REVIEW ARTICLE

Medical Waste Proper Disposal and Techniques - A Review of Multiple Devices

Authors
Melanie Daniels[1], Ronny Priefer[1,*]

Affiliations
[1]Massachusetts College of Pharmacy and Health Sciences University, Boston, MA

***Corresponding Author**
Email: ronny.priefer@mcphs.edu

Abstract

Every year municipal solid waste continues to grow as the US population expands. Municipal solid waste includes substances that pose a harmful risk for the environment such as medical waste or pharmaceutical agents. Health-care related waste increases annually by 15% and thus concerns for proper disposal of hazardous agents such as medical waste or pharmaceutical agents increases. It is important that these agents are disposed of properly to mitigate the chances of toxins and hazardous materials from tampering with the environment, and ultimately the US's water supply. Additionally, medical waste can contribute to illicit drug abuse and potential overdoses. Methods such as flushing and disposing of these wastes in regular garbage are most common. However, medical waste disposal devices have been marketed to help reduce the risk of potential toxicities to the environment. These medical devices can be broken up into three categories: storage, sequestering agents, and immediate destruction devices. Sequestering agents are the most common devices within this review. The objective of this review is to highlight these different devices as well as describe what each can or cannot do.

Keywords: Municipal Solid Waste; Medical Waste; Hazardous, Environment; Disposal Devices

1. Introduction

Waste is a tremendous concern in the United States (US) due to improper disposal, especially from hazardous wastes. The Environmental Protection Agency (EPA) categorizes hazardous waste as any item that is dangerous or harmful to human health or the environment and requires greater attention when handling disposal.[1] In 2017, the total generation of municipal solid waste (MSW) in the US was 260 million tons. This was approximately 10 million tons more MSW generated than in 2010.[2] Waste generation continues to increase annually, including everyday items that we throw away, such as product packaging, food scraps, furniture, etc. This comes from an array of sources such as homes, schools, businesses, and hospitals.[3] Since the US population still disposes of waste improperly this leads to environmental pollution, adverse health effects, and possible toxic substances such as drugs being introduced to the environment. The healthcare industry in the US is second only to the food industry in waste production. Each year, healthcare facilities in the US produce 2 million tons of waste, and since 1992 waste production increased annually in hospitals by 15% due to the increased usage of disposables.[4] It was not until 1980 that the concern for potential healthcare medical waste began to gain traction as issues began to affect several municipal beaches. Prior to the 1980s, the federal government's general Solid Waste Disposal Act, which was a comprehensive management framework, did not specify medical waste. However, the Medical Waste Tracking Act of 1988 (MWTA) established a tracking system, required medication management involving segregation, packaging, labeling and storage of medical waste, and established record keeping requirements and penalties for mismanagement of medical waste. The MWTA expired in 1991 but continued to be a provided model for states and other federal agencies in developing medical waste programs.[5] These efforts are important as the total amount of waste generated by health-care activities increases annually with 15% of healthcare waste being considered hazardous.[6]

The EPA has become very concerned with medical waste because it not only includes regular non-hazardous waste but also substances (such as some drugs) that may be hazardous or have potential abuse concerns. Drugs that are not disposed of properly can cause problems such as poisoning, environmental pollution, substance abuse, and overdose. In 2014, nearly 56,000 children aged 7 years and younger were treated in US emergency departments for medication-related poisonings, most commonly from prescriptions that were not disposed of, or found in easy to reach locations.[7] These emergency department visits could be prevented with proper storage and disposal methods. Most of the cases that led children to emergency visits were from ingestion of acetaminophen (APAP), more commonly known as Tylenol.[7] However, there is a need for proper disposal of unused medications to prevent accidental overdoses such as with children and intentional illicit drug use contributing to the US's drug abuse problem. Two of the most common pathways that drugs are currently disposed of are either flushed down the toilet/disposed of in the garbage or brought to drug take-back programs (TBPs).[8] If a household is flushing their medications, it is advised to look at the Food and Drug administration's (FDA) flush list first (which contains only 50 brand-name drugs), to make sure the pharmaceuticals are safe for disposal in that manner.[9] This raises concerns whether households are aware of the FDA's list and are taking correct measures regarding properly flushing medications. The disposal of untreated

