Review Article

Greener Route to Prevent Pharmaceutical Pollution

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ABSTRACT

The use of pharmaceuticals and personal care products (PPCPs) is on the rise on the globe. PPCPs enter into the environment through individual human activity and as residues from manufacturing, agribusiness, veterinary use, and hospital and community use. Individuals may add PPCPs to the environment through waste excretion and bathing as well as by directly disposing of unused medications to septic tanks, sewers, or trash. Because PPCPs tend to dissolve relatively easily and do not evaporate at normal temperatures, they often end up in soil and water bodies. Some PPCPs are broken down or processed easily by a human or animal body and/or degrade quickly in the environment. However, others do not break down or degrade easily. The likelihood or ease with which an individual substance will break down depends on its chemical makeup and the metabolic pathway of the compound. Varying concentrations of drugs found in water sources can have ill effect on the aquatic life and human health. For pharmaceutical pollution, the solution calls upon all health care sectors to participate in preventing pharmaceutical pollution. Green Pharmacy aims at zero pharmaceutical waste in our environment. It offers an opportunity for social action that will greatly benefit our environment at all levels of our society. It encourages health providers and clients to focus on healthy lifestyle and prevention to ensure their well-being through regular wellness practices. It provides education and opportunity for everyone involved with the life cycle of medicine to participate in reducing pharmaceutical pollution. With relatively simple yet firm commitments to change our habits, becoming stewards of medicine rather than consumers of medicine we effectively become part of the solution. This review paper delineates about the powerful approaches of green pharmacy that provides comprehensive solution to pharmaceutical pollution affecting much of well being on globe.

Keywords: RCRA; SDCP; Biomagnification; Endocrine disruptors; Green pharmacy.

INTRODUCTION

The discovery of a variety of pharmaceuticals in surface, ground, and drinking waters around the country is raising concerns about the potentially adverse environmental consequences of these contaminants. Minute concentrations of chemicals known as endocrine disruptors, some of which are pharmaceuticals, are having detrimental effects on aquatic species and possibly on human health and development.The consistent increase in the use of potent pharmaceuticals, driven by both drug development and our aging population, is creating a corresponding increase in the amount of pharmaceutical waste generated. Pharmaceutical waste is not one single waste stream, but many distinct waste streams that reflect the complexity and diversity of the chemicals that comprise pharmaceuticals. Pharmaceutical waste is potentially generated through a wide variety of activities in a health care facility, including but not limited to intravenous (IV) preparation, general compounding, spills/breakage, partially used vials, syringes, and IVs, discontinued, unused preparations, unused unit dose repacks, patients' personal medications and outdated pharmaceuticals. In hospitals, pharmaceutical waste is generally discarded down the drain or landfilled, except chemotherapy agents, which are often sent to a regulated medical waste incinerator. These practices were developed at a time when knowledge was not available about the potential adverse effects of introducing waste pharmaceuticals into the environment. Proper pharmaceutical waste management is a highly complex new frontier in environmental management for health care facilities. A hospital pharmacy generally stocks between 2,000 and 4,000 different items, each of which must be evaluated against state and federal hazardous waste regulations. Pharmacists and nurses generally do not receive training on hazardous waste management during their academic studies, and safety and environmental services managers may not be familiar with the active ingredients and formulations of pharmaceutical products. Frequently used pharmaceuticals, such as epinephrine, warfarin, and nine chemotherapeutic agents, are regulated as

hazardous waste under the Resource Conservation and Recovery Act (RCRA). Failure to comply with hazardous waste regulations by improperly managing and disposing of such waste can result in potentially serious violations and large penalties.

