Research on the Recycling of Hazardous Medical Waste

Chenglei Sun *

School of economics and management, West Anhui University, Lu’an city, Anhui Province, China

*Corresponding author e-mail: 1358532365@qq.com

Abstract. Hazardous medical waste is medical waste that will cut people, such as syringes, scalpel, scalpel, its material is good, but after the use, due to the single way of recycling, the vast majority of the hazardous medical waste is treated by centralized sterilization, crushing and incineration. It is not recycled and has a negative impact on the environment. On the other hand, criminals was selling medical waste and make use of the production of a variety of products, to obtain illegal interests, endanger the health of others. Therefore, exploring the recycling of damaged medical waste can not only realize the reuse of resources, but also crack down on illegal elements to protect people's life and health. This paper analyzes the feasibility of the recycling of the hazardous medical waste by using the model and gives some suggestions.

1. Introduction

2019 CCTV 315 party exposure part hebei, shandong, shaanxi and other provinces and cities exist bad medical waste processing plant, reveal instructions according to the party and the illegal collection of medical waste no qualification of processing manufacturers, and used as raw material to produce the daily life of the article such as supermarket shopping bags, children's toys, serious damage to consumers' health, according to the reporter investigation, to medical waste as a source of lucrative black industry chain, lead to criminals. However, medical waste is different from household waste, its composition is extremely complex and contains a large number of microorganisms and bacteria, such as without special professional treatment and flow to the market, the consequences are unimaginable. Therefore, it is of great significance to establish a closed-loop supply chain of medical products and explore its optimization approach in order to standardize the disposal behavior of medical waste and protect the health of residents.

2. Research Reviewed

The establishment of related medical waste treatment system in China started late, but after "SARS" in 2003, domestic scholars begin to study the laws and regulations of the medical waste disposal, Gao Xiaoli in reference to foreign experience in medical waste recycling, made clear that compulsory recycling of medical waste, it is forbidden to illegal speculation[1].From the perspective of health legislation, Chen pointed out that China's medical waste management has a lot of hidden dangers in both legal and supervisory aspects. Therefore, it is necessary to start from the legal perspective and improve relevant laws and regulations to promote orderly management of medical waste in accordance with the law[2].Zhang zheng and ren zhiyuan et al. compared the DBO mode with the BOT mode and concluded that the DBO mode had obvious advantages over the BOT mode in the initial stage of trial operation,
and it could be introduced into the centralized disposal of medical waste, so as to improve the disposal efficiency, reduce the disposal cost and strengthen the supervision of the competent authorities[3]. With the concept of sustainable development, Chinese scholars began to study how to reduce or eliminate the environmental impact of medical waste in the process of disposal and transportation. Ma tingting and zhao huichong pointed out that in order to avoid secondary pollution of medical waste in the process of transportation and disposal, the supervision of medical waste should be strengthened and the operation process of medical waste should be standardized[4]. zhang lingjuan analyzed the game behavior of all parties in the closed-loop supply chain system of agricultural products, and gave some suggestions for the implementation of the closed-loop supply chain of agricultural products[5]. On the basis of analyzing the remanufacturing closed-loop supply chain, tang yingxu summarized the possible future development direction of the remanufacturing closed-loop supply chain[6].

2.1. Model and analysis
According to the survey data, the medical waste in 10% to 15% of infectious waste, is the need for strict free-pollution disposal, and the other 85% - 90% belongs to the non-toxic wastes, the part of the disposal of waste is relatively easy, can also realize recycling, if recycled properly, not only can greatly reduce the cost of disposal of medical waste, medical institutions can effectively protect the environment and save resources, realize sustainable development[7].

2.1.1. Model building. To facilitate understanding, it is assumed that there are only manufacturers, sellers, medical institutions and third-party recycler in the entire supply chain system, whose decision-making objectives are to maximize their own interests. To facilitate model derivation and verification, the following assumptions are made with reference to the model of zhang lingjuan:

1) recycled goods can be used for remanufacturing, and the manufacturers, sellers and third-party recycler are risk-neutral;
2) there is only a certain correlation between product demand and retail price;
3) there is only a certain correlation between the amount of medical waste recovered and the recovery price;

| Parameter | Meaning | Parameter | Meaning |
|-----------|---------|-----------|---------|
| $C_m$     | Manufacturer's manufacturing costs | $P_m$     | The recovery price of the recycler |
| $C_r$     | Recovery of product utilization costs | $P_s$     | The operating cost of the recycler |
| $w$       | The unit price at which the manufacturer sells the product | $\beta$   | The sensitivity of medical institutions to retail prices |
| $p$       | The unit price of the product sold by the seller | $G$       | The amount of medical waste supplied |
| $c$       | The cost of selling a unit of product to a retailer | $h$       | Sensitivity of medical institutions to recovery prices |
| $D$       | Market demand for medical products | $k$       | Environmental awareness in medical institutions |
| $\alpha$  | Market capacity | $s$       | The salvage value of a recovered item that can be used |
| $\pi_m$   | Manufacturer's profit | $\pi_s$   | Seller's profit |
| $\pi_r$   | The recycler's profit | $P_r$     | The unit price at which the manufacturer buys the item from the recycler |
| $C_s$     | The marketing cost of the seller | $\pi_T$   | Total profit of the supply chain |
\[ \pi_m = (w - C_m)(\alpha - \beta P) + (s - P_r)(k + hP_m) \]  
(1)

\[ \pi_r = (P - w - C_r)(\alpha - \beta P) \]  
(2)

\[ \pi_p = (P_r - P_s - P_m)(k + hP_m) \]  
(3)

\[ \pi_T = \pi_m + \pi_r + \pi_p \]  
(4)

2.2. Game analysis

When the three parties in the supply chain jointly formulate strategies based on information sharing, equal status and joint efforts, their decision-making goal is to maximize the profit of the entire supply chain, and price strategy is formulated based on this. At this time:

\[ \text{Max} \pi_T = \pi_m + \pi_r + \pi_p = (\alpha - \beta P)(P - C_m - C_s) + (k + hP_m)(s - P_s - P_m) \]  
(5)

According to equation (4), take the first partial derivatives with respect to and,

\[ P = \frac{\alpha + \beta(C_m + C_s)}{2\beta} \]  
(6)

\[ P_m = \frac{h(s - P_s) - k}{2h} \]  
(7)

According to equation (7), it can be seen that the total profit of the supply chain increases with the enhancement of environmental awareness.

Decentralized decision making has the following relationship:

\[ \text{Max} \pi_m = (\alpha - \beta P)(w - C_m) + (k + hP_m)(s - P_r) \]  
(8)

\[ \pi_r = (P - w - C_r)(\alpha - \beta P) \]  
(9)

\[ \pi_p = (P_r - P_s - P_m)(k + hP_m) \]  
(10)

According to (9) and (10), the following is obtained

\[ P = \frac{\alpha + \beta(w + C_s)}{2\beta} \]  
(11)

\[ P_m = \frac{h(P_r - P_s) - k}{2h} \]  
(12)

Substitute (11) and (12) into equation (8) and find the following:

\[ w = \frac{\alpha + \beta(C_m - C_s)}{2\beta} \]  
(13)

\[ P_r = \frac{h(P_s + s) - k}{2h} \]  
(14)

In order to more intuitively compare the total profit of the supply chain under the two types of games, equation (13) and (14) are substituted into equations (11) and (12):

\[ P = \frac{3\alpha + \beta}{4\beta} \left( C_m + C_s \right) \]  
(15)

\[ P_m = \frac{h(s - P_s) - 3k}{4h} \]  
(16)
\[ \pi_r = \frac{3[\alpha - \beta(C_m + C_s)]^2 + 3[k + h(s - P_s)]^2}{16\beta} \]

This shows that the total profit of the supply chain under the decentralized decision dynamic game is lower than that under the centralized decision, that is, there is room for optimization of the supply chain.

### 3. Model Coordination and Optimization

In this paper, the revenue-sharing contract is used to optimize and coordinate the dynamic game supply chain under decentralized decision-making, and the profit of producers, sellers and third-party recyclers is comprehensively distributed by setting the revenue-sharing ratio, so as to mobilize the enthusiasm of all parties. The three parties shall share the sales revenue and the cost of the recovery of medical waste by the third-party recyclers in the proportion of \( \varphi_1, \varphi_2, \varphi_3 \), in which \( \varphi_1 + \varphi_2 + \varphi_3 = 1 \).

\[
\pi_m = (w - C_m + \varphi_1 P)(\alpha - \beta P) + (s - P_r - \varphi_1 P_m)(k + hP_m) \\
\pi_r = (\varphi_2 P - w - C_s)(\alpha - \beta P) - \varphi_2 P_m(k + hP_m) \\
\pi_p = (P_r - P_s - \varphi_3 P_m)(k + hP_m) + \varphi_3\alpha - \beta P)
\]

