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A Review of Hazards and Precautionary Measures in Science and Technology Laboratories

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Abstract

While working in a science and technology laboratory, hazards are frequently encountered due to the usage of equipment, tools, and apparatus, or chemicals and reagents when conducting an experiment or research. Exposure to hazards occurs via different routes; inhalation, absorption, ingestion, and injection. This could lead to some detrimental health effects. Hazard prevention or minimization is a key factor in safety precaution. Aiming to create hazards and safety awareness, this review article provides the basic types of laboratory hazards (chemical, physical, and biological hazards) and safety measures to adopt as well as emergency response to hazards.

1. Introduction

Experimental and research work play a pivotal role in the development and progress of science and technology, as a handful of inventions and innovations have been made possible through the research carried out in the laboratory [1]. The laboratory setting is a crucial component of scientific research and institutional teaching. It is a hazardous place to learn and work due to the variety of risks it presents. Chemical, biological, and physical hazards are the types of dangers being encountered [2]. Laboratory practical sessions are a necessary requirement for students majoring in science education to enable them to evaluate the theory they have learned in detail. These hands-on lessons help students improve their interest in the field of study [3]. A laboratory is a space that is furnished with various tools, apparatus, and chemicals for carrying out experimentation, research, and diagnostic operations. Different types of laboratories exist across various research centres, industries, colleges, polytechnics and universities. Science and technology laboratories (STLs) include biological, agricultural, medical, physics, electronics, chemistry, geology, mining, engineering, forensic, and research laboratories. Due to the usage of equipment, tools, and apparatus, or chemicals and reagents when conducting an experiment or research, hazards are inherent and unpredictable in STLs. Most of the time, teaching about any phenomenon that calls for scientific research and testing takes place in STLs with chemicals, endangering both the student and the instructor's health. As learners, students should be well versed in laboratory safety and familiar with the symbols used to identify typical laboratory hazards [4]. In academic laboratories across the globe, there have been a number of high-profile incidents over the past ten years that have resulted in serious injuries and fatalities. The requests for reflection and re-examination of the academic discipline's approach to safety research and policy are frequent in the wake of these incidents [5].

Research by Marendaz *et al*. [6] suggests that university laboratories are more hazardous than industrial laboratories due to the fact that universities invest less in safety and have a more permissive safety culture and management than industrial companies. According to the International Labour Organization (ILO), 6,000 employees worldwide die from illnesses and accidents related to their jobs each day. Each occupation has a number of aspects that can affect one's health. Hazards are factors that cause health status disturbances [7]. A laboratory hazard can be defined as anything that has the potential to cause harm or damage to an individual or group of people working in the laboratory. Hazards are encountered on a regular basis when working in any form of science and technology laboratory. Hazards are described by the World Health Organization (WHO) as any potentially harmful phenomenon, substance, human activity, or condition that has the potential to result in loss of life, injury, diseases, property damage, loss of livelihoods and services, social and economic upheaval, or environmental harm [8]. Exposure to hazards in school laboratories is not just exclusive to laboratory staff; students' safety and health might also be affected. While conducting experiments, students directly handle hazardous materials and may also be exposed to a contaminated environment [9].

A hazardous material can be defined as a material that poses a physical or health hazard, which includes physical, chemical, or biological agents[10]. A hazardous working environment can pose danger if not controlled. The hazardous working environment is termed "occupational health hazards" (OHH), which refers to the potential risks to health and safety for those working outside the home [7]. All over the globe, a number of hazards occur in various laboratories, leading to serious injuries or deaths of laboratory users. On December 26, 2018, China Daily reported that an explosion at Beijing Jiaotong University's laboratory resulted in the deaths of three students who were taking part in a landfill leachate experiment [11]. Working with a pyrophoric substance, the research assistant died in a lab fire at the University of California, Los Angeles [12]. While combining carbon dioxide, hydrogen, and oxygen from different cylinders to create a bacterial growth medium, a postdoctoral fellow at the University of Hawaii lost one arm in a lab explosion [2]. There was a case of blindness after a laboratory user performed a chemical experiment at the University of Technology in Taipei City [13]. A research assistant at University of California, Los Angeles (UCLA), was working with a large quantity of tert-butyllithium when the pyrophoric chemical spilled and ignited her clothing, leading to 2nd and ^{3rd} degree burns over 40% of her body, which resulted in her death [5]. Freemantle [14] reported that in Mulhouse (France), there was a blast in the chemistry building of the university, leading to the death of an individual and several people injured.

In Nigeria also, there are numerous instances of laboratory hazards or accidents that happen throughout various academic institutions that have a detrimental impact on the laboratory users. A few of these occurrences are described and analyzed thus:

Incident 1: A laboratory technician was preparing reagents for biochemistry practical when the reagent bottle fell off his hands and the chemical splashed on him. Luckily for him, only his lab coat got damaged by the chemical.

Comment: The laboratory technician was protected from harm because he realized the importance of safety and was wearing a lab coat.

Incident 2: A senior lab staff member working in an anatomy laboratory was working with a corrosive chemical when the chemical spilled on her chest area and she sustained serious injuries on the chest. Unfortunately, years later, she developed breast cancer and died.

Comment: Adequate emergency measures were not taken to address the long-term effects of the hazard caused by the chemical.
Incident 3: A student swallowed reagent while attempting to mouth pipette during a titration practical class, but emergency measures were quickly implemented.
Comment: The student did not use a Pasteur pipette to measure the reagent volume and might not be aware of the dangers or hazards associated with mouth pipetting.
Incident 4: A laboratory scientist was working with a centrifuge to separate samples. He did not let the centrifuge stop after spinning the samples for a set amount of time; instead, he forced it to stop, injuring his hand in the process.
Comment: The laboratory scientist failed to recognize the hazard of touching a moving machine, or it could be a case of a nonchalant attitude towards safety. In all of these incidences, the commonest thing is that the individuals involved fail to take cognizance of hazards and safety measures.

The occurrences of hazards in educational facilities' laboratories have exposed a significant gap or flaw in their safety protocols [15]. Laboratory staff may be exposed to a variety of risks that could harm their health and safety if preventives measures are taken. Student's safety and health may also be at risk from hazard exposure in school laboratories [16-18].

