**International Journal of Environmental Sciences**
ISSN: 2229-7359
Vol. 11 No. 7, 2025
https://www.theaspd.com/ijes.php

# Ideating Rectangular Sharps Bin Design For Safer Waste Disposal And Needle-Stick Injury Prevention In Malaysian Hospitals

**Sazana Basri[1], Rosmina Jaafar[2] and Mohd Nizam Ab Rahman[3]**
[1,2,3]Fakulti Kejuruteraan dan Alam Bina, Universiti Kebangsaan Malaysia
sazanabasri@yahoo.com[1], rosmina@ukm.edu.my[2] and mnizam@ukm.edu.my[3]

**Abstract**
*Needle-stick injury (NSI) remains a significant occupational hazard in Malaysian hospitals, with prevalence rates reported between 23 and 28 percent. While nurses are among the most affected, soft facility management (FM) staff from the Healthcare Waste Management Services (HWMS) department are also sometimes vulnerable when handling clinical waste. Factors contributing to NSI include overload capacity, improper disposal, and wrongly disposed, i.e. due to the confusion between sharps bins and yellow clinical waste bins, particularly among new or fatigued staff working night shifts. Despite the presence of standard sharps containers, issues such as poor differentiation, limited ergonomics, and insufficient placement continue to compromise safe disposal practices and place both clinical and FM staff at risk. To address these gaps, this paper introduces the ideation of a rectangular sharps bin as an innovation in hospital waste management. The proposed design emphasizes wider openings to minimize disposal errors, stackable for efficient storage, and clearer visual differentiation from yellow bins, while also incorporating ergonomic features to enhance safe handling during both disposal and collection. Although still a conceptual proposal, the rectangular sharps bin highlights the potential of design innovation to reduce NSI prevalence, strengthen compliance with universal precautions, and support safer and more sustainable healthcare environments in Malaysia.*

## INTRODUCTION

Needle-stick injuries (NSI) are among the most pressing occupational hazards in healthcare, carrying the risk of transmitting blood-borne infections such as hepatitis B, hepatitis C, and HIV. In Malaysia, several studies have highlighted the seriousness of the issue. Rampal, Zakaria, Sook, and Zain (2010) reported a prevalence rate of 23.5 percent among healthcare workers at a public hospital, with nurses being the most affected group. Similarly, Lee (2005) documented that nearly one in five healthcare workers in an orthopedic ward in Melaka had experienced at least one NSI, underscoring its persistent nature across hospital settings. Despite high levels of awareness regarding universal precautions, underreporting and unsafe disposal practices remain common (Swe, 2014). Nurses in Malaysia face heightened risk of needle-stick injuries and other blood exposure incidents, a problem that is often compounded by long working hours and extended shifts, which contribute to fatigue, reduced alertness, and unsafe handling practices (Anwar, Sathiakumar, & Delzell, 2013).

One recurring problem involves the improper differentiation between sharps bins and yellow clinical waste bins. Newly inducted staff or those working night shifts under fatigue are particularly prone to confusing the two, leading to unsafe disposal of sharps into yellow bags intended for general clinical waste. Such missteps not only compromise the safety of clinical staff but also extend risks to soft facility management (FM) personnel, particularly those working in the Healthcare Waste Management Services (HWMS) department. These staff members are responsible for collecting, transporting, and handling clinical waste bins across hospital wards. When sharps are improperly discarded into yellow bins or when sharps containers are overfilled or left unlocked, FM staff face heightened risks of accidental exposure during waste handling. This dimension of NSI has received limited attention, yet it is crucial given that waste management workers form a vital link in the hospital waste disposal chain.

