



CBRN Hazard Management in Malaysian Healthcare: A Review of the Literature and Implications for Practice

Poobalan Vengidasamy¹, Shamsul Bahri Mohd Tamrin^{1*}, Mohamed Alwi Bin Hj¹, Abdul Rahman², Gurjeet Singh a/ Harvendhar Singh²

¹Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, University Putra Malaysia 43400 UPM Serdang, Selangor, Malaysia

²Hospital Selayang, 68100 Batu Caves, Selangor, Malaysia

*Corresponding Author's E-Mail: shamsul_bahri@upm.edu.my

Abstract

The occurrence and intensity of both natural and human-made disasters are bound to increase, posing significant risks to humanity. In Malaysia's healthcare setting, a variety of procedures and practices for managing safety, health, and emergency management are implemented to ensure the comfort and protection of hospital personnel, patients, and visitors. The presence of chemical, biological, radiological, and nuclear (CBRN) hazards pose a grave risk to the health and well-being of healthcare personnel in Malaysia. The aim of this review article is to draw attention to practical implications and provide a thorough summary of the literature on CBRN hazard management in Malaysian healthcare.

Keywords: CBRN Hazard Management; Malaysian Healthcare; Disaster Management; Healthcare Safety

Introduction

In today's ever-changing world, where technology is advancing at an astonishing pace and the environment is undergoing rapid transformations, it has become crucial to acquire new skills and knowledge in diverse fields. With the continuous progress of technology, the occurrence and intensity of both natural and human-made disasters are bound to increase, posing significant risks to humanity (Huang, Wang & Liu, 2021). In Malaysia's healthcare setting, a variety of procedures and practices for managing safety, health, and emergency management are implemented to ensure the comfort and protection of hospital personnel, patients, and visitors. This includes preparing for and responding to various hazardous substances, such as chemicals and biological agents, as well as radiation-related contaminants.

The presence of chemical, biological, radiological, and nuclear (CBRN) hazards pose a grave risk to the health and well-being of healthcare personnel in Malaysia. Recent events, such as the COVID-19 pandemic, instances of chemical weapons usage in neighbouring nations, and unintentional releases of radioactive substances within medical facilities, underscore the gravity of CBRN hazards. In light of these incidents and crises, Adnan *et al.* (2022) emphasise the crucial need for Malaysian healthcare institutions to establish effective systems for managing CBRN hazards.

The aim of this review article is to draw attention to practical implications and provide a thorough summary of the literature on CBRN hazard management in Malaysian healthcare. In this review, the following two research questions are specifically addressed: What methods are currently being utilised

in Malaysian healthcare to handle CBRN hazards? How can safety, health, and emergency management be improved in this scenario? To help answer these questions, this review will refer to various sources, such as academic papers and guidelines from relevant organisations.

The primary objective of this review article is to improve the safety, health, and overall well-being of healthcare providers in view of these complex and demanding dangers. This article aims to provide a succinct overview of CBRN hazards and their impact on healthcare providers. It will delve into the existing literature concerning CBRN hazard mitigation in healthcare settings, both locally and globally. Furthermore, it will explore the specific challenges present in managing CBRN hazards within the Malaysian healthcare system and identify opportunities for improvement. Finally, it seeks to make a valuable contribution to formulating effective strategies for handling CBRN hazards within healthcare facilities in Malaysia.

The literature pertaining to CBRN hazards in healthcare settings provides a plethora of information regarding safety, health, and emergency management.

With an emphasis on these hazards, various topics are covered, including risk assessment, preparation, planning, response strategies, training, and resource allocation. Numerous studies have underscored the importance of risk assessment in effectively managing CBRN hazards within healthcare facilities. For instance, Gunduz & Laitinen (2018), highlighted the necessity of conducting routine risk assessments to identify potential hazards at workplaces and implement suitable preventive measures.

Preparedness for CBRN hazards in healthcare settings is a significant topic addressed by Mohammadi *et al.* (2022). Ablah *et al.* (2016) underscore the importance of tailored emergency preparation plans that consider input from different stakeholders to meet the unique needs of healthcare facilities. Jacobitz & Nailon (2020), in a follow-up study, highlight the necessity for regular training and drills to ensure healthcare providers are well prepared to handle CBRN hazards.

The literature on CBRN hazards in healthcare settings consistently highlights the importance of training and resource allocation. A study conducted by Yildiz & Yildirim (2022) specifically emphasises the value of ongoing training for healthcare providers. Ensuring their ability to identify and respond effectively to CBRN hazards. Additionally, Romney (2020) underscores the necessity of having sufficient resources, such as personal protective equipment, available to both healthcare professionals and patients in the event of a CBRN incident.

The significance of having a response plan is highlighted in the literature focusing on CBRN hazards within healthcare settings. Majd *et al.* (2020) conducted a study that underlined the necessity of establishing specific protocols regarding decontamination and medical treatment for patients affected by CBRN hazards. Moreover, Khorram-Manesh *et al.* (2021), conducted further research that stressed the importance of efficient coordination and communication among healthcare providers, emergency medical services, and other involved parties during CBRN incidents.

In general, research on safety, health, and emergency management in healthcare settings, with a focus on CBRN hazards, emphasises the significance of in-depth risk assessment, emergency preparedness planning, successful response strategies, ongoing training, and resource allocation to ensure the safety of healthcare providers and patients.

The importance of addressing CBRN hazards in context of Malaysian healthcare settings.

According to Kako *et al.* (2018), a study on CBRN techniques presently utilised in healthcare, the threat of handling CBRN hazards is increasing. The assessment is based on their analysis of the sector's current use of CBRN approaches. Hospitals often conduct internal training sessions and short courses that are accessible to all hospital personnel in order to keep them aware and prepared to face such emergency scenarios. In line with this, the Malaysian Ministry of Health (MOH) is responsible for organising these sessions through the local hospitals and department levels. Through these training initiatives, it ensures that all healthcare providers are equipped with the professional knowledge and skills necessary to carry out any procedure related to their current positions.

A study by O'Mathúna (2019) emphasised that CBRN hazards pose a significant risk to healthcare settings. It is crucial to address these hazards to ensure the safety of healthcare providers, patients, and the wider community. As highlighted by Bajow *et al.* (2022), "the safety of healthcare providers, who serve as the front lines of patient care, places them at a significant risk of exposure to CBRN hazards."

Within healthcare facilities, microorganisms such as viruses and bacteria can proliferate rapidly, jeopardising the safety of healthcare providers, patients, and the public. Addressing these hazards is essential to mitigate the risk of a sudden surge in cases and the spread of contagious illnesses within the hospital (Ippolito *et al.*, 2020).

In the event of a CBRN incident, healthcare settings are frequently overrun with patients. Addressing these hazards is paramount, as it serves to minimise the repercussions of a disaster by equipping healthcare providers with adequate knowledge, an efficient attitude, and the skills and practices needed for an effective response (Abrams, 2018). The impact of CBRN hazards can extend beyond healthcare settings and significantly affect the surrounding community. By mitigating the effects of a disaster and curbing the spread of infectious illnesses, the effort to address these hazards plays a vital role in protecting the entire community (Morganstein & Ursano, 2020).

