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The Development of Circular Economy in Biopharmaceutical Industrial Cluster

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With the development of the economy, the impact of industrial clusters on the economy is increasing, together with strong competitive advantage and vitality. However, together with other problems, the negative impact of industrial clusters on resources and the environment has gradually become more pronounced. The biopharmaceutical industrial cluster is one of many that are finding it difficult to avoid this problem. In order to address this issue, it has been suggested that a circular economy be applied when industrial clusters are being developed. Taking the biopharmaceutical industrial cluster as the subject, the process for developing a circular economy was studied in depth, and the existing problems were identified to confirm the necessity of having a circular economy. Then, a circular economybased biopharmaceutical industrial cluster was constructed by analyzing the current status of the biopharmaceutical industrial cluster in Shaanxi, China; subsequently, safeguard measures were proposed in order to ensure the sustainable development of the biopharmaceutical industrial cluster.

Keywords: biopharmaceutical, industrial cluster, circular economy

1. INTRODUCTION

Industrial clustering is the current trend in the development of industry. Industrial clustering plays a significant role in economic development as it brings together key industry stakeholders (Waits, 2014). This has brought great economic benefits to enterprises, making them more competitive (Lai et al., 2014). However, industrial clusters will also cause serious damage to the environment (Røyne et al., 2015) and produce problems such as resource shortage. Circular economy is a new developmental strategy (Yuan et al., 2010). Currently, the circular economy-based industrial cluster is undergoing a great deal of development, with the process and its associated measures attracting much interest and study. Zhang et al. (2013) developed a comprehensive evaluation index system for the circular economy to further evaluate its development in terms of industrial clusters.

He et al. (2017) investigated the problems existing in the packaging industrial cluster. They found that by combining the packaging industrial cluster with circular economy costs, could be reduced, communication was improved, and healthy cluster development was facilitated. Li et al. (2017) emphasized the importance of exploring the development of industrial clusters based on a circular economy. In the study, they discussed the developmental paths of a paper industrial cluster based on the circular economy concept after analyzing the current status of the paper industry. In the study of Sun et al. (2011), a back propagation (BP) evaluation model based on an artificial neural network was established to analyze the advantages and disadvantages of a circular economy for industrial clusters. Guo et al. (2011) pointed out that an industrial cluster established for the processing of agricultural products processing could safeguard resources as well as the environment, and achieve sustainable development only by developing a circular economy and proposed several countermeasures to address any development issues that might arise. In this study, a biopharmaceutical industrial cluster was investigated. The problems existing in this industrial cluster were analyzed. Moreover, Guo et al. (2011) suggested

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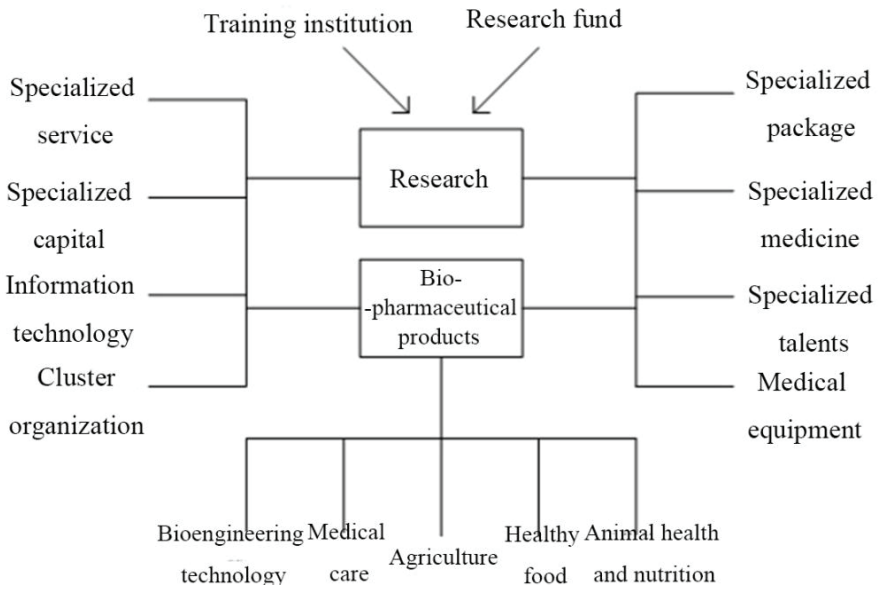

