Chapter 14

Needle Disposal Device for Use in Low-Resource Settings

G. Beukes, C. Achi, B. Bolasodun, A. Desmennu, A. Oloyo, O. Oyebola, O. Oyewola, T. Saidi, A.O. Coker & S. Sivarasu

Introduction

Used needles pose serious risks of injury to health care workers and non-medical staff who handle the waste, as well as to the general population. The safe disposal of needles and syringes used for the collection of blood and other bodily fluids and for injections is important in preventing needle stick injuries, which can cause the transmission of a variety of blood-borne pathogens such as hepatitis B virus, hepatitis C virus, and human immunodeficiency virus (Lavoie et al., 2014; Balouchi et al., 2015; Jahangiri et al., 2016). Infections occur when accidental punctures by contaminated needles inject hazardous fluids into the body through the skin, leading to chronic and fatal diseases (Lavoie et al., 2014). According to the World Health Organisation (WHO), it is estimated that among the 35 million health care workers worldwide, approximately 3 million receive percutaneous exposures to blood-borne pathogens each year, with 2 million being prone to the hepatitis B virus, 0.9 million to the hepatitis C virus and 170,000 to the human immunodeficiency virus (WHO, 2002). The degree of exposure is more pronounced in developing countries where poor handling and disposal of used sharps contribute significantly to needle stick injuries (Chalupka et al., 2008, Shoghli et al., 2013). In developing countries, the disposal of contaminated sharps is also a serious safety concern for garbage collectors and landfill workers (Patwary, O'Hare & Sarker, 2012).

Various mechanisms have been proposed to prevent needle stick injures. For example, the WHO recommends the use of sharp disposal containers for getting rid of unwanted needles (Diaz, Savage & Eggerth, 2005, Perry et al., 2012). The use of dedicated containers for the disposal of needles can reduce needle stick injuries in health care settings (Hatcher, 2002). However, the effectiveness of safety boxes is limited to the point of use as the needles should be subjected to further treatment for disposal. There are risks of injury that arise during and after final disposal of needles, particularly in places that are accessible to the public (Ziraba, Haregu & Mberu, 2016). The unsanitary disposal of needles put millions of lives at risk because dumping sites are often visited by people scavenging for goods, resulting in accidental exposure (Salkin & Kennedy, 2001; Diaz, Savage & Eggerth, 2005; Wilson, Velis & Cheeseman, 2006). This calls for innovative strategies of preventing needle stick injuries. There are growing calls for cradle-to-grave responsibilities in the management of needles (Gold, 2011). It is against this background that this chapter focuses on the design and development of a portable, cost-effective and energy-efficient needle disposal device for use in low-resource settings.

DOI: http://dx.doi.org/10.15641/0-7992-2544-0
https://openbooks.uct.ac.za/bmeafrica

Disposal in developed countries

Globally, there are many methods for processing and disposing of used needles and other sharps generated by health care facilities. In developed countries, sharp disposable containers are commonly used (Nagao et al., 2007; Alamgir et al., 2008; Lavoie et al., 2014). For example, the use of sharp disposal containers in the USA can be traced to 1983 when the Center for Disease Control and Prevention recommended their use (CDC, 1987; Perry et al., 2012). In Europe, the European Union directive endorses the use of clearly marked and technically safe containers for the handling of disposable sharps and injection equipment as close as possible to the areas where sharps are used (EU, 2010). In Japan, regulations encourage the use of sharp disposal containers in areas where needles are frequently used such as operating rooms, treatment rooms and centrally located areas of wards (Nagao et al., 2007). Sharp disposable containers have evolved over the last decades to include features such as increased puncture resistance, one-way openings, and signifiers to prevent overfilling, such as a line that indicates when the container should be considered full (Perry et al., 2012). For sharp disposable containers to be effective, the minimum design and performance requirements include that they be easily accessible to personnel and located as close as is feasible to the immediate area where sharps are used or can be reasonably anticipated to be found (Domin & Smith, 1992). In addition, the containment system should be of heavy duty and leak resistant plastic with a tight-fitting, puncture-resistant lid which is conspicuously labelled to warn of hazardous waste inside the container (Blackman Jr, 2016). It is recommended that safety boxes only be filled once and disposed of (WHO, 2005). There is no one prescribed method for the disposal of safety boxes, but any selected method must be in compliance with national and local environmental regulations (WHO, 2002).

