Erne Varga [26]
Mera d.o.o. Zrenjanin/ Serbia

RECYCLING PET PACKAGING FOR THE PURPOSE OF SUSTAINABLE DEVELOPMENT AND ECOLOGY

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Abstract:
This work is a leap from theory to practice and vice versa. This topic of the paper is the analysis of the situation, as well as the increasingly intensive need for recycling PET-packaging, as waste generated after used. The work can also serve as a proposal and handling of the generated waste, due to the increasing use of PET-material for the purpose of packing, for various types of products. The mentioned topic deserves enough entrepreneurship, engeneering, management, education in the context of ecology, as well as the adoption of new legal acts.

Keywords: *Engineering, Management, Education, PET packaging, Recycling, Ecology, Activities, New legal acts.*

1. Introduction and topic concept

In times of major issues arising from the increasing amount of PET packaging waste in our environment, along with challenges in its disposal, an ecological approach to solving this problem becomes both necessary and inevitable. This paper focuses on the essential and indispensable recycling of PET packaging, integrating both ecological and economic aspects into a viable and profitable whole, serving as an incentive for significantly improving environmental protection.

The concept presented in this paper contributes to solving this issue and offers concrete solutions for handling PET packaging waste after use.

Picture 1. *Emblem of the Association of Packaging Waste Recyclers of Serbia [1]* *

[26] erne.varga59@gmail.com, ORCiD: 0009-0001-8958-5791
* *Translation of the text on the picture: SERBIAN ASSOCIATION OF RESYCLERS OF PACKAGING WASTE*

2. General information about PET material and packaging

The role of PET materials in the packaging system/process: PET (polyethylene terephthalate) belongs to the category of synthetic (polymeric, plastic) materials. It is a result of modern innovations in organic chemistry. PET is essentially a type of polyester with enhanced properties, a pure hydrocarbon (containing only carbon, oxygen, and hydrogen). As a compound, it is highly inert and, according to research, is considered non-toxic for packaging purposes. It is produced through a chemical process from petroleum or natural gas as a condensation polymer, synthesized from one or more diacids (dicarboxylic acids) with one or more glycols.

Health and Technological aspects of PET packaging: From a health point of view, PET has excellent inertness and acts as a barrier against a wide range of potential contaminants (e.g., alcohol, chemicals, acids, alkalis, essential oils, mineral oils, and vegetable oils), without forming harmful, toxic, or carcinogenic compounds. Research indicates that PET is considered a safe packaging material for health.

Ecological Perspective of PET packaging: From an environmental standpoint, PET offers advantages because it does not decompose, even after a hundred years in landfills, and does not pollute the surroundings under normal conditions. However, since PET is derived from petroleum, there is still insufficient research on its long-term environmental impact after decomposition over a century. It is reasonably assumed that this could have negative effects on future generations. Nevertheless, PET is always recyclable, making its ecological impact significant. Because of this, the "full economic justification of its application" is achieved by closing the lifecycle of PET packaging through recycling, for which PET is highly suitable due to its properties.

Applications of PET in Packaging: Thanks to its performance and quality, PET has become the leading packaging material in both the chemical and food industries, especially for bottling and packaging liquids and beverages.

Since the end of the last century (1995/96), the bottling and packaging of food-grade liquids (e.g. mineral water, soft drinks, and juices), as well as other liquids for market distribution, have been almost exclusively done using PET containers (bottles or large dispensers).

PET as a raw material is not produced in Serbia; instead, it is imported in granular form for manufacturing purposes.

Elements of used PET waste that appear during the recycling process are shown in the following pictures:

Picture 2.

Picure 3.

Appearance of PET granules and of PET preforms [1]

Picture 4. *Examples of PET bottles made [1]*

Picture 5. *Types of plastic caps for bottles - made of polyethylene [2]*

Picture 6. *An example of the position of a label on a PET bottle [3]* *

3. ENVIRONMENTAL ASPECTS IN THE PACKAGING SYSTEM

In every modern economic or industrial sector that involves packaging processes, the issue of packaging waste inevitably arises. This is an unavoidable byproduct of the processing industry in general. The larger the production capacity (which is economically justified and desirable), the greater the amount of packaging and other waste generated. Consequently, the need for proper waste management becomes imperative.

* *Translation of the text on the picture: Label position on the bottle*

Impact and sustainability studies clearly indicate the growing problem of packaging waste accumulation-especially used PET packaging-within our environment, posing significant challenges, particularly in waterways.