healthcare waste can lead to contamination of drinking, surface, and ground waters ultimately harming humans in the near future.[6] In addition, even though the Drug Enforcement Administration (DEA) has their national take back initiatives, there were few studies on these TBPs and the effectiveness of them especially when it involves controlled substances. The DEA initiated these TBPs in 2010 in approximately 4000 communities with all 50 states participating, resulting in a return of over 242,000 pounds of controlled and non-controlled medications.[10] In two of the studies there were 11,000 to 51,000 controlled medications taken back from 11 TBP's alone. However, data was collected which showed that controlled substances made up just 9-10% of the total TBP collections. This indicated that the majority that is being obtained from these TBP's are non-controlled substances.[10] This in part could be due to the Secure and Responsible Drug Disposal Act of 2010, that congress passed informing that take-back programs cannot dispose of controlled substances unless the DEA authorizes it, or a full-time law enforcement officer is present.[11] Furthermore, the MWTA allowed for inventions and methods to be put in place to enhance proper disposal of medications. Herein, these are broken up in to three main categories: 1) medical disposal devices that store waste for later off-site destruction, 2) sequestering devices, and 3) immediate destruction of the drugs.

2. Medical Waste Storage Devices

These devices are methods that place medical waste in a storage unit which will be further collected by a company for disposal. It is suggested that any storage device uses an authorized pharmaceutical waste management company for final disposal. There are no chemical agents within that device that work to chemically destroy the substances further. These devices, once filled with medical waste are ultimately moved and incinerated to a form that is deemed non-retrievable and unusable, according to the DEA's requirements.

2.1. Stericycle

After MWTA was passed, a small startup company known as Stericycle was launched which focused at the time on medical waste management only. The company now offers a variety of waste management solutions as well as medical compliance trainings, brand protection solutions, sustainability projects, and business communication solutions.[12] In 2018, Stericycle disposed of 85 million pounds of pharmaceutical waste and 1.2 billion pounds of hazardous waste ensuring that waste did not contaminate waterways.[13] The company has multiple categories for waste disposal including biohazardous waste, industrial hazardous waste, sharps, management services, integrated waste stream solutions for hospitals, rejected cargo standards, pharmaceutical waste, household hazardous waste programs, controlled substances programs, etc. Institutions around the US use products from Stericycle such as their biohazardous bins and the red sharps containers. These are reusable containers, which can promote safe storage temporarily until a service specialist comes to exchange the containers out when they are full.[14]

Stericycle also offers teams of experts who follow the EPA guidelines to answer any questions an institution may have on proper waste disposal. Waste management customer service representatives help their industrial customers by determining which recycling options will fit the institution's need, based on budget and waste stream. Some examples they provide include using alternatives for hazardous waste by incorporating it into other products, reclaiming waste that is recoverable to make

other products, and using wastes either as fuel or heat-producing agents.[15] Stericycle provides environmental and recycling consultation for a variety of institutions as well as households across the US. Companies or households that feel uncomfortable disposing the waste themselves can use Stericycle's mail-back recycling kits that provides a fully compliant recycling alternative to customers.[16] Additionally, Stericycle provides compliance trainings to companies to follow guidelines such as the health insurance portability and accountability act (HIPAA) and occupational safety and health administration (OSHA) standards. Any institution can go on Stericycle's website to obtain employee trainings hosted by the company to make sure proper standards are being followed. Pharmaceutical proper waste disposal is another training opportunity that the company provides to make sure hazardous and non-hazardous drugs are separated.[14]

Stericycle also contributes to national drug take-back-day and has drug collection kiosks as well as seal and send envelopes. The drug collection kiosks hold unused medications and were installed in 2016 in Walgreens around the US and other participating institutions. Individuals can safely dispose of unwanted, unused, or expired prescriptions in a secure way within these kiosks. The seal and send envelopes work the same way but they can be mailed to the company for further incineration. These envelopes are intended for users who may not be able to reach one of the kiosks.[17] Stericycle's blog has much more information on these innovations and events that they contribute to around the US, including campaigns within the Opioid Crisis.