Figure 1 The composition of the biopharmaceutical industrial cluster

that it was necessary to combine a circular economy with the operations of the biopharmaceutical industrial cluster. Based on the analysis of the biopharmaceutical industrial cluster in Shaanxi province in China, several measures were proposed to ensure the development of a circular economy-based biopharmaceutical industrial cluster and the sustainable development of the cluster.

2. BIOPHARMACEUTICAL INDUSTRIAL CLUSTER

Technology is regional rather than global. Therefore, technology manufacturing activities should be localized. The biopharmaceutical industry, being a high-tech, high-income and high-risk industry, has a long industrial chain that includes research and development, production, packaging and sales of medicine. It is a technology- and knowledge-intensive industry. To ensure the smooth operation of this industry chain, different links require different resources, talents and technologies. To save capital and promote cooperation, the biopharmaceutical industry should establish an industrial cluster which is an aggregation of enterprises and related supporting enterprises that connect and interact with each other within a specific region in an industry. A biopharmaceutical industrial cluster is an aggregation of enterprises which engage in the research, development, production and sales of biological medicine in the biopharmaceutical industry. The structure of the biopharmaceutical industrial cluster is shown in Figure 1.

An industrial cluster offers several advantages as explained below.

(1) **Specialized labor division and cooperation**. In an industrial cluster, each enterprise performs its own functions and executes a single business; specific enterprises execute specified tasks all the time, which not only improves the technical level and production efficiency, but also greatly reduces operational costs. In the biopharmaceutical industrial cluster, specialized enterprises are responsible for different links of medicines. The distinct and reasonable division of labor can provide significant benefits to the development of enterprises

(2) **Resource sharing**. Enterprises in the industrial cluster can share resources because of their close geographic proximity and similar operations. In addition to materials, resources also include technologies, information and talents. The sharing of relevant information and talents among enterprises not only encourages cooperation between enterprises, but is beneficial to the joint development of enterprises.

(3) **Collaborative innovation**. Driven by the same interests, enterprises in the industrial cluster have strong collaboration and innovation. The enterprises in the cluster constitute a community of shared interests. When an enterprise produces or proposes something that is innovative, other enterprises will also improve by imitating and innovating under the influence of resource flow and sharing. The relationship between enterprises transforms from balanced to competitive and then recovers to become balanced once again. Following this cycle, enterprises in the cluster will continue to grow and develop rapidly.

However, the industrial clusters have also produced a number of negative effects despite promoting economic development. Here, the remanufacturing industry is taken as an example. In the process of development, the remanufacturing industry is dominated by high consumption, high pollution and the rapid growth of GDP, which has caused the depletion of resources and harm to the environment (Fang, 2012). Because of the concentration of enterprises within the cluster, relatively more waste is produced. The amount of waste water and gases has exceeded the self-purification capacity of the environment, placing it under enormous pressure unless

these harmful substances are not dealt with in an effective and timely manner. Moreover, because of the concentration and development of industrial clusters, the enterprises within the cluster are very large consumers of resources, which are limited. This could mean that enterprises will have to compete for resources, and vicious competition can destroy the stability of the cluster. The biopharmaceutical industry cluster is also facing these problems. If effective measures cannot be found to address these issues, then the cluster cannot continue to grow and develop.

3. CIRCULAR ECONOMY

The economic development in China has occurred at the expense of natural capital and the environment. To solve this problem, the concept of a circular economy has been adopted as a national policy for sustainable development (Geng et al., 2012; Su et al., 2013). Without a circular economy, industrial clusters will not be able to achieve sustainability. A circular economy promotes economic development and safeguards the environment in several ways, the most important of which is the efficient use of resources (Lieder and Rashid, 2016). Three principles must be followed in the implementation of a circular economy.