Current sharps bins, commonly cylindrical or compact box-shaped, meet basic international standards but still present limitations in terms of ergonomics, usability, and visibility. Insufficient supply, poor placement, and inadequate differentiation continue to exacerbate the problem. To address these gaps, this paper introduces the ideation of a rectangular sharps bin as a potential innovation in sharps waste management. The proposed design emphasizes wider openings for safer disposal, stackable for storage efficiency, and clearer visual distinction from yellow clinical waste bins, while incorporating ergonomic features that ease handling by both clinical staff and HWMS teams. The design of sharps bins (capacity, puncture-proof material, no overfilling) is critical in preventing injuries during disposal (Cheong, S. K.,

Lim,2000). Although still at the conceptual stage, the rectangular sharps bin is positioned as a forward-looking solution to reduce NSI, strengthen compliance with safe disposal protocols, and promote safer hospital environments in Malaysia

## MATERIALS AND METHODS

This study was developed as a conceptual design and prototyping project aimed at exploring a rectangular sharps bin as a potential innovation in hospital waste management. The process was conducted in three main phases: design development, prototype fabrication, and preliminary evaluation.

The design process began with the identification of common problems encountered in sharps waste disposal within hospital settings. These included confusion between sharps bins and yellow clinical waste bins, narrow disposal openings that encourage unsafe practices such as recapping, and ergonomic limitations for staff handling. These issues were translated into design criteria emphasizing a rectangular body for stackable, a wider slanted opening for safe disposal, a lockable lid to prevent spillage, and ergonomic side handles to improve handling by Healthcare Waste Management Services (HWMS) staff. Distinctive color differentiation and hazard markings were integrated to minimize confusion with yellow bins.

The rectangular sharps bin prototype was designed using computer-aided design (CAD) software and fabricated with an HP Jet Fusion 580 Color 3D Printer (HP Inc., Palo Alto, CA, USA). The printer was selected for its capacity to produce high-resolution, mechanically strong prototypes with integrated color details. Polyamide 12 (PA12) resin powder was used due to its durability, heat resistance, and suitability for medical-related prototyping. This technology is replacing the PVC filament which is sleeker in result. Post-processing steps included de-powdering, surface finishing, and curing to stabilize the material and prepare it for usability assessment.

The fabricated prototype was evaluated against the requirements of the BS EN ISO 23907:2012 standard for sharps containers. Evaluation focused on features such as puncture resistance, closure integrity, structural robustness, and handling ergonomics. The prototype was also assessed in relation to its potential usability within hospital workflows, with informal feedback sought from a small group of clinical staff and HWMS personnel regarding its design, practicality, and potential to reduce disposal errors. The study framework is illustrated in Figure 1.

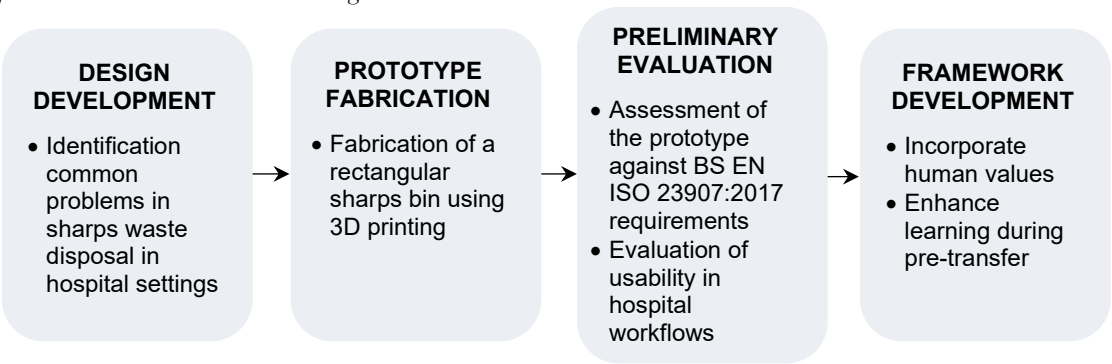


**Figure 1:** Study methodology

Although not tested in a live hospital setting, this early-stage assessment provided insights into the feasibility of rectangular sharps bin design and demonstrated how 3D printing can be used to develop tailored innovations in healthcare facility management

## RESULTS

The rectangular sharps bin prototype was successfully fabricated using 3D printing technology, resulting in a container that incorporated wider openings, a rectangular body for stackable, ergonomic side handles, and integrated hazard markings with color differentiation. Compared to conventional cylindrical sharps bins, the prototype demonstrated improved disposal access and visual clarity, minimizing the risk of confusion with yellow clinical waste bins. Informal feedback from both clinical and facility management staff suggested that the design would support safer waste segregation practices and potentially reduce NSI.

