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# Environmental Protection System Engineering and Case Studies of Agricultural Production Areas in Southern China: Taking Poyang Lake as an Example

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**Abstract:** As an important part of the Middle–Lower Yangtze Plain, the Poyang Lake Plain is an important commodity grain production base in China, which is characterized by a good environmental quality, low level of heavy metal pollution in the soil, and a low ratio of pollution sites. Therefore, environmental protection system engineering in the Poyang Lake area agrees with the environmental protection concept of giving priority to protection and is a representative case for agricultural production areas in Southern China. The main environmental problems of the Poyang Lake Plain are clarified in this paper and their causes are analyzed. Measures for environmental quality improvement and key projects based on a systematic landscape–forest–lake protection concept are proposed, which is of significance with respect to guiding the improvement of the environmental quality of the main agricultural production areas in the Poyang Lake area. The results show that environmental pollution in the Poyang Lake Plain is dominated by heavy metal pollution in the soil, the proportion of living-source pollution is increased, livestock and poultry breeding pollution has not yet been effectively curbed, and industrial and mining enterprises and the background value of heavy metals in the soil are the main causes of pollution. Accordingly, the following measures should be implemented. First, multiple environmental factors should be combined to strengthen the systematic protection and unified supervision. Second, meticulous management should be performed by focusing on the water environment quality. Third, importance should be given to environmental emergency plans and pollution sources that may enter the soil should be strictly controlled.
**Keywords:** Poyang Lake; environmental protection; system engineering; policy suggestions

## 1 Introduction

Poyang Lake is the largest freshwater lake in China. It is located in the northern part of the Jiangxi Province and on the southern bank of the Yangtze River. It is supported by five rivers: Gan, Fu, Xin, Rao, and Xiu. It is one of three lakes, which are connected to the Yangtze River and several cities and counties such as Nanchang City, Nanchang County, Jinxian, Yugan, Poyang, Duchang, Hukou, Jiujiang, Lushan, Dean, and Yongxiu. The Poyang Lake Plain is an alluvial plain that formed from the center of the Poyang Lake, with an area of approximately 20 000 $km^2$. The Poyang Lake Basin is connected to the administrative area of the Jiangxi Province, which provides unified planning and management space for the government, which is regarded as having the principal responsibility for the reform of the agricultural supply-side structure. The ecological health of the Poyang Lake

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Basin maintains the ecological security of the basin and the middle and lower reaches of the Yangtze River. It guarantees the sustainable development of the economy, society, and ecology in China. On December 12, 2010, the *Poyang Lake Eco-Economic Zone Plan* was approved by the State Council, which indicates that the ecological construction of the Poyang Lake Basin was elevated to a national strategy. According to the plan, the strategic orientation of the Poyang Lake Eco-Economic Zone is to build a national demonstration zone for the comprehensive development of the Great Lakes Basin, a water ecological security zone in the middle and lower reaches of the Yangtze River. This is an important driving area for the rise of the central region, and an important platform for international ecological and economic cooperation. In addition, as an important part of the plain in the middle and lower reaches of the Yangtze River, the Poyang Lake Plain is an important commodity grain production base in China. The air, water, and soil environment quality in general have a low level of pollution and the proportion of pollution is relatively low. Therefore, it is of great significance to improve the environmental quality of the Poyang Lake Basin to drive the "reverse degradation" of the environmental quality in southern agricultural production areas and to ensure the quality and security of agricultural products, ecological safety of the Yangtze River Basin, and implementation of the national development strategy in the Yangtze River economic belt.

