

Environmental Impact of Treatment of Pharmaceutical Packaging Materials

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ABSTRACT

In this paper, LCA method is used to explore how a certain material or a specific drug packaging waste enters the environment after different garbage disposal methods, and what impact it has on the population and community after entering the environment. Pharmaceutical packaging materials are unavoidable in human life a class of materials, the international market for product packaging increasingly strict environmental requirements, China's drug manufacturers and pharmaceutical packaging industry put forward more severe requirements, in such a situation, the drug packaging to achieve effective recycling and pollution prevention is China's drug manufacturers must face the problem. The domestic research direction is mainly LCA, and the development and application of green packaging materials and new pharmaceutical packaging materials. The international research also includes carbon footprint estimation and LCM of pharmaceutical packaging, as well as innovation in recycling technology.

KEYWORDS

Pharmaceutical Packaging Materials, LCA Method, Waste Disposal Method.

1. INTRODUCTION

At present, as one of the important packaging materials of powders, polyethylene terephthalate (PET) medicine bottles have extremely high chemical stability and cannot be fully degraded under natural conditions, resulting in extremely serious environmental pollution [1]. Defruyt said that only 2% of plastic packaging materials globally are recycled, and the rest is either incinerated or ends up in landfills, water bodies and other environments [2]. According to statistics, as of 2017, China's bottle-grade PET production exceeded 6.79 million tons, while the recovery rate was less than 10% [3], a considerable part of which came from the field of pharmaceutical packaging materials, and the serious environmental pollution and ecological damage caused by these difficult to deal with plastic packaging materials cannot be ignored.

The combination of eco-design techniques with the pre-project of the product/packaging can reduce the potential environmental impact. The use of this type of technology can extend the life of product packaging. In terms of environmental sustainability, further research and development into biodegradable packaging is also a good prospect in the near future [3,4].

The "Interim Management Measures for the Recycling of Packaging Resources" has been implemented nationwide since January 1, 1999, along with the national standard GB/ T16716-1996 "Treatment and Utilization of Packaging waste -- General Rules". The measures clarify the packaging terminology and packaging classification, and stipulate the management principles for the recycling and utilization of packaging waste such as paper, wood, plastic, metal and glass: Saving principle,

safety principle, anti-counterfeiting, operating principles, but also provides for its recycling channels, recycling methods, grading principles, storage and transportation, recycling varieties, reuse methods, reuse technical requirements, test methods, inspection rules, packaging waste treatment and reward and punishment principles.

The packaging of insulin injection was selected as the research object. In addition to the common paper packaging, the needle for insulin pen was composed of needle tube, sleeve, inner needle sleeve, outer needle sleeve, protective sheet and lubricant. The material of each part is: needle tube: stainless steel, grade ISO 962616; Tube: polyethylene terephthalate -1, 4-cyclohexane dimethanol ester (PCTG); Inner sleeve, outer sleeve: polyethylene; Protective sheet: polyethylene terephthalate; Lubricant: silicone oil (MDX4-4159 50%) Insulin pen with a needle for primary - secondary use This medicine is usually contained in a composite package containing five main medicine packages. But the specifics can vary by manufacturer and product type. Insulin injections are usually simply disposed of after use and thrown directly into the garbage bin with household waste, so it is disposed of in the same way as household waste, which will be landfill, composted and incinerated.

2. THE EFFECT OF BURNING OF DRUG PACKAGING MATERIALS

2.1. Paper shell

The paper shell in the pharmaceutical packaging is mainly composed of cellulose, which produces carbon dioxide and water when burned, because cellulose is mainly composed of carbon, hydrogen and oxygen. If the combustion is incomplete, it may also release toxic gases such as carbon monoxide.

