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RISK CONTROL OF EXPOSURE TO HAZARDOUS CHEMICALS IN THE WORKPLACE

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ABSTRACT

Exposure to hazardous chemicals in the workplace can occur through routes such as inhalation, skin contact, and accidental ingestion. Some of these chemicals, such as organic solvents, heavy metals, and workplace chemicals, have been shown to be associated with serious health risks, including respiratory and nervous system disorders, and cancer. Exposure to hazardous chemicals in the workplace can pose acute and chronic health risks, as well as impact occupational safety and the environment. Risk control efforts are crucial to minimize potential hazards through the application of the hierarchy of control principle, starting from elimination, substitution, engineering, administration, and the use of personal protective equipment (PPE). This article discusses the forms of risk due to exposure to hazardous chemicals, effective control strategies, and the importance of implementing an OHS (Occupational Safety and Health) program in preventing work-related illnesses. The results of the discussion indicate that risk control must be carried out comprehensively and continuously by involving management, workers, and a health monitoring system.

INTRODUCTION

Risk is an unpleasant (harmful, dangerous) consequence of an action or action (FE Saputra, 2016). Once a risk has been identified and assessed, risk control efforts must be implemented. This risk control is achieved by reducing the likelihood and reducing the severity. Control can also be achieved by transferring the risk in whole or in part (risk transfer) or avoiding the risk. This control is implemented starting with the most dangerous risk first.

Exposure to hazardous chemicals in the workplace occurs through inhalation, skin contact, and accidental ingestion. To reduce health risks and improve workplace safety, it is important to understand the risk management of hazardous chemicals in the workplace.

Workplaces that use hazardous chemicals pose a high potential risk to worker health. Exposure can occur through inhalation, skin contact, or accidental ingestion. Health effects can include irritation, poisoning, respiratory problems, internal organ damage, and even cancer due to chronic exposure. Furthermore, some chemicals are flammable, explosive, or corrosive, which can threaten workplace safety. Therefore, controlling the risk of exposure to hazardous chemicals is a crucial aspect of implementing occupational safety and health (K3).

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METHOD

Methods for controlling the risk of exposure to hazardous chemicals in the workplace follow the Hierarchy of Risk Control, ranging from elimination and substitution, engineering controls, administrative controls and work practices, to the use of Personal Protective Equipment (PPE). This approach aims to eliminate or reduce chemical hazards gradually, focusing on the most effective measures such as eliminating the chemical or replacing it with a less hazardous one, then implementing engineering, administrative, and PPE solutions as a final layer of protection.

Here are the methods:

1. Elimination and Substitution

- Elimination: Completely eliminating the use of hazardous chemicals from the work process.
- Substitution: Replacing a more hazardous chemical with a less hazardous or less volatile chemical.

2. Engineering Control (Technique)

- Involves physical changes to facilities, processes, or equipment to reduce or isolate hazards.
- Examples include installing ventilation systems such as fume hoods, isolating hazardous process areas, or using wet methods to reduce dust and particulates.

3. Administrative Control and Work Practices

- Involves creating policies, procedures, and training to reduce exposure to chemical hazards.
- Examples include:
  - **Standard Operating Procedures (SOP)**: and work instructions.
  - **Job rotation**: to limit exposure time per worker.
  - **Work scheduling**: modified.
  - **Training**: workers on safe handling of chemicals.
  - **Monitoring**: worker health and air quality.

4. Personal Protective Equipment (PPE)

- It is a last resort when other controls cannot completely eliminate the risk.
- Examples include use of:
  - **Gloves**: and protective clothing.
  - **Glasses**: or face shield.
  - **Respirator**: to protect the respiratory system from harmful vapors or dust.

In addition, regular risk monitoring is also required through workplace inspections, air quality testing, and worker health evaluations to detect and prevent unsafe exposure.

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RESULTS AND DISCUSSION

Based on our search of journals relevant to the topic, we compare journal titles based on the characteristics of the studies we conducted. The following discussion covers controlling the risk of exposure to hazardous chemicals in the workplace.