## 2 Environmental quality issues in the Poyang Lake Plain

### 2.1 Heavy metal as the main environmental pollutant and the aggravated contamination

The average annual pH value of the precipitation in the Jiangxi Province is 5.26 and acid rain pollution is still a serious issue. The probability of acid rain in Jingdezhen, Yingtan, and Fuzhou is higher than 80% and that in Nanchang is 100%. The water environment quality of the Poyang Lake Basin is relatively good. Five rivers, including the Ganjiang River, with water quality sections I to III occupy more than 80% of the total sections, while the ratio of the Poyang Lake is only 17.6% because of the slight pollution based on the mesotrophic eutrophication degree and excess of total phosphorus. The proportions of samples that are moderately contaminated and seriously and severely contaminated with heavy metals on the soil surface are 13.81% and 0.35%, respectively. The over-standard areas are mainly distributed in Shangrao City, Nanchang City, Leping City, Gaoan City, Zhangshu City, Pengze County, and Jiujiang City, with the main pollutants Cd, Hg, and Ni. The Hakanson index method was utilized to evaluate the potential ecological risk of heavy metal-polluted soil. The results show that Nanchang City, Nanchang County, Yugan County, Xinyu City, and Pengze County are at middle or high risk and other areas are at low risk.

### 2.2 Coexistence of point source and non-point source pollution and an increase of pollution from living sources

The distribution of the pollution sources shows that point source and non-point source pollution in the Poyang Lake Basin coexist. The overall layout of planting, livestock and poultry farming, and aquaculture in Jiangxi is determined by the topography and water system distribution of the province and makes full use of the advantages of natural resources and the ecological environment. However, due to the excessive scale and intensive development of the "Five Rivers and One Lake" region, the environmental stress degree of the Poyang Lake Basin has increased. The Ganjiang River is the main source of pollution. In 2015, Jiangxi's chemical oxygen demand (COD) of industrial, agricultural, and urban living emissions accounted for 12.86%, 30.67%, and 55.41% of the total emissions, respectively. Ammonia nitrogen emissions accounted for 10.64%, 32.62%, and 55.91% of the total emissions, respectively. It is necessary to pay attention to living source pollution because it has surpassed agricultural and industrial sources and has become the pollution source with the largest contribution. In addition, the areas of heavy metal-polluted soil are mainly found surrounding the areas of industrial cities and the lake district, which affects industrial and mining enterprises, aquaculture, and planting industries to various degrees [1]. The COD, total phosphorus production, and emissions mainly originate from livestock and poultry breeding and the total nitrogen and ammonia nitrogen production and emissions are mainly derived from the crop industry.

### 2.3 Inadequate control of livestock and poultry farming pollution

Pigs are the main animals produced on livestock farms in the Jiangxi Province. Large-scale livestock and poultry farms are mostly distributed around bodies of water, and waste, such as animal manure, is directly or indirectly discharged into reservoirs, rivers and lakes, which degrades the water quality. Pollutants produced and discharged by pig breeding are the main pollutants in livestock and poultry farming [2]. According to the census,

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the COD production of livestock and poultry farming in the Jiangxi Province is 79 1600 t, accounting for 97.0% of the province's agricultural COD production, and the COD emissions due to livestock and poultry farming are 267 600 t, accounting for 94.0% of the province's agricultural COD emissions. The total phosphorus production in poultry farming is 8 759 t, accounting for 64.2% of the total phosphorus production from agricultural sources in the Jiangxi Province. The total phosphorus emissions of livestock and poultry farming are 3 350 t, accounting for 41.4% of the total phosphorus emissions from agricultural sources in the province. The production of total nitrogen is 49 700 t, accounting for 51.7% of the total agricultural nitrogen production in the province, and the total nitrogen emissions from livestock and poultry farming are 22 700 t, accounting for 33.2% of the total agricultural nitrogen emissions in the province. In addition, the amount of ammonia nitrogen produced by livestock and poultry farming is 6 094 t, accounting for 49.7% of the agricultural ammonia nitrogen production in the province. The amount of ammonia nitrogen emissions from livestock and poultry farming is 2864 t, accounting for 32.1% of the agricultural ammonia nitrogen emissions in the province [3]. Therefore, it is necessary to strengthen the treatment and disposal of pollutants produced by livestock and poultry farming, especially with respect to resource utilization, to reduce the pollutant emissions.