2.2. Plastics

Polyethylene terephthalate (PCTG) and cyclohexane dimethyl ester are common plastic materials that produce carbon dioxide, water vapor, and some harmful gases such as carbon monoxide, sulfur dioxide, and benzene when burned. In addition to these common gases, some volatile organic compounds (VOCs) and fine particulate matter (PM_{2.5}) are also produced. These VOCs are a class of chemicals, such as benzene, formaldehyde, etc., that are released into the air during combustion. These compounds can be hazardous to human health, for example, long-term exposure to certain VOCs can cause respiratory problems. At the same time, burning plastic also produces fine particulate matter, which refers to particles smaller than 2.5 microns in diameter. These fine particles can stay suspended in the air for long periods of time and can penetrate deep into the respiratory tract and lungs of people. Long-term exposure to fine particles can lead to respiratory diseases, cardiovascular disease and other health problems. For other animals and populations besides humans, harmful gases and particles from the burning of plastics can also have a negative impact on wildlife and ecosystems in a number of ways. Wildlife such as birds, mammals and aquatic life may be affected by breathing these toxic gases and particulates. Long-term exposure can lead to respiratory problems, including breathing difficulties, lung infections, and more.

Certain toxic gases and particulate matter such as NO_x and VOCs may negatively affect the growth, reproduction and behavior of wildlife, thus interfering with the balance of the ecosystem. For example, it affects the migration behavior of birds or damages the growing environment of plants. Some wild animals may accidentally eat food containing microplastics, which can lead to digestive tract obstruction, poisoning or even death. Microplastics can also be passed up the food chain, affecting higher-level carnivores. In addition, waste from plastic combustion can accumulate in wildlife habitats, affecting their living space and lifestyle. When the toxic gases released by the burning of plastics enter the water, the water quality may deteriorate, and the particles and organic matter generated by the burning of plastics may be suspended in the water, reducing the transparency of the water. These particles can make the water cloudy and affect the ability of light to penetrate the water body, thus affecting the growth and development of underwater ecosystems. Degradation of organic

material and deposition of particulate matter may lead to a decrease in dissolved oxygen levels in the water. Dissolved oxygen is necessary for the survival and reproduction of organisms in the water, and when the dissolved oxygen content drops to a certain extent, it may lead to asphyxiation or death of aquatic organisms. The chemicals released by the burning of plastics may alter the chemical composition of the water body, such as changing the acidity and alkalinity of the water or increasing the content of harmful substances. These changes may negatively affect the physiological functions of aquatic organisms and the stability of ecosystems.

2.3. Metals

ISO 9626 is a standard specification for stainless steel needles, which are commonly used to make injection needles in medical devices. Stainless steel is usually burned at high temperatures, resulting in combustion products that are primarily oxides, such as iron oxide and chromium oxide. This combustion usually does not produce harmful gases, but some toxic metal gases may be produced in the case of hypoxia. When stainless steel is burned in an oxygen-deprived environment, its main components, iron and chromium, may produce toxic metal gases. In the absence of sufficient oxygen, iron and chromium may not be fully oxidized to oxides, resulting in the production of some harmful gases, such as carbon monoxide and nitrous oxide. These gases are potentially harmful to the human respiratory system and health. Carbon monoxide in particular is a colorless, odorless and toxic gas that has an affinity for human hemoglobin and can cause poisoning and even asphyxiation. The toxic metallic gases produced by the burning of stainless steel may also have an impact on other living things. Once released into the environment, these gases may negatively affect surrounding plants, animals, and microorganisms. For example, carbon monoxide and nitrous oxide may affect plant growth and photosynthesis, and may also be toxic for some animals and microorganisms. In addition, gases from the burning of stainless steel may also affect the air quality in the environment, which in turn affects the stability and health of the entire ecosystem. When stainless steel is burned, harmful gases such as carbon monoxide and nitrous oxide are released into the atmosphere. Carbon monoxide is a colorless, odorless and toxic gas that combines with hemoglobin to form carbon monoxide hemoglobin, resulting in reduced blood's ability to carry oxygen, potentially triggering hypoxia, poisoning and even death. Nitrous oxide, another common air pollutant, is involved in the formation of ozone. It reacts with oxygen and ozone to produce nitrites and nitrates, which in turn form nitric acid fog and fine particulate matter, causing haze and air pollution. In addition, the combustion of stainless steel may also release other volatile organic compounds, such as benzene. These compounds are also part of the air pollutants, they will react with nitrogen oxides, photochemicals to produce ozone, thereby increasing the level of air pollution.