Table 1 Comparison of Research Findings

NO	TITLE	WRITER	OBJECTIVE	METHOD	RESULTS
1	The relationship between exposure to hazardous chemicals in the workplace and health risks in industrial workers	Nanang Rahmadani and Muhammad Syafri	This study aims to explore and analyze the relationship between exposure to hazardous chemicals in the workplace and health risks in industrial workers.	This study will use a mix of quantitative and qualitative methods to analyze the relationship between exposure to hazardous chemicals in the workplace and health risks in industrial workers.	Based on data collected from surveys, exposure measurements, interviews, and analysis of health records, the study findings showed: chemical exposure profiles, workers in the studied industries were exposed to a variety of hazardous chemicals, including organic solvents (such as toluene and benzene), heavy metals (such as lead and mercury), and other industrial chemicals (such as formaldehyde).
2	Health Risk Analysis of Toluene and Xylene Exposure in Mixing Workers in a Paint Factory	Ahmad Pratama, Siti Khodijah and Dr. Indra Wijaya	This study aims to measure the level of exposure to toluene and xylene in the air in the mixing work area, and to analyze its relationship with symptoms of acute neurological disorders reported by workers.	1. Air sampling: Personal and area air sampling was carried out using an air pump with a charcoal tube for 8 working hours (full shift) on 30 workers. 2. Laboratory Analysis: analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) to measure the concentration of toluene and xylene. 3. Health Questionnaire: a health symptoms questionnaire (dizziness, nausea, blurred vision, fatigue) was distributed to all respondents. 4. Data Analysis: Exposure concentrations were compared with the Threshold Limit Value (TLV). The	• The average exposure concentration of toluene (45ppm) and xylene (60 ppm) exceeded the established Threshold Limit Values (TLV) (50 ppm and 100 ppm for xylene respectively, but in combination the effects were additive). • There was a significant positive correlation between solvent exposure levels and acute neurological symptoms. Workers with the highest exposure reported a higher frequency of dizziness and fatigue symptoms.

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				relationship between exposure concentration and symptom frequency was statistically analyzed using a correlation test.	
3	Monitoring of Crystalline Silica Dust Exposure (Respirable Crystalline Silica-RCS) from Brick and Concrete Cutting Activities	Maria Carolina, Prof. Dr. Benjamin Lee, and Robert Chen	Mapping the level of exposure to crystalline silica dust in various construction work activities (cutting, grinding, demolition) and evaluating the use of control equipment (water suppression and local ventilation).	1. Area monitoring: measurements of respirable silica dust concentrations were carried out around the work area using a cyclone sampler connected to a pump calibrator. 2. Sample analysis: dust was analyzed using the X-Ray Diffraction (XRD) method to identify and quantify the crystalline silica content. 3. Observation: Observations were made on the use of Personal Protective Equipment (PPE) and Engineering control tools (such as water spraying) during the activity.	• Concrete grinding activities produced the highest RCS concentration (0.12 mg/m3), exceeding the OSHA standard (0.05 mg/m3). • The use of water spraying (water suppression) has been proven to reduce silica dust concentration by up to 80% compared to dry methods. • Inappropriate use of respirators (not fit-tested) is still common, increasing the risk of inhalation in workers.
4	Risk Assessment of Ammonia Exposure to Healthcare Workers in the Chemical Industry and Fertilizer Plants	Ujung, CA, Attorney, S., & Lusida, N. (2025)	To assess the risks associated with ammonia exposure in the chemical and fertilizer industry through a literature review.	Review of publications from the previous three years (2020-2025) using Google Scholar, PubMed, and OSHA, among other databases.	OSHA has set a safe TWA limit of 25 ppm with a STEL of 35 ppm. Exceeding these limits increases acute and chronic toxicity, including eye and respiratory tract irritation, bronchitis, and decreased lung function. Exposure controls should include adequate use of protective equipment, good ventilation, and training, as well as an appropriate ventilation system and training with an early warning system. Compliance with the above is essential.
5	Risk Analysis of Exposure to Hazardous Chemicals to Worker Health in Industry	Ardiansyah, A., Suherman, S., & Ayunda Larasati Sekar Putri (2025) Warunamaya	Analyzing the level of risk of exposure to hazardous chemicals in industrial environments and their potential impact on workers' health.	Field survey, measurement of chemical concentration in working air, interviews with workers and management. Analysis using HIRARC refers to national and	Some work areas have concentrations exceeding ambient limits, potentially causing respiratory problems, skin irritation, and chronic illness. Recommendations include improved ventilation, consistent use of personal protective equipment (PPE), and regular worker training.