Sharp disposable containers are a temporary storage for used needles before their final disposal. The process of disposing of full sharp containers is a critical part of waste management which must be clearly delineated and enforced (Perry et al., 2012). Several technologies are used to treat and dispose of sharps stored in sharp containers; these include incineration, chemical disinfection, wet thermal treatment, and microwave irradiation (Chaerul, Tanaka & Shekdar, 2008). In order to prevent infections, the collection and disposal of the sharps container is subject to special safety requirements to avoid contamination (Hester & Harrison, 2002). Some are disposed of by high temperature incineration, while others are transported to a dump site (Mühlich, Scherrer & Daschner, 2003). Although incineration is a relatively costly treatment, it is widely used in developed countries as it is effective (Chaerul, Tanaka & Shekdar, 2008). Developed countries can afford to use high-technology incinerators to achieve complete combustion and to keep the concentration of undesirable waste compounds generated by burning to a minimum (Diaz, Savage & Eggerth, 2005). Countries such as the USA, Canada and Japan have a regulated waste disposal system where sharps are transported for disposal at dump sites that are kept out of reach of the public (Nagao et al., 2007; Alamgir et al., 2008; Perry et al., 2012). In these countries, the sharp disposal containers are collected and transported separately from other medical waste to avoid compaction and facilitate separate treatment (Mühlich, Scherrer & Daschner, 2003). The sharps are encapsulated by placing them in containers made of cardboard, plastic, or metal which are immobilised using cement, plastic foams, resins or clay (WHO, 2005). Once the immobilising material has hardened, the containers are sealed and disposed of in a dedicated disposal site as encapsulation keeps personnel in the waste management system from being injured (Diaz, Savage & Eggerth, 2005). In addition, developed countries have adopted engineering controls such as safer needle devices which blunt, sheath, or retract the needle immediately after use (Wilburn & Eijkemans, 2004). Such devices have been shown to reduce needle stick injuries (Jagger, 1996; Weese & Jack, 2008).

Disposal in developing countries

In developing countries, sharps are a cause for concern because of inappropriate treatment and disposal practices (Diaz, Savage & Eggerth, 2005, Sawalem, Selic & Herbell, 2009). For example, sharps disposal containers, incinerators and transportation networks are not always available (Mbongwe, Mmereki & Magashula, 2008). Cost constraints make the purchase of single use disposable containers unrealistic. This often results in improvised makeshift containers which pose a health hazard (Nsubuga & Jaakkola, 2005, Patwary, O'Hare & Sarker, 2011). Studies that were conducted in Uganda, Tanzania and the Dominican Republic revealed that used sharps were discarded in ad-hoc puncture-proof containers, rather than in boxes designed specifically for sharps (Muller, 2005; Moro et al., 2007; Manyele, Samwel V & Mujuni, 2010). The boxes were overfilled resulting in sharps on the floor and in areas surrounding the health facilities. The disposal of sharps in the garbage expose children and waste handlers to risk of injuries and transmission of blood-borne pathogens (Manyele, SV & Lyasenga, 2010; Ishtiaq et al., 2012; Gyawali et al., 2013).

In many parts of Africa, medical waste including sharps is not separated from municipal waste but is collected along with the rest of the waste stream (Kgathi & Bolaane, 2001, Manyele, 2004, Taru & Kuvarega, 2005). Sharps containers may be placed in less secure storage facilities, which often results in contaminated injection equipment being scavenged and reused (Salkin & Kennedy, 2001; Mbongwe, Mmereki & Magashula, 2008; Rachiotis et al., 2012). In many developing countries, medical waste, and in particular used syringes and needles, are commonly burned in the open air or in simple and often improvised units such as pits, burners (made out of brick or cement), and in drums (Diaz, Savage & Eggerth, 2005). Although the units are relatively inexpensive, easy to build, and require little or no maintenance, they are not effective in the disposal of sharps because of the relatively uncontrolled combustion conditions (Diaz, Savage & Eggerth, 2005, Sawalem, Selic & Herbell, 2009). As a result, combustion does not completely burn all of the waste, particularly if it has a relatively high moisture content (Diaz, Savage & Eggerth, 2005). Another option for disposing sharps in developing countries is the use of open dumps (Longe & Williams, 2006). While being the least costly option, the use of open dumps poses negative impacts to the public and environment because of the uncontrolled nature of disposal (Sawalem, Selic & Herbell, 2009).

Many factors militate against the safe disposal of sharps in developing countries. Medical waste management has not received sufficient attention in developing countries due to limited financial, physical and human resources (Harhay et al., 2009; Awodele, Adewoye & Oparah, 2016). Poor roads, intermittent electricity, lack of vehicles which makes transportation of waste unsafe, and the absence of effective municipal waste disposal systems are contributing factors (Abah & Ohimain, 2011; Patwary, O'Hare & Sarker, 2011; Guerrero, Maas & Hogland, 2013). Transportation of sharps to dump sites is problematic in areas without proper means of transport (Chaerul, Tanaka & Shekdar, 2008), resulting in medical waste being transported on foot and by hand, thereby increasing the danger of the waste handler being accidently pierced or cut by contaminated sharps (Tsakona, Anagnostopoulou & Gidarakos, 2007). Lack of awareness about the health hazards related to medical waste and inadequate training in proper waste management contributes to poor disposal of waste (Abah & Ohimain, 2010; Mathur et al., 2011; Madhukumar & Ramesh, 2012).

Engineering controls such as safe needle devices are expensive for developing countries and they cannot afford to adopt such risk reduction innovations without financial assistance (Ekwueme, Weniger & Chen, 2002). The problem is compounded by the rising amount of hospital waste generated due to growth of the population and increased numbers of health care facilities (Awodele, Adewoye & Oparah, 2016). As a result, the sharps are deposited openly in waste dumps and surrounding environments, often alongside non-hazardous solid waste as there are no systematic approaches to medical waste management (Abah & Ohimain, 2011; Awodele, Adewoye & Oparah, 2016; Macaulay & Odiase, 2016). Studies on medical waste management in Lagos, Dar es Salaam and Dhaka revealed that burning and burial of medical waste was a common practice at hospitals due to limited options (Mato & Kaseva, 1999; Longe & Williams, 2006; Hassan et al., 2008).