3. EFFECTS OF COMPOSTING OF PHARMACEUTICAL PACKAGING MATERIALS

3.1. Plastic

Polyethylene (PE) : Polyethylene is a common plastic that is not usually degraded by microorganisms. Conventional polyethylene materials are often difficult to degrade by microorganisms due to their molecular structure stability and chemical inertness. As a result, when polyethylene is present in compost, it breaks down very slowly and can take hundreds of years or more to fully degrade. The presence of polyethylene in compost can lead to plastic pollution of the soil. Plastic debris can seep into the soil and form plastic particles or microplastics, which not only contaminates the soil itself, but may also adversely affect microorganisms, plant roots, and soil animals in the soil. The accumulation of plastic in the soil may impede gas exchange and water penetration in the soil, affecting the soil's aeration and water permeability. This affects the growth and activity of microorganisms in the soil, which in turn affects the fertility and nutrient cycling of the soil. The

presence of plastics in the compost may damage the structure of the soil, resulting in less compactness of soil particles and less aeration, thus affecting the soil's porosity and water retention ability. The presence of plastic pollution in the soil can have an adverse effect on soil biodiversity. The presence of plastic debris can disrupt the ecosystem balance in the soil, affecting the survival and reproduction of soil microorganisms, worms and other organisms. PCTG is a more biodegradable plastic compared to conventional polyethylene. Under the right composting conditions, such as high temperature and humidity, PCTG can be broken down by microorganisms and eventually converted into carbon dioxide, water, and organic matter. Therefore, PCTG may have less negative impact on the environment during the composting process because it can be degraded into harmless substances in a shorter period of time.

3.2. Metals

The ISO 9626 standard specifies requirements for medical stainless steel needle bobbin materials. Because stainless steel itself is highly resistant to corrosion and chemically inert, it is generally the case that stainless steel materials do not produce significant chemical changes or decomposition in compost. However, under extreme conditions, such as high temperatures, high humidity, and the presence of specific microbial activity, stainless steel may experience trace amounts of corrosion or oxidation.

If stainless steel material enters the compost, its environmental and biological effects are likely to be minimal. Stainless steel is often considered to be an environmentally friendly material because it is mainly composed of metallic elements such as iron, chromium, nickel, which usually have a small impact on the environment. However, if the stainless steel material contains other added elements or organic coatings, this can have an adverse impact on the environment.

3.3. Silicone oil

When silicone oil enters the soil, it may adversely affect the living environment of soil microorganisms. Soil microorganisms are a very important part of the soil ecosystem, and they are involved in key processes such as decomposition of organic matter and nutrient cycling. The presence of silicone oil may affect the growth and metabolic activities of these microorganisms, thus weakening the biological activity of the soil.

In addition, silicone oil may alter the physical properties of the soil, including aeration and water permeability. The presence of silicone oil may cause the gaps between soil particles to become caulked, thus affecting soil aeration and making it difficult for the soil to provide enough oxygen to feed soil microorganisms and plant roots. At the same time, silicone oil may form a film on the surface of soil particles that prevents water penetration and drainage, thus affecting the water permeability of the soil and resulting in water retention or poor drainage.

Finally, the presence of silicone oil may also affect the growth and development of plants in the soil to a certain extent. Due to the influence of soil microorganisms and the change of soil physical properties, plants may be limited by root growth, resulting in the weakened ability of plants to absorb nutrients and water, thus affecting the growth and development of plants.

If the silicone oil contains harmful chemicals, its impact on soil biodiversity and ecosystems may be even more severe. These harmful chemicals may include heavy metals, organic compounds, or other substances that are toxic to living things. When these harmful substances enter the soil, they may cause direct or indirect harm to the biodiversity in the soil.

Harmful chemicals may cause certain microbial populations in the soil to be severely affected or die, resulting in changes in the structure of the soil microbial community. Some microorganisms may be resistant to these chemicals, while others may be reduced or eliminated by toxic effects, thus affecting the diversity and function of microorganisms in the soil.

