DOI 10.15302/J-SSCAE-2018.05.008

Causes and Control Strategies for Environmental Problems of Agricultural Production Areas in Southern China

Huang Caihong, Xi Beidou, Tang Zhurui, Yuan Wenchao

Chinese Research Academy of Environmental Sciences, Beijing 100012

Abstract: With the rapid development of the Chinese economy, a large number of pollutants have entered into the environment from agricultural production areas. The pollutants have gradually exceeded the capacity limits, leading to substantial environmental problems and pollution incidents, as well as a decline in the output and quality of agricultural products. This has serious impacts on the sustainable development of China's agricultural production and rural economy. Urbanization in Southern China started early and developed rapidly, initially at the expense of the environment. Consequently, the heavy-metal pollution in the region's soil is currently at a critical level and is further aggravated by widespread acid-rain pollution. This paper focuses on the main agricultural production areas along the Yangtze River and systematically discusses the environmental quality issues concerning the water, soil, and air. In addition, this study investigates the causes of pollution with regard to natural factors and influences of human activities and finally discusses pollution prevention and control strategies, which can be of great significance in promoting scientific environmental pollution control in agricultural production areas in Southern China. This is essential to the aims of ensuring sustainable agricultural development while maintaining the quality and safety of agricultural products, ensuring ecological stability, and guaranteeing people's health and safety.

Keywords: agricultural producing areas in Southern China; environmental pollution; prevention and control strategies

1 Introduction

With the accelerating pace of industrialization, urbanization, and agricultural modernization, larger quantities of pollutants have entered agricultural lands, gradually exceeding the environmental capacity limits. Overall, pollution has been increasing continuously, seriously affecting the sustainable development of China's agricultural production and rural economy. The urbanization in Southern China started early and developed rapidly. The initial economic development was at the expense of the environment, highlighted by the "cadmium rice incident" in Hunan, the "poisonous cowpea event" in Hainan, and the pollution of farmlands by manganese mines in Guizhou. Such environmental pollution events have occurred frequently. In addition, the decline in the quality of agricultural products caused by environmental pollution in agricultural land has become a barrier to international trade. Therefore, cause analysis of environmental pollution in agricultural production areas and comprehensive control strategies are essential to scientifically address environmental pollution control. This will ensure the sustainable development of agriculture, while maintaining the quality and security of agricultural products as well as people's health.

Received date: August 20, 2018; **Revised date:** August 26, 2018

Corresponding author: Xi Beidou, Chinese Research Academy of Environmental Sciences, Research Fellow. Major research fields include comprehensive improvement of rural environment, solid waste recycling, and underground water pollution treatment. E-mail: xibd@craes.org.cn

Funding program: CAE Advisory Project "Research on Key Strategic Issues of Agricultural Resource and Environment in China" (2016-ZD-10)

Chinese version: Strategic Study of CAE 2018, 20 (5): 052–056

Cited item: Huang Caihong et al. Causes and Control Strategies for Environmental Problems of Agricultural Production Areas in Southern China. *Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2018.05.008

2 Environmental status of agricultural land in Southern China

The agricultural production areas in Southern China are mainly distributed along the Yangtze River. The overall environmental quality of these production areas is affected by multiple factors impacting the water, soil, and air as well as the complex interactions between these factors. Heavy metals are the main pollutants in the region. Overall, the situation is not optimistic, with some areas being heavily polluted. Cd pollution in the soil is the main environmental problem, occurring at a wide range of pollution levels and ecological risk. The excessively polluted areas are primarily distributed in the Sichuan basin, the Dongting Lake plain, and the Guangxi sucrose-producing area. Because of the developed water network in the southern areas, rural animal husbandry has contributed significantly to aquatic pollution, which has led to obvious environmental stress in agricultural lands.

2.1 Atmospheric environmental quality over the main agricultural land in Southern China

In 2015, the main air pollutants over the agricultural land in Southern China were $PM_{2.5}$; the annual average concentration of $PM_{2.5}$ in major cities ranged from 43 to 70 $\mu g/m^3$ (exceeding the national secondary standard by 1.23 to 2 times). The acid rain-impacted area in China is approximately 7.29×10^5 km^2, accounting for 7.6% of the country's total land area; this value represents a 5.1% decrease compared to the 2010 value. Among the acid rain areas, the proportions of heavier acid rain (pH<5.0) areas and heavy acid rain (pH<4.5) areas are 1.2% and 0.1%, respectively. Acid rain pollution is a major problem to the atmosphere in agricultural production areas in Southern China. Generally, the major constituent of acid rain is sulfuric acid, and it occurs mainly in the southern regions of the Yangtze River and to the east of the Yungui Plateau, including Zhejiang, Shanghai, Jiangxi, Fujian, mid-eastern Hunan, southern Chongqing, southern Jiangsu, and central Guangdong [1].