A needle disposal device for low-resource settings

A safe, simple, on-the-counter, needle disposal device that would effectively leave the needle unusable (by bending, breaking, crushing or cutting it) and allow for needles to be disposed of with medical grade waste would assist in preventing needle stick injuries at health care facilities and in reducing the dumping of used needles at inappropriate public locations. This section presents the design of such a device for destruction of the needle at the point of use, based on a need identified by academics from the University of Ibadan. While public hospitals and primary healthcare clinics in Nigeria were identified as potential users of the device, similar facilities in other developing countries would also benefit.

User requirements

The requirements for the device, based on the needs of potential users, are outlined below.

- The needle is separated from the syringe so that the metal and non-metal components are disposed of separately.
- The needle is rendered unusable and is left in a form that makes it easily disposable.

- Operability:
    - The device is comfortable to operate by a healthcare worker.
    - Electricity-driven operation ensures maximal ease of use.
    - A manual mode is available for instances where automation is not possible, for example due to interruption in the power supply.
- The device has a universal attachment for mounting to a variety of counter tops.
- The device has a detachable needle container for ease of disposal.
- The device prevents accidental contact between the needles and operator once separation is achieved.
- The device is easily cleaned and maintained.

Design

The device has three subsystems:

1. Needle separator
2. Needle cutter
3. Container/housing with separator for plastic and metal

Needle separator

The separator mechanism (as illustrated in Figure 1) makes use of a rhombus/diamond shaped separator, which allows the operator to insert the needle and syringe assembly and slide it in either direction to achieve separation. A separation area thickness of 0.75 mm was considered sufficient in terms of strength and separation distance between the needle plastic and the syringe. In addition, the separator needed to funnel the needle into the point of destruction. This is achieved by embedding a funnel into the separator to ensure that the needle falls directly onto the point of destruction, thereby increasing the effectiveness of the cutting mechanism. The separator was manufactured by means of a fused deposition modelling (FDM) three-dimensional (3D) printer. The material selected for the component was acrylonitrile butadiene styrene (ABS) polymer. The material is commonly used for 3D printing due to its affordability and low melting temperature (200°C–238°C). The funnel system is indicated in Figure 1.

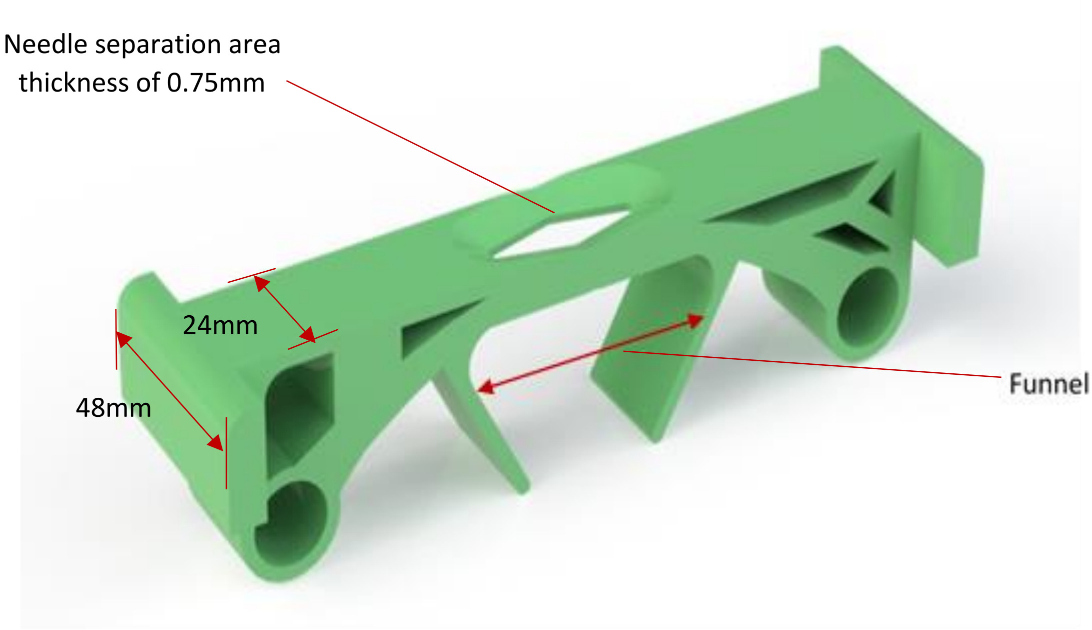

Figure 1: Needle separator with funnel to guide the needle towards the cutter for destruction.

Needle cutter

The needle cutter aims to cut the needles to achieve complete destruction. Needle cutting was achieved using a unit comprising a uni-rotating shaft and a stationary shaft. The rotating shaft comprises four rotating cutters featuring twelve teeth each, with spacer disks between the cutters. The stationary shaft supports four stationary cutters featuring four teeth and a spacer disk between the cutters. Each stationary cutter lines up with a spacer between the rotating cutters. This is illustrated in Figure 2. The stationary cutters produce the necessary shear that would cut the needles.

