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Enhancing Health of Workers in the Water Sector Through Effective Governance, Risk Management, and Environmental Safety Standards

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Abstract

The water sector is fundamental to achieving sustainable development, safeguarding public health, supporting economic advancement, and ensuring environmental preservation in any nation. This paper explores how effective governance, comprehensive risk management frameworks, and strict adherence to environmental safety standards can contribute to improving the health and well-being of engineering professionals and workers within the water sector. The research methodology comprises an extensive literature review, detailed case studies, field visits to water infrastructure projects and construction sites, and an evaluation of various safety and security practices. The study identifies numerous workplace challenges and proposes strategic interventions to address them. Occupational hazards such as chemical exposure, biological threats, environmental risks, accidents, and physical injuries remain common concerns across work environments. Ensuring adequate safety measures is essential for facilitating meaningful and sustainable progress. The study concludes that by promoting resilient occupational health strategies, strengthening governance, implementing robust risk management protocols, and enforcing environmental safety standards, the health and safety of workers involved in water projects and engineering operations can be significantly enhanced.

Keywords: Water sector, sustainable development, resilient occupational strategies, effective governance, environmental safety standards

INTRODUCTION

Nigeria's water sector plays a vital role in promoting public health, advancing sustainable development, and supporting economic growth. Workers in this sector face a broad spectrum of occupational hazards, including physical risks from operating heavy machinery, chemical exposure to disinfectants, such as chlorine, biological threats from untreated water and sewage, and ergonomic challenges from physically demanding tasks. Poor occupational health and safety (OHS) practices frequently lead to work-related injuries, illnesses, reduced productivity, and increased operational costs [1–3].

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Despite the critical importance of water supply and sanitation services as foundational public goods, the health and safety of workers responsible for operating treatment facilities, maintaining infrastructure, managing waste, and enforcing regulations often receive insufficient attention compared with broader consumer health concerns. Neglecting workforce well-being can result in service interruptions, higher non-revenue water losses, increased maintenance costs, and environmental liabilities that could otherwise be mitigated through proactive interventions [4].

The water sector includes diverse operations, such as water supply, wastewater treatment, borehole drilling, sanitation services, and water resource management. Workers across these functions are frontline contributors to the provision of essential services, especially in low- and middle-income countries, where infrastructure and institutional capacities may be limited. However, the health and safety of these workers are frequently compromised owing to inadequate governance structures, insufficient risk management frameworks, and weak enforcement of environmental safety standards [5].

Integrating effective governance, comprehensive risk management strategies, and environmental safety protocols can create safer and healthier workplaces, thereby enhancing workforce resilience and service delivery. Health educators, safety officers, and medical professionals play a crucial role in promoting workplace health and safety. Adequate training and continuous professional development are essential to equip these personnel with the knowledge and tools needed to prevent occupational hazards and respond effectively to emergencies [6].

Key hazards in the water sector include:

1. *Biological risks:* Exposure to pathogens in raw sewage, sludge, aerosols, and vector-borne diseases.
2. *Chemical risks:* Contact with chlorine, ammonia, hydrogen sulfide, disinfection by-products, and laboratory chemicals.
3. *Physical risks:* Working in confined spaces, at heights, amidst excessive noise, vibration, electrical hazards, and traffic.
4. *Environmental/climate risks:* Heat stress, flooding, and extreme weather events can disrupt safe working conditions.
5. *Ergonomic and psychosocial risks:* manual handling, long or irregular work shifts, fatigue, working alone, and exposure to harassment or workplace stress.

Many water utilities operate without integrated Environmental, Health, and Safety (EHS) management systems, structured training programs, or mechanisms to share lessons from past incidents. Fragmented regulatory oversight and weak reporting systems further diminish accountability, leading to under-reported injuries, preventable fatalities, and chronic health conditions that undermine workforce capacity and service reliability [7].

This study explores how sound governance, effective risk mitigation, and adherence to safety standards can foster healthier and more resilient workplaces, ultimately strengthening the Nigerian water sector's ability to deliver safe and reliable services.

LITERATURE REVIEW

The Occupational Safety and Health Act of 2007 was established to ensure the safety, health, and welfare of workers while also safeguarding others who may be affected by workplace activities. Legislation aims to enhance and promote safety and health standards across various sectors. In parallel, Water Safety Plans (WSPs), as outlined by the World Health Organization (WHO, 2004a), offer a structured approach to protecting public health by addressing the risks associated with water systems. The WSP framework emphasizes a thorough assessment of the entire water supply system, continuous operational monitoring, and adoption of appropriate management strategies [8].