2.2. CsRx System

A product of Stericycle, CsRx System contributes to waste disposal with a safe and secure solution to dispose of controlled substance waste and to help prevent drug diversion risk. It is a plastic jug with a one-way disposal path, which can be secured with the locking wall bracket attached to the system. This plastic jug is available in various sizes. Waste added to this container needs the addition of water to activate the deactivating agent and deterrent. However, it is not identified what active ingredients are being used for the deactivating agent and deterrent. The CsRx System is merely a storage device because once the container is full Stericycle or another company (discretion based on the institution) will ship the device to have the ingredients deemed irretrievable via incineration.[18]

2.3. Cactus Smart Sink System

Stryker Industries launched the Cactus Smart Sink System in 2010. It was created in order to reduce opportunities for illegal drug diversion of controlled substances and to prevent environmental pollution. It is marketed only for hospitals and healthcare facilities use.[19] According to the manufacturer, it is easy to use and a "green" waste solution for unused pharmaceuticals. The Cactus itself is broken up into two compartments: one compartment for solids such as pills, capsules, and patches, and then the second compartment for liquids including those found in syringes, vials, or IV bags. Each cartridge compartment lasts for 90 days and the solid portion holds 1.7 L of product while the liquid component holds 3L.[18] The system will alert the user when the cartridges are full or expired using a built-in timer selector switch. It is secured and wall-mounted, and the manufacturer claims that it renders medications, such as unused controlled substances as non-retrievable and unusable.[20] However, it is merely a storage

device because the cartridges must be moved to high temperature incineration when disposed of. There is a proprietary mixture of denaturants and deterrents found in the solid waste compartment that breaks down the solids into liquids. The liquid compartment uses a funnel system which has absorbent polymers that convert the liquids to a semi-solid state. However, both compartments will require incineration.[18] There are no studies that explain the chemical modifications that are occurring with both the denaturants and deterrents and absorbent polymers. When moving the cartridges, it can only be accessed by a key which the manufacturer recommends limited access to for proper waste control. Each individual institution's authorized waste management company should dispose of the cartridges when full. If needed Stryker provides specific coding to each cartridge so it can be tracked for proper disposal documentation and incineration of the byproduct. Additionally, this product is not intended for chemotherapy wastes, nuclear medicine wastes, or sharps of any kind.[18]

3. Sequestering Devices

Many personal use drug storage devices are sequestering systems, meaning they trap substances of concern. These systems do not break down the agents that are stored in them. Instead, the medical waste is sequestered so that it is deemed non-retrievable. Most of these devices can be discarded in the regular trash after varying amounts of time.

3.1. DisposeRx

DisposeRx are packets that contain ingredients that provide a safe solution for the disposal of unused and expired medications directly into the trash after use. The manufacturer of DisposeRx states that they created this model to solve problems of leftover drugs and to stop the opioid epidemic at the medicine cabinet. In their patent they stated that the product was intended to stop the epidemic but also to make sure products are safely disposed of so they do no pass into the sewer system where it will create toxic effects on animals and create an imbalance in the ecosystem.[21] DisposeRx consists of a powder containing 2 grams of non-toxic polymers that can be added to medications in any form to create cross linking matrix that chemically interact by trapping the drug to deter, slow, or prevent extraction of the active agent. The medications are confined in a polymerized matrix that binds to the active ingredients and solidifies within 30 seconds, which sequesters the agent.[21] Components found in the DisposeRx formulation are recognized as safe, are often included in various foods, and are not toxic, such as silica powder. The patent for DisposeRx provides a description of agents that will form gels and examples of sequestering polymers such as polyvinyl alcohol, carrageenan, alginate, and chitosan but does not go into detail about the product itself. The biodegradable sequestering gel allows no further drug extraction or potential to leech into groundwater.[21] Essentially, the user adds the powder to the prescription drug vial, fills it with 2/3 warm water, closes the cap tightly, and shakes for 30 seconds. It can then be discarded in the trash.[18] There are no published studies regarding the product's effectiveness on medications. DisposeRx has few studies that examine the device itself. The findings were to confirm that the material in DisposeRx is indeed non-toxic and non-hazardous.[18]