In addition, a gearing system reduces the force required to rotate the cutter gears and create the required cutting effect. The gearing system uses an idle pinion gear fitted to the stationary cutter shaft. The larger gear is fitted to the rotating shaft by means of a key. This ensures that the torque generated would be transferred to the rotating cutters. The gearing system allows, by the spacing of the shafts as well as the dimensions of the device, for a torque ratio of 1:2.375, which reduces the torque required to cut the needles by a factor of 2.375. Manually applied torque is sufficient to destroy the needles. The device features an attachment that allows for secure fitment of a power drill to drive the gearing system, as well as a crank, should electrical operation not be possible. The gearing system is shown in Figure 3.

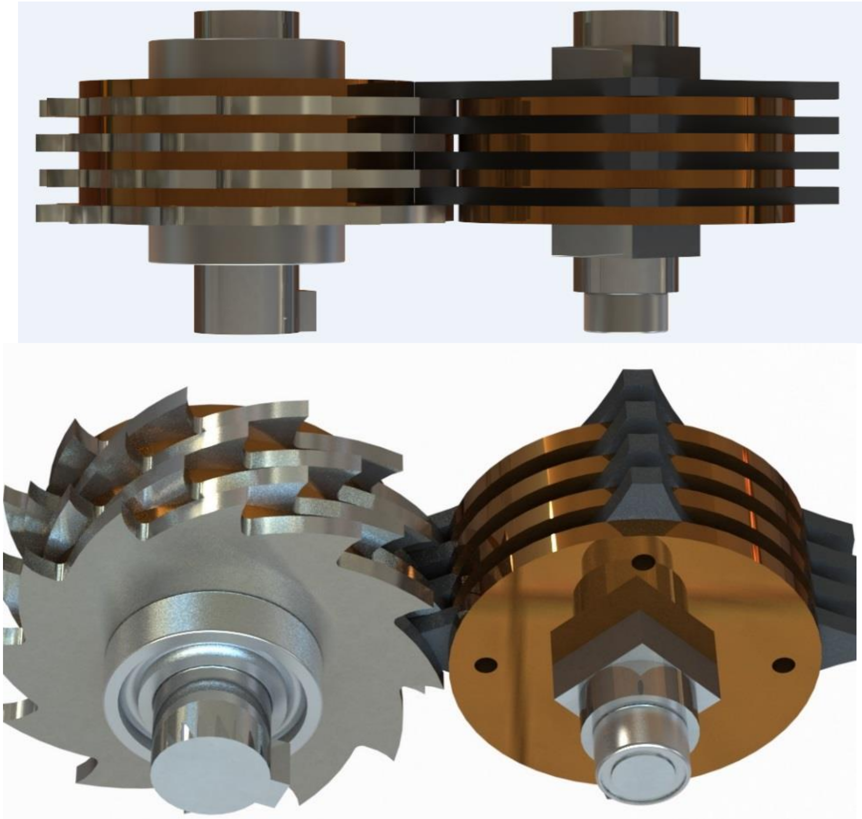

Figure 2: Needle cutter. Left: rotating cutters separated by spacers; Right: stationary cutters separated by spacers.

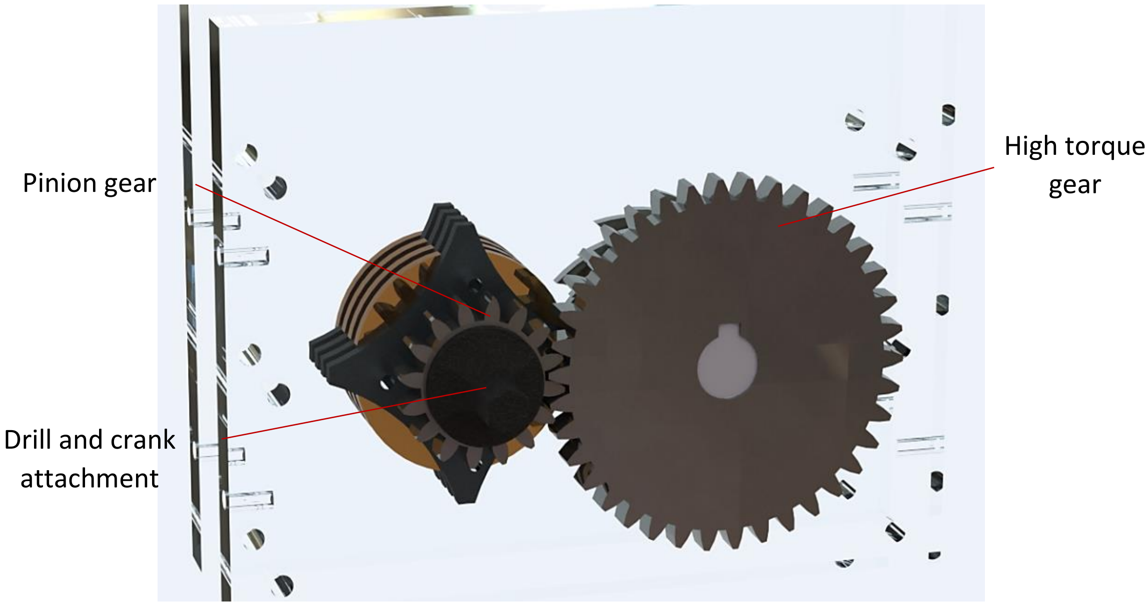

Figure 3: Gearing system to drive the cutter.