Overall, effectively addressing CBRN hazards necessitates the implementation of robust plans and procedures within healthcare facilities to ensure the safety of all individuals involved.

A current assessment of safety, health and emergency management at renowned hospital establishments within Malaysia.

In Malaysia, the Ministry of Health (MOH) bears the responsibility for regulating and overseeing the healthcare system, encompassing matters pertaining to safety, health, and emergency management in hospitals (Yadav, 2017). The MOH has formulated comprehensive guidelines and standards for healthcare facilities to ensure the quality and safety of patient care. These guidelines encompass a range of concerns, including infection prevention and control, patient safety, emergency preparedness, and disaster management.

Recent substantial investments by the Malaysian government in technology and healthcare infrastructure aim to elevate the quality and accessibility of healthcare services across the nation. However, challenges persist, particularly in rural areas where healthcare access remains a concern.

In terms of emergency management, the National Disaster Management Agency (NADMA) shoulders the responsibility of coordinating disaster management efforts nationwide, including in the healthcare sector (Che Hamid *et al.*, 2019). Healthcare facilities are mandated to have comprehensive emergency response plans in place, and healthcare providers undergo training in emergency response procedures (Ismail, 2020; Samsuddin *et al.*, 2018).

Overall, while Malaysia's healthcare system has made significant advancements in recent years, continued efforts are necessary to ensure the safety, health, and emergency management of the nation's major hospitals.

The challenges faced by healthcare providers in managing CBRN hazards.

In every hospital in Malaysia, healthcare providers, particularly medical officers, assistant medical officers, and staff nurses, assume a vital role as first-line and frontline responders in cases of reasonably anticipated emergencies (Gillani *et al.*, 2022). According to Yaqoob *et al.* (2021), healthcare providers must enhance their professional competencies to deliver high-quality healthcare before, during, and after such events. They are tasked with delivering top-tier services, backed by sound knowledge, awareness, life support training, and skills in managing related emergencies. These requirements empower healthcare providers to effectively and efficiently fulfil their duties in any emergency or disaster situation they are assigned to handle.

Unfortunately, a study by Almukhlifi *et al.* (2021) concluded that a majority of the healthcare providers in the emergency and trauma departments appear to have inadequate disaster preparedness, and it appears that most hospital staff do not seem to be prepared to handle a disaster event. For the safety, health, and emergency management plan to be effective, particularly in terms of roles and responsibilities, healthcare providers must possess in-depth knowledge and understanding of it.

A recent study by Yahya *et al.* (2022) highlights the key challenges that healthcare providers in Malaysia may encounter while managing CBRN hazards. These challenges include a lack of resources and equipment and insufficient training.

This encompasses the absence of specialised protective gear, decontamination tools, and specialised training on how to respond to CBRN incidents. Additionally, challenges might arise in coordinating response efforts among various agencies and organisations, including hospitals, emergency medical services, and local authorities (Munikanan & Vikneswaran, 2020).

Another challenge, as mentioned by O'Connor & Hammad (2016), is the potential for panic and fear among healthcare providers and patients in the event of a CBRN incident. However, through the implementation of clear protocols and the establishment of efficient communication, it is feasible to mitigate this risk and ensure that all parties are well informed about the appropriate actions to take in an emergency situation.

Overall, despite the challenges that may arise in managing CBRN hazards, Malaysian healthcare professionals are consistently striving to improve their preparedness for emergencies and strengthen their response skills.

The best practices and strategies for addressing CBRN hazards in healthcare settings.

CBRN hazards present a serious risk to healthcare facilities like hospitals and clinics. A study by Benolli Guidotti & Bisogni (2021) highlights that addressing CBRN hazards within healthcare settings requires a comprehensive and coordinated approach involving various stakeholders. The coordination involves healthcare personnel from MOH collaborating with other governmental agencies such as the Royal Malaysia Police (RMP), Emergency Rescue Services and Hazardous Material Unit Team (HAZMAT), and non-governmental organisations (NGO) providing security and emergency medical services and the community as well.

In order to achieve this coordination and collaboration, several best practices and approaches for addressing CBRN hazards in healthcare settings are recommended. According to a recent study by Alahmari & Khan (2023), every healthcare facility should develop an effective emergency plan that specifies the procedures to follow in the event of a CBRN incident. The plan should identify potential CBRN hazards and detail the steps to be taken during an emergency.

This consists of notification procedures, evacuation procedures, and communication protocols. Regular evaluation and revision of the emergency plan are crucial to ensuring it aligns with best practices and current standards.

Lam *et al.* (2018) discovered that healthcare providers, hospital personnel, volunteers, public health workers, and safety personnel lack training in emergency and disaster situations. This training gap places healthcare providers, patients, and individuals in healthcare facilities at risk, regardless of whether they are in urban or rural areas. Prior to this, Chilcott, Larner & Matar (2019), in their study, recommended comprehensive training for all healthcare providers in appropriate response techniques for CBRN hazards. Regular drills should be conducted frequently to reinforce these practices and identify areas for improvement.

Training and drills should encompass the recognition of symptoms of exposure, personal protective equipment (PPE), and effective decontamination techniques for CBRN agents. Moreover, healthcare facilities must ensure access to the appropriate PPE, decontamination equipment, and medications designed specifically for CBRN hazards. Mortelmans *et al.* (2017) proposed that all such equipment should undergo regular inspections and be replaced as necessary.

In a CBRN incident, effective communication is essential. Prior to this, Carbon *et al.* (2022) emphasised in their studies that healthcare facilities should establish a clear communication system to facilitate swift and accurate information sharing with medical personnel, emergency response teams, and governmental organisations in the event of a CBRN emergency. Healthcare facilities should collaborate with local government authorities such as HAZMAT, RMP, and emergency medical services teams from NGOs in order to ensure a coordinated response to CBRN hazards (Benolli *et al.*, 2021).

Despite these effective practices and strategies, there remain weaknesses and opportunities for improvement within the existing framework for ensuring safety, health, and managing emergencies within Malaysia. Nonetheless, it is vital to highlight that the authorities are actively striving to deal with these concerns and implement necessary enhancements.

As indicated in research by Goniewicz *et al.* (2021), a significant gap lies in the lack of uniformity in emergency preparedness and response across healthcare facilities. Furthermore, standards for educating and training healthcare providers in emergency and disaster preparedness are not widely recognised.

For hospitals to be accredited by the Joint Commission on the Accreditation of Healthcare Organisations (JCAHO), having an emergency management plan is a requirement, along with conducting two emergency and disaster-based simulations per year. According to Osman (2016), "hospitals should demonstrate their readiness for emergencies through these drills". Consistent protocols and guidelines that are universally applicable across all healthcare facilities within Malaysia are essential for effectively managing CBRN hazards.

