The Optimal Design for Recycling of Renewable Materials of Industrial Solid Waste

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Abstract. Utilization of the industrial solid waste resource, can not only effectively control the pollution of solid waste and save limited natural resources, but also ensure people's health and improve life quality. A typical case of solid waste utilization was analyzed in this paper. To maximize the total profit was selected as the optimization goal, the proportion of the preparation of materials and the weekly supply of renewable materials were selected as constraints, a mathematical model of linear programming was established and lingo software was used to solve the key parameters for the sensitivity analysis. The results showed that lingo software can effectively solve the problem and optimization results were consistent with those by manual calculation. The results of this research can be used as a fundamental rule for the recovery company to continue the production process.

1. Introduction

1.1. Introduction to solid waste

Solid waste refers to solid, semi-solid and gaseous substances placed in containers that have lost their original use value or have been discarded or abandoned without loss of use value, resulting from production, living and other activities, and laws and administrative regulations include items and substances that are subject to solid waste management too[1]. With the constant acceleration and development of economy in our country, the living standards of residents are constantly improving, and the types and total amount of solid wastes are increasing day by day. There are many ways to classify solid wastes. According to the origin of the solid wastes and the degree of harm to the environment, solid wastes are divided into three categories: industrial solid wastes, household wastes and hazardous wastes. In recent years, the output of industrial solid waste shows an overall upward trend, and shows obvious regional and industrial characteristics in China. Among them, the main sources are the thermoelectric industry, non-ferrous metal mining, ferrous metal mining, metal smelting and processing, coal mining and washing, chemical raw materials and manufacturing industries, accounting for more than 80% of the total industrial solid waste [2]. If the solid wastes are not properly handled, the toxic and hazardous substances can enter the ecosystem through environmental media such as the atmosphere, soil and surface to destroy the ecological environment and lead to irreversible ecological changes. The hazards include the following major aspects. (1) Soil

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pollution. Solid waste storage not only waste a lot of land, and even destroy the surface vegetation, causing changes of the land type, eventually causing soil erosion. More seriously, hazardous substances contained in solid waste and its leachate can change the nature and structure of the soil and affect the activity of microorganisms, which may enter the human body through the food chain and affect human health. (2) Water pollution. The pollution by solid waste to the water is presented in two ways: One is dumping waste into surface water, causing direct water pollution, second, the leachate generated during the piling of waste flows into rivers, lakes or infiltrates into the ground, resulting in water pollution. (3) The pollution of the atmosphere. During the stacking process of solid waste, some organic substances decompose under certain temperature and humidity to generate harmful gases, which produce toxic gases or malodors, resulting in regional air pollution. They release harmful gases and dusts during the transportation and handling of waste and pollute the atmosphere, affecting human's health [3].

1.2. Solid waste disposal and resource utilization

The pollution of solid waste on the environment has caused many countries attach great importance. Solid waste resource treatment, decontamination and reduction treatment has become China's pollution control technology policy. We need to actively carry out and strengthen the solid waste treatment and comprehensive utilization of research, treatment technology and health standards research to improve the utilization of solid waste resources. Dispose of solid waste is mainly used by sanitary landfill, compost, incineration, comprehensive utilization and so on in China. Data show that China's industrial waste dumping more than 500,000t industry were coal mining and washing industry, non-ferrous metal mining industry, ferrous metal mining industry, the total amount of industrial solid wastes dumped and discarded of these three industries accounted for 71.0% of the total amount of solid wastes dumped and discarded by the industrial sector. The utilization of solid waste resources not only effectively controls the solid waste pollution but also reduces the waste of our limited resources as well as improves the living environment quality and helps to ensure people's health [4]. Extraction of various metals, many waste rock, tailings and waste slag contain an amount of metal elements, if they are recycled not only have high economic benefits, and to prevent the pollution caused by spread of metal(especially heavy metals), can receive good economic and environmental benefits. Non-ferrous metal slag often contain other metals, such as gold, silver, cobalt, antimony, selenium, etc., some metal content can reach the grade of industrial deposits, even more than several times, some slag recovery rare precious metals value exceeds the value of the main metal. Fly ash and coal gangue often contain iron, aluminum, molybdenum and other metals, some chemical slag also contains a variety of metals. Thus, extracting certain valuable metals is an important way to utilize the solid waste.

