Environment Economy Assessment on Recycling of Rare Earths and Mercury from The Waste Fluorescent Lamps

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Abstract
Rare earth elements and mercury in waste fluorescent lamps belong to the category of hazardous waste. In China, the scrap of waste fluorescent lamps produced each year is more than 5 billion. The improper disposal not only causes a waste of resources, but also pollutes environment seriously. People do not pay much attention to recycling the waste lamps (only 1% of the lamps have been recycled), and the vast majority of waste lamps are still disposed by the traditional landfill and incineration. However, the study of environmental economic of rare earth elements and mercury recycling has not been carried out yet. In this paper, we have considered the pollution and ecological destruction from the stage of mining and emission, and the risks of pollutants from smelting. The actual governance cost method and the virtual treatment cost method have been used to evaluate the environmental economic of rare earth elements and mercury recycling in the both unidirectional flow mode and the recycling mode. The treatment cost of various stages and total treatment cost is estimated. It has been found that the virtual treatment cost for the unidirectional flow mode is much higher than the actual treatment cost. Moreover, the environment economic for the unidirectional flow mode is much higher than the recycling mode. This provides a novel research idea for the evaluation of environment economic.

Keywords: waste fluorescent lamps; rare earths; mercury; environmental economy assessment

1. Introduction

At present, China's fluorescent lamp production and usage is the highest in the world. As we all know, the average service life of a standard fluorescent lamp is 2~3 years, so the scrap of waste fluorescent lamps produced each year is more than 5 billion, in China. The waste fluorescent lamps contain highly toxic mercury. In terms of average 20 mg mercury filled in one lamp, the amount of mercury in waste fluorescent lamps could reach 100 tons every year. If these fluorescent lamps are not treated scientifically, it is easily to cause the leakage of mercury, pollute the environment and endanger human health. On the other hand, there are about 92% glass, 2% metal, and 2.4% phosphor in the waste fluorescent lamps. If 4 g phosphor contained in one waste fluorescent lamp, the value of the rare earths will exceed 10 billion yuan. Besides, it can be easily found that waste fluorescent phosphors contain much more rare earth metals and noble metals, which makes them rich resources of rare earth elements. Therefore, the improper disposal not only causes a waste of resources, but also pollutes environment seriously. However, people do not pay much attention to recycling the waste lamps (only 1% of the lamps have been recycled), and the vast majority of waste lamps are still disposed by the traditional landfill and incineration. The recycling of rare earths and mercury from the waste fluorescent lamps not only contributes to the environmental protection but also economically profitable. However, the study of environmental economic of rare earth elements and mercury recycling has not been carried out yet.

In this paper, we have considered the pollution and ecological destruction from the stage of mining and emission, and the risks of pollutants from smelting. The actual governance cost method and the virtual treatment cost method have been used to evaluate the environmental economic of rare earth elements and mercury recycling in the both unidirectional flow mode and the recycling mode.

2. Research Method

This article uses the cost method of environmental governance, according to the disposal of the current situation in the waste fluorescent lamps, will be divided into single flow and recycling modes, for which emissions are calculated for each stage, come with their own environmental costs itemized total item value, after comparing the results produced using recycled environmental benefits.

A typical unidirectional flow of rare earth resources and mercury in waste fluorescent lamps in the process (Fig.1a). The natural rare earth mine through artificial mining, smelting, as the raw material entering the production enterprises, manufactured after fluorescent lamps sale to consumers, reach retirement age discarded after use. Although the waste fluorescent lamp belongs to dangerous waste, the vast majority of waste lamps are still disposed by the traditional landfill and incineration. In the rare earth mining, smelting and manufacturing sectors, mainly produce waste water, waste gas and solid waste, environmental protection enterprises in the investment part of the cost of treatment for most pollutants, will discharge a small amount of pollution as shown in Fig.1.

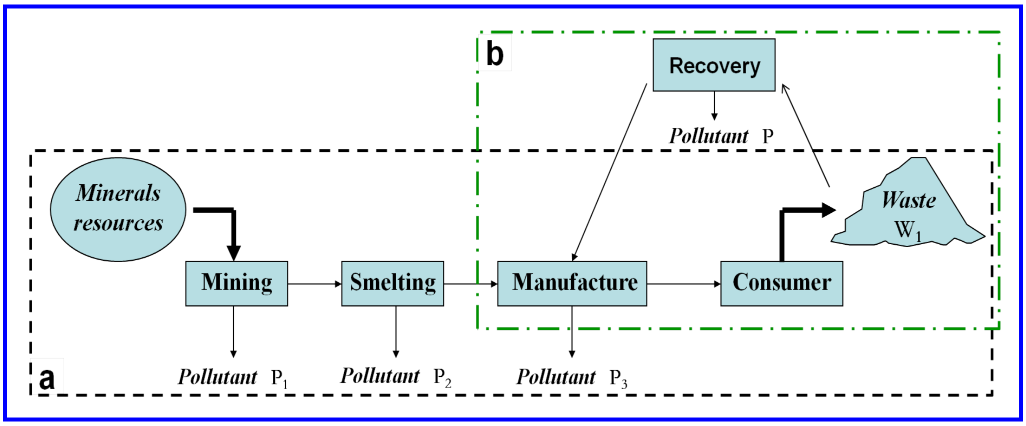

Fig.1 **a** Unidirectional flow mode, **b** Recycling mode of rare earth resources and mercury in waste fluorescent lamps

The process flow of a typical recycled rare earths and mercury in waste fluorescent lamps (Fig.1b).The consumer product flow by the manufacturer, after using, the waste recycling after the hazardous waste collected, using various types of technology for its recovery, and then processed into renewable resources, to the use of production enterprises, eventually forming a loop as shown in Fig.1.

