IJMPR, 2026, 10(8), 44-54

ISSN: 2319-5878

INTERNATIONAL JOURNAL OF MODERN PHARMACEUTICAL RESEARCH

www.ijmpronline.com

Research Article

Impact Factor: 6.669

Coden USA: IJMPR3

MANAGEMENT OF PHARMACEUTICAL WASTE

[1*]S. Sukanya, [1]Nithya Shree S., [1]Mohan M.G., [2]Yallappa B., [2]Kavya Shree B., [2]Poojitha Yadav P.

Students, Bachelor of Pharmacy, Sri K.V College of Pharmacy, Rajiv Gandhi University of Health Sciences, Chikkaballapur-5621 01 Karnataka, India.

Article Received on: 17/06/2026 **Article Revised on: 07/07/2026** **Article Published on: 01/08/2026**

***Corresponding Author**
S. Sukanya
Students, Bachelor of Pharmacy, Sri K.V College of Pharmacy, Rajiv Gandhi University of Health Sciences, Chikkaballapur-5621 01 Karnataka, India.

https://doi.org/10.5281/zenodo.21717456

How to cite this Article: [1*]S. Sukanya, [1]Nithya Shree S., [1]Mohan M.G., [2]Yallappa B., [2]Kavya Shree B., [2]Poojitha Yadav P..(2026) Management Of Pharmaceutical Waste. International Journal of Modern Pharmaceutical Research, 10(8), 44–54.

ABSTRACT

Pharmaceutical products are vital for disease prevention and treatment, but their rising production and consumption have generated significant pharmaceutical waste from households, farms, healthcare facilities, and industries due to routine use, damage, or expiry. Improper disposal releases active pharmaceutical ingredients (APIs) into the environment, contaminating surface water, groundwater, and public systems with traces of drugs like diclofenac and ibuprofen, whose effects on non-target organisms are largely unknown. Inadequate disposal knowledge leads to pollution, poisoning, antimicrobial resistance, and health risks. This review examines waste sources, disposal methods, consequences of improper disposal, and pharmacists' role in promoting safe practices. Findings highlight global waste volumes and environmental contamination, urging sustainable management strategies, policies, awareness campaigns, and advanced treatment technologies to minimize impacts on health and ecosystems.

KEYWORDS: pharmaceutical waste, environmental contamination, disposal methods, role of pharmacist in waste management.

INTRUDUCTION

The pharmaceutical sector is one of the richest sectors. Due to an increasing demand for health care, use in horticulture, livestock farming, and aquaculture, the sector has witnessed an increase in pharmaceutical Growth over the past few years. As usage rises and deterioration of pharmaceutical items and substances, there are high levels in the environment, of pollution. Following their burning in residential furnaces, the products are disposed of as gaseous waste or municipal waste.[1]

The definition provided by the Pharmacy and Poisons Board (PPB)Pharmaceutical waste is defined as waste that contains medications that are split, contaminated, outdated, and no longer in use, required, including goods that are contaminated or contain medications, including ampules, vials, bottles, and boxes, masks and gloves.[2]

In general, pharmaceutical waste includes discarded personal medications and expired medications.by patients, waste products that contain chemotherapy and extra medication, such as intravenous (IV) bags and containers holding hazardous pharmaceuticals and syringes and discarded unused medications, spill clean-up apparatus, polluted absorbents, and protective equipment, like clothing.[3] There are three types of hazardous, non-hazardous, and pharmaceutical waste, waste from chemotherapy and pharmaceuticals. Among the hazardous waste are coded by the Environmental Protection Agency (EPA) pharmaceutical waste or toxic pharmaceuticals, ignitable, corrosive, and reactive. These wastes have adverse effects on human health and the environment. There are two types of hazardous waste.[3–4] Specifically, waste that is listed and characteristic Commercial pharmaceutical products are included in listed waste. Characteristic wastes are managed according to their ignitability, toxicity, and corrosively.[3] Not Expired medications are considered hazardous waste, sample from the manufacturer, loose pills, broken or contaminated patient prescription drugs, including their packaging containers, for example they include elements that possess a low threshold for endangering human health and surroundings.[4]

According to the PPB, a pharmaceutical waste generator is any individual whose actions or those under their supervision result in pharmaceutical waste, or, in the absence of an identity, the owner or regulator of the pharmaceutical waste.[2]

The World Health Organization (WHO) in 1999 created the rules for the secure disposal of pharmaceutical waste. The document emphasizes the disposal techniques, classification of categories, and suggested disposal techniques.[5] The WHO released the guidelines for the efficient disposal of medical waste that emphasized the categories, hazards, legislative and policy aspects,

reduction, Healthcare waste sorting, transportation, storage, and disposal.[6] The United Nations Children Fund and the World Health Organization in 2015(UNICEF) established a collaborative program to guarantee safe handling of medical waste and offering consistent updates regarding the same.[7]

The Food and Drug Administration (FDA) mandates that all producers provide Environment Assessment (EA) reports that are supported by by scientific data before a new medication is registered. In 1998, the FDA released environmental evaluation of novel medication applications. The rules excluded producers whose medications had an EIC (expected introduction concentration) of less than 1 ppb of the water's active pharmaceutical ingredient (API) bodies from supplying EAs for the application of new drugs. Research has demonstrated that pharmaceutical product APIs with aquatic EIC < 1 ppb have negligible impacts on the surroundings. The FDA exclusion was formed by these findings. Criteria in the guidelines.[8]

Drugs play a significant role in health. Framework; as a result, adequate stocks are needed, regularly. The veterinary and human health fields obtain medications through purchases and donations. The Certain medications may sustain damage while being transported. It may expire due to handling, storage, regular use, and other factors. In times of calamities like famine, war, and floods, nations obtain substantial amounts of medications from their supply chain.[2]

When new or modified treatment guidelines regimens are implemented, additional regimens could become Amodiaquine, an antimalarial medication, is no longer in use. Unwanted Pharmaceuticals may be the consequence of poor inventory control and procurement practices or excessive drug use. Overly Prescription medications, false diagnoses, and self-medication lead to the pharmacological accumulation in the surroundings. Poor and tainted pharmaceuticals are a contributing factor to removal. Consequently, handling pharmaceutical waste safely Must be done in order to improve public health and the environment, in monitoring the sixth Sustainable Development Goal.[7]

