operate the cube, simply flip the switch on the side…"*

Section 3.0 Inlet water chemistry: List the contaminant treatment range that your cube can process, not just challenge water specifications.

Section 4.0 Outlet water chemistry: List the water purity range that your cube can achieve, not just competition requirements.

Section 5.0 Cube technical specification/performance sheet: Contains the dimensions of the cube, all flow rates, throughput (capacity), power requirements (voltage, operating current), clearance, operational/environmental needs (e.g., light, temperature, RH), bill of materials, stacking considerations, etc. Include an isometric drawing of the cube, and document electrical power distribution throughout including connection points. An example of a technical specification sheet can be found here:
https://static1.squarespace.com/static/5ca0cbec7eb88c308c426e4e/t/5cb7beede79c704a32acf910/1555545839391/Performance+data+sheet+for+RO.pdf

Section 6.0 Photos: Submit 6 pictures of your cube after construction has been completed. These pictures must be current. The entire cube must be visible in each picture. The pictures will be from the following points of view; side 1, side 2, side 3, side 4, top looking down, and top looking down with enclosure removed. *A drawing or solid model (i.e., CAD model) is NOT acceptable.*

Section 7.0 Safety Assessment: Describe the systems and technology in the cube, and document any hazards associated with cube operation.

Section 8.0 Laboratory floor plan: Please draw the floor plan for the laboratory where cube construction and testing will take place. Include the location of the 3D printer (if applicable) and other major fabrication tools, and list the location of the available safety equipment and spill response supplies on the diagram.

Section 9.0 Cube Hazard Analysis: Consider each treatment process within the cube, and indicate whether a hazard is present. Some of the hazards include, but are not limited to, temperature, pressure, mechanical, and electrical. Teams should document the safeguards they have incorporated relevant to each hazard present.

Section 10.0 Fabrication Hazard Analysis: In addition to the product hazards associated with the cube, there are also hazards present in the laboratory or fabrication site where prototype development and testing may occur. Teams should use the hazard identification form in the EDP template to identify any hazards associated with the lab or fabrication site, and document the control method used to safeguard against the hazard. When appropriate, students should document the PPE needed for each task. If uncertain, check with your team faculty advisor.

Section 11.0 Chemical Information: Include a description of the chemistry involved, and a list of any chemicals to be sent to the competition.

Section 12.0 Treatment Chemical Hazards and Disposal: List the properties for every chemical, typically found on the SDS. If a chemical is not flammable, please write N/A. Teams should attach a SDS for every treatment chemical that will be used inside the cube at the end of the EDP document.

Section 13.0 Standard/Safe operating procedures page: This section requires your team to conduct research related to hazards presented by your cube during start-up, operation, shutdown, cleanup / waste disposal, and in the event of emergency shutdown. Please refer to the NIOSH website to search for and locate information on hazard mitigation. When not applicable, indicate with N/A.

Section 14.0 Safety Rules: The is a summary of some safety rules. They are provided here for the convenience of signing faculty.

Section 15.0 Safety Certifications: This page is used to document that students have completed the required safety training for the laboratory and fabrication tools (e.g., 3D printer, band saw, drill press, etc.). Each team member must sign and date, and the supervising faculty member must attest that they have read the safety rules, and that students have completed the training. They are also signing to acknowledge that the team has completed the EDP, and that the faculty advisor or outside expert has completed a safety review of the cube.

Section 16.0 Management of Change Form: After the online EDP review, if you make any changes to the product design or the EDP itself, you must complete the Management of Change (MOC) form included at the end of the EDP.

3.2 Safety Audit: Onsite. At the competition site, an audit team will inspect each entry to ensure that all of the safety requirements have been met and there are no outstanding safety issues. The onsite audit team has the final say in regard to permission to compete, regardless of whether a design was previously cleared.

4.0 Competition Safety Rules

1. **No transporting chemicals.** Teams are not allowed to transport chemicals by car to the competition site. No chemicals should be transported in private, university or rental vehicles to and from the competition site, even over short distances. Common household chemicals such as baking soda, etc. are exempt from this rule. To qualify as a common household chemical, the chemical must be available for purchase at a grocery or hobby store.