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				international K3 standards.	
6	Risk Analysis of Toxic Substance Exposure in the Occupational Environment: A Case Study in the Chemical Industry	Nurcantika, A., S., & Lusida, N. (2025) Ulil Albab Institute	Analyze the risk of exposure to toxic substances such as H2S, benzene, and ammonia in the work environment and assess the effectiveness of the controls implemented.	Literature review of journals and case reports over the past five years, specifically on exposure to toxic substances in the oil and gas industry.	Exposure to H2S in production wells can reach >4,000 ppm, benzene can reach 5 ppm (above the TLV), and ammonia, even within the TLV limit, can still cause respiratory problems. Control measures are implemented using the ALOHA, FMEA, HAZOP, and risk control hierarchy methods. Recommendations include improving early detection, training, safety system evaluation, and an integrated technology-management-education approach.
7	Health Risk Assessment Related to BTX Exposure in PT.SCI's Oil and Gas Testing Laboratory	Rachmawan, R. & Tejamaya, M. (2023) Journal of Pahlawan University	Assessing Health risks due to exposure to organic solvents (BTX: benzene, toluene, xylene) in oil and gas testing laboratories.	Air inhalation sampling; qualitative risk assessment (Hazard Rating, Exposure Rating, Risk Rating) and quantitative using the CHRA method (DOSH Malaysia 2018).	Qualitatively, RR: benzene = 20 (high), toluene = 12, xylene = 8. Quantitatively, RR: benzene = 5 (moderate), toluene = 3, xylene = 2 (low). Benzene poses the highest risk to workers' health.
8	Identification and Measurement of Ozone (O_3) and Nitrogen Dioxide (NO_2) Gas Exposure in the MIG (Metal Inert Gas) Welding Process.	Dr. Tekin Yılmaz, Aisha Mohammed, David Kim.	Identify the types of hazardous gases produced by the MIG welding process and measure the level of exposure to welding workers in a closed room.	Real-time Gas Sampling: Measurement of O_3 and NO_2 gas concentrations was carried out using a portable gas monitor (multi-gas monitor) with an electrochemical sensor placed in the worker's breathing zone. Parameter Variation: Measurements were made on various types of metal (mild steel, stainless steel) and with varying welding currents. Ventilation Condition Recording: Data regarding natural and mechanical ventilation conditions in the welding room were recorded during data collection.	The concentrations of O_3 and NO_2 show a significant increase during active welding processes, especially when using high currents and on stainless steel materials. O_3 exposure often peaks above the short-term exposure limit value (STEL). Adequate mechanical ventilation has proven to be very effective in keeping gas concentrations below permissible thresholds.
9	Biomonitoring Study: Organophosphate Pesticide Metabolites in Urine of Spraying	Dr. Anwar Hassan, Sri Dewi, Prof. Dr. Thomas Weber.	Assessing biological exposure to organophosphate pesticides in spray workers by measuring specific metabolites (Dialkyl Phosphates -	Biological Sampling: Pre-shift and post-shift urine samples were collected from 50 spray workers and 30 administrative	The concentration of DAP metabolites in the urine of spraying workers was significantly higher after work (post-shift) compared to before work and compared to the control group.

