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To cite this article: Yan Li and Zhenqing Sun 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **772** 012090

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Evaluation Research on Green Degree of Green Packaging Materials

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Abstract. Green packaging materials are packaging materials which are harmless to human health, have a good protective effect on ecological environment and can be recycled in packaging materials that people produce, manufacture, use and recycle. Green packaging materials can save resources and energy; they can be naturally degraded or reused without breaking ecological balance after being discarded, moreover, green packaging materials have a wide range of sources, low energy consumption, easy recovery and high recycling efficiency. Green packaging materials are the premise and foundation of green packaging design. Based on the analysis of the shortcomings of traditional material selection methods, this paper establishes the selection principles of materials in green packaging design, and elaborates on how to use theoretical method of pan-environmental function to evaluate the green degree of green packaging materials, and finally select the best green packaging materials.

Keywords: green packaging; material selection; green degree evaluation.

1. Introduction

In recent years, with the improvement of people's living standards, the packaging requirement for products have become higher and higher, it not only requires the products to be beautifully packaged, economical, practical, but also conform to environmental protection requirements. Packaging not only makes the product easy to transport and carry, but also protects and beautifies the goods, and plays a role in extending the product shelf life and promoting sales, however, packaging brings convenience to people and also causes serious harm to the environment in which human beings live, the environmental pollution caused by packaging waste is increasing, in order to protect the environment, people have proposed green packaging concept.

2. Material Elements of Green Packaging

The material elements of green packaging include basic materials (paper materials, plastic materials, glass materials, metal materials, ceramic materials, bamboo materials and other composite materials etc.) and auxiliary materials (adhesives, coatings, inks, etc.), they are the material basis for realizing three functions of packaging (protection, convenience and sales), which is directly related to the overall functions and economic costs of packaging, the processing ways and the recycling of packaging waste. Material selection in green packaging design should follow the following principles:



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- (1) Lightweight, thin, easy to separate, high-performance packaging materials.
- (2) Recyclable and renewable packaging materials.
- (3) Edible packaging materials.
- (4) Degradable packaging materials.
- (5) Natural packaging materials developed by using natural resources.
- (6) Try to use paper packaging.

3. Green Packaging Design

The harmless materials of green packaging means that the materials used should strictly limit the levels of harmful heavy metals such as lead, mercury, chromium and other harmful elements to the human body, try to select materials that are not toxic to humans and the environment, and non-exhaustive, non-rare resource in the environment. When designing green packaging, people should try to use a single type of packaging material and use less heterogeneous or composite materials, this is because considering packaging entering the waste recycling stage, different packaging materials are mixed together, and the separation requires a large amount of work.

The energy saving of green packaging design means that people can select simple printing and manufacturing methods to save costs and save energy. The improvement of design and production methods can reduce waste in production, such as making similar products with less material, or reducing the waste of cutting. The pre-contamination and air pollution are eliminated in production by selecting environmentally friendly materials and improving production methods.

The cyclic design of the packaging structure means that the packaging structure needs to be simplified. The succinct structure and bright graphic design are a simple modern style packaging. People should try to create packaging methods that save materials and process steps. The single material is used for smart internal separation and buffer design, replace the buffer harmful to the environment, and form a unified design style. We can promote consumers' sustainable consumption habits and use design to help them build sustainable lifestyles. Glue-free structural style can be used when packaging lighter products to avoid contamination of the adhesive and facilitate recycling, and make recycling to be a habit rather than a responsibility.

4. Pan-environmental Function Evaluation Method of Green Degree of Green Packaging Materials

4.1. Pan-environmental function

The production process of materials is a complex process involving many specific material parameters. In order to simplify the problem, the material production process is treated as a black box, without regard to the specific reactions in the production process, only the relationship between input and output is studied. After simplification, the input parameters include resources and energy; the output parameters include various forms of emissions in addition to the product, as shown in Fig.1.