The cutter and spacers were manufactured from tungsten steel by a commercial company, using wire electrical discharge machining, and hardened for durability.

The rear plate of the cutter housing was machined from a 160 × 125 × 8 mm aluminium sheet, in order to counteract the reaction torque and other forces experienced during the needle cutting procedure. The front plate was manufactured from a 160 × 125 × 8 mm sheet of Plexiglas® allowing for visualisation of the needle cutting process. Each shaft was manufactured from stainless steel due to the stresses involved. A hexagonal shaft was used for the rotating cutters and a cubic shaft for the stationary cutters. This eliminated the need for keys to fixate the cutters. As previously mentioned, the cutters were all machined out of tungsten steel and hardened to ensure strength and longevity.

Container with separator for plastic and metal

A mechanism to separate the cut plastic from the cut needle was a requirement to allow for materials to be recycled. The 3D printed plastic container was manufactured from Zortrax Ultra-T Ivory plastic. The material is specifically designed for the Zortrax M-200 3D printer and is durable as well as capable of producing highly detailed prints. Chemical degradation and heat were considered for the separation of plastic, but were found to be too expensive, particularly in the case of rural clinics in Nigeria. Instead, a magnetic means was selected to separate the metal from the plastic. Two rare earth neodymium rectangular magnets (50 × 20 × 6 mm) were embedded in polymer housing (see Figure 4) and placed below the cutting mechanism. Once the needle has been cut up, the metal pieces would be caught by the magnets and the plastic would slide to the bottom of the container. Upon opening the container, the plastic can be collected and the metal pieces scraped off the magnets.

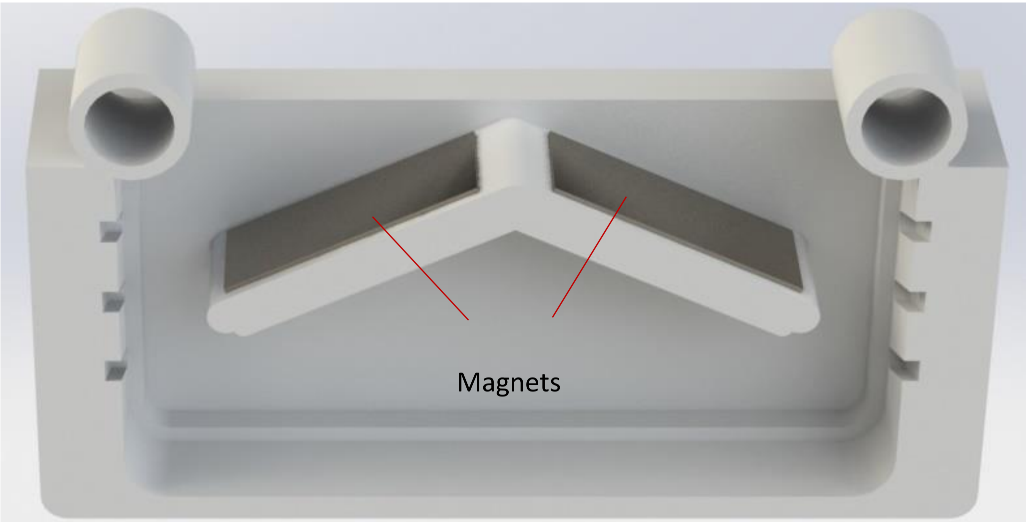

Figure 4: Container for destroyed needles, with magnetic (neodymium) separation.

The complete needle disposal device is shown in Figure 5.