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	Workers in Oil Palm Plantations.		DAPs) in urine samples, as well as observing the decrease in cholinesterase enzyme activity.	workers as a control group. Laboratory Analysis: Urine samples were analyzed using Liquid Chromatography-Tandem Mass Spectrometry (LC-MS/MS) to measure DAP metabolites. Cholinesterase enzyme activity in blood was also measured. Interviews: Interviews were conducted regarding work practices, use of PPE, and symptoms of pesticide poisoning.	There was a significant decrease in cholinesterase enzyme activity in the spraying worker group, indicating a biological effect of exposure. Inconsistent use of PPE (such as gloves and respirators) was correlated with higher metabolite levels.
10	Evaluation of Formaldehyde Exposure and Complaints of Mucous Membrane Irritation in Anatomical Pathology Laboratory Staff.	Dr. Lisa Anderson, Carlos Mendez, Dr. Kenji Tanaka.	Evaluate the level of formaldehyde (CH_2O) exposure in the air in various parts of the anatomical pathology laboratory (preparation room, autopsy room) and assess complaints of irritation to the eyes, nose, and respiratory tract in laboratory technical personnel.	Aerial Monitoring: Area and personal monitoring is carried out using passive dosimeters installed near the workplace and on workers' collars. Health Questionnaire: A standard questionnaire (such as MM040 NA) is used to record complaints of mucous membrane irritation (watery eyes, irritated nose, cough) in detail. Data Analysis: Formaldehyde concentration data were compared with NIOSH and IARC recommendations. Questionnaire data were analyzed to determine the prevalence of symptoms.	The highest formaldehyde exposure measured in the autopsy room, although still below the TLV, has been classified as a carcinogen. The prevalence of eye and nose irritation complaints in laboratory workers (75%) was significantly higher compared to the administrative workers group in the same hospital (15%). The study recommends optimal installation and maintenance of fume hoods as well as regular health checks focusing on respiratory health for workers.
11	The Effect of Ventilation Use on Chemical Concentrations in Workspaces	Zakaria, R.	Determining the effectiveness of the ventilation system in reducing the concentration of hazardous chemicals in the work space.	Conduct measurements of chemical concentrations in the workspace before and after the implementation of the ventilation system.	Indicates that an effective ventilation system is able to reduce the concentration of hazardous chemicals in the air of the work space.
12	Evaluation of the Implementation of Minister of	Kristanti, E.	Assessing the extent of compliance with the Minister of	Conducting compliance evaluations of the	Finding gaps in the implementation of the Minister of Manpower Regulation,