Climate change poses significant risks to several critical industries, particularly those dependent on natural resources, such as water, agriculture, habitats, and food security [9]. Within occupational safety and health, the focus remains on safeguarding employees' well-being by minimizing workplace hazards. Ensuring a healthy work environment is a key responsibility of occupational health professionals who advocate preventive measures and promote overall well-being.

The implementation of sound safety protocols is crucial in industries with high operational complexity. These practices not only help prevent accidents and health issues but also contribute to higher employee satisfaction, improved morale, and greater productivity. Furthermore, reducing workplace injuries and illnesses can significantly lower operational costs [10].

The WHO guidelines on WSPs, supported by the Bonn Charter (IWA, 2004), advocate for comprehensive risk management approaches spanning from the water source to its distribution. By prioritizing systematic assessments and ongoing monitoring, WSPs offer a proactive solution to ensure drinking water safety. Similarly, the healthy workplace model emphasizes not only the elimination of hazards but also the creation of supportive and engaging work environments. These workplaces are designed to enhance job satisfaction and foster a culture of safety and health.

In particular, in process industries where operational risks are significant, structured and well-enforced safety measures are vital. These measures ensure that individuals are protected, operational environments are safeguarded, and organizational performance is sustained. A strong commitment to OHS leads to a healthier workforce and a safer, more resilient workplace.

RESEARCH METHODOLOGY

In-depth information on this study was gathered through a literature review, case studies, expert opinions, and visits to selected water projects, construction sites, and investigations of various security approaches.

Conceptual Framework

A three-layer model was used.

1. *Governance (macro/sector):* laws, independent regulation, national OHS codes harmonized with environmental standards, funding mechanisms, and transparent reporting.
2. *Risk management (meso/enterprise):* Utility-level EHS management system aligned with ISO-style continuous improvement (Plan-Do-Check-Act), bow-tie/job Hazard Analysis (JHA), and hierarchy of controls (elimination → substitution → engineering → administrative → PPE).
3. *Environmental safety standards (micro/operational):* Site-specific procedures that enforce effluent criteria, chemical handling, confined-space entry, energy isolation, biosolids management, and emergency response integrated with Water/Wastewater Safety Plans and environmental monitoring.

The layers are mutually reinforcing robust governance compels and enables enterprise risk management; strong environmental standards provide measurable controls; and enterprise learning feeds back to regulatory refinement.

Methods (Scoping Review and Synthesis Approach)

This study uses a narrative scoping method drawing on international OHS conventions, sector guidance on WSPs, environmental discharge standards, and case evidence from utilities in diverse contexts. Sources include normative guidance (e.g., ILO conventions, WHO/FAO/UN-Water materials), utility benchmarking studies, and peer-reviewed literature on occupational exposure in water and wastewater settings. The synthesis provides a practical implementation roadmap and indicator set. (A full protocol and search terms can be appended to formal publications.)

Effective Governance and Worker Health

Governance refers to the structure, processes, and policies that regulate the water sector. The most durable gains arise when governance clarifies duties and aligns incentives, risk management systematically identifies and controls hazards, and environmental safety standards convert policies into enforceable practices at the asset and task levels. By executing the phased roadmap and tracking meaningful indicators, utilities and regulators can achieve measurable reductions in injuries and illnesses, while delivering safer water and sanitation. Effective governance enhances worker health in the following ways.

Policy Development and Enforcement

- Establishing OHS regulations ensures that workers operate under safe conditions.
- Strict enforcement of safety laws minimizes negligence and improves accountability.

Resource Allocation

- Adequate funding supports the provision of personal protective equipment (PPE), medical facilities, and modern technology that reduce health risks.
- Investment in modern water treatment infrastructure reduces manual handling of hazardous substances.

Capacity Building and Training

- Training workers on safe practices, emergency response, and hygiene can reduce the risk of accidents and disease outbreaks.
- Knowledge sharing promotes a safety-conscious culture across the sector.

Transparency and Accountability

- Monitoring and evaluation systems track compliance with safety standards.
- Workers are empowered to report hazards, ensuring corrective actions are taken promptly.

Figure 1 presents the water security assessment framework.

