



Study on Sources, Causes and Countermeasures of Water Pollution in Rural Areas of Guangxi in China

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ABSTRACT

With the gradual acceleration of urbanization and industrialization, considerable changes have taken place in the production and lifestyle of peasants. However, industrial wastes, domestic and production wastes, and livestock effluent discharge are increasing gradually, thereby intensifying water pollution in rural areas day by day. Water pollution sources and causes in rural areas of Guangxi Autonomous Region were analysed in the research, and the countermeasures were proposed from multiple perspectives. Results demonstrate that wastewater and waste gas emission by township enterprises, wanton production of livestock breeding, large-scale generation of agricultural nonpoint source pollutions, and rural domestic sewage and waste are the main sources of water pollution in rural areas. The long-term existences of an urban-rural dual economic structure, imperfect laws and management systems, and restrictions on rural development have created the current conditions of the water environment in rural areas. Management strategies for the rural water environment are proposed, such as coordinating economic development and environmental protection, improving treatment efficiency of rural domestic waste sewage, increasing the technological content of agricultural production, and enhancing pollution regulation of township enterprises. The conclusions in this study expand the research perspectives and enrich the research content on water pollution problems in rural areas.

INTRODUCTION

Rural areas possess extensive resources and belong to the natural ecosystem. The major natural resources in China are mainly located in rural areas. Similar to cities, rural areas are important social economic regions. China is an agricultural power, and agriculture is still the subject and basis of the national economy. Moreover, rural areas are not only the basis of urban development and the cradle of civilization, but also the education base of China's traditional cultural inheritance. In China, the rural population accounts for more than 50% of the total population. Therefore, coordinated development of the rural society, the economy, and the ecological environment is important to the creation of a new socialist countryside and harmonious society in China. With social and economic development, the natural ecosystem in rural areas is faced with unprecedented threats. To protect the stable and sound development of the national economy, protecting the rural ecology and controlling rural environmental pollution are important and challenging tasks for the country and the people. Water pollution is a critical pollution form in rural areas. Decentralized and disordered development of township enterprises during industrialization in rural areas has caused serious water pollution. In recent years, nonpoint agricultural pollution has further intensified water pollution. Water pollution in rural

areas has become increasingly serious due to domestic wastewater and solid wastes. As a result of the low treatment rate of urban domestic sewage in China, urban pollution discharge contaminates the water environment in rural areas, thus further affecting agricultural product quality and threatening the physical health of people.

Currently, Guangxi Autonomous Region in China is entering the stage of fast economic and social development, which contributes to the annual growth of the GDP (Fig. 1). Given the dual pressure of accelerating development and environmental protection, rural environmental problems in Guangxi are becoming increasingly prominent nowadays, with considerable attention being given to the environment. Annual growth and long-term residues of pesticides and chemical fertilizer applications, random disposal of agricultural films, random discharge of livestock faecal sewage, low treatment efficiency of pollutants from township enterprises, and pollutant migration from urban areas to rural areas not only threaten the health of thousands of rural residents, but also influence the health and safety of urban residents and even the entire population through water pollution, atmospheric pollution and food contamination. Guangxi is a large agricultural province with a low environmental bearing capacity. With a weak rural economic basis, agriculture develops slowly, and peasants