The first step in preventing hazards is to identifying them in the laboratory [19]. Maintaining safe conditions in laboratory environments requires the ability to identify hazards and thebasic information necessary to evaluate the hazards involved with a procedure or laboratory op eration [20].

Due to the numerous hazards associated with working in STLs, every laboratory user must strictly adhere to specific principles and safety instructions in order to prevent or limit exposure to the eminent hazards.

Ensuring safety in the laboratory requires the application of four basic principles, which include: Recognizing the hazards; Assessing hazards risks; Minimizing the risks of the hazards; and preparing for emergencies. These four basic principles are abbreviated as RAMP. The active use of these principles is necessary to ensure the safety of all laboratory users [21]. Hazard recognition can start by reading and understanding information from safety data sheets (SDS), chemical labels, and other sources of reference. At an advanced level, more details of hazards should be explained so that the laboratory users, especially the students to be able to identify hazards during experiments. Once hazards are identified, laboratory safety calls for an assessment of the risk from possible exposure of hazard. Experiments should be planned to reduce hazards based on a risk assessment. Reacting promptly to emergencies, every laboratory user must learn what actions to take in different scenarios and be ready to respond appropriately. These actions might entail performing experiments in a fume cupboard with a protective shield, donning safety goggles and gloves, boots and so on. Safety equipment, including showers, eye washes, fire extinguishers, and spill kits, must be clearly labeled and accessible to all laboratory workers. Every lab user should have access to emergency phone numbers, alarms, and escape routes [19, 21, 22, 23, 24].

A study by Fadeyi *et al.* [25] showed that there is a deficit in the awareness of safety precautions among laboratory users. The study also demonstrated that the attitude and application of safety regulations among laboratory personnel were inadequate. According to Ozdemir et al. [26] there aren't many studies in the occupational health and safety (OHS) hazard management literature that address laboratories using various hazard assessment techniques. A laboratory hazard prevention system will be possible with the help of a pre-hazards risk analysis approach and enactment strategy [27].

In a bid to prevent eminent hazards encountered in our science and technology laboratories and ensure safety, this review article aims to provide a useful summary of the various hazards in the laboratory, as well as possible precautionary measures to take, and a call for the laboratory users to be re-oriented towards hazards and safety. This would not just create hazard and safety awareness but would also help the laboratory users, whether professional or not, easily identify potential hazards. Familiarization with hazards and safety measures by following general safety precautions like wearing the proper protective gear and prioritizing regular safety would enable all laboratory users (students, laboratory staff, teachers, and researchers) to work safely, efficiently, and confidently in the laboratory.

2. Classification of Laboratory Hazards

There are many dangers or risks that surround laboratory users. Such hazards can come from toxic chemicals, poisonous fumes, gas leakages, broken glass wares, electrical wires, machines, and even unsafe laboratory premises. With a full knowledge or understanding of the risks and health hazards attached to working in a scientific and technological laboratory, the laboratory users would be able to work effectively with due application of precautionary measures. Working with equipment and chemicals in the laboratory can lead to some hazardous situations ranging from low-risk to very dangerous situations. If these hazards are not identified and regulated, they can expose the laboratory users to sickness or injuries and also cause damage to laboratory properties and the surroundings. Laboratory hazards are classified into three (3) main categories: chemical hazards, physical hazards, and biological hazards [28, 29, 30, 35].

2.1 Chemical Hazard

A chemical hazard is any substance, whether liquid, gaseous, or solid, that has the potential to harm an individual or group of people working in a laboratory. Once chemicals are absorbed into the body, three processes are imminent: metabolism, storage, and excretion [31]. Table 1 describes some different types of chemical hazards and their examples.

Table1: Types of Chemical Hazards

Chemical Hazards	Effects	Examples
Irritants	Irritants are chemicals that usually cause reversible inflammation (redness, rashes) in the area of contact, such as skin, eyes, and respiratory airways. Even though symptoms are mostly transient, they might occasionally have a long-lasting impact on other people.	Nitric acid, Sulfuric acid, Sodium hydroxide, Formaldehyde, Ammonia.
Corrosives	Corrosive chemicals causes' severe skin damage (burns) that is irreversible to living tissue. When corrosives touches a non-biological materials (metal, wood), they can destroy the material.	Amines, Glycolic acid, Imidazole, Sulfuric ,acid, Bromine, Hydrochloric acid, Sulfuric acid, Phosphoric acid, Trichloroacetic acid, Glacial acetic acid, Nitric acid, Sodium hydroxide, Potassium hydroxide, Hydrogen peroxide.
Reactive/Flammable Chemicals	These are chemicals that, when exposed to air or other substances, can result in fire outbreaks or explosions.	Picric, Perchloric acid, Acetone, diethyl ether, Sodium azide, Xylene, Toluene, Methanol, Ethanol, Acetic anhydride, Glacial acetic acid.
Allergens/Sensitizers	Sensitizers (Allergens) are substances that can cause an individual to develop an allergic reaction by the immune system in	Formaldehyde, Nitrogen dioxide, Sulfur dioxide, Diazomethane, chromium,

	healthy tissues after frequent exposure to the substance. Chemical allergies include skin sensitization causing allergic contact dermatitis and sensitization to the respiratory tract causing rhinitis and asthma.	Nickel, Phenol derivatives, Benzylic and Allylic halides, Formalin, Isocyanates.
Toxic Chemicals	Toxic chemical causes serious effects ranging from acute when breathed in, swallowed, or absorbed through the skin.	Potassium cyanide, Mercury, Sodium nitroprusside, Formalin, Diphenylamine, Barium chloride, Thiosemicarbazide, Chloroform, Barbiturates sodium azide.
Asphyxiants	Asphyxiants are gaseous chemicals that may result in breathing difficulties, unconsciousness, or even asphyxia death. Asphyxiants prevent the body from absorbing and transporting oxygen.	Hydrogen cyanide, Carbon monoxide, Helium, Nitrogen, Argon, Methane, propane, carbon dioxide.
Mutagens	Mutagens are chemicals that can cause irreversible damage or mutations to the deoxyribonucleic acid (DNA).	Diethylenenitrosamine, Diethylenesulphonate, Nitrous acid, Maleic hydrazine.
Teratogens	Teratogens are chemicals that cause birth defects. They interfere with fetus development during pregnancy.	Alcohol, Lead, Bisphenol A, Thalidomide, Mercury.
Carcinogens	These are chemicals that cause various forms of cancer (lung cancer, liver cancer, breast cancer) etc.	Mercury, lead,Vinyl chloride, Benzene, Carbon tetrachloride, Asbestos, Nickel, Cadmium.

