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General Research Paper

Institutional Causes and Countermeasures for Agricultural Chemical Pollution in China

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ABSTRACT

Environmental problems in rural areas of China can be fundamentally solved by preventing and controlling agricultural chemical pollution. On the basis of local and foreign literature, the current research used relevant statistical data regarding the use of chemical fertilizers from 1993 to 2013 and the use of agricultural films and pesticides from 1993 to 2012. Then, the paper adopted SSPS calculation, comparative analysis, and chart analysis methods to analyse the status quo of China's agricultural chemical pollution. Results show that between 1993 and 2013, the total amount of fertilizers used in 31 provinces and cities of China has significantly increased, and the intensity of fertilizer use increases yearly. Moreover, the number of provinces that exceeded the international standard for fertilizer use (225 kg/hm^2) has increased from 8 to 28. During the same period, the ratio of fertilizer use in China has changed but remained far from scientific use. Furthermore, the use of agricultural films and pesticides between 1993 and 2012 has assumed an upward trend. Overall, China's agricultural chemical pollution becomes increasingly serious, thereby endangering the rural environment and agricultural resources and threatening human health and life. As such, this study conducted a unique and in-depth analysis from an institutional perspective and provided countermeasures and recommendations for the institutional transition of China in terms of prevention and control of agricultural chemical pollution.

INTRODUCTION

Foreign research on agricultural chemical pollution has mainly focused on several aspects. For instance, the status quo of agricultural chemical pollution caused by fertilizers and pesticides is common among water sources in the United States (Thomas 1985, Reilly 1985). Nitrogen, phosphorus, and other nutrients produced in agricultural lands are also the main sources of nonpoint source pollutants in the United States. In the European Union, nitrate III pesticide is the largest source of pollution in agricultural production (Line l997, Oenema 1998). Another aspect focuses on the prevention and control of agricultural chemical pollution through legislation, technical support, further research, and legislations, such as the European Union's *Drinking Water Directive*, *Nitrate Directive*, and *Agri-Environmental Regulation*, which can become the major policy basis for agricultural nonpoint source pollution control after their issuance and implementation. Moreover, technical support can be adopted to minimize pollution. For example, covering crops, setting up buffer zones, absence of tillage or minimal tillage, and use of polymers can help prevent the loss of phosphorus nutrition (Hanson et al. 1993, Yiridoe & Weersink 1998, Wu & Babcock 1998, Frasineanu et al. 2013). Taxation subsidy and other market policy tools can also be used. All Nordic countries have applied taxation to control pesticides; in nitrate-sensitive areas of the United Kingdom, farmers can receive compensation for spontaneously limiting their production activities. Research can also be conducted from different perspectives, such as economic analysis of agricultural pollution and micro-perspective analysis of farmers' behaviour in using fertilizers and pesticides. Additionally, causes of agricultural chemical pollution, such as large-scale land reclamation, acceleration of urban process, and economic stimulation are explored.

China's studies on agricultural chemical pollution are mainly concentrated on the following areas. First, in terms of research content, local studies are mainly oriented on the status quo and causes of agricultural chemical pollution, as well as the countermeasures for this situation. Some scholars conducted their studies on the subject in a general manner; for instance, study on agricultural chemical pollution and prevention methods (Tian 2003). Other scholars conducted relatively in-depth research on a specific aspect of agricultural chemical pollution, such as research on the status quo of China's agricultural film pollution and control approaches (He et al. 2003), analysis of the policy reasons and countermeasures for China's agricultural fertilizer pollution (Huang et al. 2011), study on organochlorine pesticide pollution in the soil of China's typical areas (Xu et al. 2014), and assessment of China's policies of controlling nonpoint source pollution caused by fertilizers (Hong et al. 2015). Second, in terms of research method, some scholars conducted targeted studies that combined practices with theories over certain places or areas, such as research on Shixia small watershed of the Miyun Reservoir (Wang et al. 2004), and research on organochlorine pesticide pollution in the bottom mud of middle and low reaches of Gan River basin (Zhao et al. 2010). Some scholars conducted research from the perspective of economics (Wang et al. 2005). Other scholars studied the behaviour of farmers. For example, study on the fertilization behaviour of farmers in North China (He et al. 2006).

Overall, the current local and foreign studies on agricultural chemical pollution lack comprehensive exploration and are characterized by perspectives that are insufficient to analyse the causes, lack of long-term follow-up research on empirical analysis, and very few studies on the ecological damage in rural areas. Therefore, further research on agricultural chemical pollution is necessary. In reality, China's agricultural chemical pollution is very serious and has become a significant hindrance in the country's rural development, giving this research great practical significance.