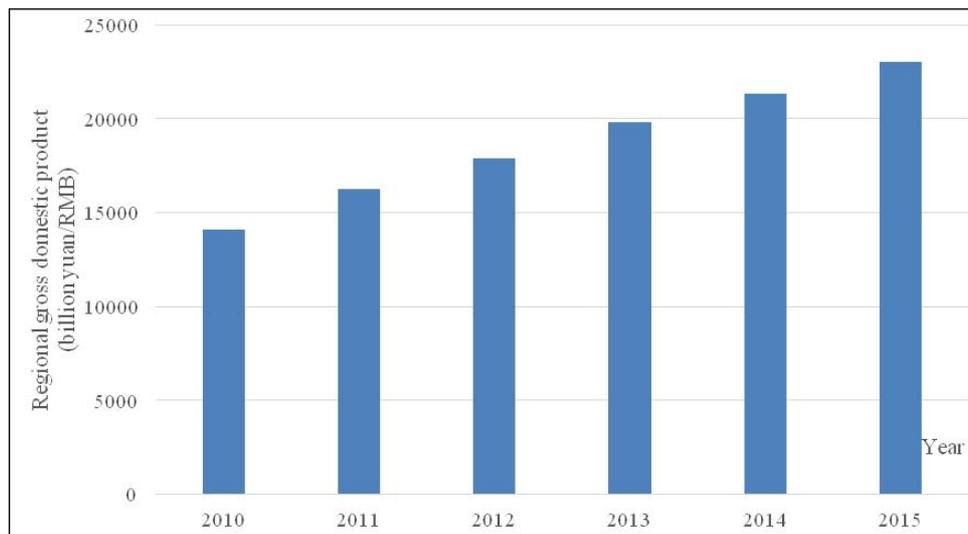


Fig. 1: GDP of Guangxi Autonomous Region from 2010 to 2015.
(Data source: China Statistical Yearbook (2011-2016))

are leading difficult lives. With the industrialization in rural areas, decentralized and disordered development of township enterprises has resulted in serious water pollution. Nonpoint agricultural pollution further intensifies water pollution. Water pollution in rural areas has worsened due to domestic wastewater and solid wastes. Considering the low treatment rate of urban domestic sewage in the Guangxi Autonomous Region, rural pollution discharges pollute the rural water environment significantly, thus influencing agricultural product quality and threatening the physical health of people.

EARLIER STUDIES

With respect to the current situation and management measures of rural water pollution, existing studies mainly focus on point sources. Research keys have shifted from point sources to nonpoint sources with in-depth studies and transition of pollution patterns. Pollution control has been implemented in various ways, from terminal management to whole process management. Direct control, economic means, and information means are integrated for water pollution control. To determine the current situation of water pollution, Zhu et al. analysed the situation and risks of polycyclic aromatic hydrocarbon in surface water in Hangzhou, China (Zhu et al. 2003). Kersebaum et al. analysed the effects of different agricultural management and land use patterns to reduce the diffusion of nitrogen pollutions, thus preventing water pollution (Kersebaum et al. 2003). Jin et al. discussed the situation of tap water and stream pollution in some regions in China, and proposed some countermeasures (Jin et al. 2004). Ai-ping analysed the water pollution

situation in rural areas in China and concluded that rural water pollution restricts rural development and threatens peasants' health significantly (Ai-ping 2009). Schaffner et al. constructed point and nonpoint source pollution models to analyse water pollution in Darchen River and its effects (Schaffner et al. 2009). Huang et al. analysed the spatial changes and sources of water pollution in Qiantang River (Huang et al. 2010). Zhang et al. analysed the water pollution control achievements of China on the basis of wetlands constructed from 1990 to 2010 (Zhang et al. 2012). With respect to water pollution countermeasures, Parker et al. studied how water pollution was addressed through legislative measures (Parker et al. 2000). Young et al. proposed the concept of green evolution and water pollution control through economic incentives (Young et al. 2000). Dosskey et al. suggested installing a buffer region on cropland to reduce water pollution (Dosskey et al. 2001). Wang analysed the relationship between industrial production and water pollution in rural areas in China, and found that unscientific industrial production modes intensified rural water pollution (Wang et al. 2008). Glicksman et al. discussed the effects of science, politics, and laws on water pollution control (Glicksman et al. 2010). Xie et al. discussed the current situation of water pollution in Xiangjiang River Basin and proposed specific management measures (Xie et al. 2016). Smith et al. analysed how serious water pollution in agriculture in the United Kingdom and China can be relieved, and proposed specific measurement measures (Smith et al. 2017). Tiquio et al. studied the coastal and marine pollution management framework in Europe and Southeast Asia (Tiquio et al. 2017). According to existing