The following guidelines and protocols are specifically designed to ensure the care and safety of every person and healthcare provider. In Malaysia, the Ministry of Health (MOH) is responsible for overseeing the safety, health, and emergency management of all health facilities. In relation to CBRN hazards, the MOH has developed several guidelines and protocols. Sulaiman (2020) identifies areas that require improvement in his study, suggesting that healthcare personnel in Malaysia may not receive sufficient training on CBRN hazards and response procedures. Therefore, there should be a heightened focus on training and drills to ensure that healthcare personnel are adequately prepared.

Reported shortages of PPE in Malaysia during the COVID-19 pandemic, as noted by Shah (2020), highlight the necessity for healthcare facilities to ensure a reliable supply of appropriate PPE to protect healthcare personnel from CBRN hazards. The MOH could improve communication with healthcare facilities and the public during CBRN incidents. Clear and timely communication is essential to ensuring an effective response. There may be a need for better coordination between the MOH and other agencies during CBRN incidents. Collaborative efforts among different agencies are necessary to ensure an effective response to CBRN hazards.

Overall, by addressing the identified gaps in healthcare settings and implementing these best practices on CBRN hazards, healthcare facilities in Malaysia can enhance their preparedness and improve the current approach to safety, health, and emergency management in response to CBRN incidents.

The specific chemical hazards that healthcare providers may encounter in their work.

In recent research conducted by Aziz *et al.* (2021), focusing on occupational toxicity and hazards, it was highlighted that healthcare providers face a range of chemical hazards within their work environments. They may encounter harmful substances in various ways. Healthcare providers could be at risk of hazardous materials such as mercury, lead, asbestos, or formaldehyde. These chemicals can result in various detrimental health consequences, including skin irritation, nervous system damage, and the possibility of cancer.

Healthcare providers engaged in the process of handling or administering chemotherapy treatments or similar toxic medications are susceptible to exposure through skin contact, inhalation, or ingestion. Such exposure can lead to fertility issues, cancer, and other adverse health effects. Within healthcare

settings, unintentional chemical spills involving substances like acids, solvents, and disinfectants may occur. These spills can have unfavourable health effects, including skin irritation and respiratory issues.

Healthcare providers assigned to operating rooms or other locations where anaesthesia is administered might also be exposed to work-related hazards. Anaesthetic gases such as nitrous oxide, halothane, and isoflurane may pose these risks. Medical practitioners could be subjected to such gases while administering anaesthesia, which could present possible health hazards. These substances can result in adverse reactions that involve breathing discomfort and dizziness, as well as additional indications.

In summary, recent research underscores that healthcare professionals face a variety of chemical hazards in their workplaces. Implementing measures to mitigate these risks is crucial to ensuring the safety and well-being of both healthcare professionals and patients.

The challenges or gaps in the existing approach in managing chemical hazards in major hospitals in Malaysia.

Despite the implementation of chemical safety programmes in major hospitals across Malaysia, a study conducted by Azarmi *et al.* (2021) has revealed certain weaknesses in their approach to addressing chemical hazards. Healthcare providers might lack knowledge of particular chemical hazards that could potentially be present in their working areas. Their understanding of the potential health impacts of encountering these hazards might also be insufficient. This gap could arise due to a lack of awareness or inadequate instruction related to chemical safety measures. In order to identify every potential toxic substance in the healthcare facility, safety analyses could be infrequent. However, ensuring the protection of both individuals and health practitioners remains essential.

Addressing these challenges and gaps is crucial to enhancing the overall safety and well-being of healthcare personnel and patients in major hospitals. There is a chance that healthcare providers may not consistently wear the right PPE for the chemicals they handle. This could be due to a lack of accessible PPE or inadequate awareness of safe work procedures (SWP) for the specific hazards associated with these chemicals. Additionally, there is a potential that decontamination procedures might not be consistently followed or not be well established, potentially exposing individuals to hazardous chemicals.

There is a chance that some hospitals in Malaysia may have adopted consistent measures for dealing with chemical hazards, resulting in imbalances in the handling of chemical safety. These imbalances can stem from hospitals lacking the necessary financial resources to allocate funds for essential equipment and advanced technologies to manage these hazards. Similarly, inadequate funds might hinder the provision of continuous education and training for healthcare providers.

By addressing all these challenges and gaps, major hospitals in Malaysia can improve their approach to chemical hazards, thereby fostering a safer work environment for both healthcare personnel and patients.

The effective strategies for hospitals to mitigate and manage chemical hazards.

Healthcare providers play a crucial role in being aware of the potential chemical hazards within their workplaces and taking the necessary precautions to protect themselves and their patients. Through a comprehensive analysis of occupational health and safety risk assessment, Gul, Ak & Guneri (2017) discovered various preventive measures that healthcare facilities can adopt to manage and mitigate chemical hazards in their work environment.

Conducting a thorough risk assessment of the hospital environment can help identify potential chemical hazards and evaluate the risk of exposure. This assessment should encompass an evaluation of the types and quantities of chemicals used within the hospital. In addition to assessing possible routes of exposure, it is important to evaluate the likelihood of adverse health effects and the severity of exposure-related consequences.

Engineering controls encompass specific measures designed to prevent or reduce exposure to chemical hazards. Examples of engineering controls are ventilation systems, containment strategies, and process controls. For instance, installing local exhaust ventilation (LEV), where hazardous chemicals are used, can help prevent the release of chemicals into the environment and reduce the risk of exposure for healthcare personnel. To protect healthcare providers from chemical hazards, PPE plays a vital role. Gloves, respirators, goggles, and protective clothing are some examples of PPE. The outcome of the risk assessment and the specific hazards in the hospital setting should serve as a guide for the selection of appropriate PPE.

Decontamination processes are used to remove or neutralise hazardous chemicals on surfaces or equipment. Specific decontamination procedures should be established for each chemical hazard present in the hospital.

These procedures should encompass appropriate cleaning supplies and methods, as well as guidelines for the disposal of contaminated materials. To ensure safety in the healthcare setting, it is crucial for healthcare providers to undergo training regarding the potential hazards associated with the chemicals they handle.

They should also receive education on how to correctly utilise PPE and conduct decontamination procedures. By staying themselves informed through education and training, healthcare providers can remain up-to-date on the current knowledge, attitudes, and practices necessary for effectively managing chemical hazards within the hospital environment. Adequate resources should be allocated to invest in modern technologies and equipment that aid in mitigating chemical hazards. Additionally, continuous training and education programmes should be provided for healthcare personnel to maintain their proficiency in this area.

It is imperative for all hospitals in Malaysia to develop standardised operating procedures (SOP) or standard work procedures (SWP) to effectively manage chemical hazards. This involves establishing a robust chemical safety programme, regularly assessing its effectiveness, and making necessary updates to meet the health and safety requirements of the hospital environment.