Adopted and modified from [19, 28, 32, 33, 34].

2.2 Physical hazards

Physical hazards are those hazards that occur in the laboratory environment when one come into contact with objects or equipment in the laboratory. The most obvious ones include cuts from sharp edges, broken glasses, slips and falls from working in moist environments, and ergonomic risks of lifting, pulling, and pushing duties. Electrical, mechanical, acoustic, or thermal dangers are additional physical hazards that go unrecognized frequently. Neglecting these could have detrimental effects. Physical hazards include electrical, heat, cold, mechanical, noise, fire, explosions, vibration, sound, and radiation hazards (nonionizing radiation, ionizing radiation) [29,35,36]. Table 2 provides a highlight of various types of physical hazards.

Table 2: Types of Physical Hazards

Physical Hazards	Effects	Examples
Heat hazards	Heat hazards are caused by heating devices; they create fire and injury hazards. Burns to the hand or fingers are possible.	The rapid heating by Bunsen burner, hot plate etc.
Sound Hazard	Sound pollution can cause eardrum perforation and damage to inner ear hair cells, resulting in temporary or permanent hearing loss.	Jackhammers, sounds from moving machines.
Mechanical Hazard	A mechanical hazard occurs when working with machines or instruments with rotatory parts. The rotating parts can hold loose or flying clothing, hair, or hands there by causing injuries. The hands, eyes, head, and limbs might be injured as a result of careless use of tools in poor condition.	Cutting Tools (scalpels, razor blades), Magnets, Glass wares, Centrifuge, Shakers, Autoclave, Projectile launchers.
Electrical Hazard	This type of physical hazard occurs as a result of using faulty electrical circuits, faulty wiring, or improper installation of equipment. This could result in electrical shock and a fire outbreak. Also prolong the use of heavy-duty and light-weight equipment can cause equipment damage, overheating, and consequently fire outbreak.	Faulty Wiring, Equipment damage and overheating, Electrical equipment near water, High Voltage equipment, Electrical equipment near flammable liquids.

Radiation hazard	Radiation hazard (ionizing and non-ionizing radiation) is caused by the decay of radioactive materials such as uranium and thorium isotopes, as well as emissions from electronic equipment or other sources. Radiation has the potential to damage human tissue. It may have an impact on bodily cells, raising the possibility of damaging genetic alterations, cancer, or, at worst, severe tissue damage that results in death. Additionally, prolonged exposure to UV rays can accelerate the aging process of the skin.	UV, infrared and visible radiation from lasers and lamps. Ionizing Radiation (alpha particles, beta particles, and gamma rays). Non-ionizing radiation (sound waves, visible light rays, ultraviolet rays (e.g., stethoscopes, microwaves, fluorescent lamps, ultraviolet bulbs, welders, and gas discharge tubes).
Sharp Objects/Broken glasses	Sharp objects and broken glass wares can result in deep cuts leading to profuse bleeding. The object may be contaminated with pathogens, resulting in severe infections.	Glass shards, Razors, Scalpels, Knives, Wire cutters, Box cutters, and other sharp edge tools.
Slips and Falls	Slippery and falling is caused by an unsafe laboratory environment, leading to serious injury to the lab user.	Wet floor, Damaged floor, Use of Slippery cleaning substances, congested laboratory room, Laboratory exit routes are blocked by equipment and storage boxes.

Adopted and Modified from [19, 29, 32, 37, 38, 39].

2.3 Biological hazards

Biological hazards are hazards caused by infectious agents called pathogens, such as viruses, bacteria, fungi, parasites, etc., which can occur as a result of handling biological samples such as urine, blood, sputum, stool, etc. These hazards can be found in every laboratory that handles tissues, physiological fluids, primary cell lines, or immortalized cell lines derived from human or animal source, in addition to clinical and infectious disease research laboratories [40]. Healthcare workers in medical laboratories are exposed to numerous biological hazards [41]. The World Health Organization (WHO) classifies laboratory biological hazards (pathogenic microorganisms) into four risk groups: Risk group 1, Risk group 2, Risk group 3, and Risk group 4 [42]. Table 3 gives a description of various types of biological hazards.

Table 3: Types of Biological Hazards

Biological hazards	**Effects**	**Examples**
Risk Group 1	The microorganisms in this category present a minimal danger to laboratory users. They are unlikely to cause disease.	Yeasts, Food spoilage bacteria and Common moulds.
Risk Group 2	These groups of microorganisms provide a moderate risk to laboratory users. They can cause serious human disease.	*Streptococci*, *Staphylococci*, *enterobacteria* (with the exception of *Salmonella typhi*), Blastomyces, Toxoplasma, Leishmania, Adenoviruses, Polioviruses, Coxsackieviruses, Hepatitis viruses, Clostridia and Vibrios.
Risk Group 3	This set of microorganisms offers a high danger to laboratory users. For such pathogens in this group, there exist potent vaccinations and therapy options.	*Salmonella typhi*, *Brucella*, *Mycobacterium tuberculosis*, *Francisella*, *Pasteurella pestis*, Chlamydia, Rickettsiae,*Coccidioides*, *Histoplasma*, HIV viruses.
Risk Group 4	The pathogens in group 4 pose a significant risk to community members and laboratory users. They pose a threat, have the potential to spread dangerous diseases, and are easily passed from person to person. Effective preventive and therapeutic methods are not available	Ebola virus, Lassa fever virus, encephalitis viruses, SARS virus.

Adopted and modified from [29, 43].

3. Laboratory Hazard Exposure Route

Exposure to laboratory hazards can occur through the following routes: inhalation, absorption, ingestion, and injection. The exposure to laboratory hazards is not only limited to the laboratory user but also the general public by the same aforementioned routes, when members of the general public come into contact with hazardous discarded waste, laboratory effluent materials, and through the pathogens escaping during the transport of infected specimens from one location to another [35, 44].

