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Guarding Against Hazard in Laboratories: Navigating Chemical Safety in The Modern Age

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Abstract

Chemical safety in laboratories is a critical concern in today's research and educational environments. The effective management of chemicals hazard is crucial to prevent accidents, injuries and environmental damage. More so, with the increasing complexity of chemical experiments and introduction of new materials, understanding and implementing safety protocols is more important than ever. Material safety data sheet (MSDS) and the globally harmonized system (GHS) are essential tools for ensuring chemical safety. While MSDS provides vital information on chemical handling, storage and disposal, GHS offers a standardized approach to chemical classification and labeling. This paper explores the importance of chemical safety in chemical laboratories and modern strategies for chemical safety, including risk assessment, personal protective equipment (PPE), and training programs, highlighting recent advancements and ongoing challenges in laboratory environments. By understanding the risks associated with chemicals and utilizing MSDS and GHS protocols effectively, laboratories and industries can minimize chemical hazards, promote a safer work environment and reduce environmental impact.

Keyword: Chemical Safety; PPE; Risk Assessment; Laboratory Hazards

1. Introduction

Laboratories are integral to scientific progress, but they also pose significant risks due to the nature of chemical substances used. Chemicals are an integral part of various laboratories and industries, their safe handling is crucial to prevent accidents, injuries, and environmental damage. Chemical safety is a critical aspect of workplace safety, and it requires a comprehensive understanding of the risks associated with chemicals and the measures to mitigate them (Fatemi *et al.*, 2022; Abedsoltan and Shiflett 2024). According to the National Institute for Occupational Safety and Health (NIOSH, 2022), laboratory accidents can lead to severe injuries, long-term health issues, and environmental hazards. Therefore, effective safety measures must be established to mitigate these risks.

Chemistry is one of the subject areas in which often hazardous chemicals are used extensively during laboratory sessions. In these classes, students are introduced to, and use, chemicals of differing types and properties. While chemicals used daily have many benefits, they can also be hazardous and present health, physical and environmental hazards. Hazardous properties include those that are corrosive, explosive, easily oxidizing, flammable, harmful, irritating, radioactive or toxic to human beings and also may pollute the environment (Ayana *et al.*, 2017). Exposure to such chemicals can lead to chemical burns, skin and eye irritations, headaches, organ disorders, cancer and even death. Depending on the severity, these effects can significantly affect a person's ability to continue work and may decrease the quality of life. Not to be

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overlooked are the potential negative impacts caused by accidental releases and incorrect disposal practices, on the environment, and by extension, the human population (Ayana *et al.*, 2017). For instance, the release of methylmercury into Minamata Bay, Japan, by the Chisso Corporation in the 1950s led to an outbreak of mercury poisoning, present an example of environmental disaster caused by chemical (Harada, 1995). In recent past, reported cases of Chemical hazard include: fires in three laboratories in Malaysian universities (Draman et al., 2010), the death of a chemistry professor from Dartmouth College, New Hampshire, due to mercury poisoning after working with dimethylmercury (USCSB, 2011), and a second-degree burn sustained by a post-doctoral fellow from concentrated sulphuric acid due to use of the wrong gloves (AIHA, 2015). Thus, safety considerations are issues for everyone exposed to potentially hazardous substances, persons who routinely work with chemicals especially, students and laboratory workers are particularly at risk.

2. Risk Assessment

Though there are hazards associated with chemical laboratory work, the potential danger may be mitigated once systems are in place to ensure safe handling and management. The use of improper techniques can lead to accidents in the laboratory environment. For example, a report has indicated that for three consecutive years, 49% of accidents on university campuses in Taiwan were related to the improper use of chemicals in otherwise standard laboratory exercises (Su and Hsu, 2008). Similarly, Adane and Abeje (2012) also reported that accidents involving chemicals can be expected to occur in cases of inexperience, and lack of awareness about the risks associated with different substances and techniques in the laboratory. This has led to a greatly improved safety management system at the University of California, Los Angeles (UCLA).

A fundamental aspect of laboratory safety is the identification and assessment of risks associated with chemical handling. The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) provides a framework for classifying chemical hazards (United Nations, 2021). Regular risk assessments should be conducted to evaluate potential hazards, including chemical spills, exposure risks, and equipment malfunctions (HSE, 2023).

3. Chemical safety

To minimize the occurrence of accidents in lab environments, it is important that all individuals working therein are educated about chemical safety. Hill and Finster (2010) noted that for many years the topic of chemical safety was included at the margins of laboratory courses or as a note in laboratory experiments. Since the late 20th century however, the approach has improved, with greater focus on safety due to a number of legal, ethical and educational reasons. Chemical safety is the result of a combination of attitude and safe practices in addition to a strict observance of procedures. Chemical safety does not come naturally to individuals, and needs to be taught and inculcated through continuous training. Key aspects of chemical safety include:

1. hazard identification and risk assessment;
2. emergency response;
3. waste management;
4. accident reporting and
5. investigation.