## 3 Analysis of heavy metal pollution sources in the soil

### 3.1 Background values and chemical species of heavy metals in soil

The parent material is the intrinsic factor affecting the heavy metal content in the soil for agricultural production. The background values of Pb, Cd, Hg, and As in the Jiangxi Province are higher than the national average values, while the background values of Cr and Ni are lower than the national average values. For example, the background value of Cd (0.108 mg/kg) is 1.8 times the national average. In addition, with respect to heavy metal pollution in the soil, not only should the content of heavy metals be considered, but the chemical species and bioavailability in the soil should also be studied. Gong [4] studied the chemical state of heavy metals in Poyang Lake wetland soil using the method of Tessier. The results showed that Cu, Pb, Zn, and Cd in Poyang Lake wetland soil are mainly in an organic and residual state, accounting for 92.88%, 89.88%, 91.15%, and 30.8% of the total contents, respectively. The contents of water-soluble, exchangeable, and other states of bioavailability only account for 1.82%, 1.32%, 1.13%, and 3.7%, respectively. However, Hu et al [5] surveyed and analyzed the farmland around the Guixi smelter and showed that Cu in the soil of the sewage irrigation field in Guixi City is mainly present in an organic state, while Zn and Pb are mainly in the residual state and the water-soluble state of Cd accounts for 86.06%. The water-soluble and ion-exchanged states of Cu, Zn, Cd, and Pb are much higher than those of normal soil and the proportion of available and potentially available states in the soil is relatively large. The unusable state is low, with Cd > Cu > Zn > Pb. This indicates that smelter wastewater discharge is the main source of heavy metals, especially Cd and Cu, in the surrounding farmland. The question of how to effectively combine the total amount reduction, bioavailable form, and biological effect of heavy metals in the soil is being addressed in soil environmental quality assessments.

### 3.2 Heavy industry and mining enterprises in the Poyang Lake Plain

Due to the parent material and human activities, the sources of heavy metal pollution in the soil are extremely complex. The parent material is the intrinsic factor affecting the heavy metal content in the soil of agricultural production land. However, with the development of the economy and society, the contribution of human activities to the heavy metal content in the agricultural soil has exceeded that of natural sources. According to recent research results in China and abroad, industrial pollution discharge, sewage irrigation, atmospheric precipitation, and farmland application of sludge, pesticides, fertilizers, agricultural film, and plastic film have become sources of heavy metal pollution in the agricultural land of Southern China. Areas of severe pollution are mainly concentrated around industrial and mining enterprises such as Dexing. Therefore, the quantity, distribution, and types of heavy industrial and mining enterprises are analyzed in this paper.

The Jiangxi Province is rich in mineral resources. The Zhuxi tungsten–copper mine in its jurisdiction has 2.86 million t of tungsten trioxide resources and is the world's largest tungsten–copper mine. Since 2012, the number of state-controlled enterprises has remained at a high level and the number of monitoring plants has increased annually (Fig. 1).