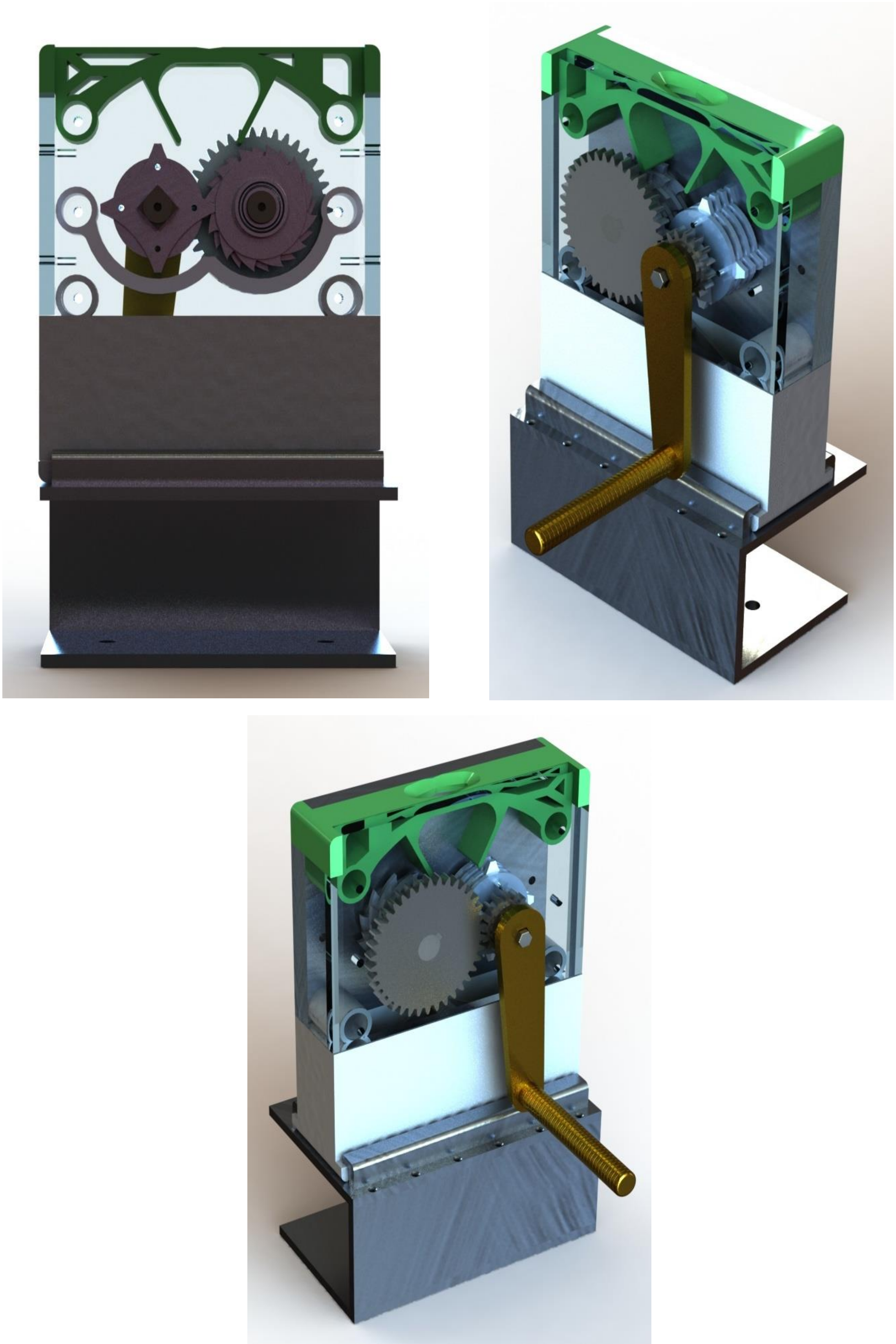

Figure 5: Needle disposal device.

Cost breakdown for one device

The total cost for the manufacture of the device was approximately ZAR 5,000, broken down as follows:

- Cutters – ZAR 3000 (material and manufacturing)
- 3D plastic:
    - Separator: ZAR 70
    - Base 1: ZAR 140
    - Base 2: ZAR 100
- Plexiglass:
    - Side plates: ZAR 20
    - Front plate: ZAR 40
- Gears: ZAR300
- Shafts: ZAR100
- Brass handle: ZAR 150
- Aluminium
    - Fixator: ZAR 240
    - Back plate: ZAR 100
- Magnets: ZAR 280 (ZAR140 each)
- Bearings: ZAR 200

Conclusion

The device allows clinical staff to dispose of and destroy needles at point of use, addressing the problem of needle stick injuries among hospital staff and the public. It allows for the recycling of materials. It is compact and designed to be affordable (approximately R5000 or Naira 135,000 per device by small scale manufacturing), therefore allowing for implementation in low-resource settings.

Acknowledgements

The authors are grateful to Charles Harris and Tyrone de Wet from the Mechanical Workshop of the Department of Human Biology, University of Cape Town, for their design and manufacturing contributions.

Research reported in this publication was supported by the Fogarty International Center of the National Institutes of Health under award number D43TW009374.

References

Abah, S.O. & Ohimain, E.I. 2010. Assessment of dumpsite rehabilitation potential using the integrated risk-based approach: a case study of Eneka, Nigeria. *World Applied Sciences Journal*. 8(4):436–442.

Abah, S.O. & Ohimain, E.I. 2011. Healthcare waste management in Nigeria: a case study. *Journal of Public Health and Epidemiology*. 3(3):99–110.

Alamgir, H., Cvitkovich, Y., Astrakianakis, G., Yu, S. & Yassi, A. 2008. Needlestick 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.

Awodele, O., Adewoye, A.A. & Oparah, A.C. 2016. Assessment of medical waste management in seven hospitals in Lagos, Nigeria. *BMC Public Health*. 16(1):269.

Balouchi, A., Shahdadi, H., Ahmadidarrehsima, S. & Rafiemanesh, H. 2015. The frequency, causes and prevention of needlestick injuries in nurses of Kerman: a cross-sectional study. *Journal of Clinical and Diagnostic Research*. 9(12):DC13.

Blackman Jr, W.C. 2016. *Basic hazardous waste management*. Boca Raton, FL: CRC Press.

CDC. 1987. *Recommendations for prevention of HIV transmission in health-care settings*. Atlanta, GA: Centres for Disease Control.