Industrial wastes are produced as a result of industrial activities, which includes any materials rendered useless during manufacturing process such as that of food and chemical industries, mills, mining operations, and factories. Types of industrial waste are dirt and gravel, scrap metal, scrap lumber, oil, solvents, masonry and concrete, plastics, chemicals, even vegetable matters from restaurants, which may be released to the environment; and can cause harm (Awadhi and Awadhi, 2019a; Awadhi and Awadhi, 2019b). Industrial wastes may be liquid, solid, or gaseous. It can be hazardous, mirror entry, or non-hazardous wastes. As hazardous waste, it may be toxic, corrosive, radioactive, ignitable, or reactive. Waste classified as mirror entry may be toxic depending on some factors. Industrial waste may pollute the soil, the air, or nearby water sources, ending up in the sea (Macula, 2010; Awadhi and Wii, 2017). Industrial waste is usually mixed into the municipal waste, making accurate assessments challenging. An estimate for the United States is as very high as 7.6 billion tons' industrial waste produced per year (Recover Inc., 2017). Most countries have enacted different legislations to deal with industrial waste problems, but compliance regimes and strictness vary. Enforcement is often a challenge. An industrial or commercial organization's ability to manage waste is essential to ISO14001 certification. Businesses are compelled by the ISO14001 standard to improve waste management and environmental efficacy annually by eliminating waste using the techniques of obtaining resources. Using methods for resource recovery like the recycling of materials such as paper, cardboard, glass, metals, and plastic bottles. Recycled materials may be bought by the building industry. Several streams of inorganic waste could be involved in the production of construction materials. Bricks and recycled concrete can be used to create artificial gravel.[9]

Drugs that are expired or leftover, an indirect indicator of waste healthcare resources, which represent missed chances to therapeutic results (either as a result of a poor decision or non-compliance) as well as an environmental burden. Furthermore, Medication waste costs the country's healthcare system money. The price of buying the medication and disposing of it properly afterward. In 2012, consumers in the United States (US) wasted over $418 billion due to suboptimal drug use, compared to approximately 300 minutes in England.[10]

The Central Pollution Control Board of India reports that 4,057 tonnes of waste are produced daily by registered healthcare facilities.[11] Contaminated medications, unwanted or discontinued drugs, and expired goods are all included in the pharmaceutical waste stream. The amount of drug waste in households is still unknown, and patients have been found to dispose of drugs improperly, including controlled substances like opioids that have the potential to become addictive. This indicates that patients are not receiving enough guidance on how to dispose of medications responsibly, and raising awareness of this issue is urgently needed, due to their unintentional presence in sewage, surface and ground waters, and other ecosystems, active pharmaceutical ingredients are ubiquitous environmental contaminants. Pharmaceuticals, their metabolites, transformation products, excipients, and additives all find their way into the environment through a variety of sources, including landfills, manufacturing facilities, household waste disposal, and sewage treatment plant effluents.[12] Twelve of the fourteen active ingredients remained in concentrations that were 90% or higher of the amount listed on the label and maintained their full potency for at least 336 months in a study by Cantrell et al. that measured the amounts of the active ingredients in the medications that had expired 28–40 years ago.[13]

The subtle effects of long-term exposure to low levels of pharmaceutical waste are still unknown, despite the fact that pharmaceuticals are typically found in the ecosystem at relatively low levels and that short-term human exposure appears to have few effects.[14] High concentrations of triclosan and carbamazepine were found in the surface waters of Kerala's Averi, Tamiraparani, and Velar Rivers in a study conducted by Ramaswamy et al.[15] According to research by Borodin et al., exposure of wild European perch (Parka fluviatilis) to oxazepam at concentrations found in surface waters affected by effluent (1.8 µg/L),, increased activity, decreased sociality, and increased feeding rate.[16-17]

The rivers of Vellar and Tamiraparani in Kerala. Brodin et al. found that exposing wild European perch (Percafluviatilis) to oxazepam at concentrations found in surface waters impacted by effluent (1.8 µg/L) increased activity, decreased sociality, and increased feeding rate. Thomas et al. have demonstrated that unmetabolized psychoactive drugs cause autism-like gene expression patterns in fish, suggesting a possible source of environmental contamination as a novel cause of idiopathicautism.[18]

Seven-star pharmacists are defined by the World Health Organization as having the traits of a caregiver, decision-maker, communicator, manager, lifelong learner, teacher, and leader. "Pharmacists are at the forefront of addressing issues of responsible drug disposal methods to end users of drugs because they are the most reputable, reliable, and easily accessible sources of drug information.[19] The decision between recovering from material derived from waste and waste disposal appears to be mostly influenced by two factors: technology and economics. Economics. It is most likely the most crucial element that restricts the recovery of dangerous industrial leftovers. The expensive price of retrieving low-value components and the resulting in a relative lack of profitability appear to keep a lot of industries from adoption of recuperation methods for by products of waste. But a number of there are currently available regulatory strategies, able to promote healing.[20]

DIFFERENT SOURCES OF PHARMACEUTICAL WASTE

Waste from pharmaceuticals may be produced by a many different activities in a medical facility, such as
Not just for intravenous (IV) preparation, syringes, General pharmaceutical waste can consist of, but is not restricted to:
Expired medications;

- Patients' personal medications that are thrown away;
- Waste products with extra medications (syringes, IV vials, bags, tubing, etc.);
- Waste products that contain chemotherapy drugs leftovers;
- Open drug containers that aren't usable;
- P-listed containers that contained acute hazardous waste medications;
- Drugs that are thrown away; and Spills, contaminated absorbents, and absorbents materials for clean-up.
- Pharmaceutical manufacturing units.
- Research and quality control laboratories.
- Hospital and health care facilities.
- Pharmacies and drug store.
- Academic institutions.
- Vaccine production and testing unit.