2. **No chemical storage**. Chemicals must not be stored in hotel rooms or other facilities not rated for chemical storage. The exception to this rule is common household items such as baking soda and salt.

3. **No unauthorized testing.** No testing in hotel or dorm hallways, warehouses, or other facilities that are not designed for chemical handling. This includes at your university and the competition site.

4. **Shipping Chemicals/hazardous materials**. Teams should work with their University EHS department to make sure everything is shipped according to all DOT/HAZ Material shipping laws. Make sure everything is properly labeled.

5. **Proper Testing.** Testing of cubes must only be done in a laboratory or other facility with chemical handling capability. Testing in hotel or dorm hallways, warehouses, or other facilities that are not designed for chemical handling is not allowed. No mixing of chemicals, including common household chemicals is allowed in the hotel or in dorm hallways.

6. **Illegal Disposal of Chemicals.** All chemicals shipped to the competition site must be disposed of in a safe and correct fashion in compliance with all local, state and federal regulatory measures. Failure to follow these rules on chemical handling will result in a multi-year suspension of your university. Please minimize chemicals shipped to the competition site to reduce disposal costs.

7. **Liquid/Solid Discharge.** Only treated water and gas under 1 psig may exit the cube during operation. No other liquid/solid discharge, including water, is allowed. Treated water will be collected in a receiving vessel supplied during the competition. All other liquids should be properly collected and contained within the cube, and properly disposed of (example, use of a holding tank). All interior components must be sealed such that challenge water does not leak or build up within the body of the cube. Cube components should be dry at the start of the competition, so that leaks can be observed.

8. **No release of gas under pressure**. Gas may be vented from the cube, but must not exceed 1 psig. Unpressurized, untreated gas discharge as a reaction byproduct is allowed without filtration for small quantities of nonflammable/nontoxic gases (e.g., water vapor, CO_2 are OK; H_2S is not OK). The onsite safety personnel may disqualify any entry where the gas discharged by a cube is deemed improper. Disqualification due to excessive gas production is at the discretion of the observing safety committee, and the ruling is final and cannot be challenged.

9. **Autonomous Operation.** Cube must work autonomously. After startup, the cube may not be opened during the challenge water purification process. When the competition

begins, students will only be permitted to input challenge water and open a valve/switch to remove the treated water.

10. **No Regulated Chemicals.** Due to the hazards involved, no chemicals regulated by OSHA will be allowed during the competition. *A number of chemicals are listed by OSHA as a special hazard. The handling of these chemicals is outside the scope of the management systems available during the competition. See www.osha.gov for details.*

11. **No Highly Reactive/Unstable Chemicals.** No chemical, raw material, intermediate or product that is highly reactive or unstable will be permitted. This includes chemicals with a GHS hazard category level 1 ranking in any of the following categories; pyrophoric solids and liquids, acute toxicity, carcinogenicity, other toxicity hazards not specifically listed, and hazardous to the ozone layer. This also includes any chemical on the extremely hazardous substances list published by EPA.

12. **No Liquid Hydrogen Peroxide Concentrations Greater than 30%.** Liquid hydrogen peroxide is very unstable and difficult to handle at concentrations greater than 30%.

13. **Pressure Restrictions.** Pressure will be restricted to 5 psig for the competition.

14. **Chemical Containment.** The primary containment must be adequate to prevent leakage of any chemicals during normal operation and transport of the cube.

    14.1.1. **Lids**. All lids on containers containing chemicals must be securely attached to the container and should cover the entire container opening. Please ensure that any holes in the lid or container are just big enough to accommodate the "through hole item" — seal if possible. Saran™ wrap, Parafilm™, aluminum foil and other similar materials are not adequate for use as container covers.

    14.1.2. **Secondary Containment.** Secondary containment is required for chemicals with a GHS health or physical hazard of any ranking (1–4). The secondary containment must be of suitable durability and size to hold the contents of any spilled chemicals and prevent them from accumulating within the body of the cube.

15. **Temperature Hazards.** All exterior surfaces of the cube must be less than 120°F. Insulation or barriers on internal components must be present to prevent accidental contact with hot or cold surfaces/components outside the range 32°F–90°F.