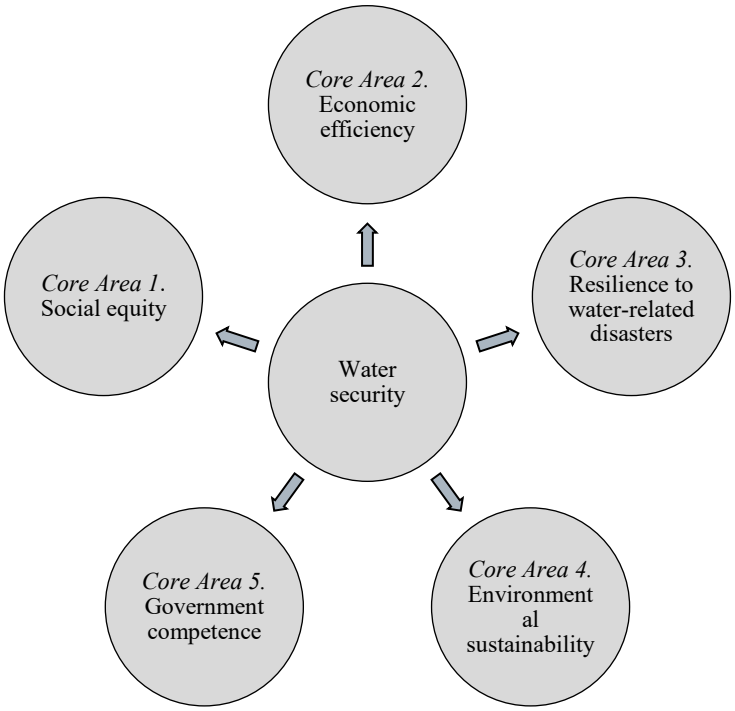

Figure 1. Water security assessment framework

Governance Elements that Matter

1. *Clear statutory mandates and role clarity:* Define which agency sets OHS standards for water utilities, who inspects them, and how sanctions/appeals work.
2. *Unified regulatory instruments:* Harmonize water quality, environmental permits, and OHS regulations to avoid conflicting requirements.
3. *Data transparency:* Mandatory reporting of lost-time injuries, near-misses, exposure incidents, and environmental exceedances; public dashboards promote accountability.
4. *Financing mechanisms:* Tariff setting and performance-based transfers include ring-fenced OHS/asset management budgets.

5. *National competency frameworks:* Accredited training and licensing for high-risk tasks (confined space, chlorine handling, and electrical isolation).
6. *Emergency preparedness:* Sector-wide mutual aid agreements, interoperable incident commands, and surge staffing for extreme events.

Risk Management and Occupational Safety

Risk management involves identifying, assessing, and mitigating risks that affect workers. In the Nigerian water sector, risk management contributes to worker health, as follows:

1. *Hazard Identification*
   - Regular inspections detect risks, such as exposure to pathogens in wastewater, chemical leaks, or unsafe equipment.
2. *Preventive and Control Measures*
   - The use of protective clothing, safety signage, and proper ventilation systems reduces exposure to harmful substances.
   - Routine equipment maintenance prevents mechanical accidents.
3. *Emergency Preparedness and Response*
   - Establishing contingency plans for accidents, chemical spills, and waterborne disease outbreaks will protect workers and the community.
   - The availability of first-aid kits, medical units, and fire safety equipment ensures quick response.
4. *Insurance and Compensation Schemes*
   - Health insurance and compensation packages cushion workers against occupational risks, ensuring financial stability.

Figure 2 shows various ESG risks, and Figure 3 presents the influences of environmental, social, and governance.