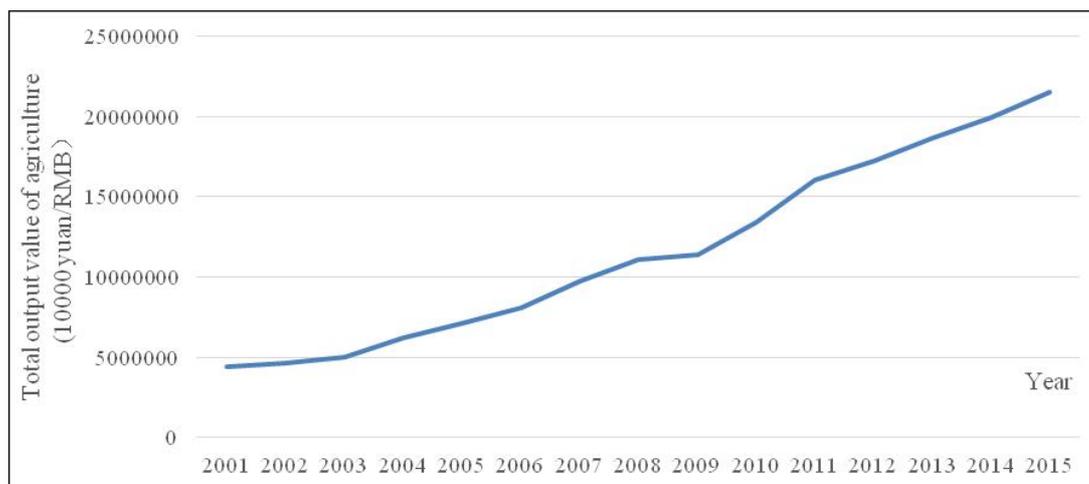


Fig. 2: Total agricultural output of Guangxi Autonomous Region from 2001 to 2015.
(Data source: China Statistical Yearbook (2002-2016))

literature, countries have achieved pollution prevention and environmental protection by monitoring environmental protection organizations and the constraints of relevant laws and standards. Moreover, they adopted manipulative policies to control rural water pollution. Moreover, economic incentive policies are prioritized by European and American countries with good economic development. As one type of environmental policy system, the wide use of economic incentive policies increases not only the flexibility of pollution control, but also social and economic benefits. However, because China developed a late understanding of rural water pollution and delayed rural economic development for a long time, constructing and perfecting infrastructures for rural sewage treatment and exploring a set of sewage treatment systems applicable to rural areas in China will take a long time. Therefore, the study analyses the current situation and problems of rural water pollution in the Guangxi Autonomous Region of China. Specific management measures are proposed. This study aims to explore scientific water pollution countermeasures in rural areas, improve the current situation of rural water pollution and living environment, solve rural water pollution problems, and guarantee environmental safety for the development of a new countryside.

MAIN SOURCES OF WATER POLLUTION IN RURAL AREAS

Wastewater and waste gas emissions by township enterprises: With the economic development of rural areas in the Guangxi Autonomous Region, the value of agricultural production is increasing year by year (Fig. 2). However, township enterprises have developed quickly in recent years. The large number of township enterprises, disordered lay-

out, low resource utilization, background technological equipment, and unreasonable product structure are accompanied with the rapid expansion of rural water pollution. The smelting industry and cement manufacture in rural areas have been generating serious industrial pollution because the creation of pollution treatment facilities has lagged behind the enterprise development level. Frequent water pollution accidents have resulted in increased rural water pollution events, which threaten the safety of domestic water, agricultural plantation and aquaculture. The survival environment of aquatic creatures is also under threat. Substandard waste gas emission by township enterprises is the primary cause of atmospheric pollution. Moreover, some pollutants return to the ground through rainfall, thereby polluting water sources. These pollutants not only contaminate surface water but also threaten underground water by permeation.

Wanton production of livestock breeding: Livestock industry plays a vital role in the promotion of agricultural and rural economic development. Guangxi ranks first in China in terms of total livestock slaughter. The contradiction between the rapid development of the livestock industry and the lack of rural water pollution countermeasures is growing gradually. Some scaled livestock farms are located close to domestic drinking water sources in rural areas. Moreover, a high amount of pesticide applications may influence rural water pollution significantly (Fig. 3). Small livestock farms, which have a small size and disordered distribution, and lack sewage processing equipment, dominate the rural breeding industry. Such farms are one of the main causes of water pollution by coliform bacteria. Fiscal expenditure for environmental pollution control allocates a small proportion for manpower, finance, and materials of