By implementing these measures, healthcare providers can reduce their risk of exposure, while hospitals can help prevent and promote a safe work environment for their staff and patients.

The specific biological hazards that healthcare providers may encounter in their work.

A recent study conducted by Razu *et al.* (2021) highlights the numerous biological hazards that healthcare providers commonly encounter within their work environment. These hazards primarily involve the exposure to infectious diseases while attending to patients with communicable illnesses such as tuberculosis, influenza, HIV/AIDS, and COVID-19. This exposure may transpire through direct interactions involving bodily fluids such as blood, saliva, or respiratory secretions, or via contact with contaminated surfaces and equipment.

Additionally, there is a risk of biological spills, which can happen when containers holding infectious or biological material break or leak.

Healthcare providers may be exposed to these spills either through direct interaction with the spilled material or through the inhalation of infectious particles. Bioterrorism is the deliberate use of biological agents to harm a population, including agents such as anthrax, smallpox, or botulism. In the unfortunate event of a bioterrorism attack, healthcare providers may face the risk of exposure to these agents. Healthcare providers who handle infectious agents, biological materials, clinical specimens, or engage in laboratory work may be vulnerable to laboratory-acquired infections (LAIs). Accidental contact with infectious agents, such as a needle stick or splashes to the eyes, can lead to the occurrence of LAIs.

The challenges or gap in current biological hazard management strategies in major hospitals in Malaysia.

A study conducted by Subramanian Arip & Subramaniam (2017) has revealed several challenges and gaps in the current approach to managing biological occupational hazards in major hospitals across Malaysia. The research highlights that inadequate training and education pertaining to infection prevention and control procedures among healthcare professionals could potentially lead to the transmission of infectious diseases within hospital premises. Observations indicate that healthcare personnel do not consistently adhere to the infection control protocols established by hospitals, hence elevating the risk of disease spread.

Certain healthcare facilities might lack efficient surveillance and monitoring systems that can identify outbreaks of infectious diseases. Inadequate implementation of these systems could impede the response time and heighten the likelihood of disease transmission. Moreover, certain hospitals could face shortages in PPE and might lack the necessary waste management infrastructure to adequately enforce infection control measures.

In addition to these challenges, healthcare facilities often encounter difficulties in efficiently exchanging information and collaborating with other health institutions. This communication barrier can complicate responses to infectious disease outbreaks. Furthermore, healthcare personnel might be at risk in the absence of essential vaccinations required to protect them against communicable diseases.

Addressing all these challenges and gaps necessitates a coordinated effort involving healthcare personnel, administration, public health agencies, and other government agencies. This collaborative approach ensures hospitals have the requisite resources, training, and support to effectively manage biohazards.

The effective strategies for hospitals to mitigate and manage biological hazards.

In a study conducted by Aminizadeh *et al.* (2022), several measures are suggested for hospitals to prevent and manage biological hazards. Establishing robust infection control practices serves as the foundation for effectively mitigating and managing biological hazards within hospitals. Such practices encompass essential steps like maintaining proper hand hygiene, following protocols for donning and doffing personal PPE, isolating patients with infectious diseases, and ensuring thorough disinfection and cleaning of the hospital environment.

Efficient waste management is of paramount importance within hospital settings to prevent the spread of infectious illnesses. Hospitals should adhere to standardised procedures that ensure the appropriate handling, transportation, and disposal of infectious waste. This encompasses items such as sharps, contaminated linens, and biological specimens.

Healthcare personnel should get an appropriate vaccination to protect themselves from infectious diseases they might encounter while working, such as hepatitis B and influenza. Hospitals should also conduct regular infectious disease outbreak surveillance. This involves monitoring the incidence of infections associated with healthcare settings, ensuring adherence to infection control procedures, and monitoring antibiotic usage.

Healthcare personnel require training and education on infection prevention and control practices, as well as the safe handling of infectious materials, to effectively prevent and manage biological risks within hospitals. Moreover, hospitals should implement environmental controls, such as appropriate ventilation and air filtration systems, to impede the spread of infectious diseases.

According to Nadarajan *et al.* (2020), hospitals can practice screening and triage protocols to effectively identify and isolate patients with infectious diseases, thereby minimising the risk of infection spread. In the event of a bioterrorist attack or an epidemic of an infectious illness, a hospital should have an emergency plan in place. These plans should encompass the management of infected patients, the detection and containment of outbreaks, as well as ensuring the safety of healthcare personnel.

By implementing these measures into practice, hospitals can effectively manage biological hazards, protect healthcare personnel and patients, and create a secure healthcare environment. To maintain the currency and efficacy of their infection control programmes and emergency preparedness plans, hospitals should regularly evaluate and update them.

The specific radiation and nuclear hazards that healthcare providers may experience in their line of work.

In the realm of healthcare, there are specific radiation and nuclear hazards that healthcare providers may encounter in the course of their work. Drawing from research on the preparedness of nurses for radiation and nuclear emergencies, Veenema *et al.* (2019) highlight a range of radiological and nuclear hazards that healthcare providers might face in their line of duty.

Healthcare personnel engaged in operating diagnostic imaging tools like X-ray machines, CT scanners, and fluoroscopy machines are susceptible to exposure to ionising radiation. This category encompasses professionals working in nuclear medicine, radiation therapy, and other fields involving the use of such radiation materials.

Exposure to gamma rays and beta or alpha particles, all of which can damage tissues and cells, is part of their occupational risk. Moreover, the occurrence of equipment malfunctioning, radioactive material mishandling, or an unfortunate accident could place healthcare personnel at risk of accidental radiation exposure.

The challenges or gaps in current radiological and nuclear hazard management strategies in major hospitals in Malaysia.

While radiation safety programmes are in place at many of the major hospitals in Malaysia, a study by Hamid *et al.* (2017) highlights significant challenges and gaps in managing radiation and nuclear hazards in healthcare settings. Notably, numerous hospitals in Malaysia may lack the necessary resources to effectively handle radiation and nuclear hazards, including adequate training and supplies.

Some hospitals might also lack access to specialised expertise in radiation safety. This can result in insufficient safety procedures and an elevated risk of exposure. A lack of understanding among healthcare personnel regarding radiation and nuclear hazards can result in unsafe procedures and further elevate the risk of exposure. Additionally, inadequate regulatory oversight of radiation safety procedures might lead to inconsistent application of safety regulations and subpar procedures.

According to Nasir, Othman & Nordin (2022), although hospitals in Malaysia may have emergency preparedness plans in place, these plans might not be fully effective or adequately implemented, especially in the context of radiation and nuclear exposures. This shortfall could result in an inadequate response in cases of accidents involving radiation and nuclear hazards. Additionally, there could be limited cooperation and coordination among hospitals, other government agencies, and NGOs for policing and monitoring radiation safety practices. Such gaps could result in inconsistencies in safety standards and potential lapses in safety practices.

Addressing these issues is crucial for hospitals in Malaysia. This can be achieved by allocating sufficient resources, fostering knowledge and awareness, strengthening regulatory supervision, enhancing emergency preparedness, and fostering collaboration and coordination between hospitals and government agencies.