LINE OF ATTACK OF DRUGS TO WATER BODIES

Pharmaceutical pollution is an emerging concern worldwide. Drugs enter water bodies in many ways which include industrial dischargers, commercial animal feeding operations, surface applications of manure and bio solids and wastewater treatment plants that treat residential, commercial and industrial wastewater. Pharmaceuticals enter wastewater treatment plants from excretion by the human body and due to disposal of unused or expired medications down the toilet or drain. The drugs that we take are not entirely absorbed by our bodies and are excreted without being fully metabolized. Drug components leach out and seep into groundwater and find their way into local wastewater treatment plants. Hospitals and long-term care facilities annually flush millions of pounds of unused pills down the drain and account for the majority of pharmaceuticals entering municipal wastewater treatment plants. Drugs and cosmetics may contain mercury, selenium and other heavy metals. These persistent, bioaccumulative and toxic substances pollute the air, land and both surface water and groundwater. Drugs do not necessarily remain in the environment for long period of time, but continual input in a water body can cause the concentration to be relatively constant. This may lead to interference with growth and reproduction in water organisms. There have been several well-documented cases of endocrine-disrupting effects on aquatic animals due to drugs entering waterways (Fig. 2 & Fig. 3). Estrogens have caused male fish to become female. Antidepressants have caused lobsters to be more aggressive. Prozac has induced reproduction in shellfish. Even extremely diluted concentrations of drug residues harm the reproductive systems of fish, frogs and other aquatic species. Tadpoles have gone smaller by 40% in size when exposed to water from the treatment plant.

Fig. 1: Stream stressed by pharmaceutical pollution

The pollutants have ill effect on human health too. According to a report, researchers have found out that human cells fail to grow normally in the laboratory when exposed to trace concentrations of certain pharmaceuticals. Some drugs found in water have promoted antibiotic-resistant germs. When the bacteria is exposed to a drug, there are chances that bacteria will mutate in such a way that would render the drug ineffective .A survey in US has shown that 80 per cent samples from various waterways have been detected with one or more pharmaceuticals in low concentrations. Examples of medications found included acetaminophen, steroids, hormones, codeine, antibiotics, antimicrobials and ibuprofen. In India, according to a news source at Patancheru, water samples from a stream have shown presence of 21 different drugs, which ranged in purpose from hypertension , heart disease, chronic liver ailments, depression, gonorrhea to ulcers. The above alarming reports have created an opportunity for all health sectors involved in health care pharmaceutical developers and manufacturers, hospitals, individual physicians and all those involved in the health care system, law enforcement agencies, pharmacies, waste management agencies, consumers, environmental protection organizations, and governmental agencies to take action and reduce potential harm to the environment.

The recent increase in awareness of environmental issues is creating an opportunity for sectors involved in health care—pharmaceutical developers and manufacturers, hospitals, individual physicians and all those involved in the health care system, law enforcement agencies,

pharmacies, waste management agencies, consumers, environmental protection organizations, and governmental agencies—to take action and reduce potential harm.

Residential, commercial, and agricultural pharmaceuticals can follow two primary pathways to the environment:

- **Excretion**
  Human and livestock excretion of drugs and metabolites following consumption (which ultimately follows sewage, septic or surface runoff pathways to wastewater or to biosolids).
- **Direct Disposal**
  Disposal of unused pharmaceuticals to the septic tank, sewer or landfill.
  If disposed of or excreted to the sewer, pharmaceuticals are sent to wastewater treatment plants that offer primary, secondary or tertiary treatment levels. Regardless of the level of treatment, most conventional wastewater treatment cannot effectively eliminate pharmaceutical compounds. Landfill leachate can contain trace amounts of pharmaceuticals as well. Often this leachate is sent to the same wastewater treatment systems that receive residential wastewater. Pharmaceuticals have been detected in landfill leachate, so disposal of pharmaceuticals at engineered landfills may merely postpone pollution of surface water and ground water. As a result, incineration is currently the best method for destruction of unwanted pharmaceuticals (Fig. 4).

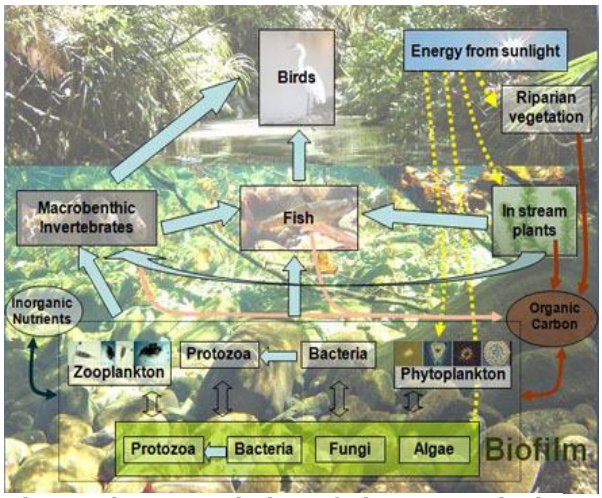

Fig. 2: Bioaccumulation of pharmaceuticals in aquatic organisms

Many cities, counties and states are struggling to prevent and remove pharmaceuticals in both wastewater and solid waste.