(1) Principle of minimization: this involves reducing the consumption of resources and using them with the maximum efficiency, and controlling the production of waste from the source by, for example, using biodegradable or reusable materials for packaging.

(2) Principle of reuse: this refers to extending the life cycle of products by means of the manufacturing process. To facilitate updating, production should be standard, which can reduce wastage of resources.

(3) Principle of recycling: this refers to the recycling of waste materials. The reuse of resources through recirculation reduces not only the amount of waste generated and the harm done to the environment, but also can solve the problem of resource shortage.

Circular economy can achieve maximum input with minimum output, solving the problem of resource shortage and establishing a better balance between the environment and development (Sima and Wang, 2012). It provides a good guidance for sustainable development.

4. COMBINATION OF THE BIOPHARMACEUTICAL INDUSTRIAL CLUSTER AND CIRCULAR ECONOMY

An industrial cluster and a circular economy have one thing in common: industrial concentration. The current problems in industrial clusters can be solved using the advantages of circular economy. An industrial cluster and a circular economy complement each other.

An industrial cluster facilitates the development of a circular economy. If there is no industrial cluster, the circulation of resources within a region cannot occur, making it difficult if not impossible for a circular economy to be established. A single enterprise cannot achieve circular economy. Even if it achieves the recycling of resources internally, it is difficult to obtain economic benefits. Enterprises in industrial clusters cooperate and compete with each other. When an enterprise in a cluster masters a new technology, the new technology will spread to the whole cluster by being circulated among enterprises, thereby forming a circular economy. Moreover, only when wastes reach a certain level can they have the value of recycling. The recycling of wastes by a single enterprise is not economically viable. Wastes can reach a higher level within an industrial cluster; then, enterprises in the cluster can establish a circulation system to deal with the wastes. In this way, lower cost of waste processing, higher efficiency and greater economic benefits can be achieved. The sharing of information among industrial clusters also benefits the development of a circular economy. The flow of information in clusters is conducive to technical flow, which can help enterprises to obtain relevant information about the circular economy and promote an effective circular economy in a timely manner.

The circular economy is the most sensible path to achieving sustainable development of industrial cluster (Guo et al., 2012). It combines reasonable resource allocation, sustainable development and ecological ideas based on ecological principles in order to achieve the exchange of resources between enterprises and take advantage of values of wastes via resource recycling. The operational process of a circular economy is shown in Figure 2.

In a biopharmaceutical industrial cluster with a circular economy, the reduction principle is used to improve resource utilization rate and allocate resources efficiently; then waste products are transformed to products or resources through principles of reuse and recycling for reutilization. By means of this circulation, resource allocation is optimized. Moreover, the reuse of waste products helps to safeguard the environment and optimizes the industrial chain.

5. DEVELOPMENT MEASURES FOR CIRCULAR ECONOMY-BASED BIOPHARMACEUTICAL INDUSTRIAL CLUSTER

5.1 The Current Status of Biopharmaceutical Industrial Cluster in Shaanxi

The pharmaceutical industry in Shaanxi is flourishing. Currently in Shaanxi, there are more than 200 enterprises manufacturing pharmaceutical products, most of which have been authenticated by Good Manufacturing Practice. Moreover, since 1999, 170 biotechnology-associated have been applied for patent.

Shaanxi has multiple advantages in terms of the development of the biopharmaceutical industry. Firstly, the Tsinling

