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Review Article

An Introduction to How to Dispose of Unused And Expired Medicine: A Review

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ABSTRACT

Medication is a chemical compound that is given to treat a disease or relieve symptoms of an illness. The disposal of drugs has a significant effect on the environment. The health care system relies on medicines. However, when people recover, they often no longer need the medicines and may simply throw them away. When you discard your medicines in the trash, they can break down in the soil, affecting plants and animals. They may also mix with rainwater and end up in ponds and rivers, impacting both animals and humans. Milk from humans, cows, and goats can contain various pharmaceuticals. It is important to keep and dispose of medicines safely so that children, teenagers, pets, or even guests cannot easily access them. Drug disposal means getting rid of drugs. Expired drugs should be thrown away in a safe and environmentally friendly way. The US FDA started a "Drug Take Back program" to prevent harmful drugs from entering the environment. Poor drug disposal practices, like flushing drugs down the toilet, burning them, or throwing them in the trash, can contaminate water supplies. Because of this, the nation is facing several issues. It's vital to understand how much the community knows about this problem. Pharmaceuticals and their byproducts can be dangerous when they are in the environment. They can expose people and animals, including aquatic creatures, to medications and increase antibiotic resistance.

INTRODUCTION

Medications, which are chemical substances utilized for treating illnesses, play a vital role in our everyday lives. Nonetheless, progress within the medical sector has contributed to an increase in

medicine waste resulting from excessive prescriptions and a growing patient population. This waste has detrimental effects on the environment, poses risks to biological health, and raises ethical concerns. It is essential to inform the public about the appropriate disposal methods for

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unused and expired drugs¹. The healthcare system depends on medications, which are frequently thrown away once patients recover. A study conducted in Delhi revealed that a significant number of individuals throw away unused medications in the trash, which may ultimately find its way into landfills, leach into the soil, mix with rainwater, and contaminate the air. The resulting waste re-enters our lives in a more dangerous manner. Milk from humans, cows, and goats can contain drugs, which may adversely affect human mental health due to the accumulation of pharmaceutical substances in aquatic flora and fauna. Consequently, it is essential to minimize the disposal of surplus medications and encourage proper disposal methods². The deterioration of pharmaceuticals can span several years and linger in the environment, leading to possible contamination of local resources such as water supplies. It is essential to dispose of medications as general waste properly to prevent unnecessary environmental pollution. Disposing of medications in an unprotected landfill is unsafe, just as flushing them down the toilet or pouring them down the sink is also not advisable³. Proper disposal of medications is essential for ensuring safety and preventing misuse. Safely discarding unused drugs helps to avoid abuse and environmental pollution. Incorrect disposal methods can result in the contamination of water and a decrease in drug effectiveness. In India, new drugs are frequently launched to address various health conditions, and when these medications break down, they may become hazardous. Although the USFDA has initiated a 'drug take back campaign' aimed at reducing drug pollution, it has not been successful in India. Poor disposal methods, such as flushing medications down toilets, incinerating them, or throwing them in garbage bins, can contribute to water contamination. Organizations should offer

consumers clear guidance on disposing of medications properly to promote a safe and eco-friendly method. Improper disposal methods can lead to problems like water source contamination and environmental damage⁴. The investigation sought to increase awareness of proper medication disposal among communities and government bodies, analyzing international approaches and gauging the community's comprehension of this important matter⁵. The expiration of pharmaceuticals can undermine their effectiveness, safety, and strength, posing health hazards. Discarded or outdated medications can contribute to antibiotic resistance, potential carcinogenic effects, and failures in treatment. Following appropriate disposal methods is essential to avoid misuse and accidental poisoning. Furthermore, expired medications may absorb moisture, alter their physical and chemical properties, and become contaminated with microorganisms⁶. Expired or obsolete medications can present risks and must be managed with caution to avoid the accumulation of harmful drugs in the environment⁷. Polar compounds, typically utilized as active pharmaceutical ingredients (APIs), are frequently labelled as "micro pollutants" owing to their occurrence in aquatic environments. The identification of trace levels of human and veterinary pharmaceutical substances along with their metabolites in surface waters indicates environmental contamination⁸. Pharmaceuticals and their byproducts present a danger to the environment, resulting in water accumulation, heightening antibiotic resistance, and exposing communities to medications, aquatic organisms, and personal care products. Pesticides also infiltrate groundwater and surface water, ultimately impacting the food chain⁹. The pharmaceutical sector is experiencing significant growth owing to the rising global demand for medications, especially in nations such as China and India. India holds the sixth position in global