16. **Electrical Hazards** All wiring and exposed electrical components must be insulated or covered to prevent the possibility of electrical shock or ignition of any component of a cube. Alligator clips and twisted wires represent both an electrical shock hazard and

an ignition source. Use more robust electrical connectors such as terminal connectors, banana plugs or binding posts.

17. **Mechanical Hazards** Guards must be present for any moving parts and pinch points. This includes gears, belts, linkages, actuator arms and any other part that may present a pinch point.

18. **Oxygen Service** All components in oxygen service must be rated by the manufacturer for oxygen service. This includes vessels, piping, filters, regulators and valves. For oxygen service, metallic components are preferred since nonmetals are more susceptible to oxygen ignition. The equipment must not have been used previously for another service. All equipment in oxygen service must be thoroughly cleaned before being placed into service. Effective cleaning will: (1) remove particles, films, greases, oils, and other unwanted matter, (2) prevent loose scale, rust, dirt, mill scale, weld spatter, and weld flux deposited on moving and stationary parts from interfering with the component function and clogging flow passages, and (3) reduce the concentration of finely divided contaminants, which are more easily ignited than bulk material. Cleaning of the oxygen system must be done by disassembling all components to their individual parts.

19. **Biohazards** If any biological organisms are used during any phase of the design, development, operation, competition and preparation of your ChemE Cube, they must be no more than Level 1 biological hazards, also called biosafety level (BSL) 1. This would include any bacterial, fungal, viral, or yeast organisms. *Proper handling procedures must be followed to minimize human exposure. All leftover cultures, stocks, media, and other regulated wastes must be collected, packaged and decontaminated according to local, state and federal regulations.*

20. **Accidents.**

If a safety incident occurs during the competition, the AIChE student chapter advisor of that team will be informed that an incident analysis report must be submitted to chemecube@aiche.org. This safety incident report must be approved by the ChemE Cube competition RAPID staff member before any team from that university is allowed to compete in any future competition.

21. **Competition Day Rules**

21.1. PPE: Each team must provide the appropriate personal protective equipment (PPE) for use in the preparation “pit” area, as identified in their EDP and must use them properly. This includes lab coats, safety glasses, gloves, face shields, and hearing protection. The personal protective equipment must be used appropriately by all team members depending on the hazards encountered during the chemical preparation.

21.2. Labeling Containers. All containers with chemicals, including bottles, beakers, syringes and plastic bags must be properly labeled. The label must minimally include the name of the chemical(s), and the name of the team. See Appendix B for more information on chemical labeling.

21.3. Spill Containment at Table. All chemical pouring or mixing in the preparation area must be done with spill containment. The team must use a large tray compatible with the chemicals, with a volume large enough to hold the chemical quantities.

21.4. Chemical Distribution. All chemicals will be made available to the teams in the chemical preparation area at least one (1) hour prior to the performance competition.

22. Requesting Assistance. There is no restriction on requesting assistance for safety related matters. Teams are encouraged to request additional safety assistance from their faculty advisor, other faculty members, other universities, other teams, and professional practitioners in industry and elsewhere.

Appendix A. Fabrication and Operation Safety

A.1 Fabrication Safety

3D Printing. Teams may use 3D printing to design and build their cube. Fused deposition modeling (FDM) 3D printers use a thread like plastic filament (feedstock) that is liquefied via a heating element which is then jetted through a nozzle.[1] Prolonged exposure to fumes from some materials can be hazardous, although occupational exposure levels for 3D printer emissions have not been established.[2] Studies of 3D printers have indicated that hazardous vapors and gases are emitted during the printing process. Acrylonitrile Butadiene Styrene (ABS) and Polyactic acid (PLA) can release ultrafine particles and volatile organic compounds (VOCs). Engineering controls such as printer design (through enclosures) and ventilation can help mitigate possible emission hazards. Check with your university for guidance on the number of printers allowed per room, and the recommended air volume replacement rate per hour recommended by the manufacturer. Confirm with your university laboratory staff that the appropriate volume exchange rate is being achieved.