3.1 Inhalation

Hazardous materials can enter the body through the nasal route by inhaling volatile liquid vapors. Toxic gases, both volatile and non-volatile, used to create mists and sprays. Solid chemicals in the form of dust, fibers, and particles can also be inhaled [45]. Inhalation of hazardous materials causes tissue poisoning and damage when absorbed through the mouth, throat, and lungs' mucous membranes. Inhalation of hazardous materials travel through the lungs' capillaries and are then transported to circulatory system, where rapid absorption occurs. Human lungs are the primary region for the absorption of most hazardous materials due to their large surface area. Solubility and reactivity are the most important factors influencing the absorption of inhaled toxic materials by the fluid lining of the respiratory tract and tissues [45, 46].

3.2 Absorption

Laboratory users can be exposed to hazardous materials by absorption through the dermal route, ophthalmic route, mucous membrane, and eyes. This may occur through the splashing or spilling of chemicals on the skin, or chemical vapors and gases entering the eyes, thereby posing danger to the affected areas of the body. Infectious microorganisms can be introduced to the body through open uncovered skin wounds, needle stick injuries due to careless handling of needles and lancets, or injury from broken contaminated glassware [29]. Injury from chemical contact with the skin occurs frequently in laboratories. Many chemicals cause skin irritation and allergic skin reactions, which directly harm the skin. Burns from corrosive chemicals are very severe. Many chemicals are absorbed via the skin in sufficient quantities to generate systemic toxicity in addition to local hazardous effects. The hair follicles, sebaceous glands, sweat glands, and cuts or abrasions of the outer layer of the skin are all entry points for chemicals into the body. Chemical concentration, reactivity, and their solubility in fat and water are some of the variables that affect how readily chemicals are absorbed through the skin. The state of the skin, the area of the body that is exposed, and the length of contact are all factors in absorption. The amount of chemical absorption is influenced by variations in skin structure. Generally speaking, toxicants penetrate thin skin far more readily than thick skin, such as the scrotum and palms, respectively. While an acid burn on the skin is immediately felt, an alkaline burn takes longer to feel and causes more extensive damage than an acid burn. Chemical penetration into injured skin increases. The skin is damaged and becomes more permeable when exposed to acids and alkalis. The eyes are also a route of fast absorption of a lot of chemicals because they have many blood vessels [29,46].

3.3 Ingestion

Hazardous materials get into the body system through the oral route. Direct ingestion of poisonous substances and infectious microbes may occur when mouth pipetting, either from aspiration or from the pipettes' mouth ends that may have come into contact with infected hands. Additionally, finger-to-mouth infection is also possible from consuming food in the laboratory. Food contamination is possible via contact with infectious material, such as in a refrigerator, benches, fingers, or infected substances [29]. Hazardous materials that get into the gastrointestinal tract (GIT) are absorbed into the blood vessels and produce systemic harm even though some of the chemicals swallowed cause irritation to the GIT and also destroy the GIT tissues. Absorption of hazardous materials takes place in the mouth and along the entire GIT and this is dependent on factors like the physical properties of the chemical and the rate at which it dissolves [31,46].

3.4 Injection

In the laboratory, accidental mechanical injuries from sharp materials like glass or metal that have been contaminated, or syringes used to handle chemicals or used in the collection of biological specimens, are more common than accidental injection exposure to hazardous materials. The intravenous form of delivery is particularly risky since it bypasses absorption by introducing the poison straight into the bloodstream [46]. As the hazardous materials circulate in the blood and are deposited in the target organs, effects may then manifest [31].

4. Laboratory Hazards and Safety Precautionary Measures

Aldandani [47] defines safety as a set of accepted practices and techniques to guarantee the protection of people's lives and properties before an incident happens. Safety also means the avoidance of damage and losses that could result from not exercising sufficient care at work [48]. The prevention of hazards in the laboratory is a set of measures, which include the application of safety awareness standards, proper training, the use of personal protective equipment (PPE), the use of less hazardous materials whenever possible, and foretelling the direction of events while working [49]. McGovern et al. [50] conducted research on laboratory professionals' compliance with universal precautions and concluded that there was relatively poor compliance with universal precautions regarding PPE and occupational health and safety.

Hazard prevention or minimization in laboratories is a shared responsibility that calls on the laboratory users to put forth effort. Hazards usually result from negligence, lack of rational thinking, and inability to follow instructions during experimentation [51]. If adequate precautions are not taken, working in a laboratory can expose laboratory users to a variety of hazards that could endanger their health and safety [9]. Basic information regarding identifying and comprehending common hazards should be included in safety education [21].

To prevent hazards and accidents in the laboratory setting, safety regulations have been established to minimize the hazards. Laboratory users must operate responsibly and be mindful that careless behavior may have long-term consequences. Hazards can be reduced to a significant extent by personal safety practices [10]. Tables 4, 5 and 6 provide a summary of hazards encountered in STLs and the necessary precautionary measures to be adopted.

Table 4: Chemical Hazards and Precautionary Measures

Chemical Hazards	**Precautionary Measures**
Irritating Chemicals	-Avoid touching chemicals with your bare hands. -Wash your hands immediately after handling chemicals. -Wear hand gloves, a face shield and other appropriate PPE. -Irritants should be labeled appropriately. -Avoid cleaning the skin with solvents. -Do not mouth-pipette any chemical or reagent. - Use a handkerchief to cover the container's cap and neck when opening a container that emits an obnoxious vapor. -Employ the use of proper engineering controls such as fume cupboards when working with irritating chemicals. - High irritants should be used and stored in regions with sufficient ventilation.