2.2 Water environmental quality of the main agricultural land in Southern China

In 2015, among 353 state-controlled sections in the Southern China river system, sections with Grade I water quality accounted for 6.25% of the total system; Grade II waters accounted for 45.39%; Grade III waters accounted for 30.31%; Grade IV waters accounted for 9.3%; Grade V waters accounted for 4.22%; and Grade Bad V waters accounted for 4.53%. However, excluding the Huaihe River basin, the river system in southern areas is considered lightly polluted. Data of the 259 state-controlled sections excluding those in the Huaihe River basin is shown in Table 1.

Table 1. Surface water quality (2015).

Region	Number of monitoring sections	Water quality (%)					
		I	II	III	IV	V	>V
China nationwide	700	2.70	38.10	31.30	14.30	4.70	8.90
Southern China	259	8.52	59.53	23.93	4.59	0.74	2.69

2.3 Soil environmental quality of the main agricultural land in Southern China

Paddy planting areas in south acidic soil, typical agricultural areas surrounded by industrial and mining enterprises, sewage irrigated area, suburbs in large and medium-size cities, high-intensive vegetable base, and areas with high background values of geological elements are high-risk areas for soil pollution [2]. Analysis of surface soil in agricultural land in Southern China show that the primary heavy-metal pollutant is Cd; the high Cd-containing areas are concentrated in the Dongting Lake plain, Pearl River delta, and Chengdu plain, while the low Cd-containing areas are distributed in the Poyang Lake plain and the Jianghan plain. Based on the medians of the eight heavy-metal composite indices (As, Cd, Cr, Cu, Hg, Pb, Zn, Ni), the top ten polluted cities are Zhuzhou, Hangzhou, Xiangtan, Jiangmen, Xinyu, Ya'an, Yueyang, Chongqing, Leshan, and Zhuhai (Table 2). With regard to Cd, Zhuzhou, Xiangtan, Xinyu, Jiangmen, Yueyang, Hangzhou, Ya'an, Huangshi, Leshan, and Changsha are the principal polluted cities in the country (Table 3).

Table 2. Medians of heavy-metal composite indices in major agricultural areas in Southern China.

Cities	Comprehensive index
Zhuzhou	2.09
Hangzhou	1.87
Xiangtan	1.31
Jiangmen	1.09

DOI 10.15302/J-SSCAE-2018.05.008

Table 2 (*continued*)

Cities	Comprehensive index
Xinyu	1.05
Ya'an	0.94
Yueyang	0.94
Chongqing	0.80
Leshan	0.80
Zhuhai	0.73

Table 3. Medians of Cd single index in major agricultural areas in the Southern China.

Cities	Single index of Cd
Zhuzhou	2.89
Xiangtan	1.78
Xinyu	1.46
Jiangmen	1.41
Yueyang	1.30
Hangzhou	1.24
Ya'an	1.11
Huangshi	1.06
Leshan	1.02
Changsha	0.93

3 Analysis of environmental pollution sources of agricultural land in Southern China

Since the 1980s, with the accelerating pace of urbanization in China, the levels of industrial "three wastes" pollution and agricultural self-pollution have increased. Certain areas in China that were only partially polluted in the 1980s are now highly polluted. The problem of heavy-metal pollution in agricultural production areas has increasingly gained prominence and is now the focus of attention for the whole society. Human activities and the input from high-intensity practices have disturbed the traditional cycling of matters in the soil system, resulting in changes in soil chemical properties and increased level of pollutants.

