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Assessment of Chemical Risk Literacy among Secondary School Students in the Context of Industrial Disaster Mitigation

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ABSTRACT

This study examines the level of chemical risk literacy among secondary school students residing in industrial areas prone to chemical disasters. The research focuses on SMAN 2 Krakatau Steel Cilegon, located near a chemical industrial zone. The aim is to assess students' understanding of hazardous chemicals, their preparedness for chemical incidents, and the role of teachers, the Regional Disaster Management Agency (BPBD), and industry in supporting such literacy. Employing a descriptive qualitative approach, data were gathered through interviews, observations, and document analysis. The findings reveal that students' literacy remains largely theoretical and disconnected from actual environmental risks. Contributing factors include a lack of contextual curriculum, insufficient teacher training, and the absence of joint simulations with BPBD and local industry. This study concludes that a risk-based education approach and contextual assessment are essential to enhance school preparedness for chemical disasters.

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INTRODUCTION

The chemical industry is a strategic sector that plays a vital role in national economic development. However, behind its significant contribution, the industry also poses a substantial risk to public safety in the event of chemical leaks, accidents, or sabotage involving hazardous substances. Major incidents such as the Bhopal tragedy (India, 1984)(Eckerman, 2005) , the Beirut Port explosion (Lebanon, 2020)) (*Beirut Explosion: What We Know so Far,* n.d.), and the Tianjin blast (China, 2015 clearly (Bloor et al., n.d.)demonstrate that failures in managing industrial chemicals can lead to large-scale disasters with high casualties and severe environmental damage.

In Indonesia, the proximity of chemical industrial zones to residential areas and educational institutions increases the urgency to equip communities—including students—with adequate chemical risk literacy (Bachri et al., 2024). This urgency is echoed in research that emphasizes the need to integrate disaster-related education into formal curricula, particularly in areas prone to industrial hazards (Kagawa & Selby, n.d.) (Kagawa & Selby, n.d.; Kınık & Çalışkan, 2024). Secondary school students, as part of the adolescent population in industrial regions, are particularly vulnerable if they do not understand the characteristics of hazardous chemicals, their potential risks, and appropriate mitigation measures in case of incidents (Cvetković et al., 2024). Unfortunately, chemistry education at the secondary level often emphasizes theoretical

knowledge, with limited integration of disaster-related issues, particularly chemical disasters, into both teaching and assessment processes (Amini et al., 2024).

In this context, teachers play a strategic role as key facilitators in developing students' chemical risk literacy. Teachers are not merely content deliverers but also critical actors in fostering awareness, directing contextual discussions on industrial risks, and designing formative assessments that reflect disaster preparedness(Wahyuni, 2023). When teachers are equipped with adequate understanding and supported by a curriculum responsive to disaster issues, learning processes can become effective tools for instilling disaster response attitudes from an early stage.

Chemical risk literacy refers to the ability to recognize chemical hazards, understand their impacts, and make informed decisions to prevent or respond to potential disasters. In the educational context, this literacy can be developed through contextual learning and formative assessments based on simulations or real case studies (United Nations Office for Disaster Risk Reduction UNDRR, 2020). Therefore, evaluating the level of chemical risk literacy among secondary school students is crucial as a basis for developing more adaptive and risk-based disaster mitigation education policies.

Based on this background, this study aims to: (1) describe the level of chemical risk literacy among secondary school students; (2) identify the factors influencing students' understanding of chemical risks; (3) analyze the role of teachers in strengthening chemical risk literacy in schools; and (4) propose appropriate assessment strategies to enhance student preparedness in facing potential chemical disasters. These objectives are intended to build a comprehensive understanding of how chemical risk literacy is formed, shaped, and assessed within school environments situated in high-risk industrial zones. The findings are expected to contribute significantly to the development of education policies and pedagogical practices that incorporate disaster preparedness into science curricula. Ultimately, this research is crucial in the field of education as it highlights the urgent need for a proactive, context-sensitive approach to learning—one that empowers students with the knowledge and skills to respond effectively to chemical hazards in their communities.

