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What-If Analysis in various operations in an Educational chemical laboratory

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ABSTRACT

Students and lab workers at the technological educational institution in India, responded to a what if analysis questionnaire regarding the hazardous labelling of a number of chemicals present in various laboratories within the particular chemical laboratory. Only one in four students, on average, correctly matched all of the chemicals in the questionnaire with their corresponding hazard labels; the percentage of incorrect responses for chemicals that were part of the curriculum was comparable to the percentage of incorrect responses for chemicals that weren't taught. The analysis of the responses reveals that the conventional ways of teaching about danger labelling and safe handling are insufficient, and better teaching strategies are required to raise students' knowledge of these topics.

Keyword- Chemical laboratory, hazardous labelling, what if analysis questionnaire, teaching strategies.

1. INTRODUCTION

The Chemicals that may be harmful either by themselves or as a result of a chemical reaction are used in the great majority of laboratories, whether they be chemical, biological, or radioactive. In order to offer a safe working environment for employees and to avert any potential harm to the larger environment, it is consequently required to detect hazards, assess potential risks, and control them. An official acts, frequently referred to as the "Occupational Safety and Health Act" (OSHA), has been formed in various zones to serve as advice for companies and employees and to promote a number of safety principles [1].

India has made available the Chemical (Management and Safety) Rules' sixth draught (CMSR). The Manufacture, Storage, and Import of Hazardous Chemical Rules, 1989, and the Chemical Accidents (Emergency Planning, Preparedness, and Response), Rules, 1996, will be replaced by the new regulation. The law, commonly referred to as "India REACH," is analogous to the EU REACH law. In 2022, it's anticipated to be released. An official statute, frequently referred to as the "Occupational Safety and Health Act" (OSHA), has been formed in a number of nations to give guidance for employers and employees and to promote a number of safety norms (Pine, 1993); for instance, see the European Union Act. With some exceptions, such as the Australian OSHA regarding the chemistry departments of Australian universities (Goodwin et al., 1999), the majority of these documents, however, do not explicitly consider students in universities and other educational institutions, even though teaching and research assistants should be considered as employees by these acts (Kaufman, 1992). Because universities have an ethical and legal obligation to safeguard students as well as the fact that students have less training than employees, standards for protecting students should be at least as strict as those for protecting employers (Sills, 1998) [2-3].

Furthermore, since future workers are trained in laboratories, a university setting is where laboratory safety is ultimately even more crucial. Safety in laboratories is a product of a general attitude and commitment, not just of rigorous adherence to rules. An important first step in creating this mentality is to educate people about safety issues properly and effectively. Accidents frequently happen not because people lack information but because they let their guard down whenever a safety practice becomes regular. Accidents are caused, not simply occur. They are brought on by human actions and inactions. Human attitude that results from the accumulation of knowledge and experience that causes people to behave in a certain way when faced with a certain stimuli.

The nature of the chemical and any potential hazards should be taken into consideration when determining the proper attitude to have when handling and using chemicals in the lab. According to rules established by the Manufacturing Chemists Association and the European Union Commission, every chemical must have this warning information labelled on it. But whether or not pupils can accurately understand the context of these labels and their indicators, as well as the potential risks, will determine their attitude [3-5].

According to Wiediger and Hutchinson (2002), one of the fundamental differences between an experienced individual and a novice is their inability to properly grasp or interpret chemical labelling, which is a substantial risk factor for accidents. Because of this, many science educators examine student misconceptions in an effort to aid in the reconstruction of their ideas and the development of their scientific literacy (Mulford and Robinson, 2002; Thijs, 1992) [6-9].

The significance of laboratory safety should be emphasised to students from an early age and should never be disregarded (Allen and Breeding, 1999). The amount of time allotted for learning determines the potential to learn (Scheerens and Bosker, 1997), while it is acknowledged that growth is sluggish and non-linear (Stavy, 1995). (Rudell et al., 1994). A study with students in the 12–13 and 15–16 age groups as well as a group of science post–graduate certificate student teachers revealed that the learning and perception of risk factors in classroom laboratories were not developing (Scott, 1998) [10-15].