3.1 Effects of natural factors

3.1.1 Heavy-metal background value in soil

The quality of the soil parent material is the intrinsic factor affecting the content of heavy metals in the soil of agricultural production areas. The background value of heavy metals in the main agricultural land in Southern China is higher than the national average value. In the Guangxi Zhuang Autonomous Region, the background values of eight heavy metals exceed the national average, especially the background value of Cd (0.267 mg/kg), which is 3.8 times the national average. This, therefore, is an important reason for why the level of Cd in Guangxi exceeds the standard. The background values of Cd, Hg, Ni, and Cr in Hunan province are also higher than the national average; the level of Cd (0.126 mg/kg) is 1.8 times the national average. The background values of Pb, Cd, Hg, and As in Jiangxi province are higher than the national average, while the background values of Cr and Ni are lower than the national average, although the background value of Cd (0.108 mg/kg) is 1.8 times the national average. In Sichuan province, the background values of the eight heavy metals are higher than the national average; the ratios of all the heavy metals are lower than 2 (Table 4).

Table 4. Reference background values of heavy metals in the soil of the study area (mg/kg).

Area	Cu	Pb	Zn	Cd	Hg	As	Ni	Cr
Sichuan	31.1	30.9	86.5	0.079	0.061	10.4	32.6	79.0
Hunan	27.3	29.7	94.4	0.126	0.116	15.7	31.9	71.4
Hubei	30.7	26.7	83.6	0.172	0.080	12.3	37.3	86.0

Table 4 (*continued*)

Area	Cu	Pb	Zn	Cd	Hg	As	Ni	Cr
Jiangxi	20.8	32.1	69.4	0.108	0.084	14.9	18.9	45.9
Anhui	20.4	26.6	62.0	0.097	0.033	9.0	29.8	66.5
Guangxi	27.8	24.0	75.6	0.267	0.150	20.5	26.6	82.1
Average value[a]	20.0	23.6	67.7	0.070	0.040	9.2	23.4	53.9

[a]Refers to the average of the national background values.

3.1.2 States of heavy metal in soil

The evaluation of heavy-metal pollution in soils should not only consider its content, but also the metal's chemical state and bioavailability. Gong [3] utilized the Tessier method to study the chemical state of heavy metals in the Poyang Lake wetland soil. The results show that Cu, Pb, Zn, and Cd in the Poyang Lake wetland soil exists mainly in organic and residual states, and accounts for 92.88%, 89.88%, 91.15%, and 30.8% of the total, respectively. Hu et al. [4] surveyed and analyzed the farmland around the Guixi smelter, and found that soil Cu exists mainly in the organic state in sewage irrigation field in Guixi City. On the other hand, Zn and Pb exist mainly in the residual state, whereas the water-soluble state of Cd accounts for 86.06% of the total Cd content. The contents of water-soluble and ion-exchanged states of Cu, Zn, Cd, and Pb in the soil are much higher than the corresponding states in normal soil. In addition, the ratios of available and potentially available states in soil are large, with the values in the order of Cd > Cu > Zn > Pb. Therefore, when developing assessment techniques for the environmental quality of soil, it is important to study different aspects of heavy metals, such as their total amount in the soil, their effective states, and their biological effects.

3.2 Effects of human activities

3.2.1 Heavy industry and mining enterprises

Areas in agricultural lands that are heavily polluted with heavy metals are concentrated in the vicinity of mining areas. Examples include the Dabaoshan mining area in Guangdong, the Diaojiang River basin in Guangxi, the Huanjiang River basin in Guangxi, the Xiangjiang River basin in Hunan, Xiangxi in Hunan, Daye in Hubei, Dexing in Jiangxi, Gejiu in Yunnan, Fuyang in Zhejiang, Panzhihua in Sichuan, and others. The results of investigations and monitoring of soil and farmlands around the mining areas in Guangdong Dabaoshan show that the quantity of heavy metals such as Cu, Zn, Pb, and Cr in the soil is higher than the national third-class standard. In Guangxi, the farmland along the Diaojiang River is heavily polluted by As, Pb, Cd, and Zn. Lastly, in Hunan Xiangxi, the content of Pb, Zn, and Cd in the soil of the Huayuan mining area exceeds the pollution warning value.

3.2.2 Agricultural production and life

According to the data of *The First National Pollution Source Survey Bulletin* released in 2010, the chemical oxygen demand (COD), total nitrogen, and total phosphorus emitted from agricultural non-point sources accounted for 43.7%, 57.2%, and 67.4%, respectively, of the total discharge of these three types of pollutants [5]. The most prominent sources of agricultural pollution are livestock and poultry farming. The COD, total nitrogen, and total phosphorus derived from livestock and poultry farming account for 96%, 38%, and 56% of total agricultural sources, respectively. The COD emission from livestock and poultry farming (1.268×10^7 t) exceeds that from industrial sources (7.151×10^7 t) and urban living sources (1.108×10^7 t), and has become the most serious among the three major pollution sources in China.