These aspects of chemical safety and their importance should be communicated to students and encouraged throughout (Al-Zyoud *et al.*, 2019).

4. Chemical hazard

A hazard is any source of potential harm, damage or adverse health effects on someone or something within the workplace. Chemical hazard is a hazard present in hazardous chemicals and hazardous materials. Exposure to certain chemicals can cause acute or long-term adverse health effects. Chemical hazards are usually classified separately from biological hazard (biohazards). Chemical hazards are classified into groups that include asphyxiants, corrosives, irritants, sensitizers, carcinogens, mutagens, teratogens, reactants and flammables. In the Laboratory exposure to chemical hazard is very possible and the use of personal protective equipment may substantially reduce the risk of adverse health effects from contact with hazardous

materials. Long term exposure to chemical hazard such as silica dust, engine exhaust, tobacco smoke, lead, etc. have been shown to increase risk of heart disease, stroke and high blood pressure (OSHA, 2024).

4.1 Types of Chemical Hazard

The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) categorizes chemical hazards into three primary types: health hazards, physical hazards, and environmental hazards (UNECE, 2024). Health hazards refer to substances that can adversely affect human health. This category includes various types of risks, such as acute toxicity, where chemicals can cause immediate harm following exposure. Additionally, some chemicals can lead to skin and eye irritation, resulting in inflammation or injury. Carcinogenicity is another critical health hazard, as certain substances may increase the risk of cancer. Reproductive toxicity is also significant, encompassing chemicals that can negatively impact reproductive health and development (OSHA, 2024; UNECE, 2024).

Physical hazards are related to the intrinsic properties of substances that pose dangers under specific conditions. For example, flammable materials can ignite easily, presenting significant fire risks. Explosives are particularly hazardous as they can undergo rapid chemical changes, releasing energy and potentially causing destruction. Oxidizing agents can enhance combustion, increasing fire hazards, while compress gases pose risks when released, potentially leading to explosions or asphyxiation. Environmental hazards concern substances that can negatively impact the environment. This includes aquatic toxicity, where chemicals can harm aquatic life, disrupting ecosystems. Additionally, some substances can deplete the ozone layer, contributing to environmental degradation (OSHA, 2024; UNECE, 2024).

5. Classes of Hazard and Their Applicable Categories

The classification of hazards is essential for understanding potential risks associated with chemicals and materials. The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) provides a structured approach to categorize these hazards into several classes. Tables 1, 2 and 3 serves as a quick reference guide once you have determined the hazard classification of a material. Each class includes one or more associated categories. By identifying the appropriate class and category, you will obtain the necessary information to assign signal words, pictograms, and precautionary statements (OSHA, 2024; UNECE, 2024).

Table 1: Physical Hazards

Hazard Class	Associated Hazard Category
Explosives	Divisions 1.1-1.6 (with 1.1 being the most hazardous, 1. 6 the least hazardous)
Flammable gases	Categories 1 and 2
Flammable aerosols	Categories 1 and 2
Oxidizing gases	Categories 1
Gases under pressure	Four groups include: compressed gas, liquefied gas, dissolved gas and refrigerated liquefied gas
Flammable liquids	Categories 1-4
Flammable solids	Categories 1 and 2
Self-reactive substances	Types A-G
Pyrophoric solids	Category 1
Pyrophoric liquids	Category 1
Self-heating substances	Categories 1 and 2
Substances which in contact with water emit flammable gases	Categories 1-3
Oxidizing liquids	Categories 1-3
Oxidizing solids	Categories 1-3
Organic peroxides	Types A-G
Substances corrosive to metal	Category 1

Table 2: Health Hazards

Hazard Class	Associated Hazard Category
Acute toxicity	Categories 1-4(with 1 being the most dangerous)
Skin Corrosion	Categories 1a, 1b, 1c and 2
Skin irritation	Categories 1a, 1b, 1c and 2
Eye effect	Categories 1a, 2a and 2b
Sensitization (skin or eye)	Category 1a and 1b
Germ cell mutagemicity	Categories 1a,1b and 2
Carcinogenicity	Categories 1a, 1b and 2
Reproductive toxicity	Categories 1a, 1b and 2 and additional category for effect on or all via lactation.