CLASSIFICATION OF PHARMACEUTICAL WASTE MANAGEMENT

There are two categories of pharmaceutical waste

1. Hazardous
2. Non-hazardous

1. **Hazardous waste**: it includes the Environmental Protection Agency (EPA) coded pharmaceutical waste or pharmaceuticals that are toxic, reactive, corrosive and ignitable. These wastes have detrimental effects to the environment and human health.[21]
2. **Non Hazardous waste**: it includes expired medicines, manufacturers sample, loose pills, damaged or contaminated patient medication, including packaging such as containers. They contain components that have a low threshold of causing harm to human health and environment.[22]

REGULATIRY BODIES THAT OVERSEE PHARMACEUTICAL WASTE MANAGEMENT

- Environmental Protection Agency (EPA)
- Department of Transportation (DOT)
- Drug Enforcement Administration (DEA)
- Occupational Safety and Health Administration (OSHA)
- State Environmental Protection Agencies.
- State Pharmacy Boards.
- Local Publicly Owned Treatment Works (POTW)

MEASURES OF PHARMACEUTICAL WASTE RECOMMEND BY WHO

Here are seven main steps to follow when unwanted drugs are displaced.[5]

Decision: The Pharmacy Company or health care facility should determine when to dispose of accumulated pharmaceutical waste.

Approval

The permission to get rid of Pharmaceutical authorities are looking for pharmaceutical waste. Worried. Disposal in Kenya is done in accordance with the supervision of the National Environment Management Authority (NEMA). The source of waste should accurately complete the disposal form and make the PPB charges a 2,500 Ksh fee. The PPB publishes a Drug Safe. Certificate of Disposal at the time of disposal.[2] In Hong Kong, as a generator of chemical waste, one must apply to the

Department of Environmental Protection (EPD), following which the applicant receives a waste generator number. The waste generator receives charges within a month, following collection. A trip ticket is issued by the waste collector to the generator after being collected.[23]

Planning
Planning is essential if funds, human resources, abilities, Time, tools, and disposal techniques must be made accessible. The amount of waste from pharmaceuticals should be estimated at this point and is calculated using weights per 0.2 metric tons per m^3 is the quantity used.

Developing working teams
The teams responsible for disposal should be made up of pharmacists, pharmacy technicians, and employees of pharmaceutical warehouses. Circumstances of the worksite, pharmaceutical composition, and volume this establishes the ratio and size of the workforce

Safety and health work teams
Protective gear like overalls, boots, gloves, helmets, and mask sought to be distributed to the teams in charge of disposal.

Sorting
Pharmaceuticals are available in various pharmacological and dosage forms. Different methods of disposal are needed for each of the categories, and some can be safely returned to the supply chain, so it is essential to sort. Pharmaceutical waste should be separated, stored securely, and labelled before disposal.

Disposal
There are various ways to get rid of waste that ought to be assessed in terms of price, security, the methods' practicality and ease of use. Note: date and where it was destroyed, how it was disposed of, Pharmaceutical name, amount and dosage, and value of goods, the rationale behind their disposal, and the name and signature of before being destroyed, a pharmacist disposes of a witness.

Security
In dealing with narcotics, psychotropic, and antineoplastic, strict protection, and regulation must be Maintained to avoid diversion during sorting, scavenging and pilfering.

HAZARDOUS WASTE MANAGEMENT STATERGY[24]

WASTE MINIMIZATION
Preventing the creation of waste, or waste reduction, is a crucial aspect of waste management. Reusing second-hand goods, fixing broken items rather than purchasing new ones, designing reusable or refillable products (like cotton shopping bags instead of plastic ones), encouraging consumers to refrain from using disposable products (like disposable cutlery), removing any liquid residue from cans, packaging, and creating products that use less material to accomplish the same goal (like light-weighting beverage cans) are all examples of avoidance strategies.

REUSE
Reuse is the practice of using a product more than once, either for the same purpose or a different one, without having to reprocess it. Reuse prevents a material from being thrown into a waste stream after its original use is over. Reusing products in their original state is ideal. Examples of this include returnable plastic pallets, empty glass jars for storage. Reuse is typically better than recycling because it doesn't require the material to have undergone a thorough treatment process, which helps reduce the amount of energy and materials used.

RE-CYCLEING
Recycling is the process of treating or reprocessing a waste product that has been thrown away so that it can be used again, either in its original form or for other purposes. Energy recovery is not included, but organic waste recycling by using fewer virgin materials, recycling helps the environment. It is possible to recycle a wide variety of materials. Waste materials can be recycled into products that are similar to their original use, like recycling paper, or they can be recycled into products that are different from their original use, like recycling plastic bottles into using waste from construction and demolition as road aggregate. Up to 13% of municipal waste in the EU is recycled.

ENERGY RECOVERY
Waste products can be used directly as a fuel for direct combustion or indirectly by being converted into another fuel. Thermal treatment includes everything from using waste as a fuel source for heating or cooking to using gas fuel to power boilers that produce steam and electricity in a turbine. Waste materials are heated to high temperatures with little oxygen available in two related thermal treatment processes: gasification and pyrolysis.

The procedure typically takes place under high pressure in a sealed vessel. Solid waste is paralyzed to produce solid, liquid, and gas products. The liquid and gas can be refined into other chemical products or burned to generate energy (chemical refinery). Activated carbon is one product that can be made from the solid residue (char). Organic materials can be directly converted into syngas, a synthetic gas made of hydrogen and carbon monoxide, using gasification and advanced plasma arc gasification. After that, the gas is burned to create steam and electricity. High-temperature and high-pressure supercritical water decomposition monophasic oxidation is an alternative to pyrolysis.

TO TAKE ACTIONS TO MAINTAIN CONTROAL WASTE FROM PHARMACEUTICALS

- Step 1: Making a plan for pharmacy management.
- Step 2: Determine what is and is not dangerous wastes

- Step 3: Put best management practices into action.
- Step 4: Assess the state of your waste generator.
- Step 5: Adhere to disposal and transportation regulations.

