

# Pharmaceutical waste and innovative green technologies for its management

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## Introduction

Pharmaceutical waste is defined as waste that consists of/contains pharmaceutical products, including cytostatic drugs and other medicines, which are returned from the department where they had been prepared, and they are expired or unusable for any other reason, also including containers and other forms of packaging contaminated from/containing pharmaceuticals (Official Gazette of Republic of Macedonia, 2007).

There is a clear distinction between pharmaceutical waste generated by the industry and household leftover medicines.

In this article, we will focus on industrial pharmaceutical waste and review the key points of proper ways to dispose of it in compliance with green technology.

## Materials and methods

For the purpose of this paper, various search engines were used for research of literature, such as PubMed, Science Direct and Google Scholar. Using keywords such as “green pharmaceuticals”, “pharmaceutical waste treatment” and “hazardous waste”, many key articles were found, and some of them were used and cited in this review.

## Results and discussion

### *Hazardous and non-hazardous waste*

Hazardous waste can be defined as having properties that make it dangerous, or capable of leaving a harmful effect on the environment and on human health. This type of waste may come in different forms, such as liquids,

solids, gases and sludge, which is why there are many different ways to dispose of it, such as through biological, physical, thermal and chemical treatment. With biological treatment, the waste is mixed with the surface soil along with microbes to metabolize the waste, such as land farming. Chemical treatment includes the processes of ion exchange, precipitation, reduction or oxidation. Thermal treatment, which we will discuss later in this article, is done with incineration. Physical treatment consists of evaporation, filtration or sedimentation (Nathanson, 2023).

On the other hand, non-hazardous waste causes no direct harm to human health or the environment. However, while it is considered as not immediately toxic, proper disposal is still necessary (Pepin et al., 2014).

In pharmaceutical technology, non-hazardous waste mostly consists of expired over-the-counter drugs; packaging materials such as cardboard boxes, blister packs and plastic containers, as well as disposable materials including masks, gloves, gowns etc. Some of this waste can be recycled, or reused, making it something to consider in the path to greener technology.

### *Pharmaceutical waste treatment in N.Macedonia compared to EU legislation*

Disposing of pharmaceutical waste in N. Macedonia is done by an external company which is contracted by the pharmaceutical plant, previously licensed by The Medicines and Medical Devices Agency of the Republic of Macedonia (MALMED). The companies dispose of the hazardous waste by incineration in installations designed for burning of hazardous waste.

Expired or unused cytotoxic drugs and cytostatics are disposed of by incineration at up to 1200°C followed by cleaning of the emitted gas with special equipment, or by

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chemical degradation which transforms cytotoxins in non-toxic compounds. When these methods are not available, processes called inertization and encapsulation are used as a last resort.

Encapsulation includes filling containers with pharmaceutical waste, adding an immobilization agent and sealing the containers.

Inertization is a variant of encapsulation and involves previous removing of the packaging material from the product. After adding water, cement and lime until a homogenous mass is formed, the mass is deposited in landfills (Kochubovski, 2015).

Macedonian legislation closely follows the EU legislation, which establishes a waste hierarchy consisting of prevention, preparing for reuse, recycling, other recovery (e.g. energy recovery) and disposal of the waste. According to the Directive 2008/98/EC implemented in countries of the EU, incineration is still the main disposal operation, not much different than N. Macedonia, although this directive is incorporated differently by each country of the Union. Some of them have much more modern incineration plants, therefore emitting less harmful gasses as by-products, or even using the energy created in this process as an alternate fuel source (Fan et al., 2021). For example, in Austria, heat and electricity generated by incinerators is proven to help reduce greenhouse gas emissions, making waste management greener and more sustainable (Herczeg, 2013).

#### *Green technologies for pharmaceutical waste treatment*

The main focus of some pharmaceutical companies striving to be greener in drug design is creating drugs which degrade naturally in the environment. This approach of building biodegradability into lead compounds early on in the drug discovery process is known as 'benign by design'.

An example of that is a new product which is similar to an older birth control pill, which uses natural estrogens paired with biodegradable progesterone. This could potentially reduce the existing negative effects such as reproductive system disorders in fish caused by estrogens.

Carbamazepine is a medicinal product that can undergo biodegradation using *Streptomyces spp.* as bioremediation agents.

Another example is valproic acid, an antiepileptic drug currently in use that can undergo rapid photo degradation during wastewater treatment (Lubick, 2008). The common wastewater treatments have proven not efficient enough in eliminating medicines. As a result, improvements have been made with using ultrafiltration, reversed osmosis, ozonation and the use of activated carbon (Toma et al., 2018).

## Conclusion

This issue is widely discussed in more developed European countries, and the matter of preserving the environment is being brought to the attention of the public more intensely in recent years. Even so, in the last couple of decades, insufficient care for the environment has done a significant amount of harm, which has brought on climate changes and the excessive waste of natural resources.

In N.Macedonia, although the eco-conscience of the people is not as advanced, there are various non-governmental organizations fighting to solve this problem.

Even though N.Macedonia strives to be equal to EU countries' legislative, improper incineration of hazardous waste and the excessive use of landfills shows that we still have a long way to go in the process of developing greener and more innovative pharmaceutical technologies for waste treatment.

After researching different regulations and technologies for the purpose of this article, we can conclude that investing in a more modern incinerator, as well as limiting the use of landfills is the best way to start heading towards a cleaner environment.

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