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## **Sustainable Development for Bamboo Industry in Anji, Zhejiang Province of China**

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### **ABSTRACT**

This study introduced the distribution and the development of bamboo industry in Anji Country, Zhejiang Province of China and analyzed the problems of bamboo industry in resource utilization and environmental impact in Anji Country. Based on the analysis, the main findings of the environmental issues of bamboo industry were inefficient utilization of bamboo resource, discharge of unthreatened wastewater and large amount of solid wastes, while the process dust, air pollutants emission from fuel gas and noise could meet the related national standards. Bamboo industry, as a traditional industrial sector, plays an important role for local economic growth not only from its merchandise value but also from its nice scenery. In order to dealing with these environmental issues for the local sustainable development the author proposed the strategies for multiple use of bamboo resource as a whole, from the bamboo cultivation management, bamboo products to waste management. The suggestions included bamboo fabric products and bamboo leave flavonoids development, bamboo charcoal as a new energy product and pollution emission control measurement. From the circular economic point of view, ecological industry park could be a model for bamboo industry. Therefore, industrial chain design and development ideas were described as well in the paper. The study was useful for Anji bamboo industry to achieve the realization of circular economy as well as sustainable development.

**Key words:** Bamboo resource, Anji, circular economy, strategy

### **INTRODUCTION**

Bamboo is an important forest resource of the world. There are more than 1500 bamboo species belonged to 87 genera in taxonomy. Most of them are present in tropical and subtropical regions, meanwhile a few species distribute in temperate and cold regions (Liu, 2001; Xie *et al.*, 2004; Bao and Li, 2005; Zhou *et al.*, 2006). Biologically, bamboo shows a fast of growth and a strong adaptability for environment. In the utilizations of the bamboo products, it covers a wide range, related to various aspects of human being livelihood. China is the earliest country in the world on research, cultivation and utilization of bamboo. Since, the last 30 years, the utilization bamboo in China has increased to a high level. A large number of bamboo products have been commercialized. Now, China has become an export country in bamboo products instead of a domestic consumption country.

Known as a kingdom of bamboo, the bamboo resources are very rich in China. The germplasm resources, plant area, accumulation and production of bamboo in China rank the first in the world. In China, more than 500 species from 39 genera of bamboo have been recorded. According to the last investigation, the bamboo forest area in China is 4.21 million ha, in which plant area of *Phyllostachys* sp. are 292 ha and with  $526 \times 10^8$  strains (Liu, 2001; Xie *et al.*, 2004).

Due to the characteristics differences of climate, soil, terrain changes and bamboo species, the bamboo distribution in China shows a clear zonal and regional. The main distribution regions are in South China, Southwest and East China. The provinces with more than  $300 \times 10^3$  ha of bamboo plant area are Fujian, Jiangxi, Zhejiang, Hunan, Guangdong and Sichuan (Xie *et al.*, 2004).

Abundant bamboo resources promote the large-scale commercialization use of bamboo in China. Since the 1990's, especially after the implementation of natural forest protection policy, a strategy of bamboo instead of timber has been carried out in China for forest area conservation. The State Forestry Administration has compiled the Planning of bamboo forest bases from 2003 to 2010. After then, the planning of bamboo forest and bamboo industry development has been made as well as in Zhejiang, Fujian, Yunnan, Guizhou and Hubei provinces. In these planning, a series of preferential and supporting policies has been greatly promoting the development of bamboo industry in China. Until now, a new industry section of bamboo in resource cultivation, processing and utilization of bamboo has initially formed in China (Liu *et al.*, 2005). At present, annual production value of bamboo industry reaches 5.5 billion US dollars. Bamboo products are exported to more than 30 countries and regions with more than 800 million US dollars of the export trade (Liu *et al.*, 2005).

Compared with the other industries in China, there are several weaknesses in the bamboo industry, for examples, lower levels of management and industrialization, extensive multi-type business model and lower resource utilization. The most bamboo enterprises in China are small scale. The products from these enterprises are producing similar items and most such items are primary products without market competition. Bamboo enterprises do not have strong ability to research and develop new high-tech product. There is not information exchange platform for bamboo industry. Meanwhile, the environmental issues from the bamboo product processing have increased during the development of bamboo industry. All of these weaknesses are limited the potential and superiority development of bamboo industry in China (Liu, 2001).

Here, we introduce a case in bamboo resource comprehensive development and utilization in China, in which the sustainability issue has been considered.

