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Improving Hazard Communication and Visibility Effectiveness in a Chemical Manufacturing Industry

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Abstract

The chemical manufacturing industry is fundamentally unsafe, since it handles and stores dangerous chemicals, yet it's important to the development of the economy. Effective hazard communication remains a core component of ensuring employees recognize risks and apply safe working behaviors. Deficiencies in visibility, placement, and clarity of safety signage continue to limit the effectiveness of hazard communication materials in too many chemical-manufacturing environments.

The present study assesses the effectiveness of hazard communication and the visibility effect on safety information in a chemical manufacturing industry. Specifically, it tries to assess the workers' knowledge, attitudes, and practices concerning hazard communication; establish visibility-related problems in safety signage and warning displays; and put forward practical improvements that could be used to enhance worker awareness and safety response.

A mixed-methods research design was adopted for this study. The research was conducted at Sumisaujana TCM Chemical Sdn. Bhd., Selangor, involving 52 operational workers from the Main Plant. Quantitative data were collected using structured questionnaires, while qualitative insights were obtained through interviews and workplace observations focusing on signage visibility, placement, and condition. Finally, the identified trends, gaps, and areas for further improvement were analyzed from the data.

The results showed that the workforce has a high level of knowledge and understanding with regard to hazard communication, such as labels, hazard symbols, and safety data sheets. Some areas were, however, found to be lacking with respect to the provision, placement, and maintenance of safety signs, which could have impaired its effectiveness. Even though the effectiveness associated with hazard communication is high, improvement is strongly advocated.

Based on the results obtained, this study recommends improvement in sign design and location as well as sign maintenance and visibility audits, hazard information updating, and greater worker feedback as means of improving hazard communication in the workplace in chemical manufacturing plants.

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1. Introduction

The chemical manufacturing industry is an essential driver of economic development worldwide; it fosters innovation, job creation, and economic growth (Mallapragada et al., 2023). The chemical manufacturing industry falls in the high-risk category because of the handling, production, and storage of hazardous chemicals, which can cause serious accidents if proper safety is not ensured. In high-risk workplaces, hazard communication plays a pivotal role in ensuring proper awareness of hazard levels and following proper working practices. Hazard communication involves the systematic use of safety signs, labels, pictograms, and Safety Data Sheets, which is regulated by a protocol such as the Globally Harmonized System of Classification and Labeling of Chemicals. In spite of these protocols, there has been a challenge in making these hazard communications visible and associated with proper actions, especially in the storage and production of chemicals where high levels of hazard-related accidents can be experienced.

Despite the implementation of hazard communication standards in many chemical manufacturing units, it is evident from research and accident reports that there are still many areas left uncovered in terms of visibility, sign postings, and understanding among the employees. Unattended, worn-out, or improperly posted safety signs can negate the efficiency of safety communication, resulting in hazards, injuries, or damage to the environment. Moreover, a lack of employee contribution and feedback can also impinge on the efficiency of the hazard communication scheme. Addressing this problem and looking for an improvement in hazard communication efficiency is, therefore, imperative in this scenario, not only ensuring safety in the workplace but also encouraging the proactive management of safety in chemical manufacturing units.

Although these hazard communication systems, such as safety signs, chemical labels, and SDS, are already provided as per the standards of the GHS, challenges still continue in chemical-manufacturing workplaces. At Sumisaujana TCM Chemical, just as in other risky chemical-manufacturing workplaces, chemical safety signs can be easily damaged, faded, improperly placed, and also misunderstood, rendering them less useful in the communication of hazards. The older the data provided in the form of visual content, the less effective the program. The study aims to address how these programs can be improved, especially the TCM chemical industry. Though numerous studies have already addressed chemical compliance, very limited research has been conducted regarding the actual visibility, location, clarity, and understanding of the provided safety information. Also, limited research, specifically in Malaysia, has explored chemical manufacturing. Though the goal of this research is to address the TCM chemical factory, if it were not carried out, organizations can continue with ineffective systems of chemical hazard communication, which can be risky because it can contribute to less safe workplaces, increased chances of workplace accidents, injuries, and adverse effects on the environment. By carrying out this research, the information gathered can be efficient in increasing the effectiveness of chemical hazard communication. Based on the identified issues and research gaps, this study seeks to answer the following research questions:

1. **How effective are the existing safety signs, pictographs, and visual cues in conveying chemical hazard information to workers?**
2. **What are the workers' perceptions and understanding of the current hazard communication materials?**
3. **How can visual communication and hazard signage be improved to enhance visibility, comprehension, and risk awareness among workers?**

The primary aim of this study is to evaluate and improve the effectiveness of hazard communication and the visibility of safety information in a chemical manufacturing industry, thereby supporting a safer working environment. To achieve this aim, the study is guided by the following specific objectives:

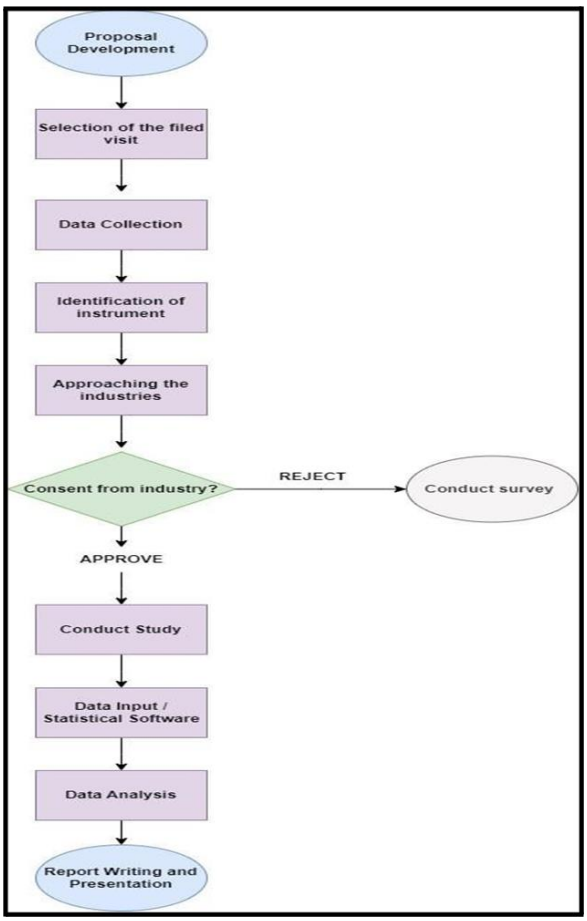
1. **To assess the level of knowledge, attitude, and practice regarding hazard communication and the visibility of safety information among workers in a chemical manufacturing industry.**
2. **To identify visibility-related issues concerning safety signage, labels, and warning displays used in the workplace.**
3. **To recommend practical improvements to enhance the visibility and clarity of hazard communication materials for better worker awareness and response.**

By systematically addressing these objectives, the study intends to provide a comprehensive understanding of current hazard communication practices, identify gaps, and propose evidence-based solutions that can enhance occupational safety and strengthen the culture of hazard awareness within chemical manufacturing environments.

2. Methodology

A structured and systematic methodological approach was used in this research in order to assess the effectiveness of hazard communication and the visibility of safety information in a chemical manufacturing industry setting. In carrying out this research, the instrumentation involved workers' knowledge, perceptions, and practices concerning hazard communication, as well as factors considered as visibility concerns in safety signage, labels, and visual warning signs in the industry setting. This research was carried out in Sumisaujana TCM Chemical Sdn. Bhd., a chemical manufacturing industry in Puncak Alam, Selangor. The research involved operational workers in the Main Plant of Sumisaujana TCM Chemical due to their direct exposure in the industry setting and frequent interactions concerning hazard communication tools such as safety signage, GHS Pictograms, chemical labels, and SDSs in the industry setting. Based on a known population of operational workers of 60 in Sumisaujana TCM Chemical, a sample size of 52 was obtained using the Krejcie and Morgan table of 1970 for representative data of the population. Data gathering in this research was conducted using a structured questionnaire as the instrumentation of the research. In this research, a five-point scale was applied concerning the research questionnaire in order to tested through the five-point scale of measurement concerning "Strongly Disagree" to "Strongly Agree" on the responses given concerning hazard communication effectiveness in Sumisaujana TCM Chemical.

The success of the hazard communication process was measured by analyzing the respondent workers' awareness of the Globally Harmonized System (GHS) symbols, the effectiveness of the positioning of safety signs, the readability of the labels, and the general perception of the effectiveness of the visual hazard communication process. Descriptive measures like mean scores were used to describe the situation of how the process of hazard communication was being practiced in the plant. The reliability of the questionnaire was analyzed by using Cronbach's Alpha. All the data collected was encoded for analysis using the Statistical Package for the Social Sciences (SPSS) software version 26. Descriptive statistics were used in the study to describe the respondents' demographic information. Inferential statistics were used in the study to test the association that may exist in the perception of the effectiveness of the hazard communication process for the selected factors. This mixed methodological approach helped the study achieve accurate results.