3.2. Element MDS

Similar to DisposeRx, Element MDS works by mixing medications with an organic, plant-based powder and tap water to form an unusable, gel-like substance that is ready for disposal in the common trash receptacles.[22] There is no further list of the

product's ingredients and the manufacturer deems the plant-based powder as harmless to handle.[22] However, there are package warnings about inhalation and swallowing the product's ingredients. Element MDS comes in a 17-ounce bottle that can hold 500 tablets or a 4 oz packet.[18] The manufacturer claims that Element MDS can be used for controlled substances and some hazardous wastes.[22] Radioactive pharmaceuticals and chemotherapy drugs should not be placed into this disposal system. There are no reported test results or references to the product's performance.[18] In order to use Element MDS, first the medication is emptied into the 17-ounce bottle and should not be filled more than 1 inch below the upper molded line. Then the MDS powder packet is poured into the container and water is added to the upper molded line. Finally, shake the product vigorously and then dispose of the container into the trash.[18]

3.3. Deterra Drug Deactivation System

Deterra Drug Deactivation System is a system launched in 2008 that can be used in multiple settings such as a person's own home, healthcare facilities, pharmacies, and non-profits. It is a pouch with a water-soluble polyvinyl alcohol pod containing MAT12 activated carbon, also known as activated charcoal.[23] Interestingly, activated charcoal is typically used when a person merits consideration for poisoning in which there needs to be gastrointestinal decontamination. When the activated charcoal absorbs with the xenobiotic (foreign substance to the body) it forms a complex that prevents systemic absorption of that xenobiotic. Drugs being disposed by Deterra Drug Deactivation System will adsorb to the charcoal based on electrostatic and non-electrostatic attractions.[24] When the Deterra pouch is introduced to a medication, the activated charcoal will form the same complex, if there is an equilibrium between the free medication and the activated charcoal. Typically, this process is irreversible. It bests absorbs substances in their nonionized, poorly water-soluble forms. Thus, activated charcoal is poor at absorbing substances such as iron, lithium, magnesium, potassium, sodium, or acids and alkalis due to ionization and polarity of these substances.[24] The manufacturer specifies to put unused medications into the pouch, fill halfway with warm tap water (so that the inner pod will release the activated charcoal), then wait 30 seconds before gently shaking the pouch, and disposing in normal trash receptacles.[18] Also, the manufacturer states that the user should not overfill the pouch, as the carbon may become ineffective to a highly diluted environment.[23] It is available in multiple sizes and prices.[18]

There are multiple studies of test results on the efficacy and safety of the Deterra Drug Deactivation System. In one study produced by Verde Environmental Technologies in Minnesota focused on the drug deactivation system in various psychoactive drugs (20 controlled substances). Each medication was measured separately and added to the Deterra pouch. Samples were taken at 8 hours, 1, 2, 4, 7, 14, 21, and 28 days. The adsorption results after 8 hours varied from 46.3% to 99.9% of total free drug. After 28 days, 100% adsorption by the activated charcoal occurred in 16 of the 20 controlled substances.[25] The one "special case" were the fentanyl patches, because the patches could adhere to the pouch itself interfering with the deactivation process. However, on day 28 there still was no detectable fentanyl in the system.[25] This study demonstrated that the activated charcoal is effective in absorbing certain hazardous pharmaceuticals if the medication is not ionized or a polar substance. There are multiple other studies presented which can be found on the Deterra System website.[23] These studies focused on testing medications to

observe if the activated charcoal effectively absorbed the medication to an extent where it is deemed irretrievable.