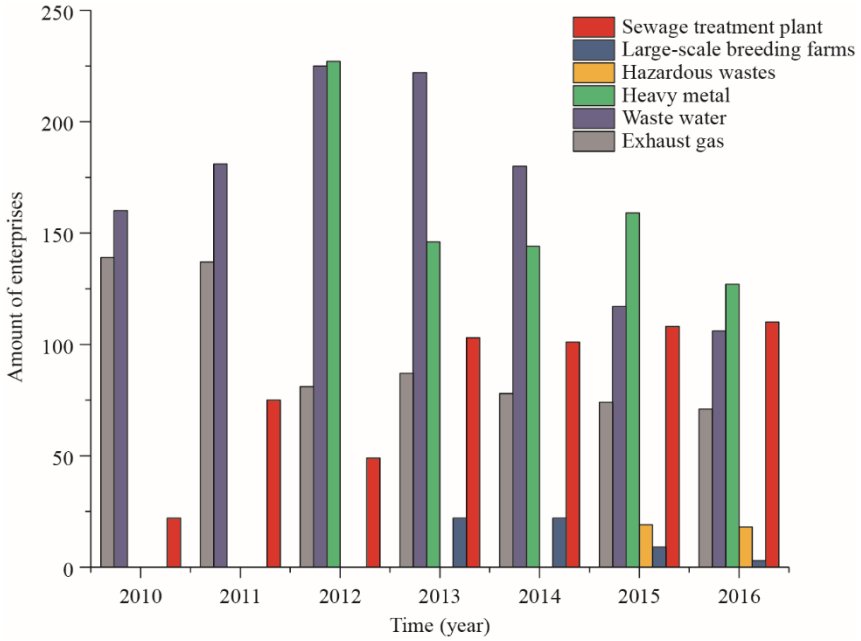


**Fig. 1.** The major types of state monitoring enterprises in Jiangxi Province from 2010−2016.

From the perspective of regional distribution, state-controlled enterprises in the Jiangxi Province are mainly concentrated in Ganzhou City (72, 45%), Shangrao City (29), and Yichun City (15). The state-controlled enterprises in these cities account for 72% of the total state-controlled enterprises in this province. In terms of the industry distribution, Jiangxi's heavy metal state-controlled enterprises include the non-ferrous smelting and rolling processing industry (53) and non-ferrous metal mining and dressing industry (48) which account for 63% of the total enterprises; 34 enterprises belong to electrical machinery and equipment manufacturing and 5 enterprises belong to chemical production and processing. Ganzhou, Ji'an, Pingxiang, Yichun, and Xinyu are all located in the Ganjiang River Basin. Shangrao is in the upper reach of the Xinhe River, where environmental problems caused by the development and utilization of mineral resources have a significant impact on the downstream areas of Poyang Lake and the Poyang Lake Plain.

Among the key cities, Jiujiang City, which is called "The North Gate" of Jiangxi, is located in the estuary of the Yangtze River near Poyang Lake. Mining is one of Jiujiang's important industries. It has four major mineral industrial systems including non-ferrous metals, building materials, chemicals, and metallurgy. There are five non-ferrous metal smelting and calendering industries in Jiujiang state-controlled enterprises, accounting for 42%, and four non-ferrous metals mining and processing industries, accounting for 33%. Nanchang City is in the mid–north of Jiangxi, on the banks of the Ganjiang River, and the plains account for 35.8% of the total area of Nanchang. The state-controlled enterprises related to heavy metals in Nanchang belong to non-ferrous metal smelting and rolling industries. The mining activities have an important impact on the water quality and heavy metal pollution of the soil in the area under Jiangxi's jurisdiction. Sulfide minerals in mine waste rock piles are the main sources of acid, causing severe acid rain. Xinyu City is located in the midwestern part of the Jiangxi Province. It is located between Nanchang and Changsha, two provincial capital cities and it is the city with the most developed economy and the highest level of urbanization in Jiangxi. The types of heavy-metal state-controlled enterprises in Xinyu City include chemical and processing enterprises and other categories. The total number of enterprises is four and their scale is small. This shows that in addition to heavy metal enterprises, there are many other types of pollution sources originating from life or agriculture.

## 4 Countermeasures for the improvement of the environmental quality of the Poyang Lake Plain

### 4.1 Strengthening the system control and unified supervision by the combination of multi-environmental factors

Guided by the important concept of "the combination of mountains, water, forests, fields, and lakes is a community of life," ecological environment protection work will be carried out in the Poyang Lake Plain, organic

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funds will be integrated, and various environmental factors, such as "water–soil–gas–living things–human," will be considered to effectively change the previous pattern of mountain and water management and the field protection. The prevention and control model of the mountain and river system will be established. It is necessary to accelerate the reform of the ecological environment protection system for agricultural production areas; break the constraints of departmental and regional division according to the requirements of clear power, responsibilities, and effective supervision; and make the Jiangxi Provincial Bureau of Agriculture the leading responsible department to unify protection, planning, and monitoring and realize the overall protection and unified supervision of the ecological environment of the Poyang Lake Plain. In addition, the infrastructure of the Poyang Lake Basin and coordinated monitoring of the production environment and agricultural products should be improved, followed by strengthening the joint control of river basins and regional joint defenses and improving the legalization and informatization level of supervision.