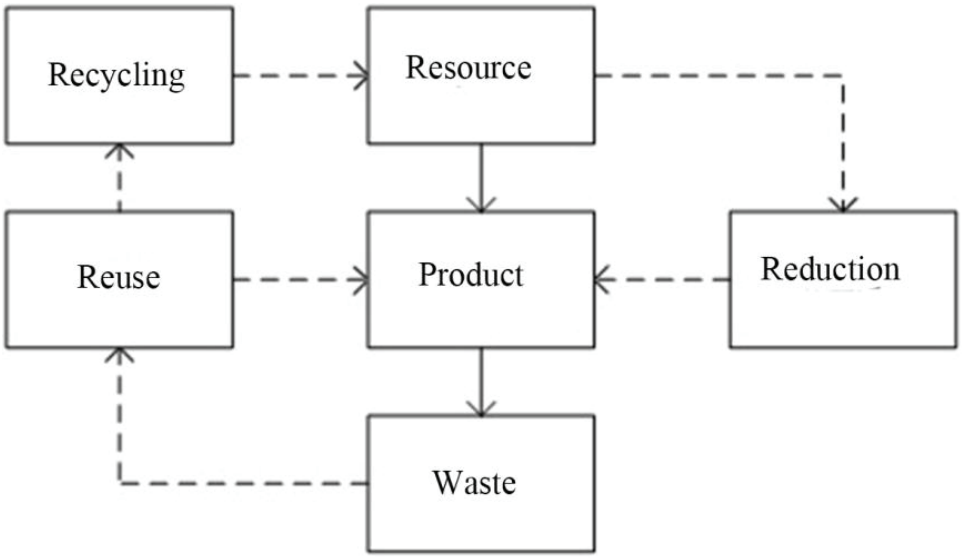

Figure 2 Circular economy operations

Mountains which is called, the biological gene pool, provide rich resources for the development of biological medicine. Secondly, there are many colleges and universities in Shaanxi. Research institutes, key national laboratories and engineering centers in Shaanxi have produced a large number of medical elites and have had some outstanding achievements in many respects. Moreover, the biopharmaceutical industry in Shaanxi has excellent innovation capabilities. Many new drugs and technologies have been developed with the support of resources and talents.

However, the rapid development of the biopharmaceutical industry in Shaanxi has given rise to a number of problems. The low technical and production level, weak risk resistance and insufficient capital investment of many small-scale pharmaceutical enterprises has limited their development. Moreover, the poor management of the medicine market has constrained the development of those enterprises. Also, many environmental problems have emerged. The ineffective management of waste products has placed great pressure on the environment. Resource consumption in Shaanxi is extremely high, and this excessiveness is not conducive to sustainable development.

5.2 The Necessity of Establishing Circular Economy-Based Biopharmaceutical Industry

To solve the current problems in the biopharmaceutical industry in Shaanxi, a circular economy-based biopharmaceutical industry cluster should be established.

Firstly, an industrial cluster can disseminate generic technology within the biopharmaceutical industry. Generic technology which can have a significant influence on the technological progress of many industries can be widely used in many fields of many enterprises, which is equivalent to a basic research result. Enterprises in the industrial cluster have a common goal: development. Their demands for generic technology are similar. The research and development of generic technology can further the progress of the whole industry. Moreover, an industrial cluster can acquire a timely understanding of changes in the market, guide the development direction of generic technology, and provide favorable conditions for the innovation and diffusion of generic technology.

Secondly, an industrial cluster can attract talented personnel and accelerate knowledge circulation. The aggregation of a large number of biopharmaceutical enterprises can improve the regional economy. Enterprises in the cluster can rapidly perceive market changes and adjust their technical research direction according to market demands. They can share talents to accelerate the transmission of knowledge among enterprises. Moreover, the concentration of enterprises can provide personnel with more employment and learning opportunities, thereby attracting new talent.

Thirdly, an industrial cluster can strengthen the innovation ability of enterprises. The development of the biopharmaceutical industry depends on the ongoing improvement of knowledge and technology. An industrial cluster provides a good platform for innovation as enterprises can share talents and technology. This allows large enterprises to further improve their technical level and enables middle and small-sized enterprises to have more opportunities for development. In this way, large enterprises guide the direction of development, and middle and small-sized enterprises can coordinate with large enterprises. Moreover, the concentration of enterprises facilitates communication between entrepreneurs to realize common development.

To resolve the resource and environmental problems and achieve better development, a circular can be integrated into the biopharmaceutical industrial cluster. The establishment of an industrial cluster can be guided based on the concept of a circular economy. Re-treatment and recycling of wastes can reduce production costs. Efficient allocation and use of resources can help address the problem of resource shortage.