MINIMIZING OF PHARMACEUTICAL WASTE[25]

Since the hazardous nature of the chemical frequently produces the therapeutic effect, there are inherent limitations on the substitution of a less hazardous drug when designing and implementing your pharmaceutical waste management program. Waste reduction, however, can reduce risks, expenses, and compliance. There are several minimization opportunities to think about and investigate in the section that follows.

1. Taking Lifecycle Effects into Account When Making Purchases
2. Making the Most of Opened Chemotherapy Vials
3. Putting a Samples Policy in Place
4. Labelling Medicines for Domestic Use
5. Using Saline Solution to Prime and Flush IV Lines
6. Analysing Container Size in Relation to Use
7. Using Patient-Specific Oral Syringes in Place of Pre-packaged Unit Dose Liquids
8. Restricted Substances
9. Giving Chemotherapy Medication
10. Monitoring Dating on Emergency Syringes
11. Keeping an eye on dating on emergency needles
12. Examining Inventory Controls to Reduce Updates
13. Examining the Management Choices
14. Getting Ready for Implementation

- Finding Your Areas of Satellite Accumulation
- Assessing Your Area of Storage Accumulation
- Implementing a Pilot Project

12. Guidelines and Protocols

At minimum pharmaceutical waste management policies and procedures should be:

- created to outline the company's methodology for determining which medications need to be managed the waste;
- deciding which unregulated medications will be handled as hazardous waste. labeling tools to make hazardous waste segregation easier;
- separating different waste streams;
- training staff (e.g., which staff, what information); Reviewing Inventory Controls to Minimize Outdates
- establishing and overseeing storage and satellite accumulation areas;
- creating and preserving manifests of hazardous waste;
- assessing their level of hazardous waste generation;
- what standards are applied when choosing hazardous waste;
- arranging for frequent program evaluations;
- providing management with updates; and,
- utilizing pharmaceutical waste management as a precursor to a facility-wide
- "A Handbook on the Management of Hazardous Waste for Florida's Pharmacies," For Solid and Management of Hazardous Waste.

METHODS OF DISPOSING OF PHARMACEUTICAL WASTE

There are eight methods of disposal of pharmaceutical waste, return to donor, incineration, immobilization, landfill, sewer, chemical decomposition, burning in open containers.[1,4,26,27]

RETURN TO DONOR

Large pharmaceuticals that are challenging to dispose of, such as antineoplastic and unwanted/expired donations, should be returned to the manufacturer or donor for disposal. Cross-border transfers can be used to dispose of pharmaceutical waste. This approach involves moving hazardous waste across international boundaries. It is regulated by the Basel Convention on Tran's boundary Transfers of Hazardous Wastes. However, the procedures around this method take a long time to warrant transfer.

LANDFILL

The direct disposal of untreated pharmaceutical waste in a landfill is referred to as landfilling. disposal location. The most popular disposal method is a landfill. There are three types of landfills.

(a) Open uncontrolled non-engineered dump

In developing nations, it is a common practice. This procedure shouldn't be utilized to get rid of ntreated waste. It can be used as a last resort after immobilization. In the waste should be filled with municipal waste instead of event immobilization. Refrain from scavenging. Watercourses should be kept apart from open dumps to prevent contamination.

(b) Engineered landfill

The second-best method to dispose of immobilized pharmaceutical waste. The technique has features to minimize release into the aquifer.

(c) Heavy duty sanitary landfill

These locations are over the water table, well-maintained, and isolated from waterways. This approach to waste disposal is the safest because it provides protection for the aquifer. Trash is pressed down and covered with dirt to maintain the environment for hygienic waste.

IMMOBILIZATION

There are two methods of waste immobilization, namely; encapsulation and energization.

(a) Encapsulation

Waste into a solid block within a drum. The following procedure is used; clean drums. Do not use drums that previously contained explosive materials. Cut drum lids open and bend them back. Fill drums with solid or semi-solid waste, controlled substances, liquids, powders, or antineoplastic to 75% capacity. Fill the drum with cement, lime and water in the ratio of 15:15:5. Add a

significant quantity of water to achieve consistency. Bend back and weld the lid. Place the drums at the bottom of the landfill and cover with fresh municipal waste.

(b) Inertization

This technique can be used with basic equipment and is inexpensive. Grinder, concrete mixture, cement, lime, and water are among the materials needed. Supply. It can be used to get rid of controlled substances, solid or semi-solid waste, either antineoplastic or powders. The process used is as follows: Put on protective clothes. Like masks and gloves. Distinct packaging materials, including plastics, blister packs, cardboard and papers from pharmaceutical companies. Combine water, lime, and pharmaceutical waste. And cement in the following proportions: 65%, 15%, 15%, and 5% to create a uniform waste. A concrete mixer truck can be used to transport the waste to a landfill. Decant into regular either spread into municipal waste or urban waste.

BURNING IN OPEN CONTAINER

Small amounts of pharmaceutical waste should be disposed of using this method. This method of disposing of pharmaceuticals should not be burned at low temperatures in order to prevent air pollution. It works well with medications that are packaged in paper and cabinets. Polyvinyl chloride (PVC)-containing materials should not be burned.

CHEMICAL DECOMPOSITION

It is only practical if there is access to chemical expertise and incineration is not feasible. It is laborious and time-consuming, and the chemicals needed must always be accessible. It can be used to dispose of antineoplastic less than 50 kg. Ought to be carried out obeying the advice of the manufacturer.

INCENARATION

This technique can be used with basic equipment and is inexpensive. Grinder, concrete mixture, cement, lime, and water are among the materials needed, supply. It can be used to get rid of controlled substances, solid or semi-solid waste, either antineoplastic or powders. The process used is as follows, Put on protective clothes. Like masks and gloves. Distinct packaging materials, including plastics, blister packs, cardboard and papers from pharmaceutical companies. Combine water, lime, and pharmaceutical waste. And cement in the following proportions: 65%, 15%, 15%, and 5% to create a uniform waste. A concrete mixer truck can be used to transport the waste to a landfill. Decant into regular either spread into municipal waste or urban waste.