3.4. Drug Buster

Similar to Deterra, Drug Buster uses activated charcoal to neutralize active agents in pills, liquids, controlled substances, transdermal patches, and more. There is a range from product to product of how long the immediate destruction takes. For Drug Buster it is reported to take 15 minutes to break down non-hazardous pharmaceuticals into inactive substances which can then be discarded into the trash.[26] However, the manufacturer recommends waiting 2 hours prior to dispose in the trash, or 24 hours before emptying contents into the recycling bin. The user first puts the unwanted drugs into the bottle, inverts and swishes the bottle twice, and after 2 hours may discard the bottle. This product cannot accept potassium supplements, antacids, gassing agents, and hazardous medications, most likely because the activated charcoal will not absorb these ionized agents.[18] It is important to not overfill the product again, and in some cases foaming may occur.

3.5. Rx Destroyer

Rx Destroyer contains activated charcoal to bind to the medications just like Deterra and Drug Buster. However, Rx Destroyer also contains a patented ready-to-use liquid, so no water needs to be added. Simply load medications into the bottle, replace the cap, shake the mixed solution and discard into common trash receptacles. This product is not intended for hazardous medications on the U and P-lists, nor needles or syringe waste. The manufacturer states this product can be used repeatedly until full and to store the Rx Destroyer in a controlled area when not in use. Once medications are attached to the activated charcoal, they require a temperature of 920^{o}C to release the drugs.[27] The activated charcoal absorption process is typically not irreversible because it requires thermal reactivation at high temperatures (as noted above), solvent extraction, ozone treatment, irradiation, and other methods. Thus, even though activated charcoal is deemed non-retrievable for medications it is technically still possible to retrieve the medications, however it would require extreme laboratory experimentation.[18]

There are few studies performed on Rx Destroyer that focused on the efficacy of the activated charcoal. None of the studies had any direct testing with pharmaceuticals. Dr. Nowicki, president of PACS Professional Analytical and Consulting Services, performed tests on the characterization of the activated charcoal used in the device. The study focused on the adsorption potential of the charcoal in comparison to other commercial grade products, and it was determined that Rx Destroyer's activated charcoal is sufficient to adsorb all pharmaceuticals.[28]

3.6. NarcX

Similar to the other activated charcoal containing products, NarcX has a blend of ingredients that make tablets, capsules, etc. non-retrievable and indigestible. Products discarded into this device do not require incineration or pickup from a company. They can be disposed of in regular trash receptacles. The user must add medications to the fill level and be aware not to overfill the device followed by applying a tamper proof cap for disposal. It is not recommended to use this device with antacid medications or any patches, such as Butrans or Fentanyl patches. The blend of ingredients are patent pending and has not been disclosed but the company states it is like activated charcoal.[29] The manufacturer's website includes articles that have test data on the device itself, such as the ability of the system to bind and

remove drugs in the solution. The study focused on independent DEA registered analytical lab testing on oxycodone and free levels of this narcotic in the NarcX device. The researchers used liquid chromatography-mass spectroscopy (LCMS) to determine the free levels of oxycodone. Two different conditions were evaluated. One 10mg oxycodone tablet in 1,100 grams of NarcX liquid, as well as a second study with a 10mg oxycodone tablet in 50 grams of the NarcX solution were evaluated. No detectable free oxycodone in the 50-gram sample was observed after 5 hours. For the 1,100 grams sample solution, the sequestering of oxycodone took less than an hour.[18] The NarcX is effective for trapping of both narcotics and non-narcotic substances but not for insoluble substances such as needles or patches.

3.7. Pill Catcher

Unlike other sequestering agents the Pill Catcher contains a different active ingredient, bentonite clay, in conjunction other dry ingredients. Bentonite clay is an absorbent silicate clay formed from volcanic ash, which exhibits colloidal properties when water is introduced. Usually bentonite clay is combined with sawdust because the combination provides absorption of both water and oil-based medications when the two ingredients are used in a 1:1 mixture. Depending on the volume of the mixture, medications can be added up to equal that of bentonite-sawdust itself.[30] The Material Safety Data Sheet for Pill Catcher lists the ingredients as bentonite clay containing naturally occurring crystalline silica and quartz. Pill Catcher comes in pint, quart, and gallon bottles, allowing for multiple quantities to hold medications for disposal. When medical waste is added to the bottle, the medication becomes a thick slurry to tacky clay material and has the potential for being less likely to leach into water sources.[18] The tacky clay sludge material is due to the interaction of the bentonite clay and water, allowing for the pharmaceuticals to be encapsulated, thus limiting the risk to others, animals, and entry to freshwater resources. Other substances can be used with bentonite clay for further absorption, such as sand or fuller's earth (later discussed in Pill Terminator) but must be in an equal ratio so that the medications limit exposure to water supply and potential diversion.[31]