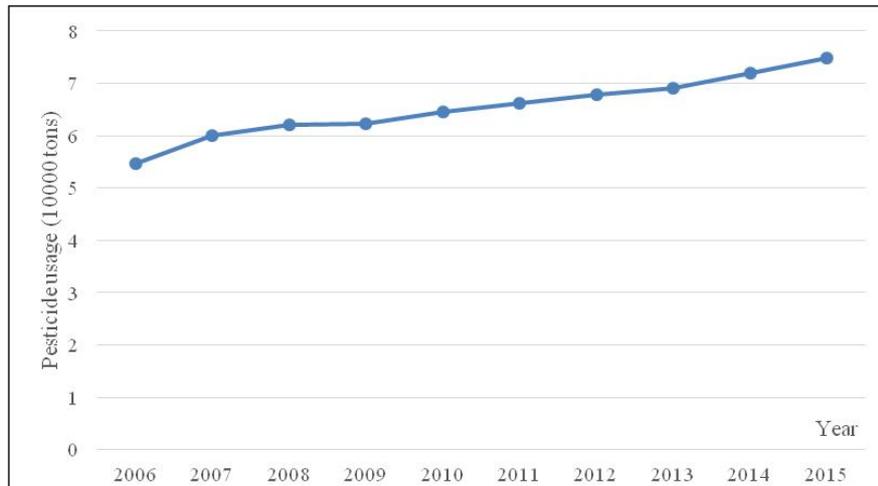


Fig.3: Application quantity of pesticides in Guangxi Autonomous Region from 2006-2015.
(Data source: China Statistical Yearbook (2007-2016))

rural water pollution control. Given such a small amount for rural water pollution control, deteriorated water quality, water eutrophication, and other negative consequences occur as a result.

Large-scale production of nonpoint agricultural pollutants: With continuous rural economic development, the planting industry in rural areas has begun to abandon the use of traditional farmyard manure, which entails intense labour and gradually increasing production costs, and has started to use chemical fertilizers, which are more economically efficient (Table 1). Nitrogen (N) and phosphorus (P) are the principal components of fertilizer. The actual utilization of fertilizer is generally only a small part. Thus, many unused N and P fertilizers are carried into rivers or lakes by farmland drainage or rainfall. As a result, N and P contents in water exceed standards and deteriorate water quality. Most pesticides linger on the soil surface after being sprayed on farmlands. Later, they are carried to water indirectly or directly by penetration or rainfall. Pesticides with an actual insect killing effect account for only a small proportion. Furthermore, the excessive use of pesticide not only threatens human health, but also influences the economic benefits of the planting industry in rural areas.

Generation of rural domestic wastes and other wastes: Domestic sewage and waste pollution is one important cause of rural water pollution (Table 2). Domestic sewage in rural areas mainly comes from washing and domestic water. Washing powder and soap are widely used for clothes washing in rural areas, but non-phosphide detergent, which intensifies phosphorus pollution in rural rivers, is rarely used. Extremely low utilization of domestic garbage is one way for rural waste to pollute water sources. Rural residents often pile up

or dump domestic garbage on open lands randomly. This action not only wastes cultivated land sources, but may also spread pathogenic bacteria. Once pathogenic bacteria enter the water through rainwater, they can contaminate surface water and even underground water.

MAIN CAUSES OF WATER POLLUTION IN RURAL AREAS

Long-term existence of an urban-rural dual economic structure: The long-term existence of an urban-rural dual economic structure is the root cause of rural water pollution. An urban-rural dual economic structure is composed of a traditional agricultural department and a highly modernized industrial department, which have significant differences. Urban-rural economic development is seriously unbalanced in the Guangxi Autonomous Region. Thus, the industrialization level is higher than the urbanization level, thereby resulting in further non-uniformity between urban and rural development and restricting the steady, fast, and sound development of the national economy. Such a situation is disadvantageous for rural water environmental protection in the Guangxi Autonomous Region. Moreover, unreasonable environmental policies, capital investment, and environmental protection infrastructure all emphasize urban areas and neglect rural areas. Such a phenomenon is critical. With a continuous increase in investment and attention, water pollution control and protection systems in urban areas are being perfected day by day. Nevertheless, water environment in rural areas in the Guangxi Autonomous Region is deteriorating gradually due to weak investment, infrastructure construction, and policy and legal system for rural water pollution control.