pharmaceutical markets concerning volume production. Nevertheless, a considerable number of products remain unused or expire, with approximately half of patients not adhering to their prescribed dosages. Furthermore, 50% of medications are sold, administered, or prescribed incorrectly, resulting in waste and the accumulation of unused products¹⁰.

PURPOSE OF DRUG DISPOSAL

By following these guidelines, you can safely and responsibly eliminate unwanted pharmaceuticals. Considering the impact on the environment, the best method for destroying pharmaceuticals is through high-temperature incineration paired with adequate flue gas treatment. Nonetheless, it is important to note that there are alternative methods for effectively managing waste besides this one. Although Sri Lanka has access to this advanced facility, there remain some disposal and treatment methods that are somewhat less safe. In the country, the NMRA exclusively oversees the disposal of pharmaceuticals, in collaboration with both national and provincial health authorities. We also engage with other governmental bodies as necessary³. The aim of this quantitative cross-sectional study was to examine consumer awareness about suggested disposal techniques, real disposal behaviours, and the impacts of disposing of pharmaceuticals on environmental conditions and public health¹¹.

SOURCES AND DRUG DISPOSAL IMPACT

Pharmaceutical waste, which is generated from a variety of activities, creates organic pollutants detrimental to both ecosystems and public health. It exists in chemical, non-hazardous, and hazardous forms, with various industries being the sources. The following are sources of medication waste:

- 1) Mismanagement of expired medications.
- 2) Disposal of leftover or unwanted medications in hospitals, clinics, pharmacies, or homes.
- 3) Materials that include residues from chemotherapy drugs.
- 4) Packaging waste from medications.
- 5) Waste produced by pharmaceutical manufacturing companies.
- 6) Incorrect and direct disposal of unnecessary or expired medications in trash, sinks, or via urine or feces.
- 7) Discharge from molecular farming and pesticides^{10,12}.

STEPS TO BE TAKEN

The steps to be taken when disposing of medications that are no longer needed are summarized here:

- 1) Decision:** Unnecessary pharmaceuticals gather in healthcare facilities, provincial health departments, purchasers, health campaigns, and private organizations. Designated officers, overseeing pharmacists, and other responsible individuals determine when it is necessary to take action to dispose of collected pharmaceutical waste, with the pharmacy or medical facility making the final decision on when to proceed.
- 2) Approval:** The disposal of pharmaceuticals must be approved and sanctioned by the National Medicines Regulatory Authority (NMRA). The appropriate authorities must grant clearance to discard pharmaceutical waste.
- 3) Planning:** Disposal planning involves identifying resources such as funding, expertise, workforce, specialized time, location, equipment, and disposal options. It is important to utilize a tape measure and convert volume to weight using a density factor of 0.2 metric tons per cubic meter to ensure the required resources are available.



4) Assembling work teams: Pharmaceutical warehouses should create teams composed of pharmaceutical technicians and general medical personnel, with the size and makeup determined by the volume and nature of the tasks and the working environment.

5) Health and safety for work teams: Employees must consistently wear protective gear such as overalls, boots, masks, gloves, and caps. Masks are crucial for preventing the release of powders during crushing and disposal, and extra precautions must be taken when managing antineoplastics.

6) Categorization: Pharmaceuticals are divided into various subcategories that require distinct disposal methods, including controlled substances such as opioids, antineoplastics, and antibiotics. The process of identifying and segregating medications can be labour-intensive and demands considerable human resources, making it a challenging endeavour.