Through these efforts, hospitals can bolster their capacity to effectively manage radiation and nuclear hazards, thereby promoting a secure healthcare environment for both patients and healthcare workers.

The effective strategies for hospitals to mitigate and manage radiation and nuclear hazards.

In a study by Hendrickx *et al.* (2016), several measures are suggested to prevent and manage radiation and nuclear hazards in hospitals. Implementing these measures is crucial to ensuring the safety and health of both patients and healthcare personnel. Hospitals should establish a comprehensive radiation safety programme that encompasses guidelines for responsible handling of radioactive materials and

the appropriate utilisation practices related to radiation-emitting devices. This ensures that healthcare personnel are well informed and trained to minimise the risks associated with radiation exposure.

Healthcare personnel who work with radiation and radioactive materials undergo comprehensive training in the proper handling and utilisation of these substances. Individuals exposed to radiation should consistently monitor their exposure levels to ensure they remain within safe limits. To minimise exposure, healthcare personnel should be equipped with appropriate personal protective equipment, such as lead aprons, thyroid shields, and dosimeters. Furthermore, hospitals should establish standard operating procedures for the proper handling, transportation, and disposal of radioactive waste. In areas where these hazards are present, hospitals should also implement engineering controls, such as radiation protection measures, to effectively reduce exposure to ionising radiation.

Additionally, it is important for hospitals to establish comprehensive emergency plans to address an accident involving radiation or radioactive materials. Regular calibration of hospital radiation equipment is essential to ensure accurate measurement of radiation levels and optimal functionality. Hospitals should have decontamination rooms and procedures readily available in the event of potential radioactive material contamination on surfaces or clothing.

By implementing all of these measures, hospitals can effectively protect healthcare personnel and patients while assisting in the prevention and management of radiological and nuclear health hazards. Consistently reviewing and updating radiation protection and contingency plans is imperative for hospitals to ensure their timeliness and effectiveness.

The importance of emergency preparedness in healthcare settings, particularly in relation to CBRN hazards.

All healthcare facilities must be prepared for emergencies, especially when it comes to responding to CBRN hazards. These types of hazards have significant implications for the health and safety of patients, healthcare personnel, and the broader community. Therefore, it becomes imperative for hospitals to establish a comprehensive emergency preparedness plan.

In a study titled "Emergency Departments Response to CBRNE", Razak, Hignett & Barnes (2018) highlight the significance of emergency preparedness in healthcare settings, especially in the context of CBRN hazards. The study emphasises that emergency preparedness plans play a crucial role in protecting healthcare personnel. This is achieved by ensuring that healthcare personnel are equipped with the requisite training, appropriate equipment, and resources to respond to CBRN hazards in a safe and effective manner.

A robust emergency preparedness plan plays a pivotal role in enhancing a hospital's ability to respond effectively to disasters. This plan not only identifies potential hazards but also coordinates response efforts and ensures the availability of necessary resources. An effective emergency preparedness plan can swiftly locate and isolate infected patients during biological hazards, preventing the spread of diseases and implementing infection control procedures. Additionally, the inclusion of appropriate PPE and decontamination procedures within the emergency preparedness plan can significantly mitigate the risk associated with exposure to hazardous materials such as radioactive materials or toxic chemicals.

Overall, within healthcare settings, the importance of being well prepared to respond to emergencies is essential, especially when responding to CBRN hazards. Through the establishment of a comprehensive emergency preparedness plan, hospitals can protect healthcare personnel, curtail disease transmission, minimise exposure to hazardous materials, effectively manage emergencies, and ensure the well-being of the community.

The essential components of an effective emergency management plan.

The essential components of an effective emergency management plan are highlighted in a study conducted by Sawalha (2020), which focuses on the disaster management cycle. This study emphasises the importance of a comprehensive and coordinated approach encompassing prevention, mitigation, preparation, response, and recovery from emergencies and disasters. Additionally, Squier

(2023) advocates for several significant factors that should be incorporated into a proficient approach for handling emergencies.

One of these crucial factors is risk assessment, a process aimed at identifying potential hazards, assessing their likelihood, and understanding their potential impact. Implementing risk assessment aids in recognising the emergencies or disasters that are most likely to occur in a hazardous area, predicting their possible consequences, and devising effective strategies to mitigate these risks.

Another vital component is the development of an effective communication plan. Such a plan ensures that all participants in the emergency response efforts have access to timely and accurate information. Communication plans should encompass protocols for alerting emergency services, mobilising the emergency response team, and maintaining communication with various stakeholders, including patients and their families. This comprehensive approach enhances the overall preparedness and response capacity of healthcare facilities in dealing with various emergencies."

The third essential component is the response procedure, designed to manage the immediate actions taken during an emergency. This includes measures like lockdowns, triage, and medical care.

The outcomes of the risk assessment serve as the foundation for these emergency response procedures, which should encompass detailed instructions for all parties involved.

The fourth crucial element pertains to the recovery procedure, which outlines the steps taken to recover from an emergency. This involves activities such as assessing the extent of the damage, clearing the affected area of debris, and repairing the facility. Recovery procedures should also include protocols for addressing the needs of patients, employees, and other stakeholders.

Within the emergency management plan, all the procedures should be consistently taught to all healthcare personnel. Additionally, regular drills and exercises should be conducted to assess the effectiveness of the plan and identify areas for potential improvement. To ensure its relevance and functionality, the emergency management plan should be frequently reviewed and updated. Following each emergency or disaster, an evaluation of the situation should be conducted in order to identify any flaws in the strategy and make the necessary improvements.

In essence, a successful emergency management plan should be rooted in a comprehensive risk assessment, incorporate clear communication protocols, define response and recovery procedures, provide ongoing training and drills, and continuously enhance itself through regular review and updates.

The challenges or gaps in the current approach to emergency management in major hospitals in Malaysia.

In a study conducted by Sulaiman *et al.* (2020) on healthcare facility management in Malaysian public hospitals, he revealed a range of obstacles and gaps in the current approach to emergency management within major hospitals in Malaysia. The study reveals a range of obstacles and shortcomings in the present emergency management approach within these hospitals. It emphasises that many healthcare personnel lack awareness of and adequate training in emergency management procedures. This deficiency can lead to confusion, delays in action, and potential errors during emergencies.

In Malaysia, certain hospitals may lack comprehensive emergency management plans in place or have outdated and insufficient plans. Consequently, these facilities could display inadequate responses to critical hazards such as CBRN emergencies. Moreover, communication systems during emergencies might be inadequate, particularly in rural or remote areas. This limitation poses challenges for coordinating response efforts and effectively disseminating vital information to stakeholders.