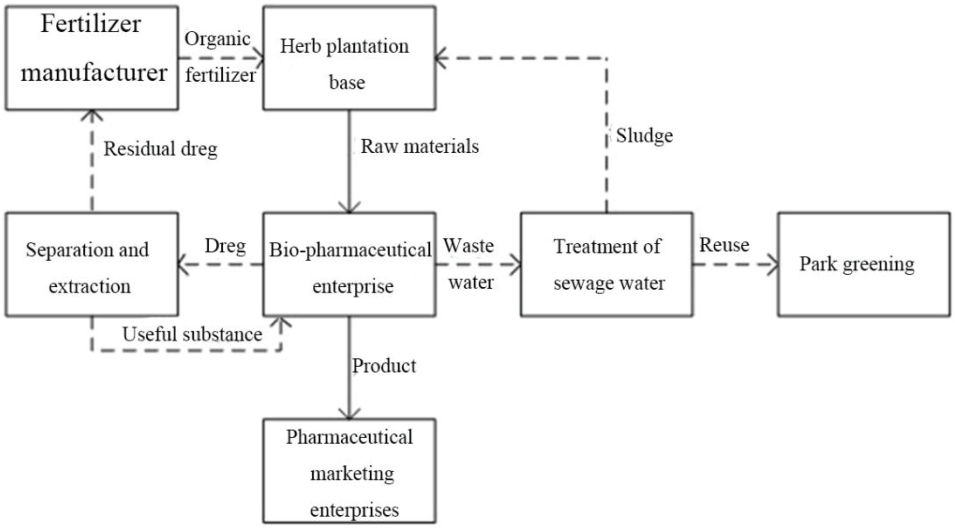

Figure 3 The sketch of circular economy-based biopharmaceutical industrial cluster

5.3 The Construction of Circular Economy-Based Biopharmaceutical Industrial Cluster

The biopharmaceutical industries in Shaanxi can be regionally concentrated so as to establish multiple industrial clusters. For example, in Southern Shaanxi, the key biopharmaceutical industries are concentrated to form industrial clusters. The focus of these clusters is on the research, development and production of biopharmaceutical products, especially the isolation and extraction of drug, production of health care medicines, and the development of biogenetic engineering. Moreover, a comprehensive waste utilization system was established to strengthen the collection and treatment of dregs and waste water. The structure of the circular economy-based biopharmaceutical industrial cluster is shown in Figure 3.

5.4 The Development Countermeasures of Circular Economy-Based Biopharmaceutical Industry Cluster

(1) Establish leading groups to strengthen the leadership in industrial development. The Shaanxi government can establish a group to lead the development of the biopharmaceutical industry, strengthen the management of the development, guide the development of enterprises, provide scientific support as problems arise during the development process and monitor the cluster's productivity and sales.

(2) Provide financial support. Annually, the Shaanxi government invests $0.05\% \sim 0.1\%$ of its budget in the development of the biopharmaceutical industry every year Some of these funds go towards the development of new drugs, research grants and facility improvements; some are used to attract talents and support the development of enterprises and attracting talents.

(3) Optimize industrial structure. The Shaanxi government should establish developmental standards that are appropriate to Shaanxi conditions in order to optimize and improve the industrial structure. When an industrial cluster is being established, relevant factors such as geographical location should be considered. For example, Chinese herb and associated industries could be concentrated in areas with rich resources in Southern Shaanxi to transform resource superiority to product superiority.

(4) Cultivate medium and small-sized enterprises. Medium and small-sized enterprises with development potential should be given support in regard to capital and technology. The advantage of an industrial cluster is that it can accelerate the development of such enterprises.

(5) Apply strict inclusion criteria. Attention must be paid to the quality of the business and investment that a cluster seeks to attract. Apart from technical competence, issues such as the enterprises ability to engage in clean production or not should also be considered. Enterprises which are beneficial to the common development of a cluster should be encouraged to join.