Chaerul, M., Tanaka, M. & Shekdar, A.V. 2008. A system dynamics approach for hospital waste management. *Waste Management*. 28(2):442–449.

Chalupka, S.M., Markkanen, P., Galligan, C. & Quinn, M. 2008. Sharps injuries and bloodborne pathogen exposures in home health care. *AAOHN Journal: Official Journal of the American Association of Occupational Health Nurses*. 56(1):15–32.

Diaz, L., Savage, G. & Eggerth, L. 2005. Alternatives for the treatment and disposal of healthcare wastes in developing countries. *Waste Management*. 25(6):626–637.

Domin, M. & Smith, C. 1992. OSHA's final rule on occupational exposure to bloodborne pathogens. *Journal of Healthcare Materiel Management*. 10(2):36, 38, 40 passim.

Ekwueme, D.U., Weniger, B.G. & Chen, R.T. 2002. Model-based estimates of risks of disease transmission and economic costs of seven injection devices in sub-Saharan Africa. *Bulletin of the World Health Organization*. 80(11):859–870.

EU. 2010. Implementing the framework agreement on prevention from sharps injuries in the hospital and health care sector. *Official Journal of European Union*. 53 (L134): 66–72.

EU-OSHA. 2010. Implementing the framework agreement on prevention from sharps injuries in the hospital and health care sector, concluded by HOSPEEM and EPSU. Available: https://osha.europa.eu/en/legislation/guidelines/framework-agreement-on-prevention-from-sharp-injuries-in-the-hospital-and-healthcare [2019, May 06].

Gold, K. 2011. Analysis: The impact of needle, syringe, and lancet disposal on the community. *Journal of Diabetes Science and Technology*. 5(4): 848–850.

Guerrero, L.A., Maas, G. & Hogland, W. 2013. Solid waste management challenges for cities in developing countries. *Waste Management*. 33(1):220–232.

Gyawali, S., Rathore, D.S., Bhuvan, K. & Shankar, P.R. 2013. Study of status of safe injection practice and knowledge regarding injection safety among primary health care workers in Baglung district, western Nepal. *BMC International Health and Human Rights*. 13(1):3.

Harhay, M.O., Halpern, S.D., Harhay, J.S. & Olliaro, P.L. 2009. Health care waste management: a neglected and growing public health problem worldwide. *Tropical Medicine & International Health*. 14(11):1414–1417.

Hassan, M.M., Ahmed, S.A., Rahman, K.A. & Biswas, T.K. 2008. Pattern of medical waste management: existing scenario in Dhaka City, Bangladesh. *BMC Public Health*. 8(1):36.

Hatcher, I.B. 2002. Reducing sharps injuries among health care workers: a sharps container quality improvement project. *The Joint Commission Journal on Quality Improvement*. 28(7):410–414.

Hester, R.E. & Harrison, R.M. 2002. *Environmental and health impact of solid waste management activities*. Royal Society of Chemistry. DOI: https://doi.org/10.1039/9781847550767

Ishtiaq, O., Qadri, A.M., Mehar, S., Gondal, G.M., Iqbal, T., Ali, S. & Janjua, N.Z. 2012. Disposal of syringes, needles, and lancets used by diabetic patients in Pakistan. *Journal of Infection and Public Health*. 5(2):182–188.

Jagger, J. 1996. Reducing occupational exposure to bloodborne pathogens: where do we stand a decade later? *Infection Control and Hospital Epidemiology*. 17(9):573–575.

Jahangiri, M., Rostamabadi, A., Hoboubi, N., Tadayon, N. & Soleimani, A. 2016. Needle stick injuries and their related safety measures among nurses in a university hospital, Shiraz, Iran. *Safety and Health at Work*. 7(1):72–77.

Kgathi, D. & Bolaane, B. 2001. Instruments for sustainable solid waste management in Botswana. *Waste Management & Research.* 19(4):342–353.

Lavoie, M. C., Verbeek, J. H. & Pahwa, M. 2014. Devices for preventing percutaneous exposure injuries caused by needles in healthcare personnel. *Cochrane Database of Systematic Reviews*, Issue 3, Article No. CD009740: 1–76.

Longe, E. & Williams, A. 2006. A preliminary study of medical waste management in Lagos metropolis, Nigeria. *Journal of Environmental Health Science & Engineering.* 3(2):133–139.

Reddy V.K., Lavoie, M.C., Verbeek, J.H., Parantainen, A. & Pahwa, M. 2012. Devices for preventing percutaneous exposure injuries caused by needles in health care personnel. *Cochrane Database of Systematic Reviews*. 11: CD009740. DOI: 10.1002/14651858.CD009740.pub3.

Macaulay, B.M. & Odiase, F.M. 2016. Medical waste management practices in developing countries: a case study of health facilities in Akure, Nigeria. *International Journal of Environment and Waste Management.* 17(2):103–127.

Madhukumar, S. & Ramesh, G. 2012. Study about awareness and practices about health care waste management among hospital staff in a medical college hospital, Bangalore. *Iranian Journal of Basic Medical Sciences.* 3(1):7–11.

Manyele, S. 2004. Effects of improper hospital-waste management on occupational health and safety. *African Newsletter on Occupational Health and Safety.* 14(2):30–33.