Protecting the integrity of our water resources is one of the most essential issues and Green Pharmacy provides a basis for putting our beliefs into action. This will have a positive effect of the health and vitality of our world. The purpose of Green Pharmacy is to reduce pharmaceutical pollution and provide safe disposal options for unwanted and expired medications. People rely heavily on pharmaceuticals in the current medical system. All of us are medication consumers at some point of time in our lives. A large variety of drugs including prescription drugs, over-the-counter medicines and veterinary medicines in varying concentrations have been found in various waterways. The environmental protection agency of US considers the presence of pharmaceuticals and personal care products in the environment as one of the most significant emerging threats of the 21st century. Pharmaceuticals and personal care products refers in general, to any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock. Pharmaceuticals and personal care products comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, and cosmetics. These products are found to be pseudo-persistent because they enter the environment faster than they can be removed. Hence arises the need for protecting the environment where Green Pharmacy can play an important role. Green Pharmacy tries to engage all sectors involved in the production, distribution, sales and consumption of medicines in environmentally preferable practices.

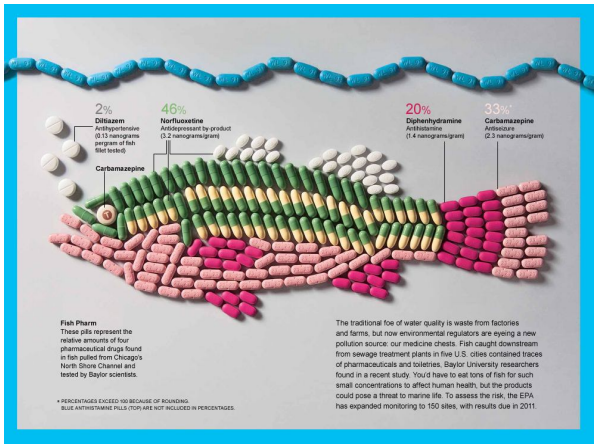

Fig. 3 Relative amount of 4 pharmaceutical drugs found in fish pulled from Chicago's North Shore Channel

The manufacturing sector should opt for innovative drug design that can improve delivery systems to require lower doses for efficacy. They can use recyclable materials for packaging or package size can be reduced to minimize the unused portion of prescriptions. Complete and direct information about proper disposal techniques can be added to packaging. The pharmaceutical industry can provide more information directly to physicians. They can grade their medicines for persistence, bioaccumulation, and toxicity. Pharmaceutical industry can provide funding for the proper disposal of unused or expired medicines. This would help in promoting advanced recycling strategies. Pharmaceutical industry could also devote a portion of its huge advertising campaign to educate both physicians and consumers about the environmental and health issues associated with drug products and cosmetics. For manufacturers, “reverse distribution,” which allows pharmacists to return unsold drugs back to the manufacturer, could be enlarged to include unused medication and expired medication. Hospitals for a healthy environment should enhance their focus on hazardous waste and pharmaceutical waste and develop best management practices for disposing pharmaceutical waste .Some of the pharmaceuticals may be passed into the sewer line. This includes solutions in IV bags containing only saline, lactate or nutrients such as glucose, vitamins, salts and other electrolytes. Hazardous waste may be sent to hazardous waste incineration agencies. Non-hazardous drugs may be segregated into a non-red, non-yellow container, such as beige or white with blue label “non-hazardous pharmaceutical waste–incinerate only” or may be disposed at a regulated medical waste or municipal incinerator that is permitted to accept non-hazardous pharmaceutical waste.