In addition, harmful chemicals may spread through the biological chain in the soil, affecting other organisms in the soil, including plants, soil animals, and other microorganisms. This can cause the number of certain species in the ecosystem to decrease or disappear, upsetting the balance of the ecosystem. For example, if certain soil animals in the soil are affected, it may affect the structure and aeration of the soil, which in turn affects the root growth and water uptake of plants.

4. EFFECTS OF LANDFILLS FOR DRUG PACKAGING MATERIALS

4.1. Plastic

PCTG is usually a biological substance, which is difficult to degrade in the natural environment, especially in landfills. This may lead to the long-term existence of PCTG in landfills, which is not easy to decompose. Although PCTG itself is relatively stable, climatic conditions and pressures in landfills can cause it to leak into the surrounding soil and groundwater, causing pollution to the environment.

The amount of precipitation in the area where the landfill site is located may affect leakage from the landfill. Large amounts of precipitation may increase the water level inside the landfill, dissolving hazardous materials in the waste and leaking into the soil and groundwater through percolation. Changes in air temperature may affect the rate of decomposition and chemical reactions of waste in a landfill. Higher temperatures may promote the decomposition of organic material, releasing harmful gases or dissolving into the water.

Waste in a landfill may be subject to pressure from compaction above, resulting in increased soil compactness inside the landfill. This may allow fewer gaps between the waste, thereby reducing the soil's resistance to leakage and increasing the likelihood of hazardous materials leaking into the soil and groundwater. Fluid accumulation in the landfill can have an impact on the stability of the landfill, especially the accumulation of waste fluid at the bottom of the landfill can increase the risk of groundwater leakage.

PE is a type of plastic that breaks down very slowly and may even take hundreds of years to fully degrade. Therefore, landfilling PE can cause plastic to remain in landfills for a long time. PE in landfills may break down and produce tiny particles, which may seep through the soil into groundwater and pollute the water quality. In addition, PE may also enter groundwater directly through seepage from the soil surface.

4.2. Metals

Stainless steel is a corrosion-resistant material that may persist for a long time in landfills without breaking down easily. This can cause stainless steel to accumulate in landfills, taking up landfill space, and may become a major component of the landfill over time. Stainless steel is often a high-value material, and landfilling stainless steel can result in a waste of resources. In landfills, stainless steel cannot be recycled, resulting in waste and loss of resources.

4.3. Silicone oil

Silicone oil in a landfill may be subjected to pressure from waste above, or due to percolation at the bottom of the landfill, resulting in leakage of silicone oil into the surrounding soil and groundwater. Silicone oil is at a higher risk of leaking, especially if the landfill is poorly managed or if the landfill infrastructure is broken. Once the silicone oil is in the groundwater, it may migrate along the groundwater stream, further impacting the wider groundwater resource. Silicone oil may react with other chemicals in landfills or be subject to dissolution by water, causing it to dissolve into water solubles. These dissolves may be more easily transmitted through groundwater flows to the

surrounding groundwater, increasing the risk of groundwater contamination with silicone oil. Silicone oils may contain harmful substances such as volatile organic compounds or other chemical components that may negatively affect water quality once they enter the groundwater. They may contaminate groundwater and render it unfit for drinking or other uses, creating hazards for nearby residents and the environment.

5. CLOSING REMARKS

Understanding the performance of various pharmaceutical packaging materials and the consequences of different pharmaceutical packaging materials in different garbage disposal methods is not only related to human life and health, but also affects almost every population and community. For sustainable development in the future, priority must be given to more environmentally friendly packaging materials and waste disposal technologies. The use of degradable or recyclable materials is encouraged to reduce the burden on the environment. At the same time, the support of relevant policies and legislation is essential to guide industry practices, raise public awareness and drive innovation in waste management technologies.

In conclusion, through this study, we highlight the importance of implementing effective pharmaceutical packaging waste management strategies that take into account environmental, technological and policy factors. It is hoped that this paper will provide valuable information and inspiration for researchers, policy makers and environmental protection advocates in related fields to work together to contribute to a sustainable future for the planet.

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