SEWER

When waste is disposed of into drains, tiny amounts of diluted waste are released into sewers. The technique works well for getting rid of liquids, intravenous fluids, and tiny quantities of antiseptics or disinfectants. This method shouldn't be applied to get rid of antineoplastic and undiluted disinfectants or antiseptics.

INCENARATION

Incineration can be carried by two method

- Medium temperature incineration
- Novel high temperature incineration

(A) MEDIUM TEMPERATURE INCENARATION

Solids, semi-solids, powders, and controlled substances can all be disposed of with it if there are no high-temperature incinerators or if there are less secure alternatives such as improper landfill disposal. The two chambers of the incinerator reach 8500C. The second chamber has a combustion retention time of 2 seconds. It is recommended that pharmaceutical and municipal waste be combined in a 1:1000 ratio.

Halogenated materials should not be disposed of in medium-temperature incinerators. Compounds (>1% halogenated compounds) as trace amounts of halogen ultimately in combustion gases.

NOVEL HIGH TEMPERATURE INCENARATION

This method can be used to dispose of solids, semi-solids, liquids, powders, controlled substances and antineoplastic. Such incinerators, e.g., cement kilns, operate at temperatures above 12000C, have short gas residence time, proper emission controls, and long combustion retention time, expensive and use sophisticated technology. This incinerator disintegrates all organic waste components and absorbs any toxic products of combustion. They can be utilized to get rid of large amounts of pharmaceutical waste in a short period of time. Pharmaceuticals should be put in small amounts (5%) in the furnace compared to fuel feed (95%). Prior to burning, remove packaging materials and grind the pharmaceuticals to avoid blockage of fuel feed.

MITIGATION TO CONTROL PHARMACEUTICAL WASTE IN THE ENVIRONMENT

Research examining the negative impacts of the environmental impact of pharmaceuticals is limited. Pharmaceutical firms, including During Pharmaceuticals, concentrate on 88% of human medications lack environmental data regarding patient health, dosage, and efficacy, poisoning. Nations such as Germany, France, and the Netherlands and Sweden has created a plan of action for tackle pharmaceutical waste in the environment. Reduction in order to achieve long-term benefits and cost-effectiveness, options should be specifically tailored to the pharmaceutical life cycle.[28,29]

CROSS-CUTTING

The government ought to give top priority to risk APIs, create fresh approaches to water monitoring quality, risk evaluation, and modelling in conjunction with research and pharmaceutical companies. Rules should be created to specify the environmental and water standards of pharmaceuticals.

DESIGN
Apart from creating a green pharmacy, Pharmaceutical firms ought to create personalized or efficient medications and biological treatments.

AUTHORIZATION
Prior to authorizing a prescription drug, the government ought to supervise rules and ascertain the risk to the environment. Prior to the market launch medications that pose a significant environmental risk ought to be subject to severe restrictions. The sector ought to provide choices for risk mitigation, eco-labelling, and post-approval monitoring and mitigation.

PRODUCTION
The government and the pharmaceutical industry sector ought to create an environmental standard. Outlining the limits for effluent discharge, disclosure of discharge of waste water and moral production methods.

CONSUMPTION
The medical field ought to recommend eco-friendly medications, customized medications and specific delivery systems while reducing the number of inappropriate prescriptions. The sector and the health and awareness by eco-labelling in by eco-l by eco-lb. eco-lb. eco-labelling for self-consumption. The government pharmacies high pharmaceuticals. Hormones to enhance livestock growth. Effective livestock handling techniques, management, treatment.

COLLECTION AND DISPOSAL
Utilities that handle solid waste should use passive biogas fermentation and anaerobic manure storage to enhance manure handling. The Industries should introduce schemes for the processing of the singing of unused or expired medicines. The public ought to be instructed to refrain from discarding unused or expired medications in restrooms and sinks.

ROLE OF PHARMACIST IN MANAGING PHARMACEUTICAL WASTE
Overview, handling, and consequences of inappropriate disposal of pharmaceutical waste a pharmacist ought to participate in the disposal of unused pharmaceuticals. Pharmacists should be aware of available disposal methods used in their area. They should prohibit disposal by open dumpsites, burning and destruction in poorly constructed/insecure landfills as these carry a public health risk. They should inform the competent authorities on the cost of disposal, the options for disposal and locations for outsourcing disposal services.[30]

Pharmacists are imperative in the pharmaceutical management cycle to ensure rational drug use to lessen the negative effects on the environment of drugs. They should be included in the policy, distribution, application, choice, and purchase mechanism, laws, and pharmaceutical regulations. As According to an Ethiopian study, pharmacists have superior understanding of waste disposal methods in comparison to other cadets. The study found that 29% and 32% of the respondents indicated that inappropriate storage and Receiving medications with short expiration dates resulted in medication damage.[31]

The pharmacist should point out any ostentatious or overprescribing to cut down on leftovers that ultimately become not properly disposed of. Pharmacists ought to encourage and track patient adherence and ensure that all prescribed.[32]

Pharmacist sought to oversee the ordering of stocks by predicting how much inventory to order and how long it will last to avoid overstocking, which increases the risk of expiring medicines. Proper to avoid damage, storage procedures should be adhered to, Pharmacists should establish standard operating methods for getting rid of low-quality, expired, damaged and unwanted pharmaceuticals properly. Being highly resourceful in information about drugs, pharmacists should be at the forefront of recommending the most effective disposal techniques for homeowners. Physicians should undertake regular patient education, after prescribing, on appropriate means of disposal specific to each dosage type.[33]

A study conducted in Serbia discovered that hospital staff in one out of 5 hospitals had not received training on pharmaceutical waste management. Moreover, training influenced safe waste management. The study concluded that having waste management specialists and routine training opportunities can enhance management of pharmaceutical waste.[34]

Healthcare facilities must designate thoroughly trained personnel who is capable of managing waste in an emergency and normal operations. In the USA, personnel handling waste must complete training on how to dispose of hazardous waste. Every year. Learning institutions must retain training records of individuals handling pharmaceutical waste.[35]