Furthermore, analyzing the entire experiment process, and establishing the input and output equilibrium diagram of rare earth ions from waste phosphor powder as shown in Fig.2. The following relationship between material flow:

$$P_0 = (1 + \sum_{i=1}^{n=3} \beta_i) \times P_n \tag{1}$$

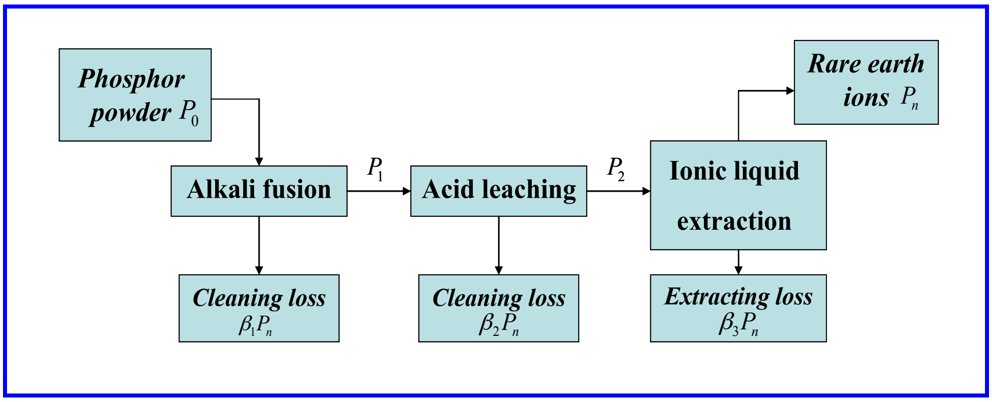

Fig.2 The input and output equilibrium diagram of rare earth ions

3. Result and Discussion

According to the amount of pollutants generated in each mode of the unidirectional and recycling flow, calculated to bring the actual and virtual treatment cost in the rare earth production process (Table 1). We can found that the actual and virtual treatment cost in the unidirectional flow patterns was 370.15 with a 1514.06 cny/t; the recycling flow patterns in the actual and virtual treatment cost was 135.10 and 15.06 cny/t. Contrast the costs of these two modes, the recycling mode will save 235.05 and 1499.00 cny/t in the actual and virtual treatment cost, respectively. compared with the unidirectional flow mode, 92.03% of the total environment cost can be saved in the recycling mode.

Table 1 Total environmental costs of recycled phosphor in fluorescent lamps (cny/t)

Item		actual costs	virtual costs
unidirectional flow mode	Waste water	78.83	312.05
	Waste gas	5.04	217.26
	Waste solid	286.28	984.75
	Total	370.15	1514.06
recycling mode	Waste water	8.83	10.05
	Waste gas	0.00	0.26
	Waste solid	126.28	4.75
	Total	135.10	15.06

Fig. shows that the material flow model of the entire recycling process of rare earth metals from waste phosphor power. According to the law of conservation of matter, in any period of time, each of the above material flow balance relation between the quality of the following:

$$PIN=\sum_{i=1}^{n=2} POT_i+PFN \quad (2)$$

The recovery rate of rare earth metals was calculated from:

$$R=\frac{PFN}{PIN}\times 100\% \quad (3)$$

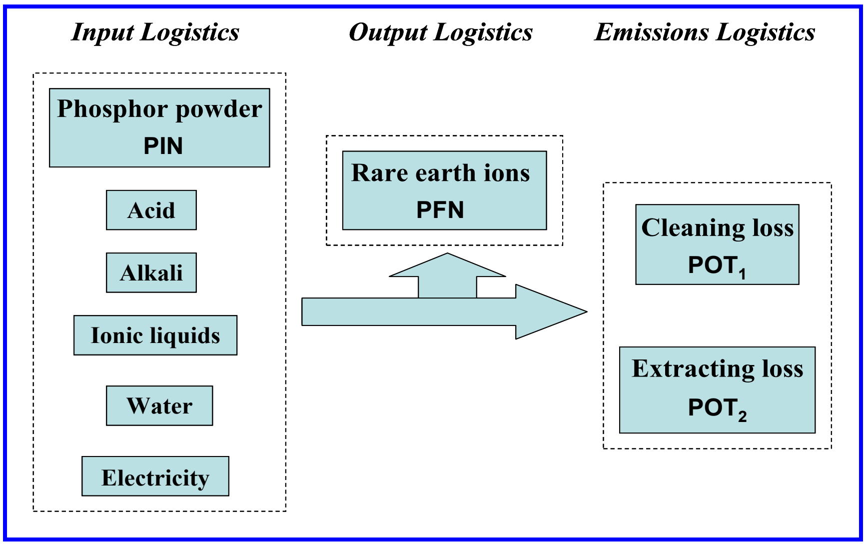

Fig.3. The material flow model of the entire recycling process of rare earth metals

Therefore, to reduce the loss of experimental process is the key to improving the recycling rate of rare earth metals.

4. Conclusion

(1)After analysis of fluorescent lamps-way flow patterns, found that virtual treatment costs about four times the actual cost of treatment, indicating that the majority of pollutants in production has not been effective governance.
(2) The environment economic for the unidirectional flow mode is much higher than the recycling mode.
(3) The recycling of rare earths and mercury from the waste fluorescent lamps not only contributes to the environmental protection but also economically profitable. Government departments should increase the investment subsidies, to promote the recycling flow mode more widely promoted.

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