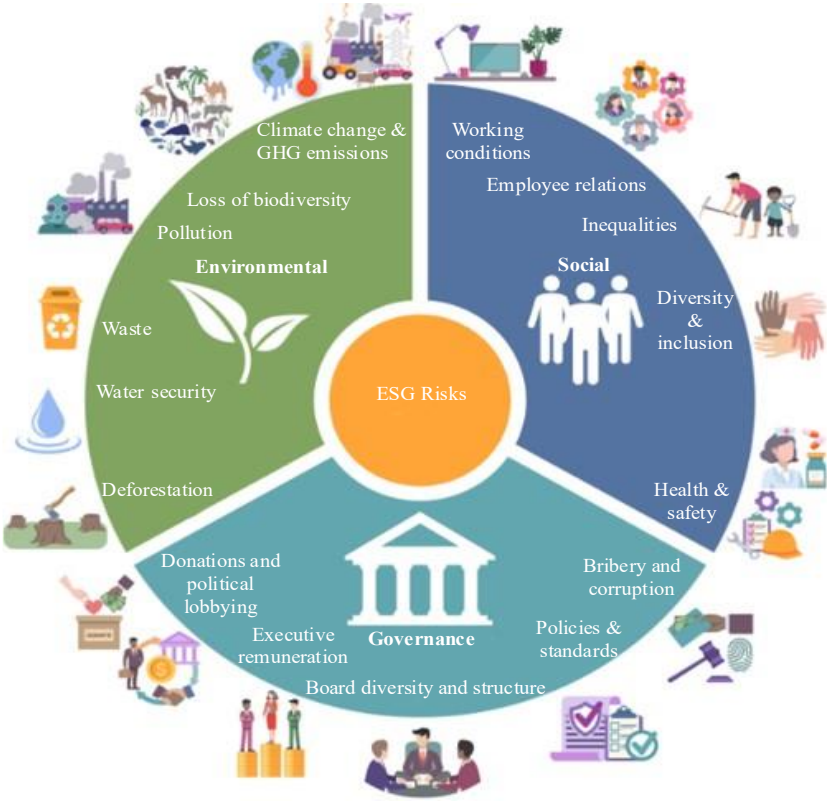

Figure 2. Enterprise risk management (ERM) risks.

Figure 3. Influences of environmental, social, and governance (ESG).

Enterprise Risk Management (ERM) in Utilities

EHS Management System: Policy, hazard identification, risk evaluation (likelihood × severity), controls, training, monitoring, and management review.

Critical Risk Controls

1. *Confined space:* permit-to-work, atmospheric testing (O_2, H_2S), standby rescue, and retrieval systems.
2. *Chemicals:* segregated storage, double containment, gas detection, automatic shut-offs, emergency showers/eyewash, spill kits.
3. *Energy isolation (LOTO):* written procedures, lock/hasp devices, verification of zero-energy.
4. *Traffic and trenching:* shoring/boxing, trench access/egress, vehicle-pedestrian separation, competent person sign-off.
5. *Biological agents:* vaccination policies where applicable, hygiene protocols, respiratory protection, and negative-pressure work zones for aerosols.
    - *Learning culture:* Just culture for incident reporting, root-cause analysis, corrective/preventive actions (CAPA), and cross-site learning.
    - *Digital tools:* Work management systems linked to risk registers and training records; portable sensors for gas and noise; telemetry to manage remote work risks.

Environmental Safety Standards and Worker Health

The health of water sector workers is closely linked to environmental safety. Environmental safety standards promote worker well-being.

1. *Waste Management*
    - Proper disposal of sludge, wastewater, and chemicals minimizes direct exposure to toxins and pathogens.

2. *Water Quality Control*
   - Adhering to safety protocols in water treatment reduces the risk of workers contracting waterborne diseases, such as cholera, typhoid, and hepatitis.
3. *Climate Resilience*
   - Integrating climate-adaptive infrastructure helps protect workers from floods, droughts, and extreme weather events, which increase occupational hazards.
4. *Sustainable Infrastructure*
   - Designing eco-friendly and worker-friendly facilities minimizes the long-term environmental and health risks.

Environmental Safety Standards with Worker Health Co-Benefits

1. *Effluent and emissions control:* Meeting discharge limits reduces pathogen/chemical exposure to operators and communities.
2. *Biosolids/sludge management:* stabilization, pathogen reduction (e.g., anaerobic digestion and composting), controlled reuse, and exposure controls.
3. *Chemical stewardship:* procurement standards (e.g., low-hazard substitutions), safety data sheet integration, and cradle-to-grave tracking.
4. *Air quality in plants:* ventilation standards for chlorination rooms, dechlorination areas, and sludge-handling buildings.
5. *Waste minimization and circularity:* Methane capture, odor management, and energy efficiency simultaneously reduce the environmental and occupational hazards.

Challenges Facing Safety Implementation in the Water Sector

Worker health risks from contaminated water and poor safety measures, governance gaps, such as inadequate data, funding, and human capacity. Risk management issues include complex regulations, inconsistent policy goals, human errors, and vulnerability in centralized systems.