## **THE STATUS OF BAMBOO RESOURCES AND BAMBOO INDUSTRY IN ANJI, ZHEJIANG PROVINCE**

Anji Country (Anji) is located in the northwest of Zhejiang province, which is the rapid development economic zone of the Yangtze River Delta. Bamboo product is the most important special product of Anji. The growing stock and commodities of bamboo, especially *Phyllostachys* sp., are ranked first in the country (Zhang and Li, 2008a). In this area, the bamboo resources are mainly distributed in the Southwest, South and Central mountain regions. The bamboo forest area is about 4467 ha, in which, the bamboo forest of *Phyllostachys* sp., is 3400 and 1067 ha of other species. The growing stock of *Phyllostachys* sp., is over 135 million and annual output of *Phyllostachys* sp. goods reaches more than 20 million pieces of bamboos (Table 1) (Liu *et al.*, 2005; Yang and Lu, 2004; Fan and Li, 2003).

Table 1: The bamboo resource changes within last decades in Anji, Zhejiang province

Years	Bamboo forest area (ha)	<i>Phyllostachys</i> sp. area (ha)	Other species area (ha)	Growing stock of <i>Phyllostachys</i> sp. (ha)	Average diameter of <i>Phyllostachys</i> sp. (cm)	Production of <i>Phyllostachys</i> sp. (10 <sup>4</sup> pieces)	Production of bamboo shoots (10 <sup>4</sup> t)
1983	3600	3000	700	70	7.7	1000	1.0
1989	3700	3000	800	70	8.0	1280	1.5
1998	4200	3300	900	90	8.3	1750	2.9
2003	4500	3500	1000	90	8.7	2000	3.5

In 2006, the per capita net income of farmers in Anji reached 8,031 Yuan RMB, by increased 14.2% compared with the net income in 2005 (Chen and Zhu, 2008). The bamboo industry revenue has become the main source of the farmers' income in Anji. Before 2004, the per capita net income of farmers from bamboo industry is around 30-40% only. While in 2005, it accounted more than 60%.

At present, the bamboo industry has become a leading industry and an important economic growth point in Anji. It has formed five series over 700 varieties of products including bamboo mat, bamboo plywood, bamboo cushion, bamboo crafts and bamboo stationery. The bamboo goods are well sold at home market and international market. However, the by-products in the bamboo industry are developed as well, such as the root carving, root-hair products, wool, broom, bamboo charcoal and fishing rods and so on. Some natural compounds like bamboo leaves flavonoids, bamboo vinegar, peptides and other biological compounds are extracted and purified as the products (Wang and Chen, 2005). Bamboo products are mainly exported to Hong Kong, Macao and Taiwan regions and Southeast Asia, Europe, the United States and other countries. The added value of bamboo has been enhanced by further processing of the bamboo products. According to the statistics data in 2007, the output value of bamboo processing industrial was over 9.0 billion Yuan RMB in Anji. The long fibers of bamboo make it to be a good papermaking raw material (Yang *et al.*, 2008). Till the end of 2007, there were 5 paper mills was using the bamboo fibers as a part of their raw materials in Anji. Because of beautiful morphological shape, higher ornamental value and unique orient culture aura, the bamboo forest plays a very important role in landscaping and landscape architecture (Zhang and Li, 2008b). In 2006, 3.63 million tourists visited Anji and the revenue from tourism was 1.239 billion Yuan RMB (Chen and Zhu, 2008).

## ANALYSIS ON ENVIRONMENTAL ISSUES FROM BAMBOO INDUSTRIES

**Destruction and waste of the bamboo resources:** The level of intensive management for bamboo forest resources is still lower in Anji. About 30% of the bamboo forests are low productivity forests or unsuccessful forests. In some undeveloped mountain areas, bamboo farmers are lack of knowledge on the sustainable management of bamboo forests. The extensive management, over-harvesting and mangling result in the structural imbalances of bamboo forests, the palliation the total increase rate of bamboo resources and the destruction of bamboo diversity. Due to the higher demand market on the bamboo shoots in winter and spring, the bamboo shoots have been dug indiscriminately in many mountain areas, which resulted in a number of nudity and putridity of bamboo roots and watered pits. It is serious harmful to bamboo growth, so that the quality of bamboo has been affected.

In the bamboo process, a lot of resources are not be fully utilized. The leaves, roots, powder and some pieces of bamboos are the main component of process solid wastes. Some new processes and techniques for bamboo waste utilization have been introduced by references. Due to the immature

level of production technical and lack of widespread of practical applications, the utilizations of solid bamboo waste is only about 30% of the total waste in practice.