CHINA'S SERIOUS AGRICULTURAL CHEMICAL POLLUTION

Agricultural chemical pollution mainly refers to the contamination brought about by agricultural production activities, which mainly include pollution of soil, water and air caused by the use of chemical fertilizers, pesticides and agricultural films (Zhiyong Zou et al. 2015). In China, the use of agricultural chemicals increases every year, causing permanent pollution to the environment.

Serious environmental pollution caused by the use of chemical fertilizer: China's use of chemical fertilizers has assumed a trend of annual increase. In 1980, the total amount of chemical fertilizers used in China's agriculture amounted to 12.694 million tons of agricultural chemical fertilizers (pure). As of 2013, the number increased to 59,118,600 tons (pure). Fig. 1 shows the trend of 31 provinces between 1993 and 2013. As shown in Fig. 2, the intensity per unit (amount of chemical fertilizer used/crop acreage) of China's chemical fertilizer use continued to increase. In 1993, only eight provinces exceeded the standard intensity of chemical fertilizer use at 225 kg/hm^2, which was formulated by developed countries. However, in 2013, up to 28 provinces exceeded the international standard in this respect. Low chemical fertilizer utilization rate also characterizes China's chemical fertilizers use. Nitrogen, phosphorus and potassium fertilizer utilization rates were only 30%-35%, 10%-20% and 35%-50%, respectively, which were 15%-20% lower than those in developed countries (Peng et al. 2001). Last characterization is the unscientific structure ratio of chemical fertilizers used in China. The structure of fertilizers used has changed and tended to become more reasonable (Fig. 3). However, fertilizer use was still based on nitrogen, and very small amounts of phosphate and potassium fertilizers were used. In particular, potassium fertilizer was insufficiently used.

The overuse of chemical fertilizers leads to gradual acidification of soil, and decreased productivity of cultivated

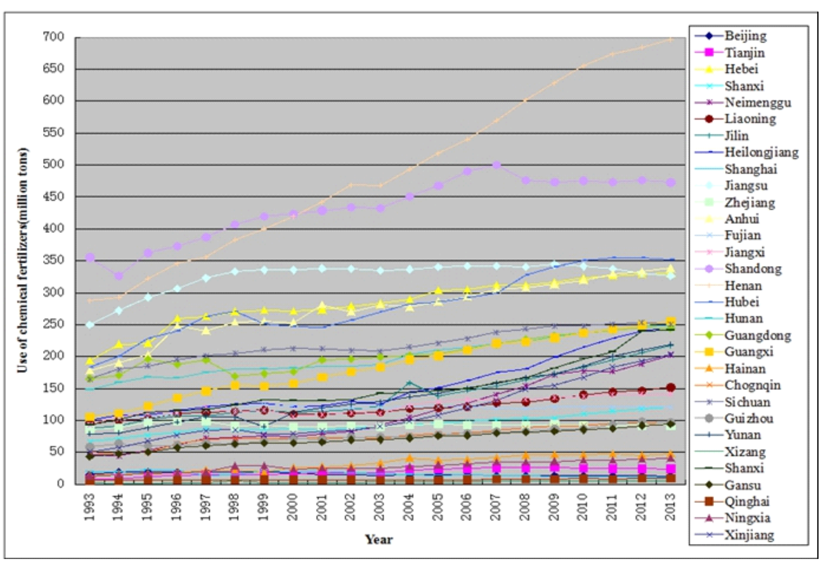

Fig. 1: Use of chemical fertilizers in China from 1995 to 2013.