Toxic/Corrosive Chemicals	-Handle toxic corrosive chemicals with great care to avoid splashing. - Always include a clear label indicating the contents on every bottle. -Wear a face shield, chemical-resistant gloves, and a laboratory coat for protection against toxic/ corrosive chemicals. -Keep chemical bottles tightly closed. - Before opening a container of corrosive and toxic chemical, cover the bottle's cap and neck with a piece of cloth. -Do not add water to acid, but always add acid to water when diluting concentrated acid.
Reactive/Flammable Chemicals	-Keep reactive or flammable chemicals away from sunlight. -Keep reactive flammable chemicals away from sources of ignition. -Avoid smoking in the laboratory. Flammable/Reactive chemicals should be kept at ground level in a fireproof metal box in the laboratory. -Use flammable chemicals under the fume hood. -Never heat flammable liquids directly with a flame. Use a hot water bath to heat them. -Explosive chemicals like picric acid should be stored under water. - Keep perchloric acid in the fume cupboard.. - Picric acid needs to be kept in a water-filled container that is securely closed with a cork or rubber stopper. - Ether should be stored in dark or brown bottles out of the sun. -Cylinders carrying inflammable gases be kept outside the laboratory.
Asphyxiants	-Use PPE to minimize exposure. -Asphyxiants should be kept and used in well-ventilated settings.. - Avoid using small spaces like closets to prevent oxygen from being displaced.
Allergens and Sensitizers	-Use appropriate PPE to avoid exposure to allergens and sensitizers. -Work involving sensitizers must be done only in a designated area of the lab (lab work bench/fume hood). -The designated work area must be marked with warning signs that identify the chemical.
Carcinogens/Mutagens/Teratogens	-All these hazardous materials must be handled with great care. -They must be labeled appropriately for easy identification. -Bottles containing these hazardous materials should be in plastic-locked, odor-proof, airtight containers for additional safety. -Symbols, hazard statements, and pictograms should be glued to the carcinogenic, mutagenic, and teratogenic containers. -Appropriate PPE should be worn when handling these materials. -Carcinogens, mutagens, and teratogens should be handled in a well-ventilated atmosphere to minimize the risk of inhaling the substances.

Adopted and modified from [24, 26, 29, 31, 32, 33, 38, 52].

Table 5: Physical Hazards and Precautionary Measures

Physical Hazards	Precautionary Measures
Heat Hazard	-Before storing any heated equipment (Bunsen burner, hot plate), ensure it is cool. -Always put on goggles and a lab coat when using a burner or hot plate to safeguard the eyes and clothing. -Handle heating equipment with temperature-resistant gloves but never with bare hands. -Utilize tongs or test tube holders while handling hot tools and containers. -Heating devices should be turned off when they are not in use. -Ensure all heating devices and gas valves are turned off before leaving the laboratory. -Keep heads, hands, hair, and clothing away from the flame or heating area. Use a spark lighter only to ignite gas burners. -For heating solutions, only borosilicate containers should be used. (Kimax, Pyrax, etc.). -Flammable or reactive substances should be kept away from heating devices or other ignition sources. -Flammable or reactive substances should be kept away from heating devices or other ignition sources.
Mechanical Hazard	-Safety can be maintained when laboratory equipment is properly taken care of. -All laboratory equipment should be turned off before leaving the premises. -Students must only use equipment with lab technician supervision. - Ensure that any device attached to a rotor is tightly fixed before utilizing it. -Ensure that guards, lids, or coverings are used to cover the shafts, belts, and pulleys of rotating machines. - When using exposed, rapidly moving parts for demonstration, wear eye protection. -Use cotton gloves for a better grip when working with heavy machinery. -Avoid the use of tools in poor working conditions. -Always check tools for defects or damage. -Handle cutting tools with extreme care. - Do not use cracked glass wares for experiments as they are susceptible to breakage. -Dispose of broken glass in an appropriate waste bin. -Avoid using projectiles with sharp edges.
Sound Hazards	-Avoid prolonged exposure to high levels of sound. -Use PPE for ear protection against noise levels greater than 85 decibels. -Monitor sound-generating equipment to ensure they do not exceed the normal sound limit.
Electrical Hazards	-Ensure that the external wiring of equipment is checked -before use. -Power cords should never be disconnected by pulling on the wire; instead, hold the plug end. -Always operate machinery the way the manufacturer intended. -Ensure equipment water sources (sink) are properly insulated and grounded. -Be cautious to keep electrical equipment away from flammable liquids and in a well-ventilated environment. -Always be sure a circuit has one source of resistance or more (bulb, electric motor). - Make sure to handle high-voltage equipment carefully. -Before using electrical equipment in the classroom, make sure it is in good working order.
Radiation Hazards	-Minimize skin exposure to radiation, use PPE. -Never stare directly at a UV light source without wearing protective eyewear. -Students should use lasers with close supervision. - Use lasers in a well-lit space to make the eye pupils tiny.

	-Adjust laser placement to prevent direct or indirect eye contact with the beam. Use radioactive materials with millicuries-measured emissions. - Limit the amount of time of exposure to radiation. -Utilize a Geiger counter to measure radiation levels over the course of exposure. -Stay away from radiation source as possible.
Slips and Falls	-Ensure that the laboratory floor is kept tidy. -Clean spills of chemical spills on the floor immediately to avoid a fall. -Avoid wet laboratory floors. -Ensure that the laboratory corridors, fire doors, and exit routes are not obstructed. - Dress appropriately for the laboratory; dangling jewelry, long hairs, and baggy clothing should be avoided. -Wear a non-slippery shoe in the laboratory. -Arrange the workstation so that equipment and materials are easily accessible.

Adopted and modified from [1, 26, 37, 39, 53, 54, 55].

Table 6: Biological Hazards and Precautionary Measures

Biological Hazards	Precautionary Measures
	-Always wear appropriate PPE while handling infectious material. -Every specimen should be treated as infectious. -Always use bio-safety cabinets when handling infectious materials. Always put on hand gloves before handling any biological material. -Cover open wounds with a water-resistant bandage before putting on gloves. -Handle sharp-edged instruments with great care. -Disinfect all sharp edge tools before and after work. -Make use of a bio-hazard bag for disposing infectious material. - Before and after work, thoroughly clean the workbench and the tools with 70% alcohol. -Always transport infectious material in a trolley. - Ensure that all contaminated material is autoclaved before being disposed of or incinerated. - Bio-safety cabinet should be disinfected daily with 70% alcohol. - The refrigerator should be defrosted once every two months. - The bio-safety cabinet should be fumigated on a monthly basis. -Clean the incubator twice in a month with 70% alcohol.

Adopted and modified from [29, 38, 56, 57].

5. Emergency Response to Hazards

When accidents occur in the laboratory, there should never be a panic. As soon as possible, alarm should be raised, and necessary actions must be taken to avert the hazard. The laboratory premises should be evacuated if necessary to limit further harm. Laboratory users should have knowledge on what to do in different circumstances and be ready to act promptly. Showers, eyewash stations, fire extinguishers, sand spill response kits must all be properly marked and available in all laboratory facilities [23, 56].