Manyele, S. & Lyasenga, T. 2010. Factors affecting medical waste management in lowlevel health facilities in Tanzania SV. *African Journal of Environmental Science and Technology.* 4(5).

Manyele, S.V. & Mujuni, C.M. 2010. Current status of sharps waste management in the lower-level health facilities in Tanzania. *Tanzania Journal of Health Research.* 12(4):257–264.

Mathur, V., Dwivedi, S., Hassan, M. & Misra, R. 2011. Knowledge, attitude, and practices about biomedical waste management among healthcare personnel: a cross-sectional study. *Indian Journal of Community Medicine.* 36(2):143.

Mato, R. & Kaseva, M. 1999. Critical review of industrial and medical waste practices in Dar es Salaam City. *Resources, Conservation and Recycling.* 25(3):271–287.

Mbongwe, B., Mmereki, B.T. & Magashula, A. 2008. Healthcare waste management: current practices in selected healthcare facilities, Botswana. *Waste Management.* 28(1):226–233.

Moro, P.L., Moore, A., Balcacer, P., Montero, A., Diaz, D., Gómez, V., Garib, Z. & Weniger, B.G. 2007. Epidemiology of needlesticks and other sharps injuries and injection safety practices in the Dominican Republic. *American Journal of Infection Control.* 35(8):552–559.

Mühlich, M., Scherrer, M. & Daschner, F. 2003. Comparison of infectious waste management in European hospitals. *Journal of Hospital Infection.* 55(4):260–268.

Muller, N. 2005. *Evaluation of a disposable needle-removal device in Uganda.* Seattle, WA: United States Agency for International Development (USAID).

Nagao, Y., Baba, H., Torii, K., Nagao, M., Hatakeyama, K., Iinuma, Y., Ichiyama, S., Shimokata, K. et al. 2007. A long-term study of sharps injuries among health care workers in Japan. *American Journal of Infection Control.* 35(6):407–411.

Nsubuga, F.M. & Jaakkola, M.S. 2005. Needle stick injuries among nurses in sub-Saharan Africa. *Tropical Medicine & International Health.* 10(8):773–781.

Patwary, M.A., O'Hare, W.T. & Sarker, M.H. 2011. Assessment of occupational and environmental safety associated with medical waste disposal in developing countries: a qualitative approach. *Safety Science.* 49(8):1200–1207. DOI: 10.1016/j.ssci.2011.04.001.

Patwary, M.A., O'Hare, W.T. & Sarker, M.H. 2012. Occupational accident: an example of fatalistic beliefs among medical waste workers in Bangladesh. *Safety Science.* 50(1):76–82. DOI: 10.1016/j.ssci.2011.07.004.

Perry, J., Jagger, J., Parker, G., Phillips, E.K. & Gomaa, A. 2012. Disposal of sharps medical waste in the United States: impact of recommendations and regulations, 1987–2007. *American Journal of Infection Control.* 40(4):354–358.

Rachiotis, G., Papagiannis, D., Markas, D., Thanasias, E., Dounias, G. & Hadjichristodoulou, C. 2012. Hepatitis B virus infection and waste collection: prevalence, risk factors, and infection pathway. *American Journal of Industrial Medicine.* 55(7):650–655.

Salkin, I.F. & Kennedy, M. 2001. *Review of health impacts from microbiological hazards in health-care wastes.* Available:

https://www.who.int/water_sanitation_health/medicalwaste/en/microbhazards0306.pdf [2019, May 06].

Sawalem, M., Selic, E. & Herbell, J.-D. 2009. Hospital waste management in Libya: a case study. *Waste Management.* 29(4):1370–1375.

Shoghli, A., Mousavi Nasab, N., Ghorchian, F., Masoumi, H. & Momtazi, S. 2013. Study of the Needle Sticks Injury (NSI) among the Zanjan Educational Hospitals Staff. *ZUMS Journal.* 21(85):131–141.

Taru, P. & Kuvarega, A.T. 2005. Solid medical waste management. The case of Parirenyatwa Hospital, Zimbabwe. *Revista Biomédica.* 16(3):153–158.

Tsakona, M., Anagnostopoulou, E. & Gidarakos, E. 2007. Hospital waste management and toxicity evaluation: a case study. *Waste Management.* 27(7):912–920.

Weese, J.S. & Jack, D.C. 2008. Needlestick injuries in veterinary medicine. *The Canadian Veterinary Journal.* 49(8):780.

WHO. 2002. *The World Health Report 2002: reducing risks, promoting healthy life.* Available: https://www.who.int/whr/2002/en/ Available: [2019, May 06].

WHO. 2005. *Management of solid health-care waste at primary health-care centres: a decision-making guide*. Available: https://www.who.int/water_sanitation_health/publications/manhcwm.pdf?ua=1 [2019, May 06].

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.

Wilson, D.C., Velis, C. & Cheeseman, C. 2006. Role of informal sector recycling in waste management in developing countries. *Habitat International.* 30(4):797–808.

Ziraba, A.K., Haregu, T.N. & Mberu, B. 2016. A review and framework for understanding the potential impact of poor solid waste management on health in developing countries. *Archives of Public Health.* 74(1):55.