RESEARCH METHOD

This study employed a descriptive qualitative research design, chosen for its ability to provide in-depth insights into the phenomenon of chemical risk literacy within the school context. The qualitative approach allows researchers to explore the knowledge, perceptions, and experiences of participants in their natural settings—an essential feature when analyzing education-related disaster preparedness (Braun & Clarke, 2006). The research was conducted at SMAN 2 Krakatau Steel Cilegon, a senior high school situated near a major chemical industrial zone in Banten Province, Indonesia. Data were collected from three key respondent groups: (1) 20 Grade XI science students, (2) 2 chemistry teachers, and (3) 2 school administrators, specifically vice principals responsible for curriculum and student affairs. These participants were selected using purposive sampling, targeting individuals with direct exposure to chemistry education and school disaster management policies.

The data collection methods consisted of in-depth interviews, direct observations, and document analysis of teaching materials and school protocols. This triangulated approach enhances the validity and richness of the data by capturing multiple

perspectives(Afijah, 2021). Thematic analysis was employed using the six-phase framework (Braun & Clarke, 2006), involving coding, theme identification, and pattern interpretation to construct a comprehensive narrative of students' chemical risk literacy. This methodological structure aligns with recent recommendations for disaster education studies, emphasizing context-specific, qualitative inquiry to reveal gaps in school-level preparedness (Amini et al., 2024; Ninasafitri et al., 2024)).

RESULTS AND DISCUSSION

Findings

This study yielded three main findings related to (1) the level of chemical risk literacy among students, (2) factors influencing their understanding, and (3) the roles of teachers, BPBD, and industry in building preparedness for chemical disasters. These findings were obtained through interviews, observations, and document analysis at SMAN 2 Krakatau Steel Cilegon, located in a densely industrialized chemical zone in Cilegon City, Banten Province.

1. Chemical Risk Literacy of SMAN 2 Krakatau Steel Cilegon Students

   Most students understood chemicals in the context of school laboratories and basic experiments, such as acid-base tests, combustion reactions, or solubility. However, they lacked deeper understanding of hazardous industrial chemicals such as ammonia, chlorine, or ammonium nitrate, which can cause large-scale disasters in the event of leaks or explosions.

   A student stated:

   "We know about some dangerous chemicals, but we have never learned about incidents like gas leaks or how to save ourselves if an accident happens at the nearby plant." (Interview, Grade XI Science Student)

   Observations revealed the absence of chemical risk information boards, hazardous substance-based evacuation procedures, or emergency simulations involving student participation. This suggests that students' chemical risk literacy remains passive and does not yet promote active preparedness.

2. Factors Influencing Chemical Risk Literacy

   Several key factors were identified as contributing to the low level of chemical risk literacy among students at SMAN 2 Krakatau Steel Cilegon:

   a. Non-contextual Curriculum and Learning Materials

      The lesson plans used by teachers only briefly touch on hazardous substances without linking them to real-life situations, despite the school's location amid the Krakatau Steel industrial zone and petrochemical facilities.

   b. Lack of Teacher Training and Stakeholder Synergy

      Teachers have not received training on chemical disaster education. Furthermore, there have been no collaborative initiatives between the school, the Cilegon City BPBD, or local industry to support risk-based learning.

      "So far, there have been no joint training sessions or simulations from BPBD or nearby factories for students or teachers." (Interview, Chemistry Teacher)

3. Absence of Specific Protocols and Chemical Disaster Simulations

   While the school has evacuation procedures for general emergencies like fires and earthquakes, it lacks protocols for chemical incidents. Simulations that involve hazardous materials and require coordinated response with local emergency

services are nonexistent. This gap reflects the broader findings of(Amini et al., 2024), who emphasize the importance of simulations and real-case scenarios in disaster education for enhancing preparedness behavior.

Discussion

The findings of this study reveal significant gaps in chemical risk literacy among students at SMAN 2 Krakatau Steel Cilegon, despite their proximity to high-risk chemical industrial zones. Most students exhibited a limited understanding of industrial hazardous chemicals, focusing primarily on basic laboratory substances. This indicates that the current chemistry curriculum and teaching practices are insufficiently contextualized to the students' real-world environment. Scientifically, this research contributes to the discourse on disaster education by confirming that theoretical instruction alone does not cultivate the practical competencies needed for chemical disaster preparedness. As highlighted by (Amini et al., 2024), disaster literacy must be built through experiential learning and realistic simulations to foster genuine behavioral readiness.