5.1 Laboratory First Aid

First aid in a laboratory is the prompt assistance provided to a victim of injury. Knowing what to do right away in the event of an accident can lessen the pain and effects of catastrophic accidents. For instance, first aid in some circumstances, such as the management of bleeding, can save lives. It can also stop a wounded person from getting worse, for instance, covering and treating injuries, positioning a victim in an optimal position, providing support, and calling for help right away. Therefore, laboratory employees should obtain fundamental practical first aid training, paying special attention to the kinds of hazards that could arise in a laboratory [38].

5.2 Fire Outbreak Emergency Measures

Fire outbreaks can be caused by a lot of reasons, including overloading or overheating of equipment or reactive or flammable chemicals. Emergency measures to take during a fire hazard include the following:

- Electric and gas connections must be immediately turned off.
- Fire extinguishers should be used to fight and tackle fire outbreaks.
- Buckets of water to put out paper and wood fires. However, electrical fires or fires brought on by flammable chemicals must never be put out with water.
- Buckets of dry sand to curtail and put out a free-flowing liquid fire by smothering the flames.
- The fire brigade must be called in the event of large flames [26, 38].

5.3 Emergency Measures for Accidental Swallowing of Chemicals

- When an acidic solution is swallowed, it is advised to promptly out spit the solution and rinse the mouth with water and seek medical care immediately.
- To neutralize the acid, antidotes such milk of magnesia, that is 8% magnesium hydroxide or egg white diluted in water can be taken orally.
- Rinse the mouth immediately if an alkaline solution is swallowed .To counteract the alkali, antidotes such lemon juice or 5% acetic acid can be administered orally. About 3 to 4 cups of water should also be consumed. And seek medical attention.
- It is important to note that vomiting should not be encourage when acid or alkali solution has been swallowed [56].

5.4 Emergency Measures to Chemical Spills/Hazardous Materials

- Treat all spills as a potential health hazard and report them immediately.
- If a chemical spills into the eyes, flush the eyes with lots of water for about 15 minutes and go to the hospital right away to get help.
- Immediately change out of all contaminated clothing while taking a shower if chemicals have been spilled over a sizable portion of the body using a moderate detergent or soap and water.
- If you have an acid/base spill kit, neutralize acids and bases. When neutralizing, keep splashing and contact to a minimum.
- When infectious material spilt, cover the contaminated materials with paper towels soaked in 1% hypochlorite solution and allow to stay for about 10 minutes then clean up the region and dispose the towel in the bio-hazard waste bag. Disinfect the area once more, and wash hands after clean up. Remove contaminated items and accessories [56-59].

5.5 Emergency Measures for Inhalation of Hazardous Materials

In the case of inhalation of toxic substances, take the individual outside to receive fresh air and seek medical care right away. In some cases, emergency respirators may be used.

5.6 Emergency Treatment for Bleeding

- When a cut injury occurs, wash immediately with soap and water.
- Apply pressure on the injury using a piece of cotton wool.
- Use an iodine tincture to disinfect the area.
- Cover the wound with water-resistant clothing.
- If the injury has been caused by contaminated glassware or needle, apply pressure on the injury site to bleed for about 2 minutes.

- Also seek medical care [38].

5.7 Emergency Measures for Burns

When burns occur as a result of heat, immerse the affected region in cold water or apply a cold water-soaked pad to the affected area for about 10 minutes before dressing the injury. When chemical burns occur on the skin, immediately wash with lots of water and neutralize. If the acid burns, use sodium bicarbonate to neutralize it; otherwise, seek medical care. If it is an alkali burn, use powdered boric acid to neutralize it. Also seek medical care for severe burns [38].

6.0 A Call for Action

All parties involved in laboratory operations across various research centres, institutions, and industries, including administrators and researchers, should be accountable for safety as a fundamental notion. Priority should be given to safety by all stakeholders to laboratory practices as this may inspire students' awareness of the importance of safety and influence how they handle the hazards encountered in the laboratory.

It is of paramount importance to create a departmental safety committee in all laboratories to tirelessly ensure that safety rules and regulations and standard operating procedures (SOP) are followed.

Re-training of laboratory personnel is crucial to improve their safety knowledge and their practices regarding the prevention of laboratory hazards. This can be achieved by the establishment of laboratory safety seminars or workshops to create more safety awareness that would help reduce the frequency and seriousness of incidents in the laboratories, guarantying the safety and well-being of laboratory users, and secure the protection of the facilities, equipment, and laboratories.

Laboratory hazard and safety courses should not only be limited to those studying laboratory related courses like science laboratory technology, medical laboratory science, etc., but should be introduced to the curriculum of other fields of study, specifically for those studying science and technology related courses .

Making a safety presentation or demonstration to students is crucial to helping them become familiar with standard safety practices and teaching them how to respond to major or frequently occurring hazard situations in the laboratory.

Every laboratory user (staff, students, and researchers) has a fundamental duty to eliminate potential hazards and work safely. It is therefore crucial to emphasize that understanding how to do laboratory work properly is just as vital as following laws and regulations. As a result, students must consider their responsibility for safety when carrying out their tasks.

7.0 Conclusion

Laboratory hazards are caused by unsafe laboratory practices such as failure to use personal protective equipment (safety boots, protective goggles, coat, face field, nose mask etc.), improper dressing for the laboratory, untidy working environment, congested laboratory room and making use of faulty equipment. Laboratory hazards are also caused by the nonchalant attitude of lab users toward safety and a lack of knowledge and skill.

Preventing eminent hazards in the laboratory requires a set of precautionary measures, which include the application of safety awareness standards, proper training, the use of personal protective equipment, working with less hazardous- materials whenever possible, and foretelling the direction of events while working in the laboratory as well as preparing for emergencies to curb hazards.

To guarantee the safety of laboratory users and the laboratory facilities, hazards must be identified and proper precautionary measures be enforced by all stakeholders.