7) Waste management: Achieving an ideal disposal solution is not always feasible, as options vary significantly based on the circumstances. These guidelines are designed to provide the simplest, safest, and most practical recommendations.

8) Safety measures: Narcotics and psychotropic substances necessitate stringent security and monitoring to avert diversion and theft from waste disposal sites. The best approach is immobilization, and pharmaceuticals should be enveloped in municipal waste before being discarded.

RESULT OF PROPER DISPOSAL OR LACK OF DISPOSAL

In general, outdated medications do not pose a significant threat to the environment or public health. However, improper disposal could lead to contamination of local sources or water supplies used by neighbouring towns, which might be hazardous. Unsecured landfills can expose outdated medications to children, and if expired drugs are retrieved from leftover supplies or during organization, they could be resold and misused. Nearly all medications lose effectiveness after their expiration date, and some may even lead to harmful side effects.

1. Drug abuse and poisoning:

Storing expired medications in unsecured landfills or homes can result in accidental poisonings, overdoses, and theft of drugs. Around 95% of accidental medicine consumption occurs without parental awareness, and stolen pharmaceuticals may find their way into the market for resale and misuse.

2. Antimicrobial resistance:

Over the last five decades, millions of tons of antibiotic compounds have been released into the environment, contributing to antibiotic resistance. This resistance is responsible for approximately 700,000 deaths each year due to failures in antibiotic treatment. Research indicates that bacteria adapt and become more resistant as a result of antimicrobial substances released from pharmaceutical companies, healthcare facilities, and agricultural runoff. In Hyderabad, local water bodies have been found to contain high levels of drug residues, while researchers from the Indian Institute of Technology reported significant concentrations of carbapenem-resistant bacteria and extended spectrum efflux pump (ESBL) in the sewage treatment plants of Delhi. These two instances suggest that improper disposal of



medications could also play a role in treatment failures.

3. Contaminated food:

The drinking water in India has antimicrobial multiresistant genes, resulting in bacteria that are resistant to ciprofloxacin and *Salmonellae*. This is thought to contribute to the *E. coli* outbreak in Europe. Additionally, the drinking water is contaminated with harmful substances, including multiresistant *Salmonella* found in water used for crop irrigation, while nearly 80% of Pakistan's crops are irrigated with wastewater.

4. Cytotoxicity:

Cancer treatments are cytotoxic, meaning they kill both healthy and cancerous cells. Improper disposal of these drugs can lead to mental disabilities, cancer, and infertility issues. Studies indicate that antineoplastic drugs possess mutagenic and carcinogenic properties. In Finland, children born to mothers who handle anticancer medications displayed a higher rate of spontaneous miscarriages and abnormalities.

5. Impact on animals:

The use of diclofenac in cattle in South Asia has resulted in a decline in the vulture population. Pharmaceuticals for humans, animals, and birds are present in water bodies. Industrial estrogens contribute to the feminization and demasculinization of male fish. Tetracyclines and quinolones can be toxic to animals and microorganisms. In India, certain antibiotics are harmful to microorganisms, animals, and plants. The presence of medications in goat, cow, and human milk can adversely affect human health.

6. Genotoxicity:

Chemical substances can harm genes, causing mutations that may lead to cancer. Environmental pollutants from genotoxic waste significantly affect land, air, and water ecosystems. The WHO reports that 20% of hospital waste is hazardous, while 80% is considered non-hazardous. Hazardous waste may contain substances that are mutagenic, carcinogenic, or teratogenic^{2,3}.

SUGGESTIONS FOR SAFE DISPOSAL

Guidelines for the safe disposal of pharmaceuticals provide recommendations for handling unwanted or expired medications while adhering to federal, state, and local regulations. These secure disposal methods are appropriate for circumstances with limited resources and equipment, promoting public health and environmental safety, and addressing insufficient advice.