Challenges from Governance and Institutions

1. *Fragmented mandates and weak coordination* between federal actors (Federal Ministry of Water Resources (FMWR), River Basin Authorities), state water utilities, and regulators (National Environmental Standards and Regulations Enforcement Agency (NESREA) for environment; SON/NAFDAC for standards) blur accountability for workers and environmental safety.
2. *Outdated/contested legal framework:* Repeated failure to pass a comprehensive National Water Resources law has left gaps in regulation, permits, and basin-level oversight.
3. *Chronic underfunding and weak cost recovery* in state water utilities drive deferred maintenance and poor safety investments. (e.g., high non-revenue water and operating costs far exceeding revenues in Lagos, Cross River, and Kaduna.)
4. *Data poverty:* Patchy utility performance and health, safety, and environmental (HSE) reporting systems, making benchmarking and regulatory enforcement difficult.
5. *Slow roll-out of the national action plan (NAP)* commitments on governance, M&E, and commercialization at the state level.

Enterprise Risk Management (Utilities and Contractors)

1. *High-energy, high-hazard operations* (chlorination, confined spaces, energized equipment, traffic work zones) with inconsistent permit-to-work and lockout/tagout practices.
2. *Workforce competency gaps* for critical tasks (gas testing, rescue, and chemical handling) exist due to limited structured certification pathways.
3. *Power reliability issues* that compromise treatment and safety systems.
4. *Psychosocial and security risks* (field staff harassment and night call-outs) with a limited incident learning culture.
5. *Supply chain fragility* for treatment chemicals and PPE (price volatility, counterfeit risk).

Environmental Safety Standards

1. *Compliance gaps* with the Nigerian Standard for Drinking Water Quality (NIS 554:2015) and NESREA environmental regulations, especially for continuous monitoring, sludge/biosolids handling, and lab QA/QC.
2. *Inconsistent effluent control* at wastewater and fecal sludge facilities; weak chain-of-custody for hazardous wastes.
3. *Flooding and climate risks* overwhelm treatment plants and lagoons, thereby increasing exposure and incidents. Table 1 presents the information risk assessment matrix.

Table 1. Illustrative risk assessment matrix.

Hazard	Example task	Likelihood	Severity	Risk rating	Primary controls
Chlorine gas release	Cylinder changeover	Medium	High	High	Gas detection, automatic shutoff, ventilation, escape respirators, training
H_2S in confined space	Sewer inspection	Medium	Catastrophic	Extreme	Permit-to-work, testing, ventilation, retrieval system, standby rescue
Heat stress	Valve repairs in the hot season	High	Medium	High	Work-rest cycles, hydration, shade, scheduling, acclimatization
Electrical shock	Pump maintenance	Low	High	Medium	LOTO, verification of isolation, insulated tools, training
Musculoskeletal injury	Manual handling of covers	High	Medium	High	Mechanical aids, team lifts, ergonomic redesign
Vehicle collision	Night response	Medium	High	High	Defensive driving, journey management, lighting, reflective PPE

Cost–Benefit Considerations

Investments in engineering control and competency systems typically yield net savings through fewer lost-time injuries, lower insurance premiums, reduced overtime, avoidable spills, and improved equipment reliability. A conservative utility business case includes (i) estimating baseline incident costs (medical, lost time, damage, penalties), (ii) quantifying avoided incidents using benchmark data, and (iii) including co-benefits (lower non-revenue water from safer, more reliable maintenance; reduced chemical consumption from optimized dosing). Many interventions (e.g., lockout hardware, gas monitors, and ventilation maintenance) have short payback periods.

Intervention Strategies to Address the Challenges

A range of intervention strategies has been employed to tackle workplace hazards and promote safety. These strategies include engineering controls, administrative measures, PPE, and behavioral approaches. By implementing such interventions, organizations can enhance worker safety, minimize risks, and encourage safer work practices. These actions aim to reduce injuries, occupational illnesses, environmental incidents, and property damage.

Process Safety Interventions

Interventions focused on process safety aim to control and reduce risks associated with hazardous materials, equipment, and operational processes. These efforts are essential for preventing accidents and ensuring safe handling of industrial processes.

Occupational Health and Safety Interventions

OHS interventions are geared toward safeguarding the well-being of workers in the workplace. Identifying potential risks through methods such as job safety analysis (JSA) and Safety Data Sheets (SDS) helps to understand hazards. Once hazards are recognized, control measures are applied to minimize risks through risk assessment and hazard control (RAHC) procedures. Additionally, workers are provided with appropriate PPE, such as safety clothing, goggles, gloves, and respirators, depending on the nature of the hazard. Ergonomic risks such as musculoskeletal injuries are also addressed by assessing and modifying tools and equipment to ensure safer work environments.

Environmental Interventions

Environmental strategies aim to reduce the negative impacts of industrial operations on the environment. Challenges, such as inadequate infrastructure, contaminated water sources, and increased health risks due to climate change, require targeted solutions to safeguard both ecosystems and communities. These interventions aim to establish and maintain robust environmental safety standards.