Resin-based 3D printers, such as sterolithography (SLA) printers are known to produce harmful resin vapors. Use these types of printers in a well-ventilated area. Treat anything that has been contaminated with resin as hazardous waste and properly dispose of it by either completely curing the resin or using hazardous waste disposal.

Some metal 3D printers use atomized metal powder, which can be flammable. Use appropriate PPE and anti-static measures when handling, and document/understand the use of the laboratory's fire suppression equipment.
Outside of emissions, students should be aware of loose powder or dust when removing an object from the printer.

Students will be required to obtain a copy of the university's laboratory safety rules related to 3D printing, and faculty will need to indicate by signature that the students have read and understand the university rules related to the use of the 3D printer. Some excellent precautions to follow when 3D printing may include:[3]

- Consult the Safety Data Sheets (SDSs) of printing materials

[1] https://www.graphicproducts.com/articles/3d-printing-hazards/
[2] https://www.safetyandhealthmagazine.com/articles/18295-d-printing-and-worker-safety
[3] https://www.graphicproducts.com/articles/3d-printing-hazards/

- Provide OSHA safety training to individuals that work with hazardous 3D printer chemicals
- Provide training in the correct and safe operation of the 3D printer
- Use 3D printers in a well-ventilated area
- When using metal materials keep workspaces free of any static electricity
- Do not open 3D printer covers once a print job is underway
- Equip the facility with Class D fire extinguishers and train on proper use
- Wear a protective P100 respirator dust mask when accessing the printer stage area
- Handle uncured (e.g. resin before UV treatment) printing materials with neoprene or nitrile gloves
- For print processes that use an alkaline bath to dissolve support material, provide an emergency eyewash station in the immediate vicinity of the work
- Wear eye protection around liquid materials that can splash
- Use solvent-absorbent pads for spills of printing material
- Keep model and support materials away from areas where food and drink is stored, prepared, or consumed

It is not anticipated that students would be permitted to service a 3D printer. If troubleshooting is needed, consult with your advisor or laboratory manager, and call the 3D printing company for assistance. It is likely that during a printer jam (e.g., clogged FDM nozzle), the first response of the user would be to open the cover to investigate the issue, which may expose the user to emissions from the printing process. Refer to the user manual for guidance on how to evacuate emissions from the printer prior to opening, or the need for additional PPE such as a respirator (see above). Review the printer manual to identify any user openings such as user access slots which typically are designed to prevent injury to a user when accessing the machine (reducing the opportunity for pinch points, cuts, or other mechanical energy injury). Note, the OSHA lock out tag out standard applies when servicing any 3D printer. [4]

3D printers have hot surfaces, and it is important to allow enough time for the extruder to cool before retrieving any printed product.[5] Printers may have an interlock system design to prevent a user from opening too soon. Heed the instructions and warnings provided by the 3D printer manufacturer in the manual and on the printer itself.

Finally, housekeeping may be required in between printing jobs. Consult the university's hazardous dust control program or with your faculty advisor to understand how to properly dispose of any accumulated combustible dust in accordance with university

[4] https://www.osha.gov/laws-regs/standardinterpretations/2004-04-07
[5] https://www.safetyandhealthmagazine.com/articles/18295-d-printing-and-worker-safety

policy. Any vacuum cleaners used should be approved to handle combustible dust if combustible dust is being used in the printing process.

Other Fabrication Methods. Appropriate training and safety measures should be taken when working with hand tools (e.g., taps, shears) and power tools (e.g., drill press, band saw). Teams should work with their University EHS department to understand the requirements for safe use of these tools.

A.2 Operation Safety

Students may select a variety of internal components to include in their cube. Some of these may be designed by the students (may be 3D printed), and others may be procured and inserted into the cube. When designing the cube, students should plan to locate internal components for ease and safety during installation and access for troubleshooting. Consideration for how power will be distributed and safely managed will be necessary. In addition, students will need to consider the mechanics of how challenge water will enter, how final product will leave, and how to manage waste accumulation and disposal. Liquid spills will forfeit a team's current run, so it will be important to consider how samples will be collected for testing during development and on competition day.