Therefore, one may anticipate that students would become more knowledgeable of safety issues as their studies came to a close. However, despite the fact that laboratory safety is a crucial part of undergraduate education, only a small percentage of US colleges and universities offer safety courses or mandate them for chemistry majors, with only 1-2% doing so a decade ago (statistics cited in Senkbeil, 1994) [16-19].

The goal of this study was to determine whether students at the particular Department Educational Institution in India, were able to correctly identify the risks associated with the chemicals they handle in their laboratory work, as well as how the students' progress through the different semesters affected this knowledge. A questionnaire (What If Analysis) was given to the students and lab staff members as part of this; the questionnaire, an analysis of the responses from the returned surveys, and the results are all described. The Figure 1 shows the general chemical hazards.

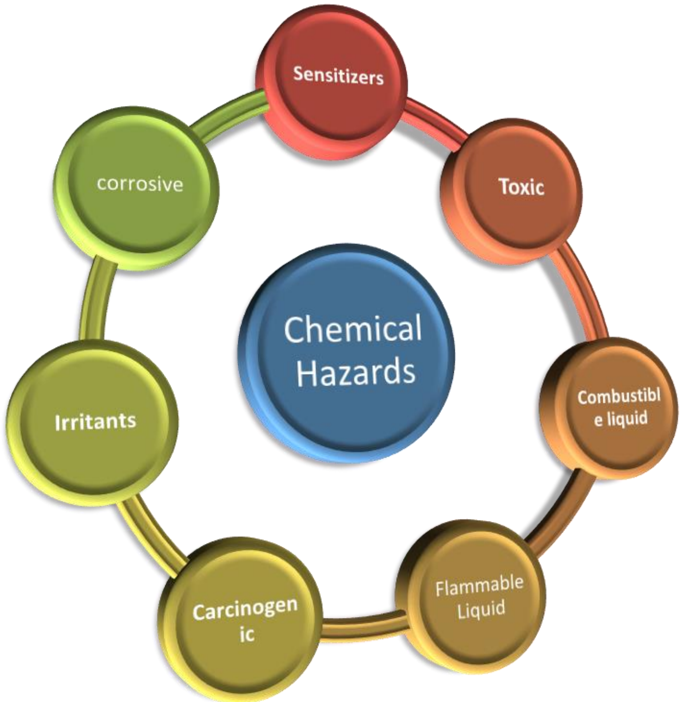

Fig.1 Chemical hazards

For obtaining the objective, in the Phase-I Important chemical safety Indian standards, Literature review, Methodology, Result/Discussion, and Conclusion are discussed.

2. Literature Review

An essential component of post-secondary scientific programmes is experimental activity. The growing number of students enrolling in STEM (Science, Technology, Engineering, and Mathematics) programmes has made it difficult to sustain individual laboratory work that serves hundreds of students annually in terms of logistical and resource allocation [20-23].

As a result, the majority of contemporary laboratory instruction is frequently verificatory (also known as conventional, explanatory, or jokingly referred to as "cookbook"), in order to accommodate more students in a rotation system that includes multiple predetermined experiments for them to undertake.

Hofstein and Lunetta (1982, 2003) published two of the earliest reviews on laboratory teaching. Although these studies focus on science in schools rather than science in higher education, some of the fundamental distinctions and findings are pertinent to and have influenced the current review. As a result, the operational definition of laboratory work provided by Hofstein and Lunetta (1982) is also used in this review. Laboratory work is described as "contrived learning situations in which students engage with materials to investigate phenomena" in this document (p. 201) [24-26].

Together, the two reviews by Hofstein and Lunetta show how school laboratory work has untapped potential but consistently fails to translate its instructional objectives into meaningful learning results for children. They contend that further investigation of goals and how particular laboratory activities and evaluation formats might be structured to complement these are necessary if laboratory instruction is to fully realise its potential (Hofstein & Lunetta, 2003, p. 46). The evaluations contend that previous research has a history of concentrating on a constrained conceptualization of abilities, which has restricted the applicability of the findings [27-28].

They contend that studies did not support teacher-student interactions in the laboratory and how these represented the desired curricula in terms of how teachers implemented the curriculum. Bradforth et al. (2015) contend that effective teachers in the setting of undergraduate scientific education do so by connecting their pedagogy to their own research [29-30].