A key factor inhibiting students' preparedness is the absence of context-based teaching and learning strategies. Teachers lack access to professional development and localized resources to deliver content relevant to industrial risks. This supports findings by (Kınık & Çalışkan, 2024), who argue for the institutionalization of disaster literacy within formal curricula through teacher capacity-building. The implications are clear: integrating disaster literacy into science education requires a curriculum that not only teaches chemical properties but also relates them to real hazards students might face in their communities.

Furthermore, this study emphasizes the need for collaborative synergy among schools, the Regional Disaster Management Agency (BPBD), and the chemical industry. While teachers are frontline facilitators of risk literacy, BPBD and industrial actors have essential roles in simulation training and the provision of practical learning tools. The absence of such cooperation in the studied school reflects the "preparedness divide" theorized by(Paton & Johnston, 2001), where institutional knowledge fails to reach grassroots education systems. Practically, this study recommends that formal partnerships—such as MoUs between schools, BPBD, and local industries—be developed to co-create sustainable risk education programs.

From a scientific perspective, this study highlights the intersection of chemical education and disaster risk reduction (DRR) as an underexplored but urgent domain in educational research. It advances the argument that chemical literacy must evolve beyond textbook theory into a form of civic competence—enabling students not only to understand but also to act in response to chemical threats. In practical terms, this means schools in industrial areas must implement localized case-based assessments, conduct routine chemical disaster drills, and integrate risk mapping into classroom discussions. Such steps will ensure that students are not merely informed but are empowered to respond effectively to emergencies.

In conclusion, this discussion demonstrates that chemical risk literacy is not only a curricular enhancement but a necessary public safety investment. By aligning science education with disaster preparedness, schools can play a pivotal role in building resilient communities—particularly in industrially vulnerable zones like Cilegon.

CONCLUSION AND IMPLICATIONS

Conclusion

This study found that the level of chemical risk literacy among students at SMAN 2 Krakatau Steel Cilegon remains relatively low, despite the school's location in a high-risk chemical industrial zone. Students' understanding is still limited to theoretical concepts of chemicals, with insufficient connection to actual risks such as gas leaks, tank explosions, or exposure to hazardous substances from nearby industrial activities.

Three key findings emerged:

1. The lack of integration of chemical disaster topics in both chemistry instruction and assessment;
2. The low capacity of teachers to deliver material on chemical risk mitigation, due to the absence of relevant training and contextual teaching resources;
3. The absence of systematic collaboration between the school, BPBD Cilegon, and local industry to support practical chemical risk literacy through training, simulations, or emergency response protocol development.

These findings indicate that chemical risk literacy has not yet become an integral part of science education in industrial areas, even though the threats posed by hazardous chemicals are immediate and far-reaching.

Implications

1. Implications for Schools and Teachers
   a. Strengthening teacher capacity is essential, particularly through training programs on chemical disaster literacy involving BPBD and industry practitioners.
   b. Schools need to develop contextual learning modules and assessments, especially those based on local case studies involving industrial chemicals.
2. Implications for Local Government and BPBD
   a. BPBD Cilegon is expected to act as a key facilitator of school-based disaster education, including the provision of teaching materials and integrated simulations on chemical risks.
   b. Local governments can mandate schools in industrial areas to develop specific evacuation protocols for chemical incidents, distinct from those for general emergencies like earthquakes or fires.
3. Implications for the Industrial Sector
   a. Chemical industries are obliged to fulfill their corporate social responsibility (CSR) by supporting school-based disaster education, including the provision of protective equipment, technical simulations, and direct involvement in student and teacher education.
   b. A formal partnership should be established among industry, schools, and BPBD in the form of educational memoranda of understanding (MoUs) to build collaborative and contextual learning systems.

By establishing a risk-based learning ecosystem supported by cross-sectoral collaboration, chemical risk literacy in secondary schools can be systematically and sustainably enhanced—particularly in high-risk industrial zones such as Cilegon.

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