There is a possibility that certain hospitals in Malaysia lack the necessary equipment, supplies, insufficient staff, and trained personnel to handle emergencies efficiently, especially those involving CBRN hazards. Effective emergency management often necessitates coordination with other agencies, such as emergency medical services, public health departments, and within governmental

organisations. Unfortunately, instances may arise where hospitals and these agencies do not coordinate seamlessly, thus posing challenges in both emergency response and subsequent recovery efforts.

Plans and practices for emergency management may often receive minimal evaluation and improvement. This limited assessment could lead to a lack of knowledge regarding which aspects are functioning well and which areas require enhancement, ultimately rendering the emergency management efforts ineffective. It is imperative for healthcare facilities, government agencies, and other stakeholders to collaborate in order to enhance emergency management planning, training, and coordination. To address these issues and gaps, a dedicated commitment to consistently reviewing and improving emergency management protocols is essential.

The implications of the review for healthcare providers, policymakers, and other stakeholders.

This review emphasises the importance of addressing CBRN hazards within Malaysian healthcare settings. Its implications are extensive and hold significant impact for healthcare providers, policymakers, and stakeholders alike.

According to Garritty *et al.* (2023), a lack of training and resources stands as the primary reason for the insufficient handling of CBRN hazards by healthcare providers. It is imperative for healthcare providers to be aware of the perils and possess the knowledge to both prevent and mitigate these hazards. The review stresses the importance of having emergency preparedness plans alongside regular training and drills. These measures ensure that healthcare providers are well equipped to respond appropriately during an emergency incident.

The review highlights the imperative for policymakers and government organisations to prioritise emergency preparedness and allocate adequate resources to manage CBRN hazards. This may require investing in appropriate equipment, training, and other resources to ensure healthcare providers are adequately prepared to respond to CBRN hazards.

Additionally, to effectively address the CBRN hazards, policymakers need to collaborate with healthcare providers as well as other stakeholders, including public health organisations, emergency medical services, and the public. The overarching conclusions drawn from this review underscore the significance of prioritising the management of CBRN hazards within healthcare settings.

They accentuate the ongoing need for sustained investments and unwavering attention directed towards emergency preparedness and swift response measures. It is incumbent upon healthcare providers, policymakers, and an array of stakeholders to unify their efforts and accord paramount importance to the triad of safety, health, and effective emergency management. By doing so, the healthcare sector can stand resilient against the challenges posed by CBRN hazards.

The areas that need improvement and approaches to address the challenges healthcare providers face in managing CBRN hazards.

Several areas requiring improvement in managing CBRN hazards in healthcare settings in Malaysia have been identified based on the study by Yahya *et al.* (2022). Healthcare providers face the challenge of inadequate training and knowledge for effectively preventing and managing CBRN hazards.

Addressing this challenge necessitated a robust solution, rigorous training, and regular drills simulating emergency situations.

Crucially, each hospital must establish and implement comprehensive emergency management plans specifically tailored to address CBRN hazards. These plans need to encompass well-defined communication pathways, response protocols, and the necessary materials and equipment. Hospitals must make sure their communication systems are trustworthy and effective in emergency circumstances. This might entail the use of numerous communication channels, including backup systems, and ensuring that everyone involved is aware of emergency procedures.

To effectively manage CBRN, hospitals must ensure an adequate stock of essential supplies and equipment, including radiation detectors, decontamination tools, and personal protective equipment. This might entail the necessity of acquiring new equipment and supplies.

Hospitals should engage in collaborative emergency preparedness efforts with various organisations, including private healthcare providers, emergency medical services (MRCS, St. John, JPAM), hazardous material management teams (HAZMAT), the Royal Malaysian Police (PDRM), and other relevant parties. This collaborative approach facilitates a more robust and coordinated response to CBRN hazards.

In tackling these challenges directly, hospitals need to possess the necessary resources and equipment to effectively counter the risks posed by CBRN hazards. Therefore, healthcare facilities, government entities, and other stakeholders must unite to prioritise and elevate the importance of emergency preparedness. Through fostering collaboration, securing vital resources, and prioritising emergency planning, healthcare providers and relevant authorities can establish a safer environment and a more effective response framework for managing CBRN hazards.

Conclusion

In conclusion, the review highlights the potential exposure of Malaysian healthcare providers to a range of CBRN hazards within their work environment. Despite the existing measures aimed at prevention and management, the current approach to safety, health, and emergency management in major hospitals in Malaysia exhibits several challenges and gaps.

As outlined in the review, hospitals in Malaysia confront various challenges. This includes inadequate awareness and training among healthcare providers, insufficiencies in emergency preparedness plans, particularly concerning CBRN events, communication difficulties, scarce resources, inadequate coordination with external agencies, and insufficient evaluation and improvement of emergency management procedures.

To effectively address these challenges, a strong recommendation is for healthcare institutions, government agencies, and other relevant stakeholders to collaborate closely. This collaborative effort should focus on enhancing emergency management coordination, refining planning strategies, and providing comprehensive training to all involved parties.

In response to chemical hazards, a more robust approach to risk assessment is essential. This includes establishing effective engineering controls, ensuring the availability of appropriate personal protective equipment, and establishing well-defined decontamination procedures. For biological hazards, the implementation of rigorous infection control measures and efficient waste management protocols is paramount. Similarly, radiation and nuclear hazards necessitate the establishment of a comprehensive radiation protection programme alongside robust dose monitoring practices.

Furthermore, a crucial aspect of managing these hazards is the consistent evaluation of emergency management procedures. Regular assessments are necessary to identify areas for improvement and enhance the effectiveness of response and recovery efforts. By adopting these comprehensive strategies, healthcare providers, government entities, and other stakeholders can collectively work towards minimising the impact of CBRN hazards and promoting the safety and well-being of all those involved.

Conflict of Interests

The authors affirm that they do not have any conflicting objectives.

Acknowledgement

The authors are thankful to the institutional authority for completion of the work.