References

[1] S.K. Shrivastava, Safety Procedures in Science Laboratory, *International Journal of Engineering and Scientific Research*. 5 (2017) 54–64.
[2] Y. Yang, G. Reniers, G. Chen, F. Goerlandt, A bibliometric review of laborator safety in universities, *Safety Sci*. 120(2019). https://doi.org/10.1016/j.ssci.2019.06.022
[3] N.K.J. Ayana U.C. Walters, W. Lawrence, Chemical laboratory safety awareness, attitudes and practices of tertiary students, *Saf. Sci*. 96 (2017) 161–171. https://doi.org/10.1016/j.ssci.2017.03.017.
[4] D. Wangdi, S. Tshomo, Investigating Chemical Laboratory Safety Based on Students' Ability to Recognise the Common Laboratory Hazard Symbols, *Educational Innovation and Practice EIP Spring* (2016) 41–52.
[5] A.D. Ménard, J.F. Trant, A review and critique of academic lab safety research, *Nat. Chem.* 12 (2020) 17–25. https://doi.org/10.1038/s41557-019-0375-x.
[6] J.L. Marendaz, J.C. Suard, T. Meyer, A systematic tool for Assessment and Classification of Hazard in Laboratories (ACHiL). *Saf. Sci*. 53(2013) 168–176.
[7] D. Rajan, Occupational Hazards: A Comparative Study among Medical Laboratory Technicians, *Siddhant- A J. Decis. Mak*. 14 (2014) 189. https://doi.org/10.5958/2231-0657.2014.00522.9.
[8] World Health Organization, *Women and Health Taday's Evidence Tomorrow's Agenda*. Switzerland: WHO Press (2009).
[9] L.S. Marin, F.O. Muñoz-Osuna, K.L. Arvayo-Mata, C.R. Álvarez-Chávez, Chemistry laboratory safety climate survey (CLASS): A tool for measuring students' perceptions of safety, *J. Chem. Heal. Saf.* 26 (2019) 3–11. https://doi.org/10.1016/j.jchas.2019.01.001.
[10] A. Abd Elrazek Mahmoud, S. Said Sabry, Safety Training Program for Clinical Laboratory Workers Regarding Prevention of Occupational Hazards, *Am. J. Nurs. Res.* 7, (2019) 116–127.
[11] Chinadaily, Lab Blast Kills Three Students in Beijing University. http://www.chinadaily.com.cn/a/201812/26/WS5c233187a310d91214051076.html (Accessed September 8, 2022).
[12] J.H, Gibson, I. Schröder, N.L. Wayne, A research university's rapid response to a fatal chemistry accident: Safety changes and outcomes, *Journal of Chemical Health and Safety* 21(4) (2014) 18– 26. doi:10.1016/j.jchas.2014.01.003.
[13] T. C. Wu, C.W. Liu, M.C. Lu, Safety climate in university and college laboratories: impact of organizational and individual factors, *Journal of Safety Research*, 38(2007) 91–102.
[14] M. Freemantle, Blast kills French chemistry professor. *Chemical and Engineering News* 84 (14) (2006) 13.
[15] American Chemical Society. Creating safety cultures in academic institutions: a report of the safety culture task force of the ACS committee on chemical safety. (2012).
[16] R. Pells, Bristol University evacuated after student accidentally makes explo-sive chemical used in terror attacks. Independent, (2017) February 16, 2017.
[17] B. Clerkin, Princeton University labora- tory accident sends three people to the hospital. Times of Trenton,(2012) May 23, 2012.
[18] B. Wolford, V. Yee, BC student hurt in lab accident. Boston.com, 2011 June 26, 2011.
[19] S. Asiry, L-C. Ang, Laboratory Safety: Chemical and Physical Hazards; In: W.H. Yong, Biobanking: Methods and Protocols, Methods in Molecular Biology Volume 1897 © Springer Science+Business Media, LLC, part of Springer Nature (2019) (Chapter 21),pp 243–252. doi:10.1007/978-1-4939-8935-5_21.
[20] C.R. Álvarez-Chávez, L.S. Marín, K. Perez-Gamez, M. Portell, L. Velazquez, F. Munoz-Osuna, Assessing College Students' Risk Perceptions of Hazards in Chemistry Laboratories, *J. Chem. Educ.* 96 (2019) 2120–2131. https://doi.org/10.1021/acs.jchemed.8b00891.
[21] R.H. Hill, Recognizing and understanding hazards — The key first step to safety, *J. Chem. Heal. Saf.* 26 (2019) 5–10. https://doi.org/10.1016/j.jchas.2018.11.005.
[22] I. Schröder, E. Czornyj, M.B. Blayney, N.L. Wayne, C.A. Merlic, Proceedings of the 2018 Laboratory Safety Workshop: Hazard and Risk Management in the Laboratory, *J.Chem. Heal. Saf.* 27 (2020) 96–104. https://doi.org/10.1021/acs.chas.0c00012.
[23] Committee on Professional Training - ACS (2017) 'Committee on Professional Training Laboratory Safety', *American Chemical Society*, pp. 1–3.
[24] L.A.C. Burnett, G. Lunn, R. Coico, Biosafety: Guidelines for working with pathogenic and infectious microorganisms, *Curr. Protoc. Microbiol.* (2009) 1–14. https://doi.org/10.1002/9780471729259.mc01a01s13.
[25] A. Fadeyi, A. Fowotade, M.O. Abiodun, A.K. Jimoh, C. Nwabuisi, O.O. Desalu, Awareness and practice of safety precautions among healthcare workers in the laboratories of two public health facilities in Nigeria. *Niger. Postgrad. Med. J.* 18(2011) 141–146.
[26] Y. Ozdemir, M. Gul, E. Celik, Assessment of occupational hazards and associated risks in fuzzy environment: A case study of a university chemical laboratory, *Hum. Ecol. Risk Assess.* 23 (2017) 895–924. https://doi.org/10.1080/10807039.2017.1292844.
[27] N.J. Cho, Y.G. Ji, A Study on Application Method & System Introduction of Laboratory Pre-hazards Risk Analysis, *J. Korean Soc. Saf.* 31 (2016) 126–135. https://doi.org/10.14346/jkosos.2016.31.4.126.
[28] I. Kimber, D. A. Basketter, R. J. Dearman, Chemical allergens What are the issues?, *Toxicology* 268(3) (2010)., 139–142.

doi:10.1016/j.tox.2009.07.015 268 (2010) 139–142

[29] M. Cheesbrough, District Laboratory Practice in Tropical Countries, Part 1:(2005)pp50-99.
[30] E. B. F. Galante, D. M. B. Costa, T. C. C. França, R. S.Viaro, Risk assessment in a chemical laboratory, *Occupational Safety and Hygiene* (2016) IV, 105.
[31] UNL Environmental Health and Safety, *Toxicology and Exposure Guidelines*, (2002) .
[32] Health and safety in the science classroom : kindergarten to grade 12, *Alberta Education* (2019) pp 61-120.
[33] A.T. Karlberg, M.A. Bergström, A. Börje, K. Luthman, J.L.G. Nilsson, Allergic contact dermatitis - Formation, structural requirements, and reactivity of skin sensitizers, *Chem. Res. Toxicol.* 21 (2008) 53–69. https://doi.org/10.1021/tx7002239.