Pharmacists ought to educate those involved (prescribers, politicians) and act as any kind of environmental monitors. Levels to increase public consciousness of the risks of improper disposal and the effects of various pharmaceutical compositions. A study conducted in Palestine discovered a substantial correlation ($P<0.001$) between training and enhancement of knowledge and practice among medical personnel who handle pharmaceutical waste. The hospital administration was advised by the study to regularly provide training that is focused on healthcare workers.[36]

A study conducted in Nepal found a strong correlation between understanding and methods for disposing of waste. Respondents with knowledge followed safe disposal procedures. Participating in ongoing medical Safe waste was influenced by training and education

levels. Disposal procedures. This makes it clear that training waste Handlers is necessary to implement safe disposal procedures.[5]

The drug control agency, the health ministry, waste management specialists, the ministry of the environment, on-governmental organizations and pharmacists (NGOs) ought to evaluate, inspect, and keep an eye on drugs. Disposal operations. Monitoring can be accomplished by drafting national laws and environmentally friendly disposal techniques to stop the use and discharge of hazardous drugs into the environment.[37]

Lastly, Pharmacists should be trained by higher education institutions to prior to practice, work on pharmaceutical waste. The curriculum ought to be reorganized to incorporate sources and hazards associated with pharmaceutical waste, disposal techniques, and methods of neutralizing pharmaceuticals, treatment, and removal waste, the consequences of improper disposal, and removal policies and guidelines for treatment. This initiative will offer thorough comprehension of how medications interact with nature, which is essential to attaining future safety disposal procedures.[31]

DISCUSTION

Drug disposal has emerged as a critical component of pharmaceutical care, particularly in the context of growing concerns related to environmental safety, public health, and medication misuse. Traditionally, pharmacists were primarily involved in compounding and dispensing pharmaceutical products. However, the contemporary role of the pharmacist has significantly evolved into that of a patient care provider and drug therapy manager. This transformation necessitates a paradigm shift in pharmacy practice from a product-oriented approach to a patient-oriented model, wherein pharmacists actively participate in patient education, medication management, and safe drug disposal practices. Patient-oriented pharmaceutical services emphasize not only the appropriate use of medications but also the responsible handling and disposal of unused, leftover, or expired drugs. Improper drug disposal can lead to contamination of soil and water bodies, contribute to antimicrobial resistance, and increase the risk of accidental poisoning or intentional misuse. Therefore, pharmacists play a crucial role in empowering patients with the knowledge and skills required to dispose of medications prudently and safely. Current FDA guidelines strongly discourage the flushing of unused or expired medications down toilets or drains, as this practice allows pharmaceutical compounds to enter wastewater systems and persist in theenvironment. Instead, solid dosage forms such as tablets and capsules should be mixed with unappealing substances like kitty litter or used coffee grounds to deter consumption.

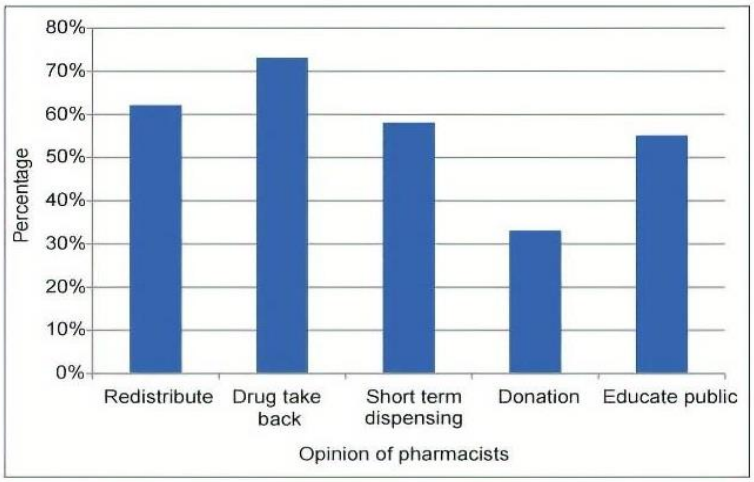

Figure 2: Ways to minimize pharmaceutical wastage (multiple responses chosen)

Table 1: Knowledge of pharmacists regarding disposal of returned drugs bb pharmaceutical distributers [single option market].

Type of preparation	Dispose to landfill (%)	Incineration (%)	Interization (%)	Flushing (%)	I do not know (%)
solids	46(55)	41(49)	21(25)	4(5)	21(25)
Semi solids	41(49)	-	12(14)	-	31(37)
liquids	31(37)	-	21(25)	36(43)	27(32)
Controlled drugs	16(19)	56(67)	14(17)	4(5)	23(27)
p-listed waste	12(14)	62(74)	4(5)	3(4)	18(21)

Table 2: knowledge of pharmacist regarding various aspects of drug disposal.

Statement about knowledge regarding drug disposal and its environmental effects	Percentage of pharmacists marking correct answer (%)
Improper drug disposal affects the environment and ecosystem	49 (58)
Wastewater treatment removes most of the drugs	47 (56)
It is acceptable to dispose solid and semi-solid drugs in garbage	28 (33)
It is acceptable to dispose liquid medications by sink	46 (55)
It is acceptable to dispose liquid medications by flushing	47 (56)
Incineration is the environmentally sound way of drug disposal	58 (69)

These mixtures should then be placed in sealed, disposable, and non-transparent containers before being discarded in household trash or, preferably, returned through community drug take-back programs. Such programs represent an environmentally sound and secure disposal route, although their availability and utilization remain limited in many regions.