Safety Audits and Inspections

Routine safety audits and inspections play vital roles in improving HSE performance. These evaluations systematically examined workplaces to identify hazards, assess existing safety protocols, and recommend corrective actions to ensure compliance with safety standards.

Overall, integrating these intervention strategies strengthens workplace resilience, supports health and safety, and contributes to sustainable operations, while addressing both immediate and long-term risks. Benefits of integrating governance, risk management, and environmental safety.

When effective governance, robust risk management, and strong environmental safety standards are combined, the following outcomes emerge.

1. Reduced occupational injuries and illnesses.
2. Improved physical and mental well-being of workers.
3. Increased productivity and reduced absenteeism.
4. Enhanced institutional trust and reputation of the Nigerian water sector.
5. Contribution to national goals of public health and sustainable development.

CONCLUSION

The health and well-being of workers in the water sector, project implementation sites, and engineering operations can be significantly enhanced by adopting resilient occupational strategies, robust governance frameworks, effective risk management, and strict adherence to environmental safety standards. Workers in Nigeria's water sector are regularly exposed to occupational hazards that threaten their health, safety, and productivity. However, by implementing sound governance practices, proactive hazard identification and control mechanisms, and enforceable environmental safety protocols, the risks faced by these workers can be minimized, thereby improving their overall well-being.

A safe and healthy workforce not only strengthens the operational capacity of the water sector but also supports Nigeria's broader development goals, including sustainable development and public health protection. Ensuring worker health is both an ethical responsibility and a strategic priority essential to delivering reliable, cost-effective, and climate-resilient services. Sustainable improvements are achieved when governance frameworks clearly define roles and responsibilities, risk management systems systematically identify and mitigate hazards, and environmental safety standards translate policies into enforceable actions at the workplace and task levels.

Through the implementation of phased action plans and monitoring of key health and safety indicators, utilities and regulators can achieve measurable reductions in workplace injuries and illnesses. This, in turn, ensures a safer and more efficient delivery of water and sanitation services for communities.

Workers in the sector, including utility operators, field technicians, laboratory staff, construction teams, and sanitation workers, face a wide range of hazards. These include biological exposure, hazardous chemicals, ergonomic strain, heat stress, workplace violence, and psychosocial risks. Despite the sector's essential role in climate adaptation and public health, OHS systems remain fragmented, especially in low- and middle-income countries.

This study synthesizes the existing evidence on the factors influencing worker health in the water sector and proposes an integrated framework linking sector governance, enterprise-level risk management, and enforceable environmental safety practices. The central pillar of this framework is

the empowerment of health educators, safety officers, and medical professionals through continuous professional development and targeted training programmes. Keeping these personnel informed of the latest safety protocols and emerging challenges is critical to fostering safer workplaces.

Additionally, the study underscores the importance of leadership in cultivating a culture of safety within organizations. Active support from management is vital for successful health and safety programs. Organizations that prioritize worker well-being not only improve employee satisfaction and morale but also enhance productivity and reduce costs associated with injuries and health-related disruptions.

Recommendations

1. *Capacity building:* Health educators, safety officers, and physicians must be equipped with up-to-date knowledge and skills to effectively address diverse health and safety challenges. Continuous professional development and specialized training programs are essential to ensure that they remain current with best practices and emerging occupational hazards.
2. *Integrated mitigation:* Effective mitigation measures, strategic planning, engineering controls, and coordinated responses from various stakeholders, along with strengthening legal frameworks, are necessary to support environmental protection and workplace safety.
3. *Supportive environmental policies:* Legislative frameworks should reinforce eco-friendly behaviors, sustainable waste management, and energy efficiency to further reduce workplace risks.
4. *Climate-resilient infrastructure:* Investments should be directed towards infrastructure that minimizes worker exposure to hazards during extreme conditions, such as elevated chemical storage, automated dosing systems, and remotely controlled valves.
5. *Research and monitoring:* Enhance research capabilities and surveillance systems, including routine exposure monitoring and collaboration with public health institutions, to track hazards and improve response mechanisms.
6. *Workplace health promotion:* Empower health educators, safety officers, and medical professionals with sufficient training to lead workplace health initiatives and ensure the effective implementation of safety measures.
7. *Strengthening surveillance:* Routine exposure assessments and partnerships with health organizations should be expanded to improve risk identification and prevention.

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