References

- Ablah, E., Brown, J., Carroll, B., & Bronleewe, T. (2016). A community-based participatory research approach to identifying environmental concerns. *Journal of Environmental Health*, 79(5), 14-19.
- Abrams, A. M. (2018). *Emergency/Disaster Preparedness of Rural Healthcare Providers*. North Dakota State University.
- Adnan, M. S. B., Hart, A., Hertelendy, A. J., Tin, D., Abelanos, S. M., Issa, F., & Ciottone, G. R. (2022). Malaysian Disaster Medicine Research: A Bibliographic Study of Publication Trends. *Prehospital and disaster medicine*, 37(6), 836-842. <https://doi.org/10.1017/s1049023x22002187>
- Alahmari, A. A., & Khan, A. A. (2023). Chemical, biological, radiological, and nuclear preparedness of public hospitals in Riyadh. *Disaster medicine and public health preparedness*, 17, e401. <https://doi.org/10.1017/dmp.2023.66>
- Almukhlifi, Yasir & Crowfoot, Gary & Wilson, Amanda & Hutton, Alison. (2021). Emergency healthcare workers' preparedness for disaster management: An integrative review. *Journal of Clinical Nursing*. <https://doi.org/10.1111/jocn.15965>
- Aminizadeh, M., Farrokhi, M., Ebadi, A., Masoumi, G., Kolivand, P., & Khankeh, H. (2022). Hospital preparedness challenges in biological disasters: A qualitative study. *Disaster Medicine and Public Health Preparedness*, 16(3), 956-960. <https://doi.org/10.1017/dmp.2020.434>
- Azami, S., Pishgooie, A. H., Sharififar, S., Khankeh, H. R., & Hejrypour, S. Z. (2021). Challenges of hospital disaster risk management: A systematic review study. *Disaster medicine and public health preparedness*, 1-8. <https://doi.org/10.1017/dmp.2021.203>
- Aziz, T. A., Amin, R. R. H., Ahmed, Z. A., Sleman, H. J., & Aziz, B. H. (2021). Occupational toxicity and health hazards of the healthcare providers at healthcare facilities in Sulaimani City, Iraq. *Iraqi Journal of Pharmaceutical Sciences (P-ISSN 1683-3597 E-ISSN 2521-3512)*, 30(2), 41-49. <https://doi.org/10.31351/vol30iss2pp41-49>
- Bajow, N., Alkhalil, S., Maghraby, N., Alesa, S., Najjar, A. A., & Aloraifi, S. (2022). Assessment of the effectiveness of a course in major chemical incidents for front line health care providers: a pilot study from Saudi Arabia. *BMC medical education*, 22(1), 350. <https://doi.org/10.1186/s12909-022-03427-2>
- Benolli, F., Guidotti, M., & Bisogni, F. (2021). The CBRN threat. Perspective of an interagency response. *International Security Management: New Solutions to Complexity*, 429-448. http://dx.doi.org/10.1007/978-3-030-42523-4_29
- Carbon, D., Arnold, A., Gørgen, T., & Wüller, C. (2022). Crisis communication in CBRNe preparedness and response: Considering the needs of vulnerable people. *International Journal of Disaster Risk Reduction*, 79, 103187. <https://doi.org/10.1016/j.ijdr.2022.103187>
- Che Hamid, H. E., MSaad, N. J. A., Mat Razali, N. A., Khairuddin, M. A., Ismail, M. N., Ramli, S., ... & Shah, P. N. N. A. (2019). Disaster management support model for Malaysia. In *Advances in Visual Informatics: 6th International Visual Informatics Conference, IVIC 2019, Bangi, Malaysia, November 19–21, 2019, Proceedings 6* (pp. 570-581). Springer International Publishing. http://dx.doi.org/10.1007/978-3-030-34032-2_50
- Chilcott, R. P., Larner, J., & Matar, H. (2019). UK's initial operational response and specialist operational response to CBRN and HazMat incidents: a primer on decontamination protocols for healthcare professionals. *Emergency Medicine Journal*, 36(2), 117-123. <https://doi.org/10.1136/emered-2018-207562>
- Garrity, C., Tricco, A. C., Smith, M., Pollock, D., Kamel, C., & King, V. J. (2024). Rapid reviews methods series: involving patient and public partners, healthcare providers and policymakers as knowledge users. *BMJ Evidence-Based Medicine*, 29(1), 55-61. <https://doi.org/10.1136/bmjebm-2022-112070>
- Gillani, A. H., Li, S., Akbar, J., Omer, S., Fatima, B., Ibrahim, M. I. M., & Fang, Y. (2021). How prepared are the health care professionals for disaster medicine management? An insight from Pakistan. *International journal of environmental research and public health*, 19(1), 200. <https://doi.org/10.3390/ijerph19010200>
- Goniewicz, K., Goniewicz, M., Włoszczak-Szubzda, A., Burkle, F. M., Hertelendy, A. J., Al-Wathinani, A., ... & Khorram-Manesh, A. (2021). The importance of pre-training gap analyses and the identification of

- competencies and skill requirements of medical personnel for mass casualty incidents and disaster training. *BMC public health*, 21, 1-11. <https://doi.org/10.1186/s12889-021-10165-5>
- Gul, M., Ak, M. F., & Guneri, A. F. (2017). Occupational health and safety risk assessment in hospitals: A case study using two-stage fuzzy multi-criteria approach. *Human and Ecological Risk Assessment: An International Journal*, 23(2), 187-202. <http://dx.doi.org/10.1080/10807039.2016.1234363>
- Gunduz, M., & Laitinen, H. (2018). Construction safety risk assessment with introduced control levels. *Journal of Civil Engineering and Management*, 24(1), 11-18. <http://dx.doi.org/10.3846/jcem.2018.284>
- Hamid, A. H. B. A., Rozan, M. Z. A., Ibrahim, R., Deris, S., & Yunus, M. N. M. (2017, January). Resources planning for radiological incidents management. In *AIP Conference Proceedings* (Vol. 1799, No. 1, p. 030001). AIP Publishing LLC. <http://dx.doi.org/10.1063/1.4972911>
- Hendrickx, C., D'Hoker, S., Michiels, G., & Sabbe, M. B. (2016). Principles of hospital disaster management: An integrated and multidisciplinary approach. *B-ENT*, 12(26/2), 139-148.
- Huang, D., Wang, S., & Liu, Z. (2021). A systematic review of prediction methods for emergency management. *International Journal of Disaster Risk Reduction*, 62, 102412. <http://dx.doi.org/10.1016/j.ijdr.2021.102412>
- Ippolito, M., Vitale, F., Accurso, G., Iozzo, P., Gregoretti, C., Giarratano, A., & Cortegiani, A. (2020). Medical masks and Respirators for the Protection of Healthcare Workers from SARS-CoV-2 and other viruses. *Pulmonology*, 26(4), 204-212. <https://doi.org/10.1016/j.pulmoe.2020.04.009>
- Ismail, S. A. (2020). *Factors associated with knowledge, attitude, practice and perception in flood disaster management among critical care nurses in the east coast hospitals of Malaysia* (Doctoral dissertation, Universiti Sains Malaysia).
- Jacobitz, K. L., & Nailon, R. E. (2020). The role of a regional poison center in assessing and managing disaster risk. *Health security*, 18(3), 195-204. <https://doi.org/10.1089/hs.2019.0124>
- Kako, M., Hammad, K., Mitani, S., & Arbon, P. (2018). Existing approaches to chemical, biological, radiological, and nuclear (CBRN) education and training for health professionals: findings from an integrative literature review. *Prehospital and disaster medicine*, 33(2), 182-190. <https://doi.org/10.1017/s1049023x18000043>
- Khorram-Manesh, A., Goniewicz, K., Hertelendy, A., & Dulebenets, M. (Eds.). (2021). *Handbook of disaster and emergency management*. Kompendiet. <http://dx.doi.org/10.5281/zenodo.5553076>
- Lam, R. P., Balsari, S., Hung, K. K., Hsiao, K. H., Leung, L. P., & Leaning, J. (2018). How do doctors and nurses in emergency departments in Hong Kong view their disaster preparedness? A cross-sectional territory-wide online survey. *Disaster medicine and public health preparedness*, 12(3), 329-336. <https://doi.org/10.1017/dmp.2017.71>
- Majd, P. M., Seyedin, H., Bagheri, H., & Tavakoli, N. (2020). Hospital preparedness plans for chemical incidents and threats: a systematic review. *Disaster Medicine and Public Health Preparedness*, 14(4), 477-485. <https://doi.org/10.1017/dmp.2019.91>
- Mohammadi, S. B., Amirheidari, B., Dehesh, T., Moghadam, M. N., Yazdi-Feyzabadi, V., Hassani, E., & Habibzadeh, H. (2022). Identification and analysis of parameters and global experiences of hospital preparedness against chemical, biological, radiological and nuclear disasters: a scoping review. *Journal of Clinical Research in Paramedical Sciences*, 11(1). <https://doi.org/10.5812/jcrps-123626>
- Morganstein, J. C., & Ursano, R. J. (2020). Ecological disasters and mental health: causes, consequences, and interventions. *Frontiers in psychiatry*, 11, 1. <https://doi.org/10.3389/fpsy.2020.00001>
- Mortelmans, L. J., Gaakeer, M. I., Dieltiens, G., Anseeuw, K., & Sabbe, M. B. (2017). Are Dutch hospitals prepared for chemical, biological, or radionuclear incidents? A survey study. *Prehospital and disaster medicine*, 32(5), 483-491. <https://doi.org/10.1017/s1049023x17006513>
- Munikanan, V. (2020). Cbrn Hazard Response by Leading Agency In Malaysia. *Solid State Technology*, 63(6), 8386-8394.
- Nadarajan, G. D., Omar, E., Abella, B. S., Hoe, P. S., Do Shin, S., Ma, M. H. M., & Ong, M. E. H. (2020). A conceptual framework for Emergency department design in a pandemic. *Scandinavian journal of trauma, resuscitation and emergency medicine*, 28(1), 1-13. <https://doi.org/10.1186/s13049-020-00809-7>