2. Linear programming to solve renewable materials recycling process optimization design

2.1. Problem description

A recycling company that specializes in the recycling of four types of solid waste and can form marketable products. The product can be made in three different levels, depending on the mixing proportion of the materials used. While there is some flexibility in the mix at each level, the quality standard specifies the minimum or maximum (by weight) percent of certain materials that are allowed in the grade of the product, together with the composite fees and prices for each level, as Table 1 shows. Recycling companies reclaim their solid waste from some regular sources, so they are often able to maintain steady productivity. Table 2 shows the weekly amount of each material that can be recovered and disposed of, as well as handling costs. Try to determine:

(1) At least half of each material must be collected and disposed of for each material. The amount of each grade of product produced and the exact mix of solid waste used maximizes the company's total weekly profit (total sales minus compounding and handling).

(2) The company receives a donation of 30,000 yuan per week, dedicated to the treatment of solid waste. The company decided to effectively blend various materials into all grades of products within the constraints listed in Table 1 and Table 2 in order to maximize weekly total profit (total revenue minus total cost).

Table 1. Solid waste preparation product grades and requirements.

Grade	Specification	Composite fee(CNY/kg)	Price(CNY/kg)
A	Material 1 is not more than 30% Material 2 not less than 40% Material 3 is not more than 50%	3	8.5
B	Material 1 is not more than 50% Material 2 not less than 10%	2.5	7
C	Material 1 is not more than 70%	2	5.5

Table 2. Solid waste recovery and treatment costs.

Solid waste	The amount of weekly recycling(kg)	Processing fee(CNY/kg)
1	3000	3
2	2000	6
3	4000	4
4	1000	5

2.2. Problems 1 analysis and solution

The goal of this problem is to maximize the company's total profit per week, total profit = total revenue-cost.

2.2.1. Setting variables. Let X11 denote the quantity of solid waste 1 required to produce A product; X12 denote the quantity of solid waste material required to produce A product; X13 denote the quantity of solid waste material needed to produce A product; X14 denote the quantity of solid waste material required to produce A product; X21 X22 represents the quantity of solid waste material 2 needed to produce B product; X23 represents the quantity of solid waste material needed to produce B product; X24 represents the quantity of solid waste material required to produce B product; X31 represents the quantity of solid waste material required to produce B product; C product requires the amount of solid waste 1; X32 represents the amount of solid waste 2 required to produce C product; X33 represents the amount of solid waste 3 required to produce C product; X34 represents the amount of solid waste 4 required to produce C product; The maximum profit is z.

2.2.2. Constraints based on the title. The material used by the A product is not more than 30%: X11 / (X11 + X12 + X13 + X14) ≤30% Not less than 40% of the material used by the A product is available: X12 / (X11 + X12 + X13 + X14) ≥40%; Not more than 50% of material 3 used by A products is available: X13 / (X11 + X12 + X13 + X14) ≤50%; The material used by the B product 1 is not more than 50% available: $X21 / (X21 + X22 + X23 + X24) \leq 50\%$ The material used by the B product 2 not more than 10% available: $X22 / (X21 + X22 + X23 + X24) \geq 10\%$; Less than 70% of the material used by C products 1 available: $X31 / (X31 + X32 + X33 + X34) \leq 70\%$

From solid waste 1 weekly recovery of 3000 available: $X11 + X21 + X31 \leq 3{,}000$ from the solid waste 2 weekly recovery of 2000 available: $X12 + X22 + X32 \leq 2000$ by the solid waste 3 weekly recovery of 4000 available: $X13 + X23 + X33 \leq 4000$ by the solid waste 4 weekly recovery of 1000 available: $X14 + X24 + X34 \leq 1000$

The minimum required volume of processing (collected and processed more than half) Material 1 processing at least 1500 kg per week: $x11 + x21 + x31 >= 1500$ Material 2 processing at least 1000 kg per week: $x12+x22+x32>=1000$ Material 3 at least 2,000 kilograms per week is required for handling: $x13+x23+x33>=2000$ Material 4500kilograms per week at least: $x14+x24+x34>=500$