- 1) It is essential to prevent water contamination. The design and placement of a landfill must minimize the risk of leachate entering aquifers or groundwater systems.
- 2) It is not recommended to dispose of non-biodegradable disinfectants, antibiotics, and antineoplastics through wastewater systems, as they can disrupt essential microorganisms vital for sewage treatment. When antineoplastics are released into water bodies, they pose risks to aquatic life and contaminate drinking water.
- 3) Disinfectants should not be released in large volumes into sewer systems or water bodies, but they can be used if sufficiently diluted.
- 4) Incinerating medications in open containers or at low temperatures can be dangerous due to the release of harmful chemicals. It is best to avoid this whenever possible.
- 5) If unwanted pharmaceuticals are kept in dry conditions and no proper disposal facilities exist,



there is no harm in their disposal if they are securely stored. Medications should be contained in drums with their contents immobilized, rather than in their original packaging, to deter diversion.

6) Diluted liquid medications such as syrups and intravenous (IV) fluids can be safely flushed down the sewage system without affecting health or the environment. Small amounts of medications or well-diluted antiseptics may also be released into water bodies. Help from hydrogeologists or sanitary engineers might be necessary for outdated or damaged systems.

7) Genotoxic and cytotoxic drugs must be disposed of chemically as per manufacturer instructions, incinerated at high temperatures, or returned to the original source through a take-back program. The secondary chamber equipped with gas-cleaning apparatus must be heated to 1200°C to effectively eliminate all cytotoxic substances.

8) It is the responsibility of manufacturers to dispose of solid, liquid, and gaseous effluents following environmental regulations.

9) All biomedical waste must be managed in compliance with the 1996 Bio-Medical Waste (Handling and Management) Rules.

10) Extra precautions are necessary when storing and getting rid of discarded medications. Keeping records of all waste disposals is essential^{2,3,13}.

APPROACHES FOR SECURE DISPOSAL

Many individuals throw expired or unused medications in trash bins, which can create hazards for children and pets. This may result in significant toxicity or poisoning. Furthermore, these drugs can wind up in landfills alongside other solid waste, which presents considerable environmental and public health concerns. Ensuring the correct disposal of medications is essential for

safeguarding public health. The World Health Organization outlines several disposal methods:

1. Landfill: Landfills are sites where waste is disposed of directly beneath the soil without any prior processing. Solid waste is primarily dumped at landfills, making this the earliest and most common method of waste disposal. There are two types of landfills:

- **Engineered landfill:** This type of landfill includes safeguards to stop toxins from leaking into the aquifer. The second-best option for disposing of medications involves placing them directly in the landfill along with immobilized pharmaceutical waste.

- **Engineered sanitary landfill:** Landfill locations designated for pharmaceutical waste must be properly developed and maintained, emphasizing the protection of the aquifer. Optimal landfills should be raised above groundwater levels and positioned away from streams. Solid waste is compacted daily for sanitary disposal.

2. Return to donor or manufacturer: The general public is not able to safely discard medications, so it is advisable to return unwanted drugs to their manufacturer or an authorized individual. This is especially important for high-risk medications like antineoplastics, and donations may be returned if they are unwanted or unrequested, particularly as they approach their expiration dates.

3. Immobilization waste: encapsulation: Pharmaceuticals are encased in either steel or plastic drums, which must be cleaned to avoid explosive hazards. Seventy-five percent of these containers are filled with cement, cement/lime mixtures, bituminous sand, or plastic foam. Prior to filling, the lids should be cut open and bent back. A mixture of lime, cement, and water in a



ratio of 15:15:5 is poured in, with additional water possibly required. The lids of steel drums should be welded or seam-welded. The drums are then covered with municipal solid waste and placed in a landfill^{2,14}.

4. Waste immobilization: inertization: Isolate precursors and restricted substances from packaging materials. Extract pills and capsules from blister packs, grind them using a grinder, and combine the resulting powder with lime, cement, and water in a ratio of 65:15:15:5. If necessary, add more water and place the mixture in a pit or drum.

5. Sewer: Liquid medications, such as syrups and IV fluids, can be safely diluted and discharged into sewers over time without risk to public health or the environment. Diluted quantities can also be released into rivers. Malfunctioning or damaged sewers may require the expertise of a hydrogeologist or sanitary engineer.