Specification sheets from manufacturers for procured equipment (pumps, filters, etc.) should be reviewed to determine compatibility with chemicals in the challenge water as well as any chemicals selected for treatment. In addition to the challenge water chemistry, additional chemicals which may be present in the challenge fluid stream include chlorine, potassium, and sodium. The impact of these chemicals on corrosion and material properties of the cube should be considered, as well as any other accumulated salts within the system. The following is a sample list of chemicals that might be used for water treatment processes including flocculation, microbial contaminant reduction, organic carbon removal, dissolved solid removal and pH adjustment. Designers should not be limited by this list, other chemicals used for water treatment are possible.

- Alum (aluminum sulfate), aluminum chlorohydrate, aluminum sulfate
- Polyacrylamide based flocculants (synthetic)
- Biopolymer flocculants (chitosan)[6]

[6] https://www.sciencedirect.com/topics/engineering/flocculants#:~:text=A%20flocculants%20are%20usually%20organic,aluminium%20chlorohydrate%2C%20aluminium%20sulphate%20etc.

- Chlorine and Chloroamines
- Chloro-dioxide
- Potassium permanganate
- Iodine
- Ozone
- Activated carbon
- Dilute hydrochloric acid, dilute sulfuric acid
- Calcium carbonate
- Magnesium oxide

Alum can be bought in liquid form or dry form. It reacts with water and results in positively charged ions. Aluminum sulfate is widely used as a flocculant in water treatment plants in the United States. It is also widely available in developing countries, sold in blocks of soft white stone, and generally called alum. There are numerous ways to use alum as a flocculant, including to crush it into a powder before adding it to water, stirring and decanting or stirring the whole stone in the water for a few seconds and waiting for the solids to settle. The benefits of alum are that it is widely available, is proven to reduce turbidity, and is inexpensive. The drawback of alum is that the necessary dosage varies unpredictably.[7] Aluminum is easy to remove from water through RO or distillation.

Electro-precipitation and electrocoagulation use an applied voltage to sacrifice ions (Fe/Al) into solution and liberate hydrogen and oxygen gas from water, thereby producing a coagulant *in situ*. Dissolved and suspended contaminants react with the sacrificed ions, and are precipitated from solution as a result. The process also can remove arsenic, selenium, vanadium, and other metals.[8] Other targets for removal include PFOS/PFOA, fluoride, and TOC. When electro-precipitation or electro-coagulation techniques are used for flocculation, chemical exposure hazards to users are reduced. Like chemical flocculation, disposal of the sludge created during the process will need to be considered. At small scales, the hydrogen and oxygen streams evolved during the process should be minimal and not create an explosion hazard. Although there are many benefits to the use of electro-coagulation, size restrictions of the competition may make this approach challenging.

[7] http://www.purewateroccasional.net/wtialum.html#:~:text=When%20alum%20is%20added%20to,and%20some%20bacteria%20from%20water.&text=Then%2C%20during%20flocculation%2C%20the%20particles,der%20Waal's%20forces%2C%20forming%20floc.

[8] https://ecolotron.com/electrocoagulation/

Appendix B. Chemical Handling and Disposal

B.1 Introduction

All students who handle chemicals either at their host institution or at a regional or Annual competition must understand the hazardous properties of these chemicals. Before using a specific chemical, safe handling methods must always be reviewed. Faculty advisers are responsible for ensuring that the equipment needed to work safely with chemicals is provided.

B.2 General Rules for Chemical Safety

A. Safety Data Sheets (SDS) must be available in the laboratory for all chemicals, including those in storage in the laboratory.
B. When purchasing chemicals, purchase the smallest quantity necessary to complete the planned experiments. The cost of disposal of unused chemicals far exceeds the savings from quantity purchases.
C. Skin contact with chemicals must be generally avoided.
D. No more than 2-gallons of flammable solvent should be out in the laboratory at any one time. Store bulk flammable containers in a flammable storage cabinet.
E. All containers (including those in storage) must be labeled – see the section on labeling below. Any unlabeled container must be treated as a hazardous substance.
F. Wear compatible gloves and apron when handling strong acids and bases.
G. Use a grounding strap and/or dip leg when transferring flammable chemicals into a storage tank.
H. Transport <u>all</u> chemicals using a safety carrier. The chemical must be in a closed container.
I. Chemical containers must be kept away from high temperatures, the edge of the lab bench, and other areas where an incident might lead to loss of containment.
J. Mouth suction for pipetting or starting a siphon is not allowed.
K. Unknown substances must be treated as toxic and flammable.
L. Do not taste or smell any chemicals.
M. Operations involving chemicals should generally be done in a laboratory hood.