One of the most notable benefits of the rectangular design was its clear visual differentiation from yellow clinical waste bins. In many hospitals, incidents of sharps being disposed into yellow bags occur due to staff fatigue, particularly during night shifts, or lack of experience among newly inducted workers. Such errors place both clinical and HWMS staff at risk. By ensuring distinct form and markings, the rectangular

sharps bin could provide a practical solution to this recurring problem, especially in high-pressure environments where mistakes are more likely to occur.

Containers with narrow or awkward insertion slots increase the chance that needles can get stuck, rebound, or even protrude, raising the risk of needlestick injury (Guth & McNicholas, 2010). Additionally, the insertion opening of the sharp bin is very limited, often causing needles to become stuck during disposal and to press against one another along the bin wall when it is full, as observed in its operation (Figure 2). In contrast, the proposed rectangular design allows the needles to fall diagonally, thereby optimizing space utilization within the bin.


**Figure 2:** Top loading view from the current sharp bin

Despite these potential benefits, the adoption of the rectangular sharps bin poses a significant economic challenge. The prototyping process using high-resolution resin-based 3D printing already indicated higher material, refer to Figure 3 and production costs compared to conventional cylindrical containers, which are mass-produced at lower prices. From the perspective of HFM responsible for HWMS, cost efficiency is a central consideration. Unless mandated, FM companies may be reluctant to replace existing bins with a more expensive alternative, even if it offers safety advantages. The financial implications include not only the unit price of the bin but also the logistical adjustments required for collection, storage, and transportation of a new design.

Figure 3: Stimulation 3D (left) and top loading view of the printed (resin) rectangular sharp bin(right)

In this context, regulatory enforcement by the Ministry of Health (MOH) would be a key determinant of adoption. Historically, major improvements in healthcare facility management practices, such as the introduction of standardized clinical waste segregation and monitoring systems, have only gained traction after being made compulsory under concession contracts. A similar regulatory approach would likely be necessary for the rectangular sharps bin to achieve widespread use. MOH endorsement, coupled with integration into contract specifications, could ensure compliance by FM providers and create a level playing field where safety takes precedence over cost.

The higher cost of the rectangular design must also be weighed against the potential savings from avoided incidents of NSI. Treatment of occupational exposures, post-exposure prophylaxis, and compensation for affected staff represent significant financial and legal liabilities for hospitals and FM companies. By reducing the incidence of sharps-related injuries, a more effective bin design could indirectly offset its higher upfront cost. Furthermore, the reputational value of demonstrating commitment to staff safety and compliance with international standards may strengthen the case for adoption despite financial constraints.

Overall, while the rectangular sharps bin presents clear benefits in terms of differentiation from yellow bins, improved ergonomics, and enhanced safety for both clinical and HWMS staff, its higher production cost poses a barrier to voluntary adoption. Adhikari et al. (2008) highlight how the physical and chemical properties of waste and its handling environment strongly affect outcomes. A similar principle applies to sharp waste in hospitals, where the design and material strength of sharp bins are critical in preventing needle stick

injuries. Issues such as narrow insertion points, improper filling, or low puncture resistance can cause needles to get stuck, push back, or pierce the container wall, increasing risk for healthcare staff. Therefore, just as composting requires the right mix of bulking agents for safe processing, sharp waste requires rigid, puncture-proof bins with proper filling protocols to ensure safe disposal and minimize occupational hazards.