6. Open container burning: Incinerating medications in open containers at low temperatures can release harmful chemicals into the atmosphere. Paper and cardboard packaging cannot be recycled, and burning polyvinyl chloride or PVC materials is not advisable. While burning pharmaceutical waste is a common practice, it should only be done for small quantities.

7. Incineration at medium temperature: In urgent situations, expired solid medications can be disposed of using a two-chamber incinerator operating at 850°C, ensuring that combustion retention lasts for at least two seconds. Medium temperature incinerators are suggested for short-term waste management. Pharmaceutical waste should be mixed with municipal garbage. Thermal treatment effectively eliminates pathogens and toxins present in clinical and hazardous waste.

8. High-temperature incineration: Furnaces are frequently utilized in high-temperature sectors such as cement kilns, coal-fired thermal power plants, and foundries. They function at temperatures exceeding 850°C, feature an extended combustion retention time, and emit exhaust gases into tall chimneys. Cement kilns are effective for the disposal of pharmaceuticals due to their elevated temperatures, which facilitate the efficient breakdown of organic waste materials.

9. Chemical decomposition: This approach is used for the disposal of antineoplastic drugs in the absence of a proper incinerator, followed by landfilling. Nevertheless, this technique is not advisable if there is a lack of chemical expertise. The process of chemical inactivation comprises several stages and requires that chemicals are consistently accessible. Chemical degradation is not suitable for large amounts exceeding 50 kg^{2,3,14,15}.

FUNCTION OF PHARMACIST IN MEDICATION DISPOSAL

A survey indicates that most pharmacists in Kuwait throw away unwanted medications in the trash, with only 23% opting for proper drug disposal methods. Nevertheless, 82% of those surveyed recognized the environmental damage caused by improper disposal, and 97% felt it was their responsibility to protect the environment. Looking ahead, 86-88% of pharmacists are willing to collect prescription medications from government hospitals and polyclinics for drug take-back programs. Merely 5% of pharmacies consistently inform customers about how to dispose of medications, while 25% address customer questions. In India, 25% of pharmacists confessed to discarding solid dosage forms, and 89% believe that pharmacy education did not cover proper disposal methods. Additionally, 58% perceive a relationship between drug disposal



practices and environmental harm, with 69% favouring the incineration of unwanted or expired medications¹⁶.

Environmental Consequences of Mismanagement of Surplus / Outdated Medications:

Unwanted pharmaceuticals are often disposed of in municipal wastewater treatment facilities, either by flushing them down toilets or pouring them down sinks. Wastewater treatment plants, both in industrialized and developing countries, manage wastewater by utilizing suspended solids or nitrogen and phosphorus compounds. At present, there are no regulations within the European Union requiring the removal of micro pollutants, including pharmaceuticals, from wastewater. According to Council Directive 91/271/EEC, member states must ensure that treated wastewater complies with standards for total suspended solids, oxygen demand, and levels of phosphorus and nitrogen. Aquatic ecosystems are endangered due to micro pollutants like drugs and their metabolites contaminating water bodies. In the Baltic Sea, pharmaceuticals primarily enter marine and freshwater environments via wastewater treatment facilities. Many medications have low solubility in sludge, resulting in the formation of liquid phases. Numerous chemicals present in wastewater are capable of breaking down and interacting with other environmental substances. Several villages in Africa lack modern sewage and wastewater treatment infrastructure, resulting in the release of drugs and their metabolites into soil and groundwater. Most household waste is disposed of in landfills, and a 2016 study identified 15 chemicals in leachate from municipal landfills. These pharmaceuticals can induce biological effects even at minimal concentrations, potentially harming aquatic organisms. Nevertheless, much remains unknown regarding the ecotoxicological