Liquid medications require additional precautions, as they are more likely to be disposed of improperly through sinks or toilets. The recommended practice involves mixing liquids with substances such as salt, flour, charcoal, or non-toxic powdered spices (e.g., turmeric or mustard) to create an unappealing odour and texture before disposal. Similarly, medications packaged in blister packs should be rendered unusable by wrapping them in multiple layers of opaque tape and placing them in sealed, non-transparent containers. Medication bottles should have their lids sealed with strong adhesive tape and be discarded in a manner that prevents visibility and access. Despite the clarity of these guidelines, awareness and adherence among both pharmacists and patients remain inconsistent. Evidence from international studies further highlights disparities in disposal practices. A study conducted in Kuwait reported that 73% of pharmacists disposed of pharmaceutical waste through general trash, indicating limited reliance on specialized disposal methods. In contrast, a study from New Zealand revealed that third-party contractors were commonly used for the disposal of solid and semi-solid formulations. However, a substantial proportion of liquid medications and class B drugs were disposed of via pharmacy sinks, raising significant environmental concerns. In the present context, the finding that nearly one-third of pharmacists were unaware of the ultimate fate of medications returned to distributors suggests a critical gap in knowledge regarding downstream waste management processes. Regulatory frameworks such as the Resource Conservation and Recovery Act (RCRA) provide clear guidelines for the handling and disposal of pharmaceutical waste, particularly hazardous substances. Controlled drugs, anticancer agents, antibiotics, antiseptics, and disinfectants require specialized disposal techniques due to their toxic, cytotoxic, or antimicrobial properties. Pharmaceuticals listed under P and U categories are classified as hazardous waste and must be incinerated under strict supervision, which may involve pharmacists, environmental authorities, or law enforcement agencies depending on national regulations. Disposal requirements also vary based on waste generator status. Pharmacies generating less than 1 kg of acutely hazardous waste or less than 100 kg of hazardous waste per month are classified as conditionally exempt small quantity generators. Although these facilities generate relatively small amounts of waste, they are still legally obligated to identify, segregate, document, and dispose of pharmaceutical waste through state-licensed or authorized facilities. Failure to comply with these regulations can result in environmental harm and legal consequences.

Among all disposal methods, incineration is widely regarded as the most effective and environmentally safe approach for pharmaceutical waste management. Even when medications are disposed of correctly in household trash, there remains a risk of chemical leaching into soil and groundwater over time. Incineration significantly reduces this risk by thermally destroying active pharmaceutical ingredients. Post-incineration residues are collected in leak-proof containers and transferred to specialized landfills designed specifically for pharmaceutical waste. These highly engineered sanitary landfills are strategically located away from water bodies and maintained above the water table to prevent contamination.

A major barrier to compliance with pharmaceutical waste regulations is the lack of awareness and understanding of existing laws and guidelines. Studies indicate that the availability of formalized and accessible disposal guidelines greatly influences disposal behaviours among healthcare professionals and end users. Educational interventions have proven to be effective in addressing this gap. For instance, the study by Jarvis et al. demonstrated that a simple educational newsletter significantly improved pharmacists' knowledge and positively influenced their attitudes toward proper medication disposal.

Importantly, the responsibility for preventing pharmaceutical waste does not rest solely with physicians or regulatory authorities. Pharmacists, as accessible healthcare professionals, are uniquely positioned to counsel patients on proper medication use, adherence, and disposal. By reinforcing the importance of completing prescribed therapies and avoiding unnecessary stockpiling of medicines, pharmacists can reduce the volume of unused drugs requiring disposal. Such interventions not only minimize pharmaceutical waste but also improve therapeutic outcomes and patient

safety.

In conclusion, strengthening the role of pharmacists in patient education, increasing awareness of regulatory requirements, and promoting standardized disposal guidelines are essential steps toward improving pharmaceutical waste management. Integrating drug disposal counselling into routine pharmacy practice represents a sustainable and patient-centred approach to addressing the growing challenge of pharmaceutical waste.

CONCLUSION

Pollution of the environment due to inappropriate disposal Pharmaceuticals are becoming more widely acknowledged as a significant danger to ecosystems around the world. Pharmacists are responsible in their pharmacy for pharmaceutical waste; they ought to be informed about the best practices for disposing of drugs and Participate in the effort to address the issue of medication waste. National guidelines are required, as is a formalized procedure for getting rid of and destroying expired and unused drugs to reduce their possible effects on the surroundings. Pharmacists have the power to change this, problem that impacts the environment and public health. Pharmaceutical waste is still a developing area in environmental control in medical facilities. The Pharmaceutical waste management presents a significant challenge to the medical community, city officials, and policy planner's workers and employees in the recycling sector. It is multidisciplinary in character, including nursing, pharmacy, quality, infection prevention, and environment services risk management, assurance, etc. The administration of with new waste, waste is becoming a more complicated task. The development of classifications and disposal methods. It is continuously released. Consequently, there is a need for implementing an economical system to deliver improved facilities for medical treatment and also need the installation of a new system to guarantee appropriate waste management and to cut down on waste production creation by raising everyone's awareness and educating them.