4. Immediate Destruction Devices

Medical waste can also be immediately destroyed and deemed as non-retrievable, and thus thrown in the regular trash. Each of these agents in this category permanently alter the substance's chemical state through an irreversible method. No further destruction is thus needed. There is only one product that alters the chemical identity of the pharmaceutical being disposed while the other is through an incineration process.

4.1. Pill Terminator

Pill Terminator contains a variety of chemicals that make medications irretrievable when added. The ingredients included are calcium hypochlorite, fuller's earth, and an absorbent polymer. The calcium hypochlorite is a strong oxidizing (bleaching) agent which ultimately chemically alters the drugs and renders them inactive and thus safe for disposal.[32] In order to use, the expired or unwanted medications are added into the Pill Terminator bottle, warm water is added, capped, shaken for five seconds, and then the entire container is discarded into the trash. The Pill Terminator solution physically destroys the medications and denatures their chemical composition. It is advised to not reopen the container once this process has begun because it will present a strong odor deterrent due to the release of chlorine. The

product comes in a 300 ml bottle and a gallon size jug.[33]

There have been multiple studies investigating the efficacy of Pill Terminator which can all be found on the manufacturer's website. The first study was conducted by Dr. Matt Traynor at the University of Hertfordshire in which morphine was chosen as the representative drug to be used in an analysis of the effectiveness of Pill Terminator. High-performance liquid chromatography (HPLC) was used to separate the mixture of components to identify the individual portions of leftover morphine and the Pill Terminator ingredients. When the morphine was mixed with a sample of Pill Terminator and water and stirred for 2 minutes it was shown that after 48 hours 98.45% of the morphine was degrading.[18] Another study at Western New England University demonstrated the effectiveness of morphine degradation without stirring, which may be more likely scenario in everyday use. Approximately one gram of Pill Terminator was added to 10 mg of morphine, and the mixture was shaken for 15 seconds, then 8.5 grams of water was added. A pink gel formed and periodically sample were taken for analysis. It was reported that nearly half of morphine was destroyed within the first 2 hours with an additional 11% after 48 hours.[34] These two studies showed that Pill Terminator is effective at the degradation of medications. There is one more study regarding Pill Terminator with aspirin tablets. However, no chemical analysis was performed to assess if the aspirin was chemically degraded.[18]

4.2. Mediburn Medical Waste Incinerator

Elastec has developed and is marketing an immediate, transportable drug destruction incinerator, Mediburn, for on-site disposal of medications as well as general waste. The device can be used at hospitals, clinics, pharmacies, laboratories, blood banks, police departments, and veterinarians. The manufacturer states Mediburn has had great success at eliminating medical hazardous wastes. Mediburn is available in two separate portable sizes and requires minimal training to operate. The air within the incinerator reaches high exhaust temperatures of 1000^{o}C to effectively destroy any medications that enter the machine. The main mission of the company is to market a product, such as Mediburn, to prevent illegal dumping of hazardous materials in the environment. These machines can be found in 155 countries and can be used to effectively destroy prescription drugs, controlled substances, hazardous wastes, etc.[35]

5. Conclusion

As the US population continues to expand there is more waste being generated annually. Specifically, health-care related waste is annually increasing by 15% due to increased usage of disposables. Thus, healthcare has become second in the US in waste production. This raises concerns for the proper disposal of pharmaceutical and hazardous wastes. It is important that these wastes are disposed of properly due to concerns, such as environmental damage (specifically drinking water sources), illicit drug abuse which can contribute to the opioid epidemic, and potential overdoses. Ultimately, it is not enough to dispose of medical wastes via flushing or in the regular garbage. These two methods are frequently used but contribute to environmental damage. The US population developed more awareness for the harms of medical waste after the MWTA was passed in 1988, and since then practices such as recycling and composting have assisted to help decrease or redirected waste. Furthermore, three categories of devices are available to help mitigate improper disposal of pharmaceutical and hazardous wastes. Most of the products

on the market are sequestrants which store pharmaceuticals to be deemed irretrievable, and can be disposed of in regular garbage. These devices help to decrease the chances of hazardous wastes being flushed into water supplies and illicit drug abuse contributing to the Opioid Crisis. However, none of these medical disposal products are approved by any federal agency and none are evaluating these products at this time.