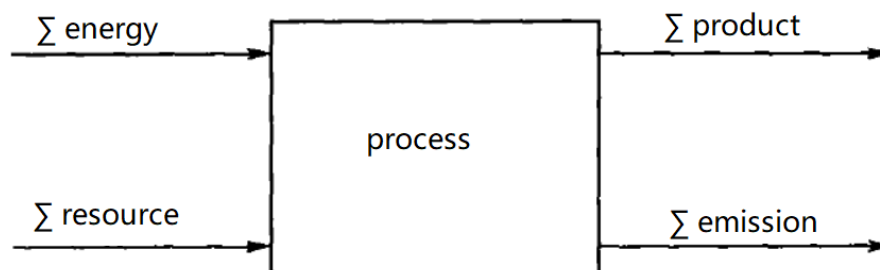


Fig.1 Input output parameters of a process

In the material production process, there are four parameters for interaction between the system and the outside world: resources, energy, emissions, and products (as shown in Fig.1). These four parameters have an effect on the outside world, in which the product has a positive effect on the outside world, and

the other three have a direct or indirect negative effect on the outside world. Therefore, in the material evaluation, it is necessary not only to consider the direct hazard of pollutants, but also consider the indirect hazards of resource consumption and energy consumption. The scope of these hazards and impacts is called the pan environment. It is described with function expression to get a pan-environmental function loop. The value of pan-environmental function is defined as a measure of the comprehensive degree of resource consumption, energy consumption, and environmental impacts and pollutant emissions in the process.

Obviously, the general mathematical expression of pan-environment function is:

$$ELV = \psi(n) = f(R(n), E(n), P(n)) \quad (1)$$

In the formula, ELV is a pan-environmental function, whose value is also called a pan-environmental load, which is a function of the material process number n . R is the resource environmental factor of the material, E is the energy environmental factor of the material, and P is the pollutant factor of the material. R , E , and P are functions of the process number n . For the whole process of materials, the pan-environment function is:

$$ELV = \int_0^n f(R, E, P) dn \quad (2)$$

Here, the pan-environmental function does not study the single environmental factors R , E or P in isolation, it combines the resources, energy and waste involved in the material and conducts comprehensive research.

$$R(n) = y_1(a_i) \quad (3)$$

$$E(n) = y_2(b_j) \quad (4)$$

$$P(n) = y_3(c_k) \quad (5)$$

In the formula, a_i represents the superposition of various resource consumptions throughout the life of the material, b_j represents the superposition of various energy consumptions, and C_k represents the superposition of various wastes. Since the environmental impact factors of resource environmental factors, energy environmental factors and pollutant environmental factors are relatively independent, their contribution to the pan-environment function can be superimposed. The pan-environmental function ELV is added and processed

$$ELV = a'R + b'E + c'P \quad (6)$$

In the formula, a' , b' , and c' are weighting coefficients. Since the environmental factors of R , E , and P have different dimensions, in order to can superimpose, it is necessary to conduct non-quantization processing separately. Here the concept of environmental equivalent index is introduced, and the environmental equivalent index is defined as:

$$I_{ij} = \frac{C_{ij}}{S_{ij}} \quad i = 1, 2, 3, \dots, n; j = 1, 2, 3 \quad (7)$$

In the formula, C_{ij} is the measured data of the i -th item in the j -th environmental factor, and its unit is the occurrence amount per unit of product, S_{ij} is the national or industry standard of the i -th item in the j -th environmental factor. Obviously the environmental equivalent index is a non-quantitative value. $J=1$ is the resource environment factor item, $j=2$ is the energy environment factor item, and $j=3$ is the pollutant environmental factor item.

$$R = \sum I_{i1} \quad i = 1, 2, 3, \dots, n \quad (8)$$

$$E = \sum I_{i2} \quad i = 1, 2, 3, \dots, n \quad (9)$$

$$P = \sum I_{i3} \quad i = 1, 2, 3, \dots, n \quad (10)$$

4.2. Evaluation of material green degree

The green degree of the material is an important basis for green products. When selecting green packaging materials, first, the materials that meet the basic requirements of the packaging from the candidate materials are selected; then according to the material selection principle of the green packaging design, the green degree of the selected materials is evaluated, and finally the materials with the highest green degree are selected, that is the best material.