Through researcher-practitioner collaboration and reflection exercises, concentrating on teachers' teaching practises may significantly contribute to their professional learning (Ping et al., 2018). The implementation of previous research's findings was constrained by its propensity to concentrate on a constrained conceptualization of abilities. Some of the aforementioned research's arguments have prompted curricular changes with the main goal of enhancing student learning, particularly learning in lab settings [11].

For instance, Good Practical Science, which was released in the UK in 2017 and provides a framework for schools to build science curricula around practical work, was published in the UK in 2017 (Gatsby Foundation). The school "should have laboratory facilities so that students can carry out extensive practical science research," according to one of the reform document's recommendations (p. 13). The phrase "extended investigations" refers to lab exercises that call for a longer trajectory than a single session and, presumably, a higher level of inquiry [12].

However, the research argues that many schools "are not making full use of [the available laboratory facilities]," therefore pupils have yet to benefit from this kind of laboratory work. (p. 14). When they are, it is also necessary to demonstrate how much the students genuinely learn from laboratory work.

Similar conclusions were published in America's Lab Report a decade earlier (The National Academies of Sciences, 2006). Their findings suggest that there is a lack of precision in the definitions of "the laboratory" and "laboratory activity," which "make[s] it difficult to derive definite conclusions on the optimal ways to laboratory teaching and learning" (p. 2), at least in the context of school science education. The design of new curricula that reflect scientific inquiry, incorporate more investigative elements, authenticity, or some form of problem orientation has been done in an effort to enhance learning in the laboratory. This effort has been informed by research and recommendations for curriculum reform

3. WHAT IF ANALYSIS METHOD

What If Analysis involves altering cell values to examine how such changes may impact the results of formulas on the worksheet. Scenarios, Goal Seek, and Data Tables are the three different What-If Analysis tools that are included with Excel. Data tables and scenarios use collections of input values to predict potential.