Table 3: Environmental Hazard

Hazard Class	Associated Hazard Category
Acute aquatic toxicity	Categories 1- 3
Chronic aquatic toxicity	Categories 1- 4

NOTE: Category 1, Type A: Extremely Hazardous; Category 2, (Type B And C): Very Hazardous; Category 3, (Type D And E): Moderately Hazardous; Category 4 (Type F And G): Not Very Hazardous

6. Standards For Ensuring Chemical Safety

Chemical safety is required in order prevent chemical hazards in the laboratory or any other place where chemicals are being used. Some types of Documents used to ensure chemical safety in the laboratory are: Material Safety Data Sheet (MSDS) and Globally Harmonized System for Classifying and Labeling Chemicals (GHS) (OSHA, 2024; UNECE, 2024).

6.1 Material Safety Data Sheet (MSDS)

A material safety data sheet (MSDS) Now commonly referred to as a safety data sheet (SDS), is a detailed document that provides critical information about hazardous chemicals and substances. Its purpose is to ensure the safe use, handling, storage and disposal of these materials (OSHA, 2024; UNECE, 2024).

6.1.1 Key Components of MSDS

1. Identification
   - **a)** Product identifier: The name of the chemical.
   - **b)** Manufacturer or distributor details: Name, address, phone number, and emergency contact information.
   - **c)** Recommended use: Describes the intended use of the chemical and any restrictions.
2. Hazard(s) identification
   - a) Classification of the substance of mixture: According to the hazard classification system (e.g. OSHA's Hazard communication standard, GHS).
   - b) Label element: Including symbols (Pictograms), signal words (e.g. danger, warning), Hazard statement and precautionary statement
   - c) Other hazard: Information on hazard not otherwise classified.
3. Composition/information on ingredient
   - a) Substance: Chemical identity, common name, synonyms, CAS number and any impurities.
   - b) Mixture: The identity and concentration of all hazardous component.
4. First aid measures
5. Fire-fighting measures
6. Accidental release measures
7. Handling and storage
8. Exposure controls/ personal protection
9. physical and chemical properties
10. stability and reactivity

11. Toxicological information
12. Ecological information (non-mandatory)
13. Disposal consideration (non-mandatory)
14. Transport information (non-mandatory)
15. Regulatory information (non-mandatory)
16. Other information.

6.2 Globally Harmonized System (GHS)

The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) is an internationally agreed upon system set by the United Nations to standardize the classification and labeling of chemicals. The primary aim of GHS is to ensure that information on the physical hazards and toxicity of chemicals is communicated in a consistent and comprehensive manner, thereby enhancing the protection of human health and the environment during handling, transport and use of these chemicals (OSHA, 2024; UNECE, 2024).

6.2.1 Key Features of GHS

1. **Classification criteria**: GHS establishes criteria for classifying chemicals according to their health, environmental and physical hazard. These criteria cover a broad range of hazard classes. Such as explosives, flammables, carcinogens, and toxins, among others.
2. **Hazard communication elements**
   - **a)** Labels: GHS mandate specific elements that most be included on labels such as: Pictograms, signal words, hazard statement, precautionary statement.
   - **b)** Safety Data sheets (SDS): Detailed document providing comprehensive information about a chemical substance or mixture including its properties, hazard, safe handling and emergency control measures
3. **Standardization and harmonization:** GHS promotes international consistency by providing a unified approach to classifying and labeling chemicals. This helps eliminate confusion and discrepancies that arise from varying national and regional systems. By harmonizing these systems, GHS facilitate international trade and improve regulatory efficiency.
4. **Implementation and Adoption:** While GHS itself is not a regulation, it serves as a guideline that countries and regions can adopt into their regulatory frameworks. Different countries may implement GHS at different paces and with varying degrees of stringency, but the overall goal is to achieve a global standard.

6.2.2 Benefits of GHS

1. Improved safety
2. Regulatory efficiency
3. trade facilitation
4. Environmental protection, etc.

6.3 Personal Protective Equipment (PPE)

Personal protective equipment is essential in minimizing exposure to hazardous substances. Recent studies emphasize the importance of appropriate PPE selection based on the specific chemicals used in a laboratory (ESHA, 2024). It is crucial that laboratories provide adequate PPE training to ensure that all personnel understand how to properly use and maintain protective gear.

6.4 Training and Education

Comprehensive training programs are vital in fostering a culture of safety within laboratories. The implementation of regular training sessions, including emergency response drills and chemical handling procedures, has been shown to reduce the likelihood of accidents (Doke, 2024; Bes and Strzałkowski, 2024). Furthermore, integrating technology such as virtual reality simulations can enhance training effectiveness (Holuša et al., 2023).

7. Conclusion

As laboratories evolve and incorporate more advanced technologies and chemicals, the need for robust safety measures is imperative. By focusing on risk assessment, proper use of PPE, and continuous training, laboratories can significantly reduce the potential for accidents and ensure a safer working environment. Ongoing research and development of new safety protocols will further enhance chemical safety in the modern age.

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