These well-documented facts, which are evident to all, highlight that only a systematic approach to recycling can effectively address the problem of waste congestion, both for packaging waste in general and PET packaging waste specifically.

▪ Many authors deal with this issue and there are ideas for good ecological and production practices (which are currently in the domain of theory, so they are insufficient). In the context of socially responsible organization, concrete practical solutions, actions and deeds are needed.

This means that a "Waste Management System" and a "Recycling System" should be formally defined and incorporated into law, making it a mandatory requirement for all stakeholders-from distributors to consumers.

Picture 7. and 8. *Examples for the collection and sorting of waste materials [1]* [*]

4. RECYCLING AS AN ECOLOGICAL AND ECONOMIC SOLUTION FOR WASTE PET PACKAGING

Solving this issue requires engineering, and management (including education and awareness of key concepts) to ensure necessary recycling and promote ecology through concrete actions.

[*] *Translation of the text on the picture/on the buckets: GLASS – METAL – PAPER ...*

To successfully integrate both ecological and economic aspects-ensuring a profitable recycling system-it is essential to establish a "Reverse Supply Chain Management" for the PET packaging waste market. This concept mirrors the standard supply chain for goods but operates in the opposite direction, involving reverse material flow and financial transactions, supported by competitive incentive pricing.

Key facts (axioms) for implementing this approach include:

"Used PET packaging is waste, but not garbage or trash" - it should not be discarded. Instead, it is a valuable recyclable material (by-product) that can undergo an unlimited number of recycling cycles while retaining its functional properties and market value.

Recycling involves grinding PET packaging into flakes, which can then be mixed (10-20 %) with raw materials to manufacture various technical plastic materials.

In product cost calculations, the packaging cost share is well-defined, enabling a reverse flow of materials and pricing adjustments.

By merging ecological and economic factors within the packaging system, recycling becomes both justifiable and attractive, encouraging participation from manufacturers to consumers.

Currently, PET is primarily used as non-returnable, single-use packaging, which mostly ends up in landfills or waterways-a critical mistake with serious consequences. Even after its primary use, PET remains a valuable raw material with market value and profit potential. Therefore, used PET packaging should be made returnable, with financial incentives to encourage consumer participation (even through regulatory enforcement if necessary).

Collecting used PET packaging should be facilitated with a **pet-o-mat** recycling device (easily installable at retail locations), issuing tokens/receipts for each returned unit. Consumers can redeem these tokens/receipts for discounts on future purchases, making participation financially attractive.

A successful systematic PET packaging recycling model is illustrated in the following picture:

Picture 9. *PET Packaging Lifecycle [1]* [*]

Conclusion

A systematic and well-structured PET packaging recycling process offers environmental benefits (protecting nature), economic advantages (turning waste into profit instead of disposal), and job creation within the recycling chain. Additionally, it reduces import costs of PET raw materials, making recycling a financially attractive opportunity for all stakeholders in the packaging industry.

The most effective recycling system requires mandatory regulations, meaning the introduction of new legal acts and policies governing PET waste management. These regulations should obligate all market participants (producers, distributors, and retailers) to buy back an amount of used PET packaging equivalent to what they put on the market, whether by unit count or weight. Compliance should be verified through invoices, delivery notes, or fiscal receipts along the supply chain.

[*] *Translation of the text on the picture/A legend: 1-Crude oil; 2-Producer of granules and preforms; 3-Manufacturer of products that are filled in PET packaging; 4-Shops; 5-The consumer; 6-Gargabe can-regular; 7-Recycled PET bin; 8-Recycling center; 9-A factory for the production of new products.*

The collection of used PET packaging units is recommended to be carried out with the so-called Pet-o-mat devices (which can be easly installed at any point of sale), with the issuance of token/receipt for each returnable packaging unit. Collected tokens/receipts can further serve the customer, for the purchase of sweet goods at a reduced price, which is certainly a stimulating opportunity for consumers.

PET, in any form (granulate, packaging, post-consumer packaging, or ground flakes), holds monetary value. This presents a unique opportunity for both profit generation and environmental conservation, making PET recycling an essential and viable solution.

The creation of the „interest" defined by the legal act among all individuals in the chain (from producers, trough distributors and traders, to consumers) is of key importance, and this is the only way to solve the problem of waste PET packaging.

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