In terms of the total discharge and emission intensity of agricultural non-point source pollution, different regions differ from each other significantly. In the southern regions such as Anhui, Jiangsu, and Hubei, there is a higher use of fertilizers, whereas areas like Hunan, Hubei, Anhui, and Guangdong have higher pesticide utilization. The total output of meat, eggs, and milk in Sichuan province is relatively high by Chinese standards; thus, the risk due to livestock and poultry farming is high. The large production of aquatic products in Fujian, Guangdong, Jiangsu, Zhejiang, and other provinces also indicates a high risk of aquaculture pollution. Agricultural plastic films and aquaculture have become new sources of agricultural non-point source pollution.

DOI 10.15302/J-SSCAE-2018.05.008

3.2.3 Other sources of pollution

(1) Sewage irrigation

China's sewage irrigation area was approximately 3.3× 10^6 hm^2 in 1999, accounting for 7.3% of the country's total farmland irrigation area. In recent years, China has vigorously developed water-saving agriculture, and the proportion of sewage irrigation has declined rapidly. Sewage irrigation in the southern area is mainly caused by water pollution from industrial sewage; the current sewage-irrigation area accounts for approximately 10% of the national sewage irrigation area and the sites are mainly distributed in Wuhan, Chengdu, Changsha, Shanghai, and Guangzhou.

(2) Atmospheric particulate-matter dust

Results show that the contribution of atmospheric particulate falling dust to the total accumulation of As, Cr, Hg, Ni, and Pb in cultivated land is 43–85%. In the Yangtze River delta, the heavy-metal content of atmospheric particulate matters in the study area is generally higher than that of heavy metals in local soil. This is also true for Cd, Cr, Cu, Pb and Zn, but not Fe and Mn. The point and line sources of pollution in cultivated land are more serious than the surface pollution [6]. The influence of heavy metals in atmospheric depositions on agricultural land should be investigated more thoroughly.

(3) Solid-waste stacking

Solid wastes from polluted farmlands, mining and smelting, as well as electronic waste, industrial solid waste, municipal solid waste, sludge, and landfill leachates are the main sources of solid-waste pollution in China. Zhejiang, Guangdong, Hunan, and other regions are the main areas for the disposal of electronic waste; therefore, farmland pollution caused by electronic waste is very serious in local areas. The main pollutants include heavy metals such as Cd, Cr, Cu, Ni, Pb, and Zn; persistent organic pollutants, and others.

4 Environmental pollution prevention and control strategy for agricultural land in Southern China

4.1 General principles and ideas

To resolve the problem of environmental pollution in the immediate and long-term future, it is necessary to strengthen certain development concepts such as "only protect and not develop," "define famer by capacity," and "support farmers by quality". Moreover, it is necessary to upgrade and protect agricultural land, focusing on the development of green and precision agriculture. To fully implement scientific development concepts, the basic ideas involve "coordination among four groups of elements," i.e., environmental protection and socio-economic construction; environmental quality improvement and sustainable agricultural development; environmental pollution control and human health protection; and the investment of resources of the central and local governments as well as the community, to promote environmental protection during agricultural production. We should give priority to environmental protection, paying equal attention to grain output and quality; support prevention-oriented and comprehensive management; adhere to bottom-line thinking; and implement risk management and control measures. In addition, we should also take advantage of scientific and technological innovation, strengthen the close management of environmental protection during agricultural production, improve the public's awareness of environmental protection, and work hard to build an effective system to protect agricultural land.

4.2 Strategies

4.2.1 Environmental constraints in regional development

To improve the regional development and planning of agricultural land in Southern China, economic development must be guided by the environment. It must follow natural laws and regional resource characteristics, consider the environmental capacity of the region as an important criterion, strictly control the level of production as it approaches the capacity or overload levels, and clarify the regional agricultural layout. All of these recommendations should be considered to adjust the regional development strategy.

4.2.2 Integrated environmental protection

The environmental pollution of agricultural land involves multiple media and the synergistic effects of multiple factors. Specific actions have already been implemented, such as the National Air Special Project, Water Pollution Control Action Plan, Water Special Project, and Soil Pollution Control Action Plan. These actions have demonstrated our commitment to continue to promote the concept of environmental protection using a comprehensive and systematic governance approach, employ classify-and-partition programs, and adapt to local conditions. This will

enable us to form a systemic control strategy composed of regional joint efforts.