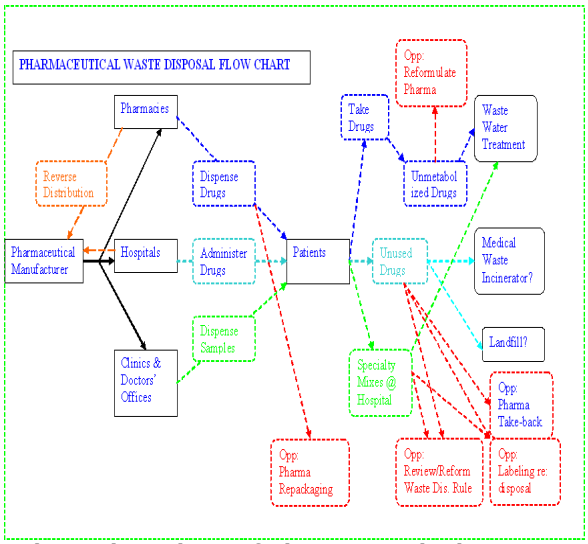

Fig. 4 Flow chart of pharmaceutical waste disposal

Physicians, veterinarians and dentists should also participate in the solution. The time when a doctor is prescribing a medication is an ideal moment to educate patients about proper disposal habits. The physician should not prescribe more medication than required. They can prescribe starter packs and refill packs. Environmental impact of the medications should be considered when prescribing. Pharmacists can keep a record of patient’s medication consumption and regularly review them. He can learn which drugs have the highest eco-toxicity and can educate patients, consumers, and colleagues about the importance of proper disposal of pharmaceutical waste. Smart Disposal Campaign Programs (SDCP) have been started by the American Pharmacist Association to raise awareness amongst consumers about potential environmental and societal impacts of improperly disposed off medicines. It helps to promote environmental friendly consumer behavior through different communication networks

Pharmacies should serve as take-back sites for proper pharmaceutical disposal. They can have recycle bins, which allow consumers to bring their unused and expired medicines back whenever they shop. As certain medications find their way into an illicit drug market, law enforcement agencies can participate in take-back programs to ensure that these substances are handled only by a pharmacist or a physician. Such take back pharmacies have been established in many countries. All prescription drugs except controlled drugs , all over the counter drugs, medication samples, vitamins and supplements, medicated ointments, lotions, creams, oils, liquid medicines in leak proof containers, homeopathic remedies, pet medications, suppositories etc are easily accepted at the take back pharmacy. However, controlled prescriptions like narcotics, valium and codeine are not taken back. Further, IV bags, bloody and infectious waste, personal care products, empty containers, thermometers , hydrogen peroxide ,aerosol cans, inhalers are not accepted by the pharmacies.The US Environmental Protection Agency’s (EPA) Resource Conservation and Recovery Act (RCRA) regulate the disposal of solid waste and define various categories of waste. The EPA defines solid waste as garbage, refuse, sludge or other discarded material. RCRA hazardous wastes are a subcategory of solid waste. “F” List Wastes are waste produced during common industrial or manufacturing processes such as degreasing. Examples

include solvents like trichloroethylene and carbon tetrachloride. “K” List Wastes, or source-specific, wastes are waste streams generated by specific industrial sectors, such as ink formulators, petroleum refineries and producers of veterinary pharmaceuticals, explosives, pesticides and inorganic pigments. “P” and “U” List Wastes involve discarded commercial chemical products, or unused pure or commercial-grade chemical products. Chemicals on the "P" list are fatal or irreversibly damaging to humans and animals at low doses. Those on the "U" list pose a hazard to human or environment health when improperly managed. Compounds appearing on these lists include pesticides and pharmaceuticals. Characteristic Wastes are not on the lists above but qualify as hazardous if they exhibit the characteristics of ignitability, corrosivity, reactivity or toxicity. U.S. EPA has been involved in giving grants to hospitals to develop best management practices for disposing pharmaceutical waste. US EPA maintains an active program called the contaminant candidate list to identify the contaminants in public drinking water. Such practices should be encouraged worldwide.