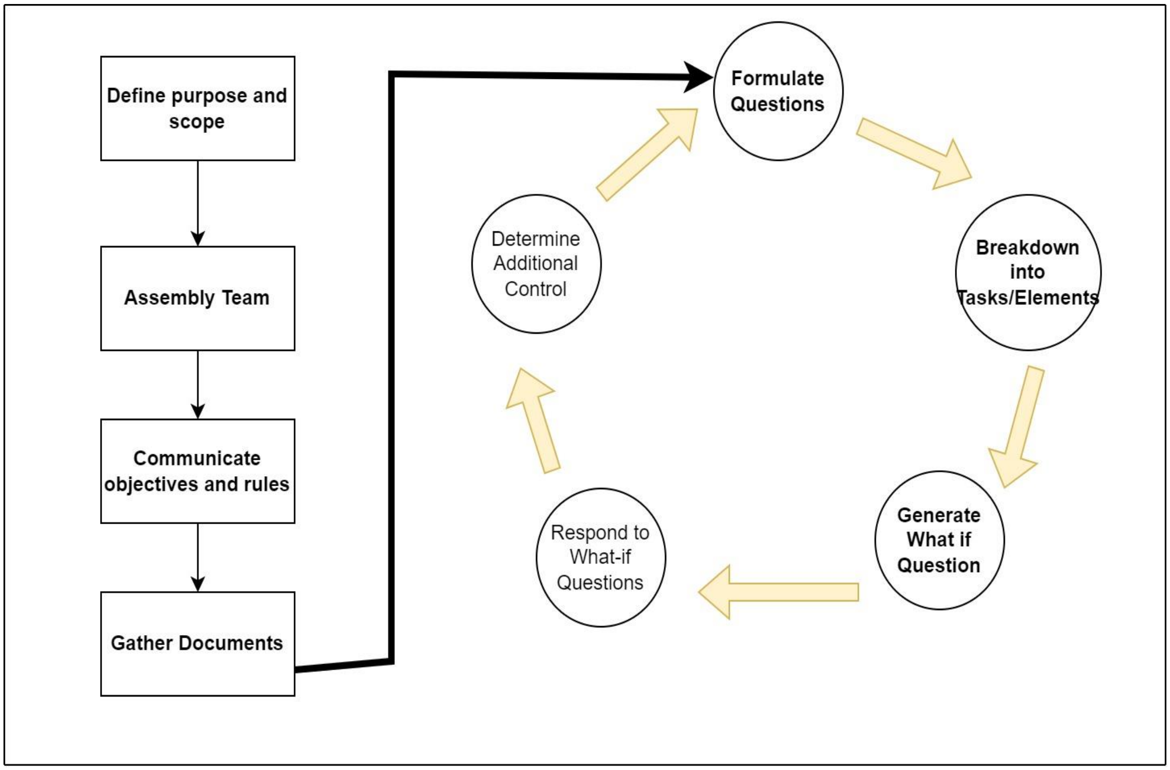

Fig.2 Methodology -workflow

Figure 2 express the methodology of the research and the steps involved such as define purpose and scope, assembly team, communicate objectives and rules, and gather the documents.

In this method, we need to frame the question related to the research objective and data will be collected.

The speculatively consider potentially dangerous situations, assess the risk they pose, and decide how best to reduce that risk. Performing a What If Analysis entails carrying out the following actions:

- Make a Hazards Analysis that contains the specifics of the What If Analysis you wish to conduct, including the analysis's start and finish dates.
- Determine which Systems or Nodes are the sources of the dangerous scenario.
- Define components by mentioning the following things:
- The mechanism from which the risky situation arises.
- The circumstances in which the scenario might take place.
- What results in the situation.
- The dangers of that potential outcome.
- The protections now in place to lessen the danger in that situation.
- The likelihood and magnitude of the risk associated with the scenario's

3.1 Ask "WHAT IF? "

- What if a chemical spill occurred in the laboratory?
- What if a student accidentally ingested a toxic chemical?
- What if there was a fire in the laboratory?
- What if an explosion occurred due to improper handling of chemicals?
- What if there was a gas leak in the laboratory?
- What if a student was not wearing the proper personal protective equipment (PPE)?
- What if there was a power outage during an experiment?
- What if a chemical reaction resulted in the formation of hazardous fumes or gases?
- What if a student was exposed to radiation during an experiment?
- What if a chemical waste disposal system malfunctioned?
- What if a student accidentally spilled a chemical on their skin while working in the laboratory?

3.2 Determine the laboratory accident in which the event could occur and control measures

- What if a chemical spill occurred in the laboratory?
- Event: A chemical spill can occur if a student accidentally drops a container of chemicals or if there is a malfunction in the equipment being used.
- Control Measures: The laboratory should have spill kits readily available for immediate response in case of a chemical spill. The spill kit should contain absorbent materials, neutralizers, and personal protective equipment (PPE) such as gloves, goggles, and aprons. All students and personnel should be trained on how to properly use the spill kit

and respond to a chemical spill. Additionally, students should be required to follow proper handling and storage procedures for chemicals to minimize the risk of a spill occurring.

- What if a student accidentally ingested a toxic chemical?
- Event: Accidental ingestion of a toxic chemical can occur if a student fails to follow proper safety procedures, such as not washing their hands after handling chemicals, or if a student accidentally ingests a chemical that resembles food or drink.
- Control Measures: The laboratory should have clear safety protocols in place for handling chemicals, including guidelines on proper hand hygiene and personal protective equipment (PPE) use. Students should be trained on these protocols and required to follow them at all times. Additionally, all chemicals in the laboratory should be properly labeled and stored to minimize the risk of accidental ingestion. In the event that a student does ingest a toxic chemical, emergency medical services should be called immediately, and the student should be provided with appropriate first aid until help arrives.
- What if a fire occurred in the laboratory?
- Event: A laboratory fire can occur due to a variety of factors, such as a malfunction in the equipment, improper storage or handling of chemicals, or failure to follow proper safety procedures.
- Control Measures: The laboratory should have fire safety protocols in place, including regular fire drills and training on proper use of fire

extinguishers. Additionally, all chemicals should be properly labeled and stored, with flammable materials stored in appropriate containers and away from potential ignition sources. All equipment should be regularly inspected and maintained to ensure proper functioning. In the event of a fire, all students and personnel should evacuate the laboratory immediately and emergency services should be called