4.2.3 Pollution control guided by documentation

As the production environment improves, different control units should integrate the "prevent-repair-regulate" concept to refine the technical support system and thus to form series of local scientific and operable management documents and integration models. In addition, efforts should be made to increase the implementation of scientific and technological advances, increase the promotion of technology, and ensure the smooth implementation of policies and measures.

4.2.4 Monitoring and controlling based on technology

The degree of environmental pollution in agricultural land has continuously intensified; new types of pollutants have emerged and sources of pollution have become increasingly diverse. It is necessary to consider the soil cycle as a core concept, monitor multi-environmental systems based on the concept of "integration of atmosphere and soil," and focus on the development of accurate and efficient monitoring equipment, such as unmanned aerial vehicles.

4.2.5 Atmosphere centered on the Central Triangle

In addition to the Yangtze River delta and the Pearl River delta, the Central Triangle areas, dominated by Hunan, Hubei, and Jiangxi are heavily polluted. Highly concentrated acid rain has had a significant impact on the region's ecology. It is necessary to establish a regional joint prevention mechanism in the Central Triangle region, investigate air pollution sources, focus on reducing emissions and controlling pollution, and reduce the adverse effects on soil quality by the dry and wet deposition of air-borne particulate matters.

4.2.6 Water environment and the tributaries of each basin

It is necessary to focus on protecting the tributaries and avoid their over-exploitation. This can be achieved via the "river chief mechanism" policy, whereby the river systems are jointly controlled. In addition, increasing the level of monitoring of pollution sources, as well as the coordinated monitoring of soil and agricultural products in the tributaries of various river basins, especially the tributaries of the Xiangjiang River and Ganjiang River in the Yangtze River basin, would contribute toward preventing and controlling pollution.

4.2.7 Prevention of soil pollution

There are a few regions heavily polluted by heavy metals in southern agricultural land, especially in the middle reaches of the Yangtze River. Over 85% of soils are considered lightly polluted or non-polluted. However, once polluted by heavy metals, the soil is very difficult to reclaim. Therefore, the government should upgrade and strengthen the protection system of the main rice-producing areas in the south, such as the Yangtze River basin, Dongting Lake, and Poyang Lake.

4.2.8 Improvement of agricultural product quality and distribution system

It is necessary to carry out pilot demonstrations of green production, establish a product-tracking system based on quality, and research and implement environmentally friendly agricultural production and organic certification systems. Moreover, the process of marketing agricultural products should be accelerated, with the aim of increasing the market share of high-quality agricultural products. These measures will aid in the improvement of the environmental quality of agricultural land. The application of these practices, meant to ensure the quality and security of agricultural products, should become a major national initiative in the future.

Reference

[1] Ministry of Environment Protection of the PRC. 2015 state of the environment bulletin [R]. Beijing: Ministry of Environment Protection of the PRC, 2015. Chinese.

[2] Ministry of Environment Protection, Ministry of Land and Resources of the PRC. 2014 national soil pollution status survey bulletin [R]. Beijing: Ministry of Environment Protection, Ministry of Land and Resources of the PRC, 2014. Chinese.

[3] Gong X F, Huang Z Z, Zhang J, et al. Speciation of Cu, Zn, Pb, Cd in the wetland of Poyang Lake [J]. Journal of Agro-Environment Science, 2006, 25(2): 388–392. Chinese.

[4] Hu N J. Study on environmental geochemistry of heavy metal and assessment in sewage-irrigated paddy soil in Guixi region [D]. Chengdu: Chengdu University of Technology (Master's thesis), 2003. Chinese.

[5] Ministry of Agriculture, Ministry of Environment Protection, National Bureau of Statistics of the PRC. First national pollution source survey bulletin [R]. Beijing: Ministry of Agriculture, Ministry of Environment Protection, National Bureau of Statistics

DOI 10.15302/J-SSCAE-2018.05.008

of the PRC, 2010. Chinese.

[6] Shi R G, Zheng X Q, Gong Q, et al. Heavy metal pollution source analysis and control strategy in soil of agricultural producing area [J]. The Administration and Technique of Environmental Monitoring, 2017, 29(4): 9–13. Chinese.