impacts of medications, as 88% of human pharmaceuticals lack comprehensive data on their environmental toxicity. Moreover, determining which organisms are adversely affected by these medications is complicated due to their presence in combinations. The discharge of antibiotics into the environment has led to the emergence of antibiotic-resistant genes and bacteria, resulting in increased antibiotic resistance. This can allow antibiotic resistance to spread from environmental sources to drinking water supplies, posing a risk to human health. Groundwater supplies drinking water to 75% of the European population, and pharmaceuticals have been detected in drinking water and groundwater across the globe. In 2015, the World Health Organization endorsed a global action plan to combat antibiotic resistance, aiming to optimize usage and enhance public awareness regarding resistant microbes. In 2017, the European Union introduced the European One Health Action Plan targeting antibiotic resistance. The COVID-19 pandemic has resulted in an uptick in medication usage, especially antibiotics, leading to a rise in their concentrations within sewage systems. During the pandemic, antiviral drugs, antimalarial medications, antibiotics, pain relievers, and various combinations of these medications were analysed due to the lack of specific treatments for the SARS-CoV-2 virus. Research indicates that antibiotics prescribed during COVID-19 treatment have elevated levels in aquatic environments throughout the pandemic. Raanan Bloom, Ph.D., an environmental assessment expert from the FDA, has raised concerns regarding drug residues in surface waters and municipal drinking water systems, likely arising from natural body processes related to medication consumption. Many drugs are not completely absorbed or metabolized within the human body and may be released into the environment after passing through wastewater treatment facilities. Pharmaceuticals are processed



in wastewater treatment plants employing biological, chemical, and mechanical methods. The processes of biodegradation and sorption are utilized. Medications known for having low sorption include rosuvastatin, metoprolol, tramadol, diclofenac, and carbamazepine. The Secure and Responsible Pharmaceutical Disposal Act of 2010 amended the Controlled Substances Act (CSA) to restrict the distribution, importation, manufacturing, possession, and use of prohibited drugs. This amendment was enacted due to the increase in non-medical use of prescription drugs and accidental overdose deaths^{19,20}.

Safe disposal of unused and unwanted medications in the home:

1) For pills, capsules, or other solid waste: To prevent accidental ingestion of medications, place them in an unattractive container like an empty can or bag, mix in some cat litter, seal it with opaque tape, double-bag it, and then throw it away.

2) For liquid medications: If you have cat litter or coffee grounds, you can add them to the liquid. Ensure that all personal details on the container are eliminated. Next, secure the container with duct tape or another type of opaque tape to avoid leaks, double-bag it, and dispose of it in the trash.

3) Regarding unused vials, ampoules, and IV bags: Disposing of medication waste at home can be done by incineration, burying it in the ground, flushing it down the toilet, or returning it to pharmacies or medical facilities. Proper disposal remains a global issue, as improper handling can lead to serious environmental consequences. Mixing medications with regular waste poses risks to public health, the ecosystem, and biodiversity. Hazardous byproducts, particularly from antibiotics, estrogen, antineoplastics, and immunosuppressants, can induce teratogenic, mutagenic, and carcinogenic effects in both

animals and humans. In rural areas, waste may be burned, which can result in health and environmental hazards due to pollution and toxic fumes. In Brazil, ANVISA established RDC 222 in 2018 to set standards for managing health service waste. However, there is currently no national policy that governs how households should collect and dispose of pharmaceuticals^{20,21}.

Expert recommendations for safe home disposal:

The World Health Organization offers guidelines for properly disposing of medications, which include methods such as landfilling, flushing, and incineration. However, these approaches are not appropriate for the average person. The writer suggests an easy solution: securing medications in their original packaging or combining them with cement or ceramic materials. This process creates solid bricks or flower pots, stopping them from interacting with water or air. This straightforward method enables individuals to dispose of medications at home instead of throwing them in the trash².