According to the life cycle theory, the life cycle of the materials includes the following processes: raw material-finished material - finished product – use, the evaluation of the green degree of waste materials is the evaluation for the entire life cycle of materials, namely in the whole process of the life cycle, the materials are comprehensively evaluated in energy, resources, and environmental protection.

The green degree of materials can be expressed with pan-environment function: $ELV = \psi(n) = f(R(n), E(n), P(n))$

The steps to green degree evaluation of the material:

(1) Calculate I_{11} , I_{12} , I_{13} according to formula (7). Specifically, formula (7) is to calculate a dimensionless comparison value, if the S_{11} data is insufficient, any one of several materials to be evaluated and compared may be selected, and its C_{11} is used as the standard data S_{11} for use, C_{11} of other materials is compared. (2) The calculation results in step (1) are put into the formulas (8), (9), and (10), and the values of R , E , and P are obtained. (3) The result in step (2) is put into formula (6), calculate the value of ELV . Here, the weight is determined according to the product and the environment in which it is located. In areas where energy and resources are relatively scarce, designers tend to choose larger weight values; while areas with relatively abundant energy and resources are the opposite. (4) Compare the calculated ELV values of various materials, the lower the ELV value, the higher the green degree value of the material, and the better the green performance of the material.

5. Application Examples

The above method is further discussed below by specific examples. For example, in the choice of green packaging materials, resin high-density polyethylene and polypropylene all conform to the basic requirements of the design, then the level of green level is the decisive factor in the choice of the best material. The green degree of the two materials is evaluated by using the above method.

Table 1. Quantitative data of 1kg plastic LCA

inputs and outputs of energy consumption and emissions		unit	HDPE	PP
energy consumption		MJ	16.94	18.47
resource	crude oil	kg	1.16	1.27
	water	kg	9.50	3.10
	others	g	4.70	5.90
waste gas	coal dust	g	2.00	2.00
	CO ₂	kg	0.94	1.10
	SO _x	g	6.00	11.00
	NO _x	g	10.00	10.00
	hydrocarbon	g	21.00	13.00
	others	g	0.60	0.70
waste water	BOD	mg	100.00	60.00
	COD	mg	200.00	400.00
	suspended particles	g	2.10	1.90
waste residue	sludge, dust, etc.	g	5.00	5.00
	waste	g	27.00	26.00
data origin		PWMI	PWMI	

According to the above table, the data of PP is used as the reference data, and the data of HDPE is compared and calculated, the calculation result of HDPE is as follows:

Table 2. HDPE calculation results

inputs and outputs of energy consumption, emissions, etc.	<i>I</i>	<i>E</i>	<i>R</i>	<i>P</i>	weight	ELV
energy consumption		0.917	0.917		(0.3,0.3, 0.4)	6.1806
resource	crude oil	0.916		4.777		
	water	3.065				
	others	0.796				
waste gas	coal dust	1				
	coal dust	1				
	SO ₂	0.855				
	hydrocarbon	1.615				
	others	0.857				
waste water	BOD	1.667				
	COD	0.5				
	suspended particles	1.105				
waste residue	sludge, dust, etc.	1				
	waste	1.038				

Resources: Crude oil 0.9164.777, water 3.065, others 0.796, waste gas dust 111.181, CO₂ 0.854, SO₂ 0.545, NO_x 1, hydrocarbon 1.615, others 0.85, waste water BOD 1.667, COD 0.5, suspended particulates 1.105, waste sludge, dust, etc. 1, waste 1.03.

According to the selected weight above, the values of PP are taken as 1, and the *ELV* value of PP is calculated to be 5, 6. It can be seen that under this weight, the green degree of PP is better than that of HDPE. If the weights are selected differently, the evaluation results of the material green degree will also be different.

6. Conclusion

The theoretical method of pan-environmental function is applied to the evaluation of material green degree in the selection of green packaging materials in this paper, and the problem of material selection under the basic design requirements is successfully solved, which is scientific, objective and workable. The method is simple and easy to implement, and has strong practical value.

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