Municipal water agencies should develop policies that maintain proper water quality. Strict regulations should be proposed for preventing hospitals from disposing medicines directly into the municipal water system. Environmental organizations should support take-back programs and follow approaches to recycle drugs and spread awareness and educate the masses. Each of us has a responsibility to keep our environment clean when discarding unused medication. The consumer should ensure that they protect children and pets from potentially negative effects of drugs while discarding. Consumers should not throw the medicines down the toilet or in the garbage, but take the drugs to a take back site or hazardous waste facility. They should buy smaller containers of medicines. Preference should be given to products with recyclable packaging. They can ask their doctor about environmental impact of their medication and whether a more sustainable alternative exists. They should always choose the smallest prescription amount or refill option unless the medication is for a chronic condition. Unused medications may be donated to nonprofit organizations that redistribute medicines to charitable organizations in non-industrial countries that need basic medications. The patients should keep the medication in their original containers, fill the medicine return form and bring the medication to the take back pharmacy. They should remove all personal information from all medication containers before bringing it to take back sites. Moreover, in order to reduce pharmaceutical contamination in drinking water, the consumers should take all necessary measures to keep water sources clean.

ECOPHARMACOLOGY

Ecopharmacology concerns the entry of chemicals or drugs into the environment through any route and at any concentration disturbing the balance of ecology (ecosystem), as a consequence. Ecopharmacology is a broad term that includes studies of “PPCPs” irrespective of doses and route of entry into environment. Pharmacceutical residues may reach the environment by a number of different routes. It is generally assumed (albeit hardly verified) that the production of pharmaceuticals in industrialised countries is well controlled and unharmful to the environment, due to the local legal restrictions usually required to permit production. However, a substantial fraction of the global production of pharmaceuticals takes place in low-cost production countries like India and China. Recent reports from India demonstrate that such production sites may emit very large quantities of e.g. antibiotics, yielding levels of the drugs in local surface waters higher than those found in the blood of patients under treatment. The major route for pharmaceutical residues to reach the aquatic environment is most probably by excretion from patients undergoing pharma treatment. Since many pharmaceutical substances are not metabolized in the body they may be excreted in biologically active form, usually via the urine. Furthermore, many pharmaceutical substances are not fully taken up from the intestine (following oral administration in patients) into their blood stream. The fraction not taken up into the blood stream will remain in the gut and eventually be excreted via the faeces. Hence, both urine and faeces from treated patients contain pharmaceutical residues. An additional source to environmental pollution with pharmaceuticals is improper disposal of unused or expired drug residues. In European countries take-back systems for such residues are usually in place (although not always utilized to full extent) while in e.g. the US only voluntary initiatives on a local basis exist. Proper destruction of pharma residues should yield rest products without any pharmaceutical or ecotoxic activity. Furthermore, the residues should not act as components in the environmental formation of new such products. Incineration at a high temperature (>1000 degrees Celsius) is

considered to fulfil the requirements, but even following such incineration residual ashes from the incineration should be properly taken care of. Pharmaceuticals used in veterinary medicine, or as additives to animal food, pose a different problem, since they are excreted into soil or possibly open surface waters. It is wellknown that such excretions may affect terrestrial organisms directly, leading to extinction of exposed species (e.g. dung-beetles). Lipid-soluble pharma residues from veterinary use may bind strongly to soil particles, with little tendency to leak out to ground water or to local surface waters. More water-soluble residues may be washed out with rain or melting snow and reach both ground water and surface water streams.

CONCLUSION

Green Pharmacy aims at zero waste and offers an opportunity for social action that will greatly benefit our environment at all levels of our society. It requires consumers not to dispose of any medication down the toilet or in the trash, to purchase drugs in small amounts, limiting expired medications, use medications with low environmental impact, dispose off unused or unwanted medications at take-back sites only. Unused and unexpired medications can be donated to non-profit organizations that redistribute medications. Manufacturers should design drugs that are more ecologically sensitive and medicines that biodegrade more quickly and yield end products that are less harmful. The pharmaceutical industry could also devote a portion of its huge advertising campaign to educate both physicians and consumers about the environmental and health issues. Hospitals should develop methods for proper disposal of waste. Physicians, veterinarians and dentists should also participate in the solution. The time when a doctor is prescribing a medication is an ideal moment to educate patients about proper disposal. Pharmacies should serve as take-back sites for proper pharmaceutical disposal. They can have recycle bins, which allow consumers to bring their unused/expired medicines back whenever they shop. Our contribution towards safe and healthy environment by adopting Green Pharmacy can prove to be a powerful approach that provides a comprehensive solution to an issue which has the potential to affect much of life on Earth.

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