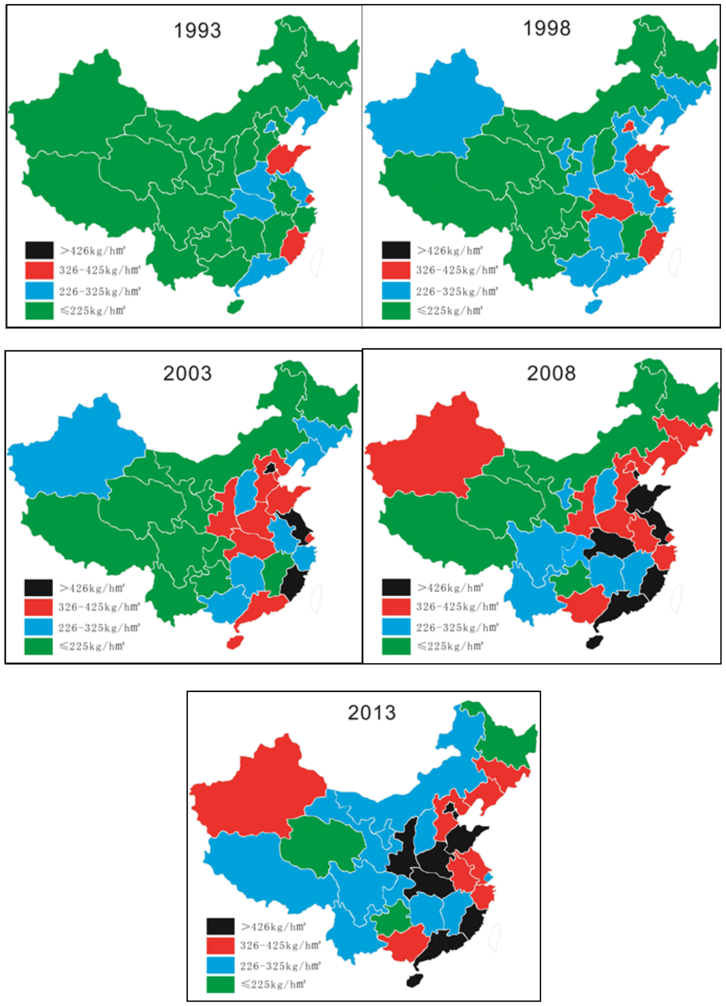

Fig. 2: Chemical fertilizer use intensity per unit in China: 1993, 1998, 2003, 2008 and 2013.

lands. When chemical fertilizers are used in excessive amounts with low utilization rate, the amounts of ammonia nitrogen and nitrate in waters, rivers and lakes increase, and eutrophication becomes increasingly serious. Thus, surface water and groundwater are also polluted. The excessive use of chemicals caused the water of Hangzhou bay to retain 75% and 27% nitrogen and phosphorus amounts, respectively; in the water of Huangpu River, the COD in livestock manure, total phosphorus, total nitrogen and other pollutions accounted for >36% of the total load of pollutants in the whole river area (Tian 2003). In Chaohu area, excessive use of chemical fertilizers caused serious economic loss to the environment, agriculture and human health, which can cost up to approximately 2.44477 billion Yuan. In the water of the Tai Lake, the total phosphorus contents from agricultural fields, rural livestock industry and rural-urban continuum were 20%, 32% and 23%, respectively, and the corresponding total nitrogen amounts were 30%, 23% and 19%; the contribution rate of which had exceeded the point source pollution caused by industries and urban life (Wen et al. 2013). Thus, the use of chemical fertilizers can be considered one of the major causes of China's agricultural pollution.

Serious environmental pollution caused by the use of agricultural film: The use of agricultural film rapidly became popular in China. Fig. 4 shows the trend of agricultural film use in China from 1993 to 2012. Agricultural films mainly include shed and mulching films. Shed film is relatively thick, unbreakable, easy to collect and generally recyclable. By contrast, mulching film is very thin. According to the national standard, the thickness of plastic mulching films should not be less than 0.012 mm, whereas China's national standard regulates that the thickness should not be less than 0.008 mm. Nevertheless, some manufacturers produce

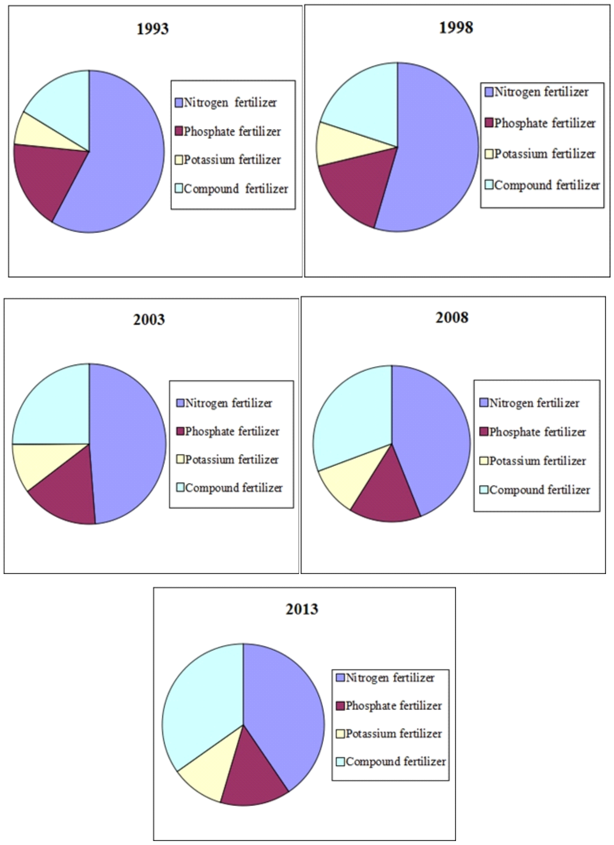

Fig. 3: Chemical fertilizer use structure in China: 1993, 1998, 2003, 2008 and 2013.