[34] F. Management, Perchloric Acid Exposure , Signs and Symptoms and Chemical Properties Personal Protective Equipment (PPE) & Personnel Monitoring Labeling & Storage Engineering Controls , Equipment & Materials, (2019) 1–3.
[35] V. Mcleod, P. Balston, Laboratory Hazards and Risks, An overview of the most common hazards encountered in typical research labs (2011).
[36] Guidelines for Chemical Laboratory Safety in Academic Institutions, ACS Committee on Chemical Safety, Washington, DC, 2016. A comprehensive document providing a broad overview of the range of safety considerations for undergraduate, graduate and continuing safety education.
[37] E. U. Udo, O. E. Aru, D. O. Okey, E. O Agwu, Investigating the Health Hazards Associated with 5G Network: A Review, *NIPES Journal of Science and Technology Research* 4(1) (2022) pp.66 – 77.
[38] B. Seyoum, Lectures Notes For Medical Laboratory Technology Student: Introduction to Medical Laboratory Technology, *Ethopia Public Health Training Initiatives*(EPTHI) *Haramaya University* (2006) pp102-121.

[39] J.D. Bancroft Bancroft's theory and practice of histological techniques. Safety and Ergonomics in the laboratory, 7th edn. (2013) *Churchill Livingstone, London*
[40] B.D. Backus, S. Dowdy, K. Boschert , T. Richards , M. Becker-Hapak, Safety guidance for laboratory personnel working with *trans*-activating transduction (TAT) protein transduction domain, *Journal of Chemical Health and Safety.* (2001) 8(2):5–11.
[41] R. R. El-Zaemey, S. Dorji, N. Rai, B. Doj, I. Lin, Exposure to occupational hazards among health care workers in low-and middle-income countries: A scoping review, *International Journal of Environmental Research and Public Health* 18(5) (2021) pp 1-41 DOI 10.3390/ijerph18052603.
[42] World Health Organization, Geneva, Laboratory Biosafety Manual, 3rd edition, (2004) NHO/CDS/CSR/LYO/ 2004.11. pp.1
[43] L.A. Gallion, M.J. Samide, A.M. Wilson, Demonstrating the importance of cleanliness and safety in an undergraduate teaching laboratory, *Journal of Chemical Health and Safety* (2015).) S1871553215000031–. doi:10.1016/j.jchas.2015.01.002
[44] T. Princeton University Safety Environmental Health, Section 5 : Health Hazards of Chemicals, (2020) 1–8.
[45] L.F. Mazzuckelli, M.M. Methner, M. Eileen Birch, D.E. Evans, B.K. Ku, K. Crouch, M.D. Hoover, Identification and characterization of potential sources of worker exposure to carbon nanofibers during polymer composite laboratory operations, *J. Occup. Environ. Hyg.* 4 (2007) D125–D130. https://doi.org/10.1080/15459620701683871.
[46] National Research Council (US) Committee on Prudent Practices in the Laboratory. Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards: Updated Version. Washington (DC): National Academies Press (US) 4 (2011). Evaluating Hazards and Assessing Risks in the Laboratory. Available from: https://www.ncbi.nlm.nih.gov/books/NBK55880/
[47] A.Aldandani, *Safety and first aid manual in school laboratories*. Riyadh: Ministry of Education. (2010).
[48] R. Ali, Concepts of laboratory safety for school teachers in Algeria, *Jordanian Journal of Educational Sciences, 3*(9) (2013), 255-261.
[49] American Chemical Society In A. A.-A. Akram (Trans.), Safety in educational Chemistry laboratories (7th ed.) (2010).Washington, DC: American Chemical Society.
[50] McGovern, Patricia M. Kochevar, Laura K. Vesley, Donald Gershon, Robyn R.M. Laboratory professionals' compliance with universal precautions, *Laboratory Medicine*.(1997) 28(11) PP 725-730. DOI 10.1093/labmed/28.11.725.
[51] Y.A. Fagihi, The Level of Awareness of Safety Measures Practiced in School Laboratories among Pre-Service Science Teachers at Najran University. Journal of Educational Issues (2018) 4(1) PP107 doi 10.5296/jei.v4i1.12908
[52] School Chemistry Laboratory Safety Guide, (2006) pp 88. NIOSH, U.S. Consumer Safety Product Commission Department of Health and Human Services Centers for Disease Control and Prevention National Institute for Occupational Safety and Health. https://www.cpsc.gov/s3fs-public/NIOSH2007107.pdf. pp8-11
[53] J. Shivaji K, An Overview: Laboratory Safety and work Practices in Infectious Disease Research, *J. HIV Clin. Sci. Res.* 5 (2018) 001–006. https://doi.org/10.17352/2455-3786.000026.
[54] R. Bane, Laboratory ergonomics: How to keep stress-related physical problems from Occurring, *Adv Med Lab.* 13 (2002).
[55] G.O. Guterl, Repetitive motion injuries, *Adv Med Lab*. 9(13) (1997) 6–8.
[56] D.S. D'Sa, S. Lakshmi, An easy Guide For Practical Biochemistry, in: Lab. Rules Regul., Fiist, *Jaypee Brothers Medical Publishers (P) Ltd*, New Delhi, 2010: pp. 1–15.
[57] P.G. Olannye, C. Godwin, A. Dunkwa-Okafor, A.G. Ogogure, Gram-Neagative Bacteria Associated with Laboratory Workbenches in Microbiology Department, University of Benin. *NIPES Journal of Science and Technology Research* 4(3) (2022) pp.53 – 60. https//doi.org/10.37933/nipes4.32022.6
[58] Florida State University Emergency Management: Chemical Spills. (Accessed 5th Oct.2022) https://emergency.fsu.edu/hazards/chemical-spills
[59] Juba, B.W., Mowry, C.D., Fuentes, R.S., Pimentel, A.S., Román-Kustas, J.K., Lessons Learned - Fluoride Exposure and Response, *J. Chem. Heal. Saf.* 28 (2021)129–133. https://doi.org/10.1021/acs.chas.0c00108