Lee (2009) reinforces the idea that in many developing country hospitals, systemic gaps in sharps safety, training, and resource allocation increase healthcare workers' vulnerability to needlestick injuries and bloodborne infections. Linking this with Malaysian studies (e.g., Jantan, 2000; Cheong et al., 2000), the evidence suggests that proper container design, training, and adherence to international standards are critical to bridging the gap between policy and practice in hospital waste and sharps management. Alamgir, Yu, Cvitkovich, and Yassi (2008) reported that needlestick and sharps-related injuries were most frequent in acute care settings, with registered nurses experiencing the highest number of exposures, often during use of needles at the patient's bedside. Licensed practical nurses were more at-risk during disposal, while care aides were more exposed after disposal, highlighting weaknesses in sharps handling and container management. Over half of needlestick injuries occurred at the bedside, and many splash exposures affected the eyes and face, emphasizing the need for protective equipment. These findings underline the importance of having puncture-proof sharps containers located close to the point of care, ensuring they are not overfilled, and providing role-specific training to minimize occupational hazards in hospitals.

In hospitals, poor container design (e.g., narrow slots, weak material, lack of fill indicators) increases the risk of sharps protruding or causing injury during disposal. ISO 23907:2012 provides a structured framework to evaluate container safety and usability, ensuring that sharps bins used in wards, ICUs, and operating theatres meet international safety standards. This supports not only the prevention of occupational needle-stick injuries but also compliance with infection control protocols. The study highlighted that training, awareness, and proper placement of sharps containers are critical in reducing the risk of needlestick injuries, underscoring how both human practices and system design must align to ensure occupational safety (Jantan, 2000).

Taha and El-Badawy (2011) reported that sharps injuries were highly prevalent among healthcare workers in Saudi hospitals, particularly among nurses, with many incidents linked to unsafe practices such as needle recapping and improper disposal. The study also noted widespread underreporting and inadequate training, which limited the effectiveness of prevention strategies. Similarly, Makmor, Ahmad, and Razali (2018) highlighted challenges in clinical waste management in Malaysia, where improper segregation at source, poor use and placement of sharps containers, and limited staff awareness remain persistent issues. Together, these studies demonstrate that across different healthcare systems, both individual practices and systemic weaknesses in sharps waste management contribute to occupational risks, emphasizing the need for consistent training, proper container design and placement, and stronger institutional monitoring to protect healthcare workers.

Wilburn and Eijkemans (2004) emphasize that needlestick injuries are preventable through a combination of strategies that integrate engineering controls, such as safety devices and sharps containers, with administrative measures and staff training supported by global WHO-ICN guidelines. Similarly, Trim and Elliott (2003) highlight that effective prevention requires a multifactorial approach, combining safer technologies with continuous education, reporting systems, and institutional commitment to safety practices. Building on these perspectives, Tuppurainen, Mäkelä, and Jokela (2018) demonstrate that innovations in sharps container design, including wider insertion slots, anti-overfill features, and ergonomic handling, can significantly reduce risks at the operational level. Collectively, these studies show that sharps injury prevention depends on both technological innovation and systemic strategies, underscoring the need to harmonize global standards, institutional policies, and design improvements to protect healthcare workers effectively.

The World Health Organization (2014) underscores that safe management of healthcare waste, particularly sharps, requires puncture-proof containers, proper segregation at the point of generation, and strict adherence to universal precautions to minimize occupational risks. In line with these guidelines, Zafar et al. (2009) demonstrated in a Pakistani teaching hospital that structured infection control education significantly improved healthcare workers' compliance with universal precautions, reducing unsafe practices that contribute to needlestick injuries. Similarly, Zuraimi and Rahman (2016) found that while Malaysian nurses generally possessed adequate knowledge of needlestick injury risks, gaps remained in translating knowledge into consistent safe practices, particularly in disposal behaviors. Collectively, these studies highlight that international standards, continuous education, and consistent compliance at the workplace level are essential to reducing sharps-related injuries and ensuring safer healthcare

environments.