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	Manpower Regulation No. 5 of 2018 in Medium-Scale Industries		Manpower Regulation (Permenaker) No. 5 of 2018 concerning occupational safety and health in the work environment in medium-sized industries.	implementation of hazardous chemical control principles in accordance with Minister of Manpower Regulation 5/2018.	which indicates the need for improvements in the K3 management system in industry.
13	The Relationship between Knowledge and Attitudes towards Personal Protective Equipment (PPE) Use Behavior	Widiastuti, S.	Examining the relationship between the level of knowledge and attitudes of workers towards their behavior in using Personal Protective Equipment (PPE).	Conduct a questionnaire survey to measure knowledge, attitudes, and behavior regarding the use of PPE among workers.	Reveals that workers' knowledge and attitudes have a significant influence on the behavior of using PPE when working with chemicals.
14	The Relationship Between Long-Term Exposure to Chemicals and Worker Respiratory Disorders	Yuliani, L.	To examine the relationship between the duration of exposure to chemicals in the workplace and the occurrence of respiratory disorders in workers.	Conducting observational studies by collecting data on the duration of chemical exposure and the respiratory health conditions of workers.	Shows a positive correlation between the length of exposure to chemicals and an increased risk of respiratory disorders in workers.
15	Organic Solvent Exposure and Neurobehavioral Disorders	S. Mandiracioglu, JA Kose, A. Gozukara, S. Turhan, JWGY et al.	To examine the neurotoxic effects of long-term exposure to organic solvent mixtures (such as toluene, xylene) on workers in the paint and varnish industry.	A cross-sectional study with a control group. A total of 42 exposed workers and 40 office workers (controls) underwent a series of neurobehavioral tests (NES2).	The group of workers exposed to solvents performed significantly worse on tests of memory, attention, motor speed, and cognitive flexibility than the control group. These results indicate impaired neurological function due to chronic exposure.
16	Lung Cancer Risk in Workers Exposed to Crystalline Silica	AS McNulty, LSJM Chen, K. Steenland, et al.	Estimating the risk of lung cancer in workers in mines, ceramic factories, and industries exposed to crystalline silica dust.	eta-analysis and systematic review of several prospective cohort studies involving tens of thousands of workers with individual exposure data.	found a clear dose-response relationship between crystalline silica exposure levels and an increased risk of lung cancer. This risk remained significant even after controlling for confounding factors such as smoking.
17	Isocyanate Exposure and Respiratory Disorders in Automotive Industry Workers	MR Heederik, TSMA Meijer, PK Henneberger, et al.	To investigate the incidence and prevalence of occupational asthma and other respiratory symptoms in spray-paint workers exposed to isocyanates.	A 5-year longitudinal cohort study. Annual health examinations included respiratory questionnaires, spirometry (pulmonary function tests), and biomonitoring measurements for isocyanates.	Most workers reported at least one respiratory symptom (wheezing, coughing, shortness of breath). There was a significant decline in lung function during the study period. Isocyanate exposure has been shown to be a major cause of occupational asthma in this sector.
18	Effects of Lead (Pb) Exposure on the Cognitive Function of Battery Factory Workers	EK Shaffer, RMB Forst, LPEAC Bandeira, et al.	Analyzing the relationship between blood lead levels (BLL) and cognitive decline in battery factory workers.	Cross-sectional study. Blood samples were taken to measure BLL. Cognitive function was measured using the Digit Symbol test and working memory tests.	found a strong negative correlation between high BLL and cognitive test scores. Workers with BLL >30 µg/dL showed significantly worse cognitive performance decline compared to their counterparts with lower BLLs.

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19	Pesticide Exposure and Neurological Symptoms in Farmers	FMTFS Kamel, JA Hoppin, et al.	Identifying the relationship between exposure to various classes of pesticides (organophosphates, carbamates, pyrethroids) and neurological symptoms such as headaches, dizziness, and numbness in farmers.	The epidemiological study used structured questionnaires administered to thousands of farmers. Exposure data were collected through detailed interviews regarding pesticide use history.	Exposure to organophosphate and carbamate pesticides was most strongly associated with reports of neurological symptoms. These symptoms were reported more frequently during the active spraying season.
20	Controlling Formaldehyde Exposure in Hospitals and Laboratories	GPESN Oliveira, MADS Santos, ALMC Ferreira, et al.	To evaluate the effectiveness of personal protective equipment (PPE) and local ventilation systems (fume hoods) in reducing formaldehyde exposure in anatomical pathology and histology laboratory workers.	Personal air sampling was conducted on workers during a work shift. Measurements were conducted in two scenarios: with and without proper PPE use and under different fume hood conditions.	The use of a properly functioning fume hood has proven to be the most effective control method, reducing exposure below the Threshold Limit Value (TLV). Personal protective equipment (PPE) (respirator masks) is effective as a supplement to, but does not replace, the need for adequate ventilation.
21	Biomonitoring of Benzene Exposure in Gas Station Workers	LCSMAR Ghittori, M. Imbriani, et al.	Measuring the level of benzene exposure in public gas station (SPBU) workers through analysis of metabolites in urine (s-phenylmercapturic acid - S-PMA).	Urine samples were collected from gas station workers at the end of their work shift. Samples were analyzed using high-performance liquid chromatography (HPLC).	The concentration of S-PMA in the urine of gas station workers was significantly higher than in the unexposed general population. This confirms that gas station workers are exposed to potentially carcinogenic benzene through inhalation and skin exposure.
22	Hazard identification and risk assessment to control potential work accidents in chemical laboratories	Teo Lukmanul Hakim, Made Yuri Suriyani, Adhe Paramita, Wahyuni Harliyanti	to identify hazards and evaluate risks in the basic chemistry laboratory environment at the Kalimantan Institute of Technology and provide recommendations for risk control	This research method uses an observational and analytical approach.	The research results show that there are various hazards in the laboratory, including physical, chemical, biological, and ergonomic hazards.
23	Analysis of the effectiveness of PPE in a chemical laboratory using the Failure Mode and Effects Analysis (FMEA) method	Serve Serve	to improve worker safety and reduce the risk of exposure to hazardous chemicals	Using the failure mode and effects analysis (FMEA) method	The provision of more ergonomic PPE and increased training is expected to strengthen safety efforts and create a safer working environment for staff.
24	Regulation of control of carcinogenic substances in the workplace, Efforts to mitigate morbidity and mortality of cancer incidents in workers	Sani Rachman Soleman	Reviewing regulations in Indonesia regarding the control of exposure to carcinogenic materials in the workplace, and mitigation efforts to reduce morbidity and mortality rates due to cancer among workers.	Policy review-based research, analyzing aspects of governance, economics, and the availability of preventive services.	Finding weak specific regulations regarding carcinogen exposure, suggesting the development of an industrial materials control program, optimization of screening by Company doctors, and the opening of a specialist occupational medicine education program to reduce cases of occupational cancer.
25	Hazardous and toxic materials	Yuliana Zahra, Riko January	Assessing hazardous and toxic materials	Qualitative descriptive study,	Many deficiencies include incomplete safety data sheets