According to the reverse algorithm, the decision variables of the sellers are first calculated, then the decision variables of the manufacturers are calculated, and then the wholesale price of the manufacturers and the recovery price of the manufacturers' recovered medical wastes are determined according to the profit sharing ratio.

\[
P_m = \frac{s - P_r - k}{2\varphi_1} \quad \frac{w + C_s}{2\varphi_2}
\]

\[
P = \frac{\alpha}{2\beta} + \frac{w + C_s}{2\varphi_2}
\]

\[
\left\{ \begin{array}{l}
\frac{s - P_r - k}{2\varphi_1} = \frac{h(s - P_s) - k}{2h} \\
\frac{\alpha}{2\beta} = \frac{w + C_s}{2\varphi_2} = \frac{\alpha + \beta(C_m + C_s)}{2\beta} \\
\end{array} \right.
\]

\[
\left\{ \begin{array}{l}
w = \varphi_2 C_m + (\varphi_1 + \varphi_3)C_s \\
P_r = s - \varphi_3(s - P_s)
\end{array} \right.
\]

Mathematical derivation proves that by reference revenue sharing contract can coordinate the optimal game ends up making the total supply chain profit, this is mainly due to the producers of closed-loop supply chain the dominant place in the game, the distributors and third-party recycler is in dominant position in the game, through negotiations, according to contract agreement rationally set the price of products and waste recycling prices, since then the closed-loop supply chain under decentralized decision making to achieve the optimal total profits.

### 4. Suggestions and Measures

#### 4.1. Establish Disciplinary Measures and Effectively Cassify Medical Waste

The effective classification of medical waste is of great significance to the later treatment and recycling. There are various types of medical waste, and the classification and treatment should be carried out at the source in advance, so that the recyclers can reduce the sorting burden and thus improve the recovery rate of medical waste.
4.2. Increase Research and Development Efforts to Tap the Value of Medical Waste

The medical waste industry has a broad prospect, so we should strengthen the research and development of medical waste, fully explore the utilization value of medical waste, realize the recycling of resources and protect the environment.

4.3. Mobilize and Regulate Various Sectors and Improve the System for the Approval of Medical Waste

The primary place of medical waste is in the hospital, so the hospital needs to strictly control the flow of medical waste, each unit and each department should establish the management system of medical waste, the implementation of a special person responsible for the establishment of medical waste ledger, sealed only by the designated professional recyclers, especially small clinics and hospitals; Secondly, the third-party recyclers should deal with and recycle medical waste in strict accordance with the law, so as to avoid the leakage of treatment materials. Finally, government departments should strengthen the inspection of the operation of recyclers, randomly check whether the amount of medical waste is consistent with the initial ledger and whether the treatment measures are in compliance, introduce punishment measures, establish a reporting platform, and encourage the public or the industry to report violations.

Acknowledgments

This work was financially supported by First-class discipline in Anhui Province: Agricultural and Forestry Economic Management; University-level quality engineering project of west Anhui university "Accounting Teaching Team (WXXY2018061), Special Zone for Financial Management".

References

[1] X.L.Gao, Research on the legal system of medical waste recovery and disposal in China, Xi'an University of Architecture and Technology, Xi'an, China,(In Chinese).
[2] Z.Chen, Problems and countermeasures of medical waste management from the perspective of healthy rule of law, Chinese Health Law, 2018,v.26;155(04):45-50,(In Chinese).
[3] Z.Zheng,Z.Y.Ren, G.G.Hou, et al, Application of DBO model in centralized disposal facilities of clinical waste, Environmental management in China,2016, 8(6):95-98,(In Chinese).
[4] T.T.Ma, H.H.Zhao, H.Y.Tao, Research on electronic information tracking management system for the whole process of medical waste disposal, Gansu science and technology,2017(15):21-22+56,(In Chinese).
[5] L.J.Zhang, Analysis on coordination mechanism of closed-loop supply chain of agricultural products from the perspective of game, Business economics research, 2017 (24) : 139-142,(In Chinese).
[6] Y.X.Tang, Research progress on remanufacturing-based closed-loop supply chain problem, Science and management, 2019, 39 (3) : 56-60, (In Chinese).
[7] B.Hu, Research on the legal system of medical waste management in China, Guizhou University, Guizhou, China, (In Chinese).