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3. Result & Discussion

This section presents and discusses the findings of the study on the effectiveness of hazard communication and the visibility of safety information in a chemical manufacturing workplace. The results are discussed based on four main themes: hazard communication knowledge and effectiveness, visibility and condition of safety signage, hazard communication practices, and overall effectiveness with continuous improvement. Data were obtained through a structured questionnaire and analysed using descriptive statistics, with mean values used to indicate respondents' levels of agreement.

3.1 Hazard Communication Knowledge and Effectiveness

A summary of the respondents' level of knowledge and understanding regarding hazard communications such as chemical labels, Globally Harmonized System Symbols, Safety Data Sheets, and hazard communications training is presented in Table 3.1. Generally, a high level of knowledge is evident in operational employees as denoted by a mean ranging from 3.73 to 4.06. A large majority of respondents were in agreement or in strong agreement to all items without a single disagreement.

The highest mean score emerged for the question "The provision of hazard communication information through labels, SDS, and hazard warning signs is adequate to support safe work practice." It appears that employees feel supported in terms of hazard communication as they carry out their work-related activities using chemical information. High levels also emerged on questions related to understanding hazard symbols and confidence in using hazard communication information to support safe work decisions related to hazard communication.

However, the lowest mean score was observed in terms of the comprehension regarding the structure and contents of the SDS. This mean score, although indicating an acceptable level, suggests that the comprehension of SDS could be comparatively weaker compared to the other elements of hazard communication. This observation raises the need for further emphasis through appropriate training or specific learning programs to ensure the utilization of SDS in the regular and emergency scenarios by the workers. The outcome establishes the efficiency in the comprehension of the workers with respect to hazard communication.

Table 3.1 : Level of Knowledge

Questions	1	2	3	4	5	Mean Value
B1) Understand the meaning of hazard symbols and pictograms on chemical labels.	0	0	11 (21.2%)	29 (55.8%)	12 (23.1%)	4.02
B2) I can correctly interpret information on chemical labels (hazards, PPE, safety measures) during work.	0	0	10 (19.2%)	33 (63.5%)	9 (17.3%)	3.98
B3) I understand the structure and main contents of the Safety Data Sheet (SDS).	0	0	21 (40.4%)	24 (46.2%)	7 (13.5%)	3.73
B4) I know when and in what situations the SDS should be referred to when working with chemicals.	0	0	11 (21.2%)	32 (61.5%)	9 (17.3%)	3.96
B5) Hazard communication information (labels, SDS, and signage) is sufficient to help me work safely.	0	0	7 (13.5%)	35 (67.3%)	10 (19.2%)	4.06
B6) GHS symbols on chemical containers are easy to understand for workers in my work area	0	0	18 (34.6%)	20 (38.5%)	14 (26.9%)	3.92
B7) The hazard communication training provided improves my understanding of chemical risks.	0	0	16 (30.8%)	29 (55.8%)	7 (13.5%)	3.83
B8) I feel confident using hazard communication information to make safe work decisions.	0	0	10 (19.2%)	32 (61.5%)	10 (19.2%)	4.00

3.2 Visibility, Placement, and Condition of Safety Signage

The data on visibility, positioning, and physical state of safety signage and hazard labels are presented in Table 3.2 below. The mean values attained in this category lie between 3.60 and 3.98, which means that these

variables attained a moderate level of agreement. These variables appear less strong, especially as a sub-field related to knowledge attained in the previous category, as far as workplace safety knowledge is concerned.
The highest average was observed for the use of hazard labels in relation to the clarity of labels on drums, containers, and pipelines. Moreover, the use of pictograms as well as multilingual signposts was identified as an effective means in improving worker understanding, especially considering the diverse work environment.
However, there have been lower mean values recorded in signage positioning at eye level, impact of light and obstructions, and handling temporary warning signs. The results have indicated that poor lighting, visual clutter, and background colors can be factors in signage visibility in a given setting. Poor signage positioning and use of temporary signage might have impacted hazard communication, particularly in non-routine and high-risk tasks. In general, the results have particularly emphasized the need to improve signage positioning, signage visibility in the environment, and regular inspection to ensure continued successful visual hazard communication.