Widespread implementation would therefore depend on MOH regulatory support, supported by cost-benefit analyses that highlight long-term savings in occupational safety and reduced liability. This underscores the importance of aligning design innovation not only with user safety but also with economic and policy frameworks that govern healthcare facility management in Malaysia. Figure 4 and Table 1 summarize the comparisons between the circular bins compared to the newly proposed rectangular bins.


**Figure 4.** The circular bins compared to the proposed rectangular bins

**Table 1:** Comparison between the circular sharps bin and the rectangular sharps bin prototype

| Criteria | Conventional Circular Sharps Bin | Rectangular Sharps Bin Prototype |
|---|---|---|
| Body Shape | Cylindrical | Rectangular, stackable |
| Opening Design | Narrow opening, causes needle jams and sticking | Wider, slanted opening for safer, smoother disposal |
| Space Utilization | Limited – needles often press against walls when full | Optimized – needles fall diagonally, improving capacity |
| Ergonomics | Less ergonomic; difficult handling | Ergonomic side handles for easier carrying by HWMS staff |
| Visual Differentiation | Similar to yellow clinical waste bins; higher confusion risk | Distinctive colour differentiation and hazard markings reduce confusion |
| Safety | Higher risk of sharps disposal errors, leading to NSI | Improved safety by minimizing disposal errors and reducing NSI |

| Criteria | Conventional Circular Sharps Bin | Rectangular Sharps Bin Prototype |
|---|---|---|
| **User Feedback** | Common complaints about disposal difficulties and confusion | Positive informal feedback from clinical & facility management staff |
| **Material Used** | Usually, PVC or mass-produced plastics | Polyamide 12 (PA12) resin, 3D-printed with high resolution |
| **Production Cost** | Lower – mass-produced and widely available | Higher – high-resolution 3D printing increases cost |
| **Maintenance & Logistics** | Compatible with existing collection & transport systems | May require adjustments in collection, storage, and transport |
| **Adoption Challenges** | Already standardized and widely used | Requires MOH endorsement or regulatory enforcement for widespread adoption |
| **Economic Impact** | Cost-effective upfront but potential hidden costs from NSI-related incidents | Higher upfront cost but potential long-term savings by reducing NSI, legal liabilities, and staff treatment costs |
| **Compliance with Standards** | Meets basic disposal needs | Designed to meet BS EN ISO 23907:2012 for sharps containers |
| **Regulatory Support Needed** | Not required – already accepted industry standard | Likely needed for mass implementation due to higher cost |

## CONCLUSION

This study presented the ideation and prototyping of a rectangular sharps bin as a potential improvement in hospital waste management. The prototype offered several advantages over conventional cylindrical bins, including wider and ergonomic-needle-disposal openings, ergonomic side handles, stackable design, and clearer visual distinction from yellow clinical waste bins, directly addressing recurring problems of unsafe disposal practices and staff confusion that contribute to needle-stick injuries (NSI). These benefits extend not only to clinical personnel but also to facility management staff in the HWMS unit, who often face risks during collection and handling. However, the higher production cost of the rectangular design remains a significant barrier to voluntary adoption by facility management concessionaires, who operate under cost-driven contracts. For meaningful implementation, regulatory enforcement and endorsement by the MOH would be essential to ensure that safety takes precedence over financial concerns. Although costlier, the rectangular sharps bin has the potential to reduce the long-term economic and health burden of NSI by lowering treatment costs, minimizing compensation claims, and strengthening occupational safety culture in hospitals.