Table 1: Application quantity of chemical fertilizers in Guangxi Autonomous Region from 2011-2015 (Data source: China Statistical Yearbook, 2012-2016).

Indexes	2015	2014	2013	2012	2011
Effective irrigation area(1,000 ha)	1618.79	1600	1586.37	1541.29	1529.24
Pure application quantity of agricultural fertilizer (10,000 tons)	259.86	258.68	255.7	249.04	242.71
Pure application quantity of agricultural N fertilizer (10,000 tons)	74.23	74.65	74.17	72.45	70.82
Pure application quantity of agricultural P fertilizer (10,000 tons)	31.06	31.25	30.91	30.46	29.57
Pure application quantity of agricultural K fertilizer (10,000 tons)	58.34	57.39	57.28	56.04	54.82
Pure application quantity of agricultural compound fertilizer (10,000 tons)	96.23	95.38	93.34	90.09	87.5

Table 2: Water applications in Guangxi Autonomous Region from 2010-2015 (Data source: Guangxi Statistical Yearbook, 2012-2016).

Indexes	2015	2014	2013	2012	2011	2010
Total water consumption (100 millions of m ³)	299.3	307.6	308.16	303.01	301.81	301.58
Total agricultural water consumption (100 millions of m ³)	201.7	209.21	209.4	211.87	193.21	194.57
Total industrial water consumption (100 millions of m ³)	55.5	56.79	57.4	51.49	57.32	55.23
Total domestic water consumption (100 millions of m ³)	39.7	39.24	38.32	36.64	45.69	46.45
Total ecological water consumption (100 millions of m ³)	2.4	2.35	3.05	3.01	5.58	5.32
Per capita water consumption (m ³ /person)	626.81	649.43	655.6	649.76	652.2	637.18

Imperfect laws and management system: A special legal institutional framework for rural water pollution control has not been created. Therefore, implementing comprehensive water pollution control in rural environments is difficult. The legal system for environmental protection in the Guangxi Autonomous Region has few regulations on rural water pollution control. Most associated regulations are guiding specifications and lack operability in practical management due to management difficulty and poor consideration of the severity of consequences. The rural water pollution cannot be solved fundamentally because of ambiguous standards, ineffective supervision, unclear penalties for rural water pollution and the absence of essential legal regulations for rural living and agricultural production. In addition, many departments have no essential evaluation standards and law enforcement basis for regions within their jurisdiction, or they have no rural water pollution monitoring in their jurisdiction. Thus, rural water pollution has become a vacuum field for monitoring, thereby delaying rural water pollution problems infinitely rather than solving them.

Restrictions on rural development: Special conditions and practical situations in rural areas are important causes of rural water pollution. Low economic development, living standards, and attention to culture are universal in the countryside in the Guangxi Autonomous Region. Therefore, peasants are not fully aware of environmental protection. Moreover, peasants have single economic sources and are struggling with poverty. They are mainly engaged in agriculture or industry for basic survival and to improve their living

conditions, and they rarely consider the effects of practical environmental pollution. This condition further exacerbates rural water pollution. Relevant environmental management departments have not conducted adequate rural development planning. Residents are widely distributed, thereby increasing the difficulty of post-pollution treatment. Moreover, the traditional lifestyle of peasants gives rise to many inconveniences to rural water pollution control.

WATER POLLUTION COUNTERMEASURES IN RURAL AREAS

Coordinate economic development and environmental protection: The guiding thought of “pollution first, control later” has been applied for a long time in the Guangxi Autonomous Region. To solve rural water pollution in the Guangxi Autonomous Region, the current social and economic situations in rural areas need to be considered. Economic investment must be controlled within the affordable range of towns, enterprises and residents. External diseconomy of rural environmental protection determines the necessity of environmental economic policies. Implementation of these policies needs to meet the requirements of market economic law. For example, market subject behaviours are adjusted or influenced by economic means, such as taxation, finance, credit loan, charge and price, thus achieving coordinated development between economic construction and environmental protection. The guiding thought is equipped with behavioural incentives and fund allocation, internalizes external diseconomy environmental expenditures by “internal constraints” through economic

means and market mechanism, and corrects external diseconomy production and consumption behaviours of producers and consumers.