### 4.2 Improving the level of environmental management with a focus on water quality

It is recommended to continue upgrading the protection, attach great importance to unpolluted and lightly polluted areas, use the water quality of Poyang Lake Basin as a criterion, restrict the agricultural development layout of the Poyang Lake Plain, promote the concept of regional, green agricultural development based on an environmental quality baseline control concept, and protect the plain environment from being "degraded" in the Poyang Lake area. General zoning of the ecological risk grades of soil in the Poyang Lake Plain was carried out, and zonal and hierarchical management of soil pollution in the Poyang Lake Plain was implemented. Based on different regions and different risk levels, it is necessary to build a refined environmental management unit to establish a regional environmental management system for the Poyang Lake Plain, promote the implementation of differentiated environmental access, and enhance comprehensive management capabilities.

### 4.3 Paying attention to environmental emergency plans and strictly controlling pollution sources that enter the soil

Because of the change in the relationship between the Poyang Lake and Yangtze River, the frequency of "very high levels of water" and "very low levels of water" increases during the year. Under different water conditions, the spatial distribution of heavy metals and ecological risk of lake sediments are notably polarized, and the transition time interval is shortened. In addition, the pollution in the southern and northern lake areas is more concentrated during the wet and dry seasons, respectively, and the effects of environmental pollution are delayed. Once an incident occurs, it cannot be reversed. Therefore, the actual situation should be fully considered before the implementation of various environmental treatment projects in the Poyang Lake area and corresponding emergency plans should be set to prevent pollution sources from entering the soil. Furthermore, the environmental impacts of industrial and mining enterprises and breeding factories should be regularly evaluated and the pollution should be controlled at the source.

## 5 Key projects

### 5.1 Implementing targeted prevention and control of multiple sources of pollution and mainly focusing on the control of radial pollution from living sources

We will focus on the pollution of the Ganjiang River Basin; strengthen the precise prevention and control projects in Nanchang, Shangrao, Xinyu, Jingdezhen, Yingtan, Zhangzhou, and Jiujiang; vigorously promote the green production and ecological governance mode; and continue to promote the comprehensive improvement of the rural environment. Important measures to increase the precise prevention and control of domestic pollution sources include remediation projects of coal washing and processing and coal-fired small boilers; promotion of the classification, collection, and comprehensive recycling of domestic waste; and rectification of informal landfills. In addition, water-saving and water-retaining irrigation technologies are combined with the application of agricultural inputs such as chemical fertilizers and pesticides; a network of abandoned agricultural film, pesticide packaging waste recycling, and comprehensive utilization is established; and the construction of livestock manure disposal facilities under the standardized scale is strengthened. Those measures may contribute to the reduction of agricultural non-point source pollution.

### 5.2 Implementing environmental risk management and control projects for different levels of pollution and establishing systematic environmental science and technology innovation, environmental protection standard systems and environmental technology management systems for agricultural products

Using risk management and control as the core, we will explore the practical experience in improving the environmental quality of agricultural products and effectively prevent environmental and human health risks. Firstly, a comprehensive regional or river basin system management model will be established by combining water conservancy engineering, bioengineering, and agricultural technology. Moreover, an environmental risk management and control plan focusing on the monitoring and evaluation of the main pollutants (heavy metals) in the soil, water, and air in the production area will be formulated. Furthermore, it is necessary to strengthen the soil pollution diagnosis, risk assessment method, monitoring equipment, and new technology research in different types of soils in mining areas and oil fields, industrial enterprises relocated to abandoned sites, large-scale project construction-affected areas, farmland, waste dumping sites, and radionuclides areas. In addition, the promotion of an innovative soil environmental protection system will eventually lead to a reproducible and scalable pollution prevention model that integrates technology and engineering with management.

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