## REFERENCES

1. Adhikari, B. K., Barrington, S., Martinez, J., & King, S. (2008). Characterization of food waste and bulking agents for composting. *Waste Management, 28*(5), 795–804. https://doi.org/10.1016/j.wasman.2007.08.018
2. Alamgir, H., Yu, S., Cvitkovich, Y., & Yassi, A. (2008). Needle-stick and other potential blood and body fluid exposures among health care workers in British Columbia, Canada. *American Journal of Infection Control, 36*(1), 12–21. https://doi.org/10.1016/j.ajic.2007.02.009
3. Anwar, A., Sathiakumar, N., & Delzell, E. (2013). Occupational health issues among nurses in Malaysia. *Occupational Medicine, 63*(5), 346–351. https://doi.org/10.1093/occmed/kqt051
4. Cheong, S. K., Lim, V. K. E., & Chew, S. K. (2000). Needle-stick injuries among healthcare workers in a Malaysian teaching hospital. *Medical Journal of Malaysia, 55*(4), 449–452.
5. Guth, J., & McNicholas, A. (2010). Sharps disposal container design and the risk of occupational sharps injury. *Journal of Hospital Infection, 74*(1), 56–60. https://doi.org/10.1016/j.jhin.2009.07.015
6. International Organization for Standardization. (2012). *Sharps injury protection – Requirements and test methods – Sharps containers (ISO 23907:2012)*. ISO.
7. Jantan, J. (2000). Sharps injury in Hospital Universiti Kebangsaan Malaysia. *Jurnal Kesihatan Masyarakat, 6*(2), 86–92.
8. Lee, L. K. (2005). Implication of the prevalence of needlestick injuries in a teaching hospital. *Malaysian Orthopaedic Journal, 1*(1), 50–54.
9. Lee, R. (2009). Occupational transmission of bloodborne diseases to healthcare workers in developing countries: Meeting the challenges. *Journal of Hospital Infection, 72*(4), 285–291. https://doi.org/10.1016/j.jhin.2009.03.016

10. Makmor, T., Ahmad, N., & Razali, M. A. (2018). Clinical waste management in Malaysia: Practices and challenges. *Environmental Management and Sustainable Development, 7*(2), 55–70. https://doi.org/10.5296/emsd.v7i2.13217
11. Rampal, L., Zakaria, R., Sook, L. W., & Zain, A. M. (2010). Needle stick and sharps injuries and factors associated among health care workers in a Malaysian hospital. *European Journal of Social Sciences, 13*(3), 354–362.
12. Swe, K. M. M. (2014). Needle sticks injury among medical students during clinical training in Malaysia. *International Journal of Collaborative Research on Internal Medicine & Public Health, 6*(5), 122–130.
13. Taha, A. Z., & El-Badawy, A. A. (2011). Sharps injuries among healthcare workers in hospitals of Abha City, Saudi Arabia. *Eastern Mediterranean Health Journal, 17*(6), 506–511. https://doi.org/10.26719/2011.17.6.506
14. Trim, J. C., & Elliott, T. S. J. (2003). A review of sharps injuries and preventative strategies. *Journal of Hospital Infection, 53*(4), 237–242. https://doi.org/10.1053/jhin.2002.1374
15. Tuppurainen, M., Mäkelä, J., & Jokela, J. (2018). Design for safety: Innovations in sharps containers to prevent injuries. *Safety Science, 110*, 368–374. https://doi.org/10.1016/j.ssci.2018.07.012
16. Wilburn, S. Q., & Eijkemans, G. (2004). Preventing needlestick injuries among healthcare workers: A WHO-ICN collaboration. *International Journal of Occupational and Environmental Health, 10*(4), 451–456. https://doi.org/10.1179/oeh.2004.10.4.451
17. World Health Organization. (2014). *Safe management of wastes from health-care activities* (2nd ed.). WHO Press.
18. Zafar, A., Habib, F., Hadwani, R., Ejaz, M., Khowaja, K., Khowaja, R., & Irfan, S. (2009). Impact of infection control education on health care workers' compliance with universal precautions in a teaching hospital, Pakistan. *Journal of Ayub Medical College Abbottabad, 21*(4), 108–112.
19. Zuraimi, N. H., & Rahman, N. I. A. (2016). Knowledge, attitude and practice of needlestick injury among nurses in Malaysia. *International Journal of Public Health and Clinical Sciences, 3*(4), 35–47.