(6) Strengthen foreign cooperation. International and domestic communication and cooperation can be positively carried in regard to talents and technology in projects involving resource utilization, clean production and environmental protection. The cluster can learn about advanced technologies in China and abroad and attract foreign enterprises with industrial strength and preferential policies.

(7) Focus on talent cultivation. Talent and technology are the core of enterprise development. Enough talent support should be guaranteed in order to achieve the long-term development of clusters. Clusters should ensure the smooth running of their circular economy by establishing training bases and focusing on education and the fostering of talent, particularly in the technical and management fields.

(8) Improve market operations. The government should support and protect the development of the circular economy-based biopharmaceutical industrial cluster by carefully implementing relevant policies, optimizing the market environment, standardizing market operations, punishing behaviors that damage the environment, and creating a market environment the facilitates the development of successful clusters.

6. CONCLUSION

If biopharmaceutical industrial clusters are to develop sustainably, it is essential that they establish a circular economy This was confirmed by the analysis of the biopharmaceutical industrial cluster and the establishment of a circular economy. Moreover, in this paper, several recommendations are offered that could ensure the successful development of industrial clusters. It is anticipated that this work offers valuable references and suggestions for the study of circular economy-based industrial clusters in the future.

REFERENCES

1. Fang, S. (2012). Policy Suggestions for Zhengzhou Textile Industry Colony to Develop Circulation Economy *International Conference on E-Business and E-Government*, 679–682.
2. Geng, Y., Fu, J., Sarkis, J. & Xue, B. (2012). Towards a national circular economy indicator system in China: an evaluation and critical analysis. *Journal of Cleaner Production*, 23(1), 216–224.
3. Guo, B. & Li, X. G. (2012). The Research on Industry Cluster Model of Eco-Industry Park. *Advanced Materials Research*, 460, 334–337.
4. Guo, WF., Wang, H. B. & Li, C. P. (2014). Research on the Development Model of Recycling-Oriented Agro-Products Processing Industry Cluster in Fujian. *Advanced Materials Research*, 912–914(4), 1714–1718.
5. Lai, Y. L., Hsu, M. S., Lin, F. J., Chen, Y. M. & Lin, Y. H. (2014). The effects of industry cluster knowledge management on innovation performance. *Journal of Business Research*, 67(5), 734–739.
6. Li, W., Yue, J. F. & An, H. Z. (2017). Exploring the Development Path of Paper Industry Cluster Under the Concept of Circular Economy. *Chung-kuo Tsao Chih/China Pulp and Paper*, 36(5), 64–67.
7. Lieder, M. & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, 115, 36–51.
8. Røyne, F., Berlin, J. & Ringström, E. (2015). Life cycle perspective in environmental strategy development on the industry cluster level: A case study of five chemical companies. *Journal of Cleaner Production*, 86, 125–131.
9. Sima Q., & Wang YB. (2012). Research on Remanufacturing Industrial Cluster Promoting Sustainable Development of Regional Economy. *Advanced Materials Research*, 347–353, 621–626.
10. Su, B., Heshmati A., Geng, Y. & Yu, X. (2013). A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production*, 42(3), 215–227.
11. Sun, Y. P., & Wang, X. M. (2011). The evaluation model for circular economy within industrial cluster based on BP artificial neural networks. *International Conference on E -Business and E -Government*, 1–4.
12. Waits, M. J. (2014). The Added Value of the Industry Cluster Approach to Economic Analysis, Strategy Development, and Service Deliver. *Economic Development Quarterly*, 14(1), 35–50.
13. Yanzi, H. E., Yue, X. & Business, S. O. (2017). A coupling research between packaging industry cluster development and circular economy factors. *Recyclable Resources & Circular Economy*, 6, 12–15.
14. Yuan, Z., Bi, J., & Moriguichi, Y. (2010). The Circular Economy: A New Development Strategy in China. *Journal of Industrial Ecology*, 10(1–2), 4–8.
15. Zhang, J., Wang, N., & Hong, J. (2013). Comprehensive Evaluation on the Development of Industry Cluster Circular Economy. *Advanced Materials Research*, 779–780(4), 1777–1780.