- Nasir, S. A., Othman, S. A., & Nordin, N. I. M. (2022). Health Risk From Radioactive Iodine (RAI) Therapy And Medical Imaging-A Short Review. *Malaysian Journal of Applied Sciences*, 7(2), 44-52. <https://doi.org/10.37231/myjas.2022.7.2.325>
- O'Connor, T., & Hammad, K. S. (2016). Emergency department nurses' perspectives on responding to terror attacks: A review of the literature. *Health Emergency and Disaster Nursing*, 3(1), 9-17. <https://doi.org/10.3389/fpubh.2021.695143>
- O'Mathúna, D. P. (2019). Health care workers' obligations in CBRNE crises. *Ethics and Law for Chemical, Biological, Radiological, Nuclear & Explosive Crises*, 185-197. https://doi.org/10.1007%2F978-3-030-11977-5_15
- Osman, N. N. S. (2016). Disaster management: Emergency nursing and medical personnel's knowledge, attitude and practices of the East Coast region hospitals of Malaysia. *Australasian emergency nursing journal*, 19(4), 203-209. <https://doi.org/10.1016/j.aenj.2016.08.001>
- Razak, S., Hignett, S., & Barnes, J. (2018). Emergency department response to chemical, biological, radiological, nuclear, and explosive events: a systematic review. *Prehospital and Disaster Medicine*, 33(5), 543-549. <https://doi.org/10.1017/s1049023x18000900>
- Razu, S. R., Yasmin, T., Arif, T. B., Islam, M. S., Islam, S. M. S., Gesesew, H. A., & Ward, P. (2021). Challenges faced by healthcare professionals during the COVID-19 pandemic: a qualitative inquiry from Bangladesh. *Frontiers in public health*, 1024. <https://doi.org/10.3389/fpubh.2021.647315>
- Romney, D. A. (2020). Chemical, Biological, Radiological, or Nuclear Event (CBRNE): Prehospital and Hospital Management. *Operational and Medical Management of Explosive and Blast Incidents*, 569-582. http://dx.doi.org/10.1007/978-3-030-40655-4_42
- Samsuddin, N. M., Takim, R., Nawawi, A. H., & Alwee, S. N. A. S. (2018). Disaster preparedness attributes and hospital's resilience in Malaysia. *Procedia engineering*, 212, 371-378. <http://dx.doi.org/10.1016/j.proeng.2018.01.048>
- Sawalha, I. H. (2020). A contemporary perspective on the disaster management cycle. *Foresight*, 22(4), 469-482. <https://doi.org/10.1108/FS-11-2019-0097>
- Squier, J. (2023). Emergency Action & Operations Planning. *Professional Safety*, 68(2), 35-40.
- Subramanian, G. C., Arip, M., & Subramaniam, T. S. (2017). Knowledge and risk perceptions of occupational infections among health-care workers in Malaysia. *Safety and health at work*, 8(3), 246-249. <https://doi.org/10.1016%2Fj.shaw.2016.12.007>
- Sulaiman, N., Abid, S. K., Nazir, U., Mahmud, N. P. N., Latib, S. K. K., Hafidz, H. F., ... & Rahim, N. A. (2020, December). Need for resilience healthcare facilities management (RHFM) in malaysia's public hospitals. A critical literature review. In *Proc Int Conf Ind Eng Oper Manag* (Vol. 59, pp. 2336-48).
- Veenema, T. G., Lavin, R. P., Bender, A., Thornton, C. P., & Schneider-Firestone, S. (2019). National nurse readiness for radiation emergencies and nuclear events: A systematic review of the literature. *Nursing outlook*, 67(1), 54-88. <https://doi.org/10.1016/j.outlook.2018.10.005>
- Yadav, H. (2017). The health care system in Malaysia. In *Health Care Systems in Developing Countries in Asia* (pp. 110-130). Routledge.
- Yahya, N. Y. B., Rahmat, R. B., Termizi, M. S. B. A., Zazali, A. K. B., & Jamalluddin, S. N. F. B. (2022). Preparedness towards Chemical, Biological, Radiological, Nuclear, and Explosive (CBRNE) threats among healthcare personnel in Pasir Gudang, Johor, Malaysia. *International Journal of Disaster Risk Reduction*, 82, 103235. <https://dx.doi.org/10.2139/ssrn.3998765>
- Yaqoob Mohammed Al Jabri, F., Kvist, T., Azimirad, M., & Turunen, H. (2021). A systematic review of healthcare professionals' core competency instruments. *Nursing & health sciences*, 23(1), 87-102. <https://doi.org/10.1111/nhs.12804>
- Yildiz, C. Ç., & Yildirim, D. (2022). The effects of disaster nursing education program on beliefs in general disaster preparedness, disaster response self-efficacy, and psychological resilience in nursing students: A single-blind, randomized controlled study. *Nursing education perspectives*, 43(5), 287-291. <https://doi.org/10.1097/01.nep.0000000000001011>