**The generation and emission of pollutants in bamboo industry**

**The bamboo industry processes and related pollutants generation:** In Anji, the bamboo industry mainly includes the enterprises for producing bamboo flooring, bamboo filament, canned bamboo shoot and craft bamboo fans. During the processing, the discharges of solid wastes, wastewater and waste gases from the enterprises resulted in destroying the ambient environment and local ecosystem.

**Bamboo flooring process:** There are 20 factories of bamboo flooring in Anji. The productivity of bamboo flooring is about 60% of total bamboo products. The pollutants from processing are solid waste, organic wastewater, process dust, mechanical noise and flue gas released from the boiler as well (Fig. 1).

**Bamboo filament splitting processing:** Because of the low investment, high production value and fast turnover in financial, about 1000 factories are bamboo filament splitting, enterprises, which became a major part of the bamboo industry in Anji nowadays. The pollutants from processing are solid waste, organic wastewater, process dust and mechanical noise (Fig. 2).

**Bamboo shoots processing:** In this processing, the products are canned bamboo shoots and dried and salted bamboo shoots. The canned bamboo shoots are produced mainly in the large-scale enterprises. The pollutant from this processing is a large amount of high salinity wastewater which is difficult for treatment.

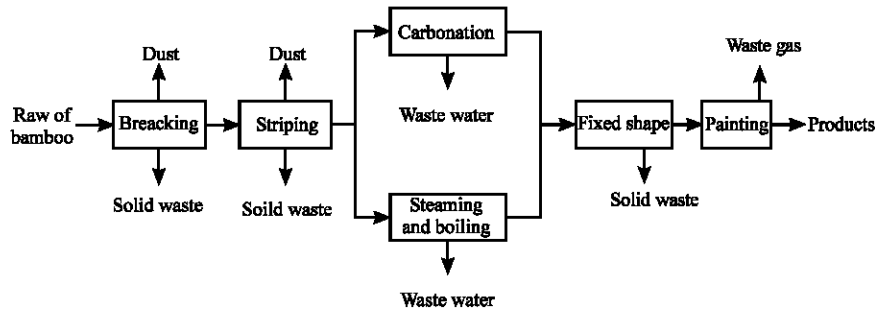


Fig. 1: The flow chart of bamboo flooring process and pollutants discharge

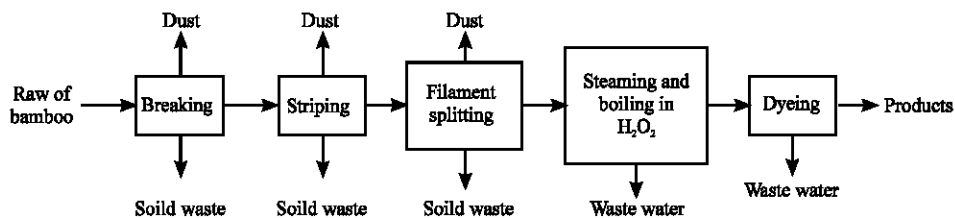


Fig. 2: The flow chart of bamboo filament splitting process and pollutants discharge

Table 2: Discharge of wastewater from different processing enterprises

Process	COD <sub>Cr</sub> (mg L <sup>-1</sup> )	Discharge amount (kg time <sup>-1</sup> )	Remark
Stewing	21400	500~1500	Changing the water more than 3 times a day
Charring	12710	7~8	8000-9000 bamboo strips for charring each time
Splitting bamboo filament	21400	500	80 bamboo filaments each time and changing the water more than 3 times a day
Canning bamboo shoots	3000-5000		High salinity wastewater

The highest concentrations of COD<sub>Cr</sub> is 500 mg L<sup>-1</sup> in according to the national standard Integrated wastewater discharge standard (GB8978-1996)

### Emissions of major pollutants

**Wastewater:** There are no effective wastewater treatment systems in the all enterprises of bamboo industry in Anji. All wastewater are discharged directly to the rivers or groundwater systems. The concentrations of COD<sub>Cr</sub> in the wastewater are between 3,000 and 21400 mg L<sup>-1</sup>, which are seriously, exceeded the national standard (GB8978-1996) (Table 2). Due to that, in some area, the wastewater from bamboo enterprises resulted in the pollution on the groundwater seriously and even affected the daily life of the humanbeing.