B.3 Chemical Storage

A. SDS's must be available for all chemicals stored.
B. ALL chemicals stored must be properly labelled.
C. No chemicals shall be stored on the top of lab benches or out in the open. Chemicals must not be stored over eye level height to prevent accidents from dropping containers.

D. Flammable and volatile chemicals must be stored in a cabinet designated for flammable storage. Refrigerated storage of these chemicals requires a refrigerator rated for storing flammables.
E. Acids and bases should be stored separately.
F. Acid-resistant trays shall be placed under stored acid containers.
G. Acid-sensitive materials such as cyanides and sulfides must be separated from acids.
H. Oxidizable materials should be stored away from acids and bases.
I. Stored chemicals must be examined on a regular basis by the laboratory personnel (at least annually) to inspect for deterioration, container integrity, and expired dates. Chemicals which are not being used should be disposed of or returned to Chemical Stores for recycling.
J. An inventory of stored chemicals must be always maintained by the laboratory owner. Leftover items shall be properly discarded or returned to Chemical Stores. Store only what you are using.

B.4 Chemical Labeling

All chemicals must be labeled, even during temporary transport. This includes lab samples, temporary containers, etc. A proper chemical label must include:

- Name, address and telephone number
- Product Identifier
- Signal word
- Hazard statement(s)
- Precautionary statements
- Pictograms

Pictograms are required on labels to alert users of the chemical hazards to which they may be exposed. Each pictogram consists of a symbol on a white background framed within a red border and represents a distinct hazard. Here are examples of GHS pictograms you may encounter.

Health Hazard

- Carcinogen
- Mutagenicity
- Reproductive Toxicity
- Respiratory Sensitizer
- Target Organ Toxicity
- Aspiration Toxicity

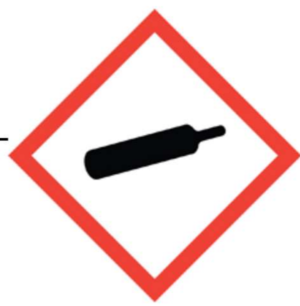
Flame

- Flammables
- Pyrophorics
- Self-Heating
- Emits Flammable Gas
- Self-Reactives
- Organic Peroxides

Exclamation Mark

- Irritant (skin and eye)
- Skin Sensitizer
- Acute Toxicity (harmful)
- Narcotic Effects
- Respiratory Tract Irritant
- Hazardous to Ozone Layer (Non-Mandatory

Gas Cylinder



- Gases Under Pressure

Corrosion

- Skin Corrosion/Burns
- Eye Damage
- Corrosive to Metals

Exploding Bomb

- Explosives
- Self-Reactives
- Organic Peroxides

Flame Over Circle

- Oxidizers

Environment (Non-Mandatory)

- Aquatic Toxicity

Skull and Crossbones

- Acute Toxicity (fatal or toxic)

B.5 Chemical Disposal

All chemicals must be disposed of in a safe and environmentally friendly manner. Any chemical substance which is corrosive, flammable, reactive, toxic, radioactive, infectious, phytotoxic, mutagenic, or acutely hazardous must be treated as hazardous waste. Do not dispose of chemicals by evaporation in a fume hood or in the sink. Do not hesitate to ask if any questions occur about the hazards of a material.

Collect and store chemical waste in containers which are clearly labeled. Do not combine containers unless the contents in each container is known, is compatible, and it is certain that it is safe to do so. Combined wastes are much more difficult and costly to dispose of properly.

Ordinary waste such as paper, cardboard, etc., may be placed in the wastebasket. However, contaminated waste must be disposed of separately in a labeled container.

Empty chemical containers must also be disposed of in an acceptable fashion. They must first be cleaned and then either returned to Chemical Stores or disposed through normal trash.