Table 4.8 : Level of Visibility

Questions	1	2	3	4	5	Mean Value
C1) Safety signage is placed in appropriate locations and is easy to see.	0	0	16 (30.8%)	35 (67.3%)	1 (1.9%)	3.71
C2) Safety signage is positioned at eye level or in a clearly visible position during work.	0	0	18 (34.6%)	34 (65.4%)	0	3.65
C3) The visibility of signage is not affected by lighting, obstructions, or background colors.	0	0	21 (40.4%)	31 (59.6%)	0	3.60
C4) The condition of signage (color, cleanliness, damage) does not affect its readability	0	0	16 (30.8%)	36 (69.2%)	0	3.69
C5) Hazard labels on drums, containers, and pipelines are clear and readable.	0	0	10 (19.2%)	33 (63.5%)	9 (17.3%)	3.98
C6) Pictogram-based or multilingual signage helps improve understanding among all workers	0	0	16 (30.8%)	22 (42.3%)	14 (26.9%)	3.96
C7) Temporary warning signs (e.g., hot work, confined space) are used and removed correctly.	0	0	18 (34.6%)	34 (65.4%)	0	3.65

3.3 Hazard Communication Practices

Table 3.3 illustrates respondents' perceptions of hazard communication practices, including supervisory communication, safety briefings, information dissemination, and accessibility of hazard-related information. The mean values range from 3.73 to 4.00, indicating a moderate to high level of implementation of hazard communication practices within the workplace.
The mean value showing the greatest importance in this collection of means involved clear communication of personal protective equipment requirements when working with chemicals. However, it's clear that there has been a focus on messaging related to personal protective equipment, which has become commonplace in chemical safety management. In contrast, the mean value showing less importance involved communications related to new chemicals and amendments to hazard information.
Although safety briefings, toolbox safety meetings, and reporting systems for damaged safety signs are considered in place, the fairly high number of neutral responses suggests that this is perhaps not always the case for all departments and shifts. This could affect the overall success rate in communication regarding hazards. Improvement in communication, updates, and worker participation in safely communicating hazards could make a significant difference in the way hazard communication is conducted.

Table 3.3 : Level of Practice

Questions	1	2	3	4	5	Mean Value
D1) Supervisors or safety personnel frequently communicate chemical hazards during safety briefings.	0	0	16 (30.8%)	27 (51.9%)	9 (17.3%)	3.87
D2) I am informed when there are new	0	0	21	24	7	3.73

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chemicals or changes in hazard information.			(40.4%)	(46.2%)	(13.5%)	
D3) Toolbox meetings or safety briefings include topics on hazard communication and signage interpretation.	0	0	16 (30.8%)	27 (51.9%)	9 (17.3%)	3.87
D4) Workers are encouraged to report damaged or unclear signage or labels.	0	0	16 (30.8%)	27 (51.9%)	9 (17.3%)	3.87
D5) PPE requirements for working with chemicals are clearly communicated.	0	0	10 (19.2%)	32 (61.5%)	10 (19.2%)	4.00
D6) Hazard information channels (supervisors, notice boards, digital systems) are easily accessible.	0	0	16 (30.8%)	27 (51.9%)	9 (17.3%)	3.87

3.4 Overall Effectiveness and Continuous Improvement

Table 3.4 presents respondents' perceptions of the overall effectiveness of the hazard communication system and the importance of continuous improvement. The results show strong agreement across all items, with mean values ranging from 4.00 to 4.69 and no disagreement responses recorded. This indicates a high level of awareness among workers regarding both the effectiveness of existing practices and the need for ongoing improvement.

Items about regular review and updating of safety signage, risks of faded or damaged signage as well as necessity of regular visibility audits yielded the highest mean scores. These results highlight the fact that workers consider the issue of hazard communication as a dynamic system which needs to be checked constantly but not implemented once. Another visual aid that the respondents greatly supported to increase understanding and awareness is the use of extra visual materials like posters, colour charts, and digital displays.

Despite the fact that the current hazard communication system is viewed as a fairly efficient one with respect to preventing the occurrence of chemical-related incidents, the more prominent focus on the improvement-related items implies that workers prefer proactive improvement to complacency. On the whole, the results indicate that to maintain efficient communication of hazards, regular audits, new signs and varied visual means of communication are critical in reducing risks associated with chemicals at the workplace.