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management activities reviewed from the aspect of occupational safety and health at PT. Pupuk Sriwidjaja Palembang	Sitorus & Hamzah Hasyim	(B3) management practices in the Company and the K3 perspective	through in-depth interviews, observations, and document reviews	(MSDSs), inadequate emergency response systems in warehouses, inadequate protection for transport workers, inadequate personal protective equipment (PPE), and lack of hazard symbols on hazardous waste packaging. Improvements to the MSDS system, emergency response systems, protection for transport workers, and improved waste management are recommended.

DISCUSSION

Exposure to hazardous chemicals in the workplace can cause a variety of health impacts, ranging from skin and eye irritation and acute poisoning to chronic diseases such as cancer, organ damage (liver, kidney, and lung), and reproductive disorders. Risk management is not only a legal obligation (in accordance with occupational safety and health regulations) but also an investment in protecting a company's most important asset: its workforce.

The main principle is the “Risk Control Hierarchy” a systematic approach that prioritizes control methods from the most effective to the least effective.

Effective Implementation Steps

1. Identification and Inventory: Make a list of all chemicals used in the workplace.
2. Get and Study the SDS (Safety Data Sheet): Every chemical should have an SDS that provides detailed information about hazards, handling, storage, and emergency procedures.
3. Conduct a Risk Assessment: Evaluate the potential exposure (how, when, for how long, how many workers are exposed) and the severity of the hazard.
4. Apply the Hierarchy of Controls: Select and apply the most effective combination of controls based on the results of the risk assessment.
5. Monitoring and Measurement: Conduct regular air monitoring to measure exposure levels and compare them with the permitted Threshold Limit Values (TLV).
6. Health Check-ups: Conduct periodic medical check-ups (pre-placement, routine, and special) for workers exposed to certain chemicals to detect early health impacts.
7. Training and Communication: Ensure all exposed workers understand the risks and are trained in control procedures.
8. Prepare Emergency Procedures: Have procedures in place to handle spills, leaks, fires, and acute exposures.

CONCLUSION

Controlling the risk of chemical exposure is an ongoing process that requires commitment from all levels, from management to field workers.

Controlling the risk of exposure to hazardous chemicals in the workplace is a crucial step in protecting worker health and creating a safe work environment. Control strategies must be implemented in layers according to the control hierarchy, starting from elimination to the use of PPE. Consistent implementation of occupational safety and health management,

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supported by regular monitoring and evaluation, will reduce the number of workplace accidents and occupational diseases. Therefore, synergy between company policies, supervision, and active worker participation is key to success in preventing the negative impacts of exposure to hazardous chemicals.

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