**Process dust:** The highest concentrations of dust monitored outside the factories can meet the Integrated emission standard of air pollutants (GB16297-1996). The limitation of the standard is 1.0 mg m<sup>-3</sup> for dust emission without collection and control system.

**Fuel gas from boilers:** In recent years, the fuel gas from the boiler has been focused on by local environmental agency for air pollutants control in Anji. So far, wet scrubber techniques are used in the most factories to decrease the dusts and other facilities are installed for control other pollutants as well. The emission concentrations of the pollutants from fuel gas now meet the Emission standard of air pollutants for coal-burning oil-burning gas-fired boilers (GB13271-2001).

**Solid waste:** The powders and fragments of bamboo produced in the processing were used as fuels to reduce the solid waste amount and the cost of production. Nevertheless, there is still nearly one-third of the remaining solid waste. Piled up to a certain amount, they were sold to other companies as a cheap fuel or to bamboo farming as a fertilizer. Only a small part of solid waste has been recycled for bamboo flooring, bamboo charring and other processes.

**Mechanical noise:** The most bamboo factories are located in open countryside or industrial parks. by plant boundary of construction of vegetation belts and other measures although the point-source noise in the factories was about 80 dB, the noise monitored at boundary of factories remains lower than 60 dB at daytime, which meet Class III criteria of the Emission standard for industrial enterprises noise at boundary.

Generally speaking, the major environmental pollution issues linked to Anji Bamboo industry are untreated wastewater discharged directly into natural water bodies and a large number of solid waste, which is needed to be treated and recycled first, than the disposal is considered. The air pollutant emissions and noise from that section have already met the national emission standard; they are not priority issues for control and treatment.

## **THE STRATEGIES ON ENVIRONMENTAL ISSUES FOR THE BAMBOO INDUSTRY IN ANJI**

As mentioned above, the environmental problems from the bamboo industry in Anji can be attributed two issues, inefficient utilization of bamboo resource as materials and wastes discharges. Taking the size of these bamboo enterprises and their production characteristics into account and comparing these two environmental issues, the former environmental impact is greater and it could affect the later due to the low cultivated management and poor bamboo quality. So, the first of all, to solve the environmental problems raise from bamboo industry in Anji, we should pay more attentions on improving bamboo resource utilization. The measures and strategies are considered as follows.

**Bamboo cultivation management:** For the sustainable development of bamboo industry, the raw bamboo material must be guarantee for sustainable supply. Bamboo is harvested every other year (biennial bearing). After many years of operation, in Anji County, it has been basically formed that a half of 70,000 ha bamboo are harvested in each year. It has been remained a certain amount of bamboo supply to the market, which kept a stable bamboo supply and balanced market prices. With the growth in demand for bamboo material, the shortage of bamboo resources will be a limitation to the bamboo industry in Anji. Expansion of bamboo source is one of the means to solve the shortage of raw materials, but it is not only measure. In sustainable developmental opinion, with scientific cultivation and management on the bamboo resources are the one of the final means to solve the shortage of raw materials. So, the local authority should focus on conducting scientific and technological cultivation and management for the bamboo farmers by training and improving environmental awareness for sustainable development. In policies, some measures such as the unified management of bamboo cultivation as well as the unified use of bamboo should be implemented. By issuing economic regulations, the government could stimulate the bamboo production and planting by using cost of subsidies and tax.

**Reasonable development and utilization of bamboo resources:** To develop some high value-added bamboo products with high technology are not only important for achieving the comprehensive development and full utilization of resource in the bamboo industry, but also important for shifting the extensive operation to intensive operation, driving sustainable utilization of bamboo resources and creating cycle economics of Anji.

**Developments of new products:** Bamboo fabric is a kind of regenerated cellulose fabrics which are made by the fiber extracted from the cellulose in bamboo with a special high-tech process and followed by the glue, spinning and other processes (Shi and Xie, 2006). This product development improves the utilization of bamboo and makes bamboo products development exceeding the traditional model. Compared with other fiber products, the bamboo fiber is easier biodegradable in nature and can be completely decomposed in the soil. It is a kind of real natural and environment-friendly fibers. The original characteristics of natural anti-bacterial, anti-bacteria, anti-ultraviolet of bamboo fiber can be kept after the repeatedly washing and exposure under the sun. The antibacterial bamboo fiber is superior to other fiber products obviously and is different from those fibers with the artificially added anti-bacterial and anti-UV agents as well (Shi and Xie, 2006).