$Xij \geqq 0$ $(i = 1, 2, 3; j = 1, 2, 3, 4)$

2.2.3. Model and solution. The mathematical model is as follows:

$$\text{Max } z =(8.5-3)(X11+X12+X13+X14) + (7-2.5)(X21+X22+X23+X24) + (5.5-2)(X31+X32+X33+X34) -3(X11+X21+X31)-6(X12+X22+X32) - 4(X13+X23+X33) - 5(X14+X24+X34)$$

$$X11/ (X11+X12+X13+X14) \leqslant 30\%$$

$$X12/(X11+X12+X13+X14) \geqslant 40\%$$

$$X13/(X11+X12+X13+X14) \leqslant 50\%$$

$$X21/(X21+X22+X23+X24) \leqslant 50\%$$

$$X22/(X21+X22+X23+X24) \geqslant 10\%$$

$$X31/ (X31+X32+X33+X34) \leqslant 70\%$$

$$X11+X21+X31 \leq 3000$$

$$X12+X22+X32 \leq 2000$$

$$X13+X23+X33 \leq 4000$$

$$X14+X24+X34 \leq 1000$$

This is a linear programming problem that can be solved by the simplex method. However, taking into account the variable more, solving time is longer, so can consider using lingo software to solve [2].

2.2.4. Solve the result analysis

X1=750, X12=1000, X13=750, X21=1500, X22=1000, X23=2000, X24=500, at this point you can get the optimal profit value of 6,000 yuan. If the problem is to remove the least amount of processing requirements, that is, to collect and process more than half of the constraints and then solve them again, the optimal solution can be obtained as follows: X11 = 1000, X12 = 1333.33, X14 = 1000, X21 = 2000, X22 = 666.67, X23 = 4000, the optimal value of z = 10333.33 yuan. As a result of the sensitivity analysis, whether there is any surplus of the four kinds of solid wastes (resources) under the optimal solution: there is no remaining solid wastes 1, 2 and 3, and the solid waste 4 remaining 1000, that is, the solid wastes 4 are completely unused. In contrast, if environmental protection enterprises simply pursue profits, they may cause some solid wastes to be completely left untreated. This shows that environmental protection enterprises cannot unilaterally pursue the maximization of benefits while giving top priority to social responsibility.

2.3. Problem 2 analysis and solution

As a company specializing in environmental protection, the company has the responsibility to collect and dispose of the four types of solid waste that are available weekly and turn it into product. The processing cost is paid first by donation (all donations must be used up), and when not enough, it is paid from the sales profit (part of the sales profit as the processing cost). At this time, the processing fee to be paid is 42000 yuan, net proceeds from the donation of -12000 yuan. At this point the largest profit (the largest total profit). The objective function is max 5.5X11 +5.5X12+5.5X13+5.5X14+5X21+5X22+5X23+5X24+3.5X31+3.5X32+3.5X33 +3.5X34

Constraints, the " actual processing of material volume<= availability of material “as” the actual processing of the amount of material=available amount of material”

X11+X21+X31=3000; X12+X22+X32=2000; X13+X23+X33=4000; X14+X24+X34=1000

Total disposal costs>= available donations ", the donations received are all used to dispose of solid waste 3 (X11 + X21 + X31) + 6*(X12+X22 +X32) +4(13+X23+ X33) +5 (X14 + X24 + X34) ≥30000

Solve the result as:

X11=1000, X12=1333.33, X13=1000, X21=2000, X22=666.67, X23=3000, X24=1000.

The expected return at this point is 51666.7. At this point we make sure that all the waste is disposed of and processed into useful products. Taking into account the total disposal costs after deducting the proceeds value of 9666.7 yuan. Although the total revenue decreased from the original 10333.3yuan, that is the total profit of environmental protection enterprises decreased, but all the solid waste was collected and disposed of, achieving recycling and achieving good social benefits[5].

3. Conclusions

In view of the status of solid waste disposal in our country, the recycling and utilization of solid waste is a problem that needs attention and urgent solution. This article analyzes a typical case of solid waste utilization. Taking the optimization of total profit as the optimization objective, the mathematical model based on linear programming was established based on the ratio of preparation materials, the weekly supply of renewable materials and the processing capacity. The mathematical model was established by lingo software. The results show that lingo software can effectively solve the problem optimally and the result is consistent with the optimal solution of manual calculation. The results of this paper can show that the development of recycling and utilization of solid waste recycling economy can achieve significant economic and social benefits.

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