Take-Back Program:

Prior to the initiation of the medication take-back program in the United States, the FDA had documented more than thirty instances of children being exposed to fentanyl patches, particularly affecting those under the age of two. Improper disposal accounted for approximately 23,783 out of 255,732 cases associated with inappropriate use of prescriptions. Misuse of prescription drugs is more prevalent among Americans than the total usage of cocaine, hallucinogens, heroin, and inhalants combined. In response to these issues, the US FDA and the Drug Enforcement Administration launched a drug take-back program in 2010 to offer a secure and responsible way to dispose of prescription medications and



raise public awareness about misuse and proper disposal methods. In the past three years, authorized collectors have gathered over 200 kilograms of unwanted medications, preventing them from harming the environment. In India, ineffective disposal methods include mail drop and drug drop boxes. However, there remains no efficient approach to safely dispose of narcotics from households or to educate individuals on safe disposal practices²².

Pharmaceutical Waste:

Various legal systems have distinct definitions of waste, with Directives 2008/98/EC from the European Parliament and Council categorizing unused and expired medications as waste. Due to safety issues, only certified pharmacies are permitted to sell any leftover medications. Many drugs are classified as unwanted or remain unused for several reasons.

- (1) The dosage of the medication might need adjustment, or the medication itself may need to be switched.
- (2) The patient may have passed away.
- (3) Medications may be used improperly (particularly antibiotics) or the treatment may not be fully completed.
- (4) An adverse effect may prompt the termination of the therapy.

The use of prescribed medications poses a significant challenge in many countries, with 59% of participants in Ghana ceasing their medication as soon as they perceived an improvement. The reasons for stopping medication include feeling better from their illness or symptoms, forgetting to take their drugs, and experiencing a decline in symptoms. In Malaysia, 76.9% of individuals stop their medication after feeling an improvement,

while 82.2% in Tanzania do so once they start to feel better. Indonesian participants discontinued their medication due to improved health, changes in prescriptions, adverse effects, alterations mandated by doctors, lack of therapeutic benefit, and a shift towards natural remedies²⁴.

Waste disposal and sewage treatment:

The disposal of pharmaceutical residues and the treatment of wastewater are vital concerns for numerous countries, as many individuals throw away unwanted medications in trash bins or toilets. Some nations employ ozone and granulated activated carbon at sewage treatment facilities to reduce micropollutants like pharmaceuticals. Nonetheless, many countries lack adequate wastewater treatment systems, resulting in the persistence of pharmaceutical contaminants in their water supply. It is critical to conduct research on pharmaceutical residues in wastewater for the industry, and photocatalytic methods, such as TCPP combined with Bi₂O₃, show promise in eliminating organic pollutants¹⁶. Unused or expired medications pose a significant environmental challenge, as they frequently end up in landfills, septic systems, and sewage. Groundwater pollution with unwanted pharmaceuticals is also observed in ponds and aquifers due to septic systems' inability to break down these substances. Medications that dissolve in water are often not eliminated in wastewater treatment, which is primarily designed to remove solids, organic materials, and nutrients such as nitrogen and phosphorus. Wastewater undergoes treatment in one, two, or three phases, depending on the complexity of the treatment plant and the needs of the community. The first phase of treatment eliminates solids and bacteria, while the second phase targets the removal of nutrients and organic materials from bacteria in aerated tanks. Tertiary treatment involves the use of chemicals to



eliminate nitrogen and phosphorus, while chlorine is used to disinfect any remaining germs¹⁷.

Impact of pharmaceutical pollution on aquatic organisms:

In a 2013 study conducted in Europe, it was discovered that 29 small waterways across 10 EU nations were tainted with veterinary medications, primarily antibiotics. These compounds can persist in drinking water and seep into natural water bodies, impacting aquatic life and animals. Research has indicated that pharmaceutical substances can have cumulative impacts on microorganisms exposed to contaminated water. There is a limited understanding of how pharmacologically active chemicals engage with ecosystems to promote antibiotic resistance²⁵.

CONCLUSION

In India, the improper disposal of medications is leading to environmental problems and creating confusion among the public. An initiative should be started to inform the public about correct disposal practices and the harmful effects of incorrect drug disposal. Non-governmental organizations, civil society groups, and regulatory bodies for drugs should play a role in putting these actions into effect. Guidance from pharmacists and medical professionals can also contribute to ensuring proper disposal.

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