**The energy from bamboo resources:** As a part of biomass, bamboo has showed a potential advantage of energy generation. Bamboo charcoal is a case of the energy utilization from the bamboo resource. Nowadays, there are a plenty of factories are producing bamboo charcoal by charring not only bamboo but also solid bamboo wastes. In the energy utilization, there are more new philosophy and techniques can be adopted and developed, for examples, pyrolysis and hydrolysis fermentation technologies for utilization the bamboo cellulose as one source of energy (Xie *et al.*, 2004).

**The utilization of bamboo leaves:** In the bamboo industry, the bamboo leaves are one of a large number of solid wastes. How to use this bamboo resource is a key point for reduce solid waste amount in the sustainable development of bamboo industry. In the different enterprises, the bamboo leaves have been used to produce the fertilizer for bamboo farming, broom makings, health care pillows and bamboo teas etc. The development of bamboo leave flavonoids, is another example for high-tech applied in the utilization of bamboo leave.

The waste liquid and residues from the bamboo leaves flavonoids proceeding can be reused to nurture bamboo for its growing. It resulted in 30% increasing of bamboo utilization efficiency.

**Pollution control:** In term of pollution control, all of the bamboo-processing enterprises are required to submit the application of pollutant emission permits to the local environmental protection department every year. After monitoring, the local environmental protection agency could check if the emissions meet regulation requirement, so that the enterprises could get an approval for production operations, or to suspend for readjusting till complying with government environment regulations. Large-scale, export-oriented enterprises are required to implement the environmental management system and get ISO 14001 certification and cleaner production certification in order to continuously improve their production process and environmental performance so as to reduce the energy consumption of the production process, reduce wastes releasing to the environment and increase their output value. Further more these factories could produce environmental friendly products in line with the international market.

In the future development in Anji County, the wastewater for bamboo industry is considered to be controlled by two ways. On one hand each factories should build up its own primary wastewater treatment work, so that the concentration of wastewater pollutants could be reduced to certain lever before discharged into the local wastewater treatment plant for further treatment. On the other hand a large scale centralized wastewater treatment plant could be established for collecting and treating the similar wastewater discharged from bamboo industry instead of scattered small work. The later might be more economic method to make the wastewater meet the national emission standards.

Government environmental protection departments should improve its monitoring and auditing system, make its great efforts to help the bamboo factories to gradually update the high energy consumption, high emission machinery and equipment. The factories could purchase new high-tech equipment to replace the old one within limited time required by government for meeting the legal emission standards. According to the pollutant emission permits the government is easy to implement the total quality control policy and ensure the good environment quality in Anji.

**Intensification: the future of bamboo industry in Anji:** With the attention to environmental issues from all shareholders of the society, as well as national and local management on the



standardization of traditional industries, the traditional industries and enterprises in developing and upgrading have been restricted certainly. These limitations are not only from environmental management, but also from the efficient utilization of nature resources and products value-added increasing. In resources science point of view, the resource utilization should be a multi-layered and multifaceted. The circular economic models, based on the basic principles of eco-industry parks, have a lot of good practices at home and abroad in many regions and sectors. Meanwhile, intensive industry can not be understood as only a simple magnification of firm size and production scale, it should include the detailed division of labor and specialization. After the intensive, the industry sector should achieve such objectives: multiple uses of resources; wastewater, waste gas and solid waste emissions decline substantially and value of the products has improved significantly.

Taking the sustainable development into consideration, all bamboo manufacturing enterprises in the Anji could be considered to locate in a region to form the bamboo industrial chain in the present and in the future, according to local conditions. The bamboo industrial chain could be a part of the local circular economy. The "circular" will be throughout the entire process chain to minimize pollutant emissions and increase the efficiency of resource utilization.

Specifically the case in Anji, we should consider the traditional bamboo processes are the major parts of whole industrial chain. Based on the major parts, such as the gross scale bamboo cultivation, processing of the fresh bamboo shoot and handicraft plants, the various deep processes of multiple uses of the bamboo resources could be developed for sustainable bamboo industry. In the industrial chain, bamboo fiber, bamboo charcoal, bamboo vinegar and bamboo leave flavonoids should be included in. The products in this intensive sector should multi-layers, from raw materials, fresh bamboo shoot, bamboo man board and hand products, to the deep-processed and value added products. In the industrial chain and procedures, all of the different factories will be linked with each other by the exchange of material and energy flow. The nature resource conservation and pollutant emission control could be achieved by efficiency using of bamboo material, water and energy.

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