Improve treatment efficiency of rural domestic sewage and reduce solid wastes: The treatment of rural domestic sewage and solid wastes focuses on relatively dense rural areas, but such wastes can be processed by centralized management means. Wastewater can be recycled by establishing a system similar to an urban drainage system, gathering rural domestic sewage by depending on the network system, and using relatively perfect processing facilities, thus realizing standard sewage emissions. In rural areas, where centralized treatment of domestic sewage is difficult to implement, algae pool technology or an anaerobic methane-generating pit is used to process domestic sewage. The former approach can control eutrophication water effectively, whereas the latter is used relatively early in rural areas and can ensure effective management of domestic sewage. Also, sewage treatment plants should be constructed in rural areas, and the combination of biological and natural treatment technologies should be the primary technique.

Increase the technological content of agricultural production and adopt environmental protection measures: Large livestock farms in rural areas must take the initiative to promote centralized development and ecological agricultural construction project for livestock breeding. Ecological breeding should be popularized based on actual situations of scattered livestock breeding in rural areas. For example, livestock faeces provide nutrients for fruit trees. Thus, large livestock farms can choose to implement sludge-gas utilization. The large livestock industry consumes a large amount of energy and can develop renewable energy sources such as livestock faeces. This approach not only reduces rural water environment pollution caused by livestock faeces, but also increases the economic efficiency of livestock and ensures high-efficiency utilization of energy. In ecological agriculture, this approach can promote a cyclic economy and agricultural clean production, thus preventing water pollution caused by agricultural production. Moreover, agricultural production should replace organic fertilizers with biological ones to increase the utilization of fertilizers. The prevention of plant diseases and insect pests in agricultural production can be facilitated by ecological fertilizers and ecological cultivation techniques to reduce the use of chemical fertilizers and establish a green cultivation system. For instance, farmland stocking is feasible, and ecological control on agricultural insect pests should be adopted to ensure sustainable, sound development of agricultural production and the safety of the rural water environment.

Enhance pollution control of township enterprises and perfect sewage control mechanism: The primary key to control water pollution caused by township enterprises lies in the construction and scientific planning of township enterprises, the perfection of their water pollution control ability, and the proper use of modern management measures. The industrial structural layout of township enterprises has to emphasize enterprises' wastewater pollution control. Enterprises should meet wastewater control standards, which can guide township enterprises, ensure that enterprises are concentrated in a uniform industrial park, and ensure the adoption of centralized sewage treatment. Combined with urban planning and development goals, such an approach promotes technological updating and ensures the upgrade of sewage treatment equipment of township enterprises, as well as guarantee effective treatment of sewage from township enterprises. Pollution control has been influenced by imperfect management systems and shortage of professional skills. Therefore, establishing and perfecting a running management system is the foundation for ensuring smooth water pollution control in rural areas and for the creation of effective measures to prevent idling and unmanaged operation of water pollution facilities. The use of uniform management measures must be consistent with the leadership of relevant government departments, the strategy implementation of basic management departments, and the smooth operation of management systems. The practical situation of current rural social and economic development should be integrated, and short-term sewage control funds should mainly come from government subsidies, which provide strong financial support for sewage treatment.

CONCLUSIONS

With intensifying water pollution in rural areas, point source pollution has not been controlled effectively. Nonpoint source pollution in rural areas is another issue that has been highlighted. Rural water pollution not only threatens domestic water, but also causes significant losses for production and economic development. In this study, the sources and causes of rural water pollution are analysed through a case study in the Guangxi Autonomous Region of China. Results demonstrate that rural water pollution mainly comes from wastewater and waste gas emission by township enterprises, wanton production of livestock breeding, large-scale generation of agricultural nonpoint source pollutions, and rural domestic sewage and waste. The current conditions of the water environment in rural areas are due to the long-term existence of urban-rural dual economic structure, imperfect laws and management systems and restrictions on rural development. Water pollution can be controlled by coordinating economic development and environmental

protection, improving the treatment efficiency of rural domestic waste sewage, increasing the technological content of agricultural production, and enhancing pollution regulation of township enterprises. This study analyses the sources, causes and countermeasures for rural water pollution. Future studies should analyse whether pollution crosses administrative regions, the relationship between water pollution and economic development, new source types of rural water pollution, and the negative effect of policy imbalance on the rural water environment.

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