Table 4.10 : Level of Improvement

Questions	1	2	3	4	5	Mean Value
E1) Safety signage and SDS information help me avoid unsafe actions.	0	0	10 (19.2%)	32 (61.5%)	10 (19.2%)	4.00
E2) The existing hazard communication system is effective in preventing chemical-related incidents.	0	0	1 (1.9%)	42 (80.8%)	9 (17.3%)	4.15
E3) Safety signage and labels should be reviewed and updated regularly.	0	0	0	16 (30.8%)	36 (69.2%)	4.69
E4) Faded, damaged, or unclear signage can increase the risk of accidents.	0	0	0	16 (30.8%)	36 (69.2%)	4.69
E5) Additional visual aids (posters, color charts, digital displays) can improve hazard communication understanding	0	0	0	18 (73.1%)	14 (26.9%)	4.27
E6) Visibility audits of signage should be conducted regularly in the workplace.	0	0	0	16 (30.8%)	36 (69.2%)	4.69

4.0 Conclusion

This research investigated the concept of the effectiveness of hazard communication and the availability of safety information in a chemical manufacturing setting with specific attention to the knowledge of the workers, the presence of the signage, the communication practices, and continuous improvement. The results indicate that the use of hazard communication systems in the examined facility is quite satisfactory, and workers are characterized by a satisfactory level of knowledge about chemical labels, the GHS symbols, the Safety Data Sheets (SDS), and the personal protective equipment needs.

Nevertheless, even with such a high degree of knowledge, this research has shown there are significant gaps in the physical perception and practice aspect involved in hazard communication. Problems to do with the positioning of signs, environmental issues associated with visibility, including lighting and obstruction and irregularity in the management of temporary warning signs were identified to limit the efficiency of safety information in day-to-day operations. These results also show that effective hazard communication is not just about regulatory compliance but appropriate attention to the presentation of visual information and possible maintenance under the real working conditions.

The findings also indicate that the practice of hazard communication, such as the safety briefings and the provision of information updates are evident but they might not be as consistent and thoroughly reinforced. Though employees tend to feel that the current system is efficient, there is a consensus that the improvement should be carried out continuously with a periodic review of signage materials, audit on visibility, and application of other visual aids. This shows a safety proactive attitude of workers and the need to continuously monitor instead of depending on the static safety measures of communication.

In conclusion, improving hazard communication in chemical manufacturing requires an integrated approach that combines clear and visible signage, effective information dissemination, continuous training, and sustained management commitment. Strengthening these elements can enhance workers' risk awareness, support safer work behaviour, and reduce the likelihood of chemical-related incidents. This study contributes practical insights into hazard communication effectiveness in high-risk industrial settings and supports the need for continuous improvement strategies to sustain workplace safety performance.

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APPENDIX A

No.	Work Activity	Figure
1.	The interview session was carried out with the workers in the operations to obtain information about the practice of hazard communications..	
2.	Questionnaire distribution and response session among operation workers.	 
3.	Condition of safety information board lacking hazard communication materials prior to intervention (Before). Improved safety information board with installed hazard communication posters and safety notices (After).	 Before  After
4.	Existing "Do Not Block Hose Reel" signage that did not follow a standardized template (Before). Standardized and updated "Do Not Block Hose Reel" signage implemented for improved visibility (After).	 Before

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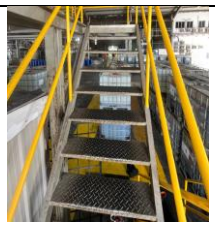
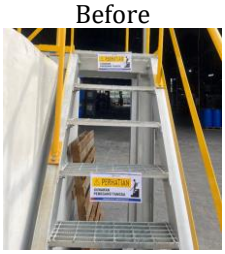
No.	Work Activity	Figure
		 After
5.	Ladder area without safety information or warning signage prior to improvement (Before). Ladder area equipped with safety signage stating "Attention: Use Handrail When Using Ladder" after improvement (After).	 Before  After
6.	Safety Data Sheet placed at an inappropriate and non-designated location prior to improvement (Before). Dedicated Safety Data Sheet station installed to improve accessibility and visibility of chemical safety information (After).	 Before  After
7.	Faded and unclear "No Smoking" safety signage observed in the workplace before corrective action (Before). Replacement of "No Smoking" signage with a new and clearly visible standardized sign after improvement (After).	 Before  After