mulching films with thickness of only 0.005 mm or less to meet farmers' requirement for input reduction. Hence, given that these films exhibit low intensity, break down easily, and are difficult to recycle, mulching films are major pollutants contributed by agricultural films to the environment. Furthermore, plastic agricultural films are distinguished by their difficulty in decomposition. Gathering on the surface and tillage layer, these plastic films hinder soil aeration and water permeability, stop the roots of crops from developing downward, and inhibit their absorption of water and fertilizer, thereby causing abnormal crop growth and reduced production. Over time, residual plastic films entering the farmland will increase, eventually leading to more serious and extensive pollution.

Even plastic film products that are easy to decompose are mostly harmful substances and can still cause serious environmental pollution. For example, plasticizer, which accounts for 40%-60% of films, should be added in the production of agricultural plastic films. However, these plasticizers are mostly phthalic acid isobutyric in nature, which is highly toxic to plants, especially vegetables. Phthalic acid isobutyric can volatilize into the air from the plastic films and enter into the cells of plant leaves through stoma, causing a significant reduction in the chloroplasts within the cells and prohibiting crop photosynthesis. In case of rainfall and irrigation, breakdown products are brought deeper into the soil or excavated, resulting in contamination of the soil, surface water and groundwater (Yan 2012).

The final harmful results include salt damage of arable soil, serious acidification, soil structural damage, severe recession in soil's microbial properties and health function, significant decline in production performance and invisible loss of arable land resources.

Serious environmental pollution caused by pesticide use: Since China began using organochlorine pesticides in the 1940s, the chemical pesticide industry has developed very rapidly in the country (Fig. 5). The pesticide amount used in 2012 was 1.8061 million tons, 2.46 times of 0.733 million tons used in 1990, and 3612.6 times of 500 tons used in 1950; these figures exceeded the world's total usage amount of pesticides by 30%.

Soluble and insoluble pesticides may be pooled into rivers by the force of rain or agricultural irrigation water, and sewage discharge of pesticide plants can also cause river pollution. The loss of farmland water is considered a main approach for pesticide entry into water. Various waters suffer from different levels of pesticide pollution: agricultural water suffers most from the harmful effects of pesticides, followed by river water, tap water and deep groundwater, with seawater being least affected by pollution. Some scholars conducted a survey on the residue of organochlorine pesticide in suspended solids of the water in the Wuhan section of Yangtze river and found that these solids contain 0.23-1.90 ng/g soprocide and 0.18-4.67 ng/g DDT (Yang et al. 2004). And analysis of the distribution of organochlorine pesticides in Jiuduansha water area showed that the river water contains 6.6-17.1 ng/L soprocide and 4.99-46.6 ng/L DDT, whereas the tidal flat sediment contains 2.32-6.30 ng/L soprocide and 5.9-70.83 ng/L DDT (Zeng et al. 2007). Moreover, a study on the groundwater of Shache & Yingjisha counties in the cotton-producing regions of Xinjiang found that DDVP and dipterex of 4 out of 20 water samples exceeded the value specified by GB 5749-2006 as Drinking Water Health Standards (Zhang et al. 2001) .

After entering into the water, pesticides easily cause negative influence on organisms living in the said water. More extremely, pesticides can cause severe poisoning of aquatic organisms. Even without causing death to aquatic organisms, the pesticide residues will gather in the bodies of aquatic organisms, endangering human health through the food chain.

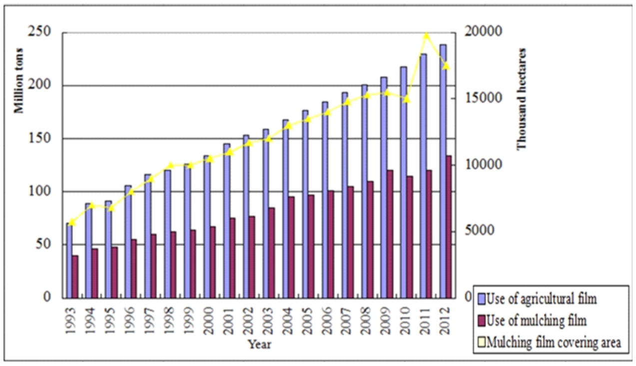

Fig. 4: Use