3.3 What if analysis document with RPN calculation about laboratory hazards in an educational building

- Here is an example of a What If Analysis document with RPN calculation related to chemical laboratory hazards in an educational building:
- Event: A chemical spill occurs in the laboratory
- Cause: A student accidentally drops a container of chemicals
- Consequence: Chemicals are spilled onto the laboratory bench and floor
- Severity (S): 8 (Environmental impact and danger to students and staff)
- Likelihood (L): 5 (Moderate likelihood due to students' lack of experience with handling chemicals)
- Detection (D): 7 (Likely to be detected immediately by laboratory personnel)
- Risk Priority Number (RPN): 280 (S x L x D)
- Control Measures:
- Provide spill kits containing absorbent materials, neutralizers, and PPE in each laboratory room (S=4, L=3, D=9, RPN=108)
- Develop and enforce protocols for handling and storing chemicals properly (S=3, L=4, D=9, RPN=108)

- Train students on proper handling and storage procedures for chemicals (S=2, L=3, D=9, RPN=54)
- Conduct regular safety inspections of laboratory equipment and facilities (S=2, L=4, D=9, RPN=72)
- Recommended Action: Implement control measures 1-4 to reduce the likelihood and severity of chemical spills in the laboratory.
- Note: RPN scores can be used to prioritize the implementation of control measures, with higher RPN scores indicating a higher priority for implementation

4 RESULT AND DISCUSSION

What If Analysis is a commonly used tool in hazard analysis to identify potential hazards and evaluate the risks associated with them. In the context of chemical laboratory hazard analysis, a What If Analysis involves systematically asking "what if" questions to identify potential hazards, their causes, and their consequences, and then evaluating the likelihood, severity, and detectability of each hazard. The Risk Priority Number (RPN) is then calculated by multiplying the scores for each of these factors. A higher RPN indicates a higher risk associated with the hazard.

To illustrate the use of What If Analysis in chemical laboratory hazard analysis, let us consider the following hypothetical scenario:

Scenario: A chemical spill occurs in the laboratory

Cause: A student accidentally drops a container of chemicals

Consequence: Chemicals are spilled onto the laboratory bench and floor

Using What If Analysis, we can evaluate the likelihood, severity, and detectability of this hazard as follows:

Likelihood:

- What if the student is inexperienced in handling chemicals? Likelihood = 5 (out of 10)
- What if the container is unstable or improperly sealed? Likelihood = 5
- What if the laboratory bench is cluttered or uneven? Likelihood = 3

Severity:

- What if the spilled chemicals are highly toxic or corrosive? Severity = 8 (out of 10)
- What if the spilled chemicals cause damage to the laboratory equipment or facilities? Severity = 6

Detectability:

- What if the spill is immediately detected by laboratory personnel? Detectability = 8 (out of 10)
- What if the spill goes undetected for a significant amount of time? Detectability = 3
- To calculate the RPN for this hazard, we multiply the scores for likelihood, severity, and detectability as follows:

RPN = Likelihood x Severity x Detectability

RPN = 5 x 8 x 8

RPN = 320

This RPN score indicates that the hazard associated with a chemical spill in the laboratory is high and requires immediate attention.

To reduce the risk associated with this hazard, we can implement control measures, such as providing spill kits containing absorbent materials, neutralizers, and personal protective equipment (PPE), developing and enforcing protocols for handling and storing chemicals properly, and conducting regular safety inspections of laboratory equipment and facilities. These control measures can be evaluated using What If Analysis to determine their effectiveness in reducing the likelihood, severity, and detestability of the hazard.

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5. CONCLUSION

In conclusion, a safety audit using the what if analysis method in educational institution chemical laboratory hazard analysis is an important tool to identify potential hazards, evaluate risks, and prioritize control measures. This method systematically examines different scenarios and consequences to identify critical areas that require attention and supports decision-making for risk management. By using risk priority numbers (RPNs), it provides a quantitative measure of risk severity and helps to prioritize control measures based on their potential impact on reducing risks. The implementation of appropriate control measures can help to prevent accidents and ensure the safety of students, staff, and faculty in educational institution chemistry laboratories. Therefore, the what if analysis is a valuable tool in ensuring the safety of personnel, facilities, and the environment in educational institution chemical laboratory operations

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