It is important that going forward the US population is conscientious of promoting practices that ensure proper medical waste segregation. There are future implications to the environment, animal, and human lives if waste is improperly managed. Every year awareness is improving with advancements such as disposal devices and reusable products. However, this is a long-term process with gradual improvements but if awareness and proper practices are put into place it will decrease environmental destruction and exposure to hazardous substances.

Declarations of Interest: The author declares no competing interests.

Acknowledgments: The authors wish to thank the School of Pharmacy at the Massachusetts College of Pharmacy and Health Sciences University for financial support of this project.

References:

[1] Learn the Basics of Hazardous Waste. United States Environmental Protection Agency website. https://www.epa.gov/hw/learn-basics-hazardous-waste. Accessed September 24, 2019.

[2] National Overview: Facts and Figures on Materials, Wastes and Recycling. United States Environmental Protection Agency website. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials. Accessed November 17, 2019.

[3] Municipal Solid Waste. United States Environmental Protection Agency Archives website. https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/. Accessed September 24, 2019.

[4] Demark R, Smith V, Fiegen A. Lean and Green Hand Surgery. J Hand Surg Am. 2018; 43(2): 179-181. doi:10.1016/j.jhsa.2017.11.007.

[5] Medical Waste Tracking Act of 1988. United States Environmental Protection Agency Archives website. https://archive.epa.gov/epawaste/nonhaz/industrial/medical/web/html/tracking.html. Accessed September 19, 2019.

[6] Health-care waste. World Health Organization website. https://www.who.int/news-room/fact-sheets/detail/health-care-waste. Accessed on November 17, 2019.

[7] Frattaroli S, Shields W, Omaki E, Molloy M. How Are Prescription Medications Stored in Urban Homes Where Children Live? Opportunities for Poisoning Prevention. Clin Pediatr. 2016; 56(7): 679-681. doi: 10.1177/0009922816668631.

[8] Where and How to Dispose of Unused Medicines. Food Drug Administration website.

https://www.fda.gov/consumers/consumer-updates/where-and-how-dispose-unused-medicines. Accessed September 24, 2019.

[9] List of medicines recommended for disposal by flushing. Food and Drug Administration website. https://www.fda.gov/media/109643/download. Accessed September 24, 2019.

[10] Egan K, Gregory E, Sparks M, Wolfson M. From dispensed to disposed: evaluating the effectiveness of disposal programs through a comparison with prescription monitoring program data. Am J Drug Alcohol Abuse. 2017; 43(1): 69-77. doi: 10.1080/00952990.2016.1240801.

[11] Klobuchar A. Secure and Responsible Drug Disposal Act of 2010. Library of Congress website. https://www.congress.gov/bill/111th-congress/senate-bill/3397/text. Accessed October 10, 2019.

[12] Stericycle Overview. Stericycle website. https://www.stericycle.com/about-us/overview. Accessed October 20, 2019.

[13] Our Social Responsibility Commitment. Stericycle website. https://www.stericycle.com/about-us/sustainability. Accessed December 1, 2019.

[14] What we do: Browse our Services. Stericycle website. https://www.stericycle.com/services. Accessed October 20, 2019.

[15] Industrial Hazardous Waste. Stericycle website. https://www.stericycle.com/services/waste-services/industrial-hazardous-waste. Accessed October 20, 2019.

[16] Mailback Recycling. Stericycle Environmental Solutions website. https://www.stericycleenvironmental.com/service/mailback-recycling/. Accessed October 20, 2019.

[17] Preparing for Drug Take Back Day. Stericycle Environmental Solutions website. https://www.stericycleenvironmental.com/preparing-for-drug-take-back-day/. Accessed October 20, 2019.

[18] Shield M, Johnson M. Medicine Disposal Products: an overview of products and performance questions. Community Environmental Health Strategies LLC. https://sfenvironment.org/sites/default/files/fliers/files/medicinedisposalproducts_march2019.pdf. Accessed October 20, 2019.

[19] Maness D. Smart Sink by Cactus Renders Controlled Substance Waste Unusable and NonRecoverable. RxInsider website. http://www.rxinsider.com/20ways/articles/17_cactus_20wayssummer16_way.pdf. Accessed September 24, 2019.

[20] Cactus Smart Sink Controlled Substance Waste Management System. Stryker website. https://www.stryker.com/us/en/surgical/products/cactus-controlled-substance-waste-management-system/cactus.html. Accessed September 29, 2019.

[21] Disposal of Medicaments. Free Patents Online website. http://www.freepatentsonline.com/y2018/0001357.html. Accessed October 10, 2019.

[22 Frequently Asked Questions. Element MDS website. https://elementmds.com/pages/faqs. Accessed November 14, 2019.

[23] Frequently Asked Questions. Deterra System website. https://deterrasystem.com/faq/. Accessed November 14, 2019.

[24] Silberman J, Galuska M, Taylor A. Activated Charcoal. StatPearls Publishing LLC. https://www.ncbi.nlm.nih.gov/books/NBK482294/?report=classic/. Accessed November 14, 2019.

[25] Korey A, Fowler W, Anderson C, et al. In-Home Deactivation System for Psychoactive Drugs (SBIR Phase 2). Verde Environmental Technologies. 2016: 1-25. https://shop.gohcl.com/Customer/hecalo/specpages/19551_Bulletin.pdf. Accessed November 14, 2019.

[26] Drug Buster Drug Disposal System. Medline Industries website. https://www.medline.com/product/Drug-Buster-Drug-Disposal-System/Pharmacy-Supply/Z05-PF19622#mrkDocumentation. Accessed October 10, 2019.

[27] Rx Destroyer Pharmaceutical Disposal. http://www.rxdestroyer.com/. Accessed October 10, 2019.

[28] Full GAED Characterization with Aqueous-phase comparisons for Sample EE-541. Rx Destroyer. 2015: 1-15. https://www.rxdestroyer.com/wp-content/uploads/1-Dr.-Nowicki-Independent-Testing.pdf. Accessed on December 1 2019.

[29] How it works. NarcX website. https://narcx.com/how-it-works/. Accessed December 1, 2019.

[30] Bentonite Clay Mixture For Disposing of Pharmaceuticals. United States Patent. https://patentimages.storage.googleapis.com/e7/59/75/ea4743be75fbb4/US8523752.pdf. Accessed October 11, 2019.

[31] Pill Catcher. United States Patent. https://patentimages.storage.googleapis.com/63/22/0a/8d329220c1bd42/US7918777.pdf. Accessed October 11, 2019.

[32] Calcium hypochlorite. PubChem website. https://pubchem.ncbi.nlm.nih.gov/compound/Calcium-hypochlorite. Accessed November 17, 2019.

[33] Drug Disposal Solution: How It Works. Pill Terminator website. https://www.pillterminator.com/how-it-works-drug-disposal/. Accessed September 24, 2019.

[34] Priefer R. Investigation of the Efficacy of the *Pill Terminator*. Western New England University. 2015: 1-2. https://cdn.shopify.com/s/files/1/1027/5393/files/Manuscript_Letter_Head.pdf. Accessed November 17, 2019.

[35] Mediburn Medical Waste Incinerator. Elastec Products website. https://www.elastec.com/products/portable-incinerators/mediburn-medical-waste-incinerator/?gclid=Cj0KCQiAz53vBRCpARIsAPPsz8X5IQMll631d2AjJd5UcVjOfuMPdqyRmtI5cpn91B-guowzcUntkKEaArT6EALw_wcB. Accessed November 17, 2019.