REFERENCES

1. Rogowska, Justyna, et al. "Pharmaceutical household waste practices: preliminary findings from a case study in Poland." Environmental management, 2019; 64(1): 97-106.
2. Pharmacy and Poisons Board. Guidelines for the safe management of pharmaceutical waste. Pharmacy and Poisons Board, Nairobi., 2018; 1(1): 1-21.
3. Jaseem, Muhammed, Pramod Kumar, and Remya Mariam John. "An overview of waste management in pharmaceutical industry." The Pharma Innovation 6.3, Part C 2017; 158.
4. Megan C. Consequences of Improperly Disposed Pharmaceuticals. Danielshealth [Internet]. 2019 [accessed on 23rd June 2020]. Available online at: https://www.danielshealth.com/knowledge-center/pharmaceutical-improper-disposal-consequences
5. World Health Organization (WHO). "Guidelines for the safe disposal of unwanted pharmaceuficals in and after emergencies: Interagency guidelines." WHO, Geneva, 1999; 1-31.
6. World Health Organization. Safe management of wastes from healthcare activities. WHO press: World Health Organization, Geneva, 2014; 2: 1-329.
7. World Health Organization. Health-care Waste [Intenet]. 2020 [accessed on 17t hJune 2020]. Available online at: https://www.who.int/news-room/fact-sheets/detail/health-care-waste.
8. Velagaleti, Ranga, et al. "Impact of current good manufacturing practices and emission regulations and guidances on the discharge of pharmaceutical chemicals into the environment from manufacturing, use, and disposal." Environmental Health Perspectives, 2002; 110.3: 213-220. http://journal.peerscientist.com
9. American Journal of Physical Sciences I SSN 2519-5549 (online) www.iprjb.org, 2020; 1(4): 1, 1–16.
10. Medicine Waste UK. Available from: http://www.medicinewaste.com. [Last cited on 2014 Apr 15].
11. Poorest US states rank among most wasteful in. Available from: http://www.prnewswire.com/./poorest-us-states-rank-among-most-wasteful-in. [Last cited on, 2014 Apr 15.
12. Over 1 million tones medical waste headache for India. Available from: http://www.thepharmatimes.in/./237-over-1-million-tonnes-medical-waste-he. Last cited on 2014 Apr 15).
13. Daughton CG. Drugs and the Environment: Stewardship and Sustainability. Las Vegas, Nevada: National Exposure Research Laboratory, Environmental Sciences Division, US EPA, Report NERI LV-ESD 10/081, EPA/600//R-10/106; 12 Sept, 2010. 196 pp. Available from: http://www.epa.gov/nerlesd1/bios/daughton/APM200-2010.pdf. [Last cited on 2014 Apr 16]. expired prescription medications. Arch Intern Med., 2012; 172: 1685-7.
14. Cantrell L, Suchard JR, Wu A, Gerona RR. Stability of active ingredients in long-expired prescription medications. Arch Intern Med., 2012; 172: 1685-7.
15. Ramaswamy BR, Shanmugam G, Velu G, Rengarajan B, Larsson DG. GC-MS analysis and ecotoxicological risk assessment of triclosan, carbamazepine and parabens in Indian rivers. J Hazard Mater, 2011; 186: 1586-93.
16. Brodin T, Fick J, Jonsson M, Klaminder J. Dilute concentrations of a psychiatric drug alter behavior of fish from natural populations. Science, 2013: 339: 814-5.
17. Thomas MA, Klaper RD. Psychoactive pharmaceuticals induce fish gene expression profiles associated with human idiopathic autism. PLoS One, 2012; 7: 32917.

18. Guidelines for safe disposal of unwanted pharmaceu. Available from: http://www.who.int/water_sanitation_health/medicalwaste/unwantpharm.pdf. [Last cited on 2014 Apr 21].
19. How to dispose of unused medicines. FDA Consumer Health Information.
20. K. E. Noll, C. N. Haas and J. W. Patterson Industrial Waste Elimination Research Center Illinois Institute of Technology Chicago, Illinois.
21. Jaseem, Muhammed, Pramod Kumar, and Remya Mariam John. "An overview of waste management in pharmaceutical industry." The Pharma Innovation 6.3, Part C., 2017; 158.
22. Megan C. Consequences of Improperly Disposed Pharmaceuticals. Danielshealth [Internet]. 2019 [accessed on 23rd June 2020]. Available online at: https://www.danielshealth.com/knowledge
23. Environmental Protection Department. Guidance on Disposal of Unserviceable/ Expired Medicines for Licensed Pharmaceutical Traders, 2020; 1-3.
24. Waste Watch: A Model for Managing Discarded Pharmaceuticals, Health Facilities Management Magazine, March 2006.
25. Smith CA, "Rationale for Inclusion of Criteria for Proper Disposal of Monograph Pharmaceutical Preparations Based on the Resource Conservation and Recovery Act," Pharmacopeial Forum, May-Jun. 1999; 25: No. 3, 8309-8312.
26. Smith CA, "Rationale for Inclusion of Criteria for Proper Disposal of Monograph Pharmaceutical Preparations Based on the Resource Conservation and Recovery Act," Pharmacopeial Forum, May-Jun. 1999; 25: No. 3, 8309-8312.
27. Kadam A, Patil S, Patil S, Tumkur A. Pharmaceutical Waste Management, an Overview. Indian Journal of Pharmacy Practice, 2016; 9(1): 1-8.
28. 15. OECD. Pharmaceutical Residues in Freshwater: Hazards and Policy Responses, OECD Studies on Water. OECD Publishing, Paris, 2019; 1-20.
29. Richman, Colin, and Staffan Castensson. "Impact of waste pharmaceuticals: an environmental hazard or greenwash?." Pharmaceutical journal, 2008; 280(7494): 335-336.
30. Business Daily. Dangers of poor pharmaceutical waste disposal [Online]. 2017 [Accessed on 26t hJune 2020]. Available online at: https://www.businessdailyafrica.com/news/Danger-poor-pharmaceutical-waste-disposal/539546-4218120-yy1mtr/index.html.
31. World Health Organisation. Practical Pharmacy For Developing Countries. Hai Africa. 2010 March; 21: 1-10. [Accessed on 2020 June 28]. Available online at: http://origin.who.int/management/resources/drugs/practical pharmacy21b.pdf
32. Kadam A, Patil S, Patil S, Tumkur A. Pharmaceutical Waste Management, an Overview. Indian Journal of Pharmacy Practice, 2016; 9(1): 1-8.
33. Gudeta, Tadesse, and Desta Assefa. "Assessment of Pharmaceuticals Waste Practices Among Private Drug Retail Outlets in Ethiopia." Journal of Primary Care & Community Health, 2020; 11: 1–8.
34. Jovanović, Verica, et al. "Management of pharmaceutical waste in hospitals in Serbia–challenges and the potential for improvement." Indian Journal of Pharmaceutical Education and Research, 2016; 50(4): 695-702.
35. Tabash, Mohammed I., et al. "Impact of an educational program on knowledge and practice of health care staff toward pharmaceutical waste management in Gaza, Palestine." Journal of the Air & Waste Management A ssociation, 2016; 66(4): 429-438.
36. Paudel, Eknaran, Eunhwa Choi, and Naveen Shrestha. "Pharmaceutical waste management in private pharmacies of Kaski District, Nepal." International journal of innovative science and research technology, 2019; 2456-2165.
37. OECD. Pharmaceutical Residues in Freshwater: Hazards and Policy Responses, OECD Studies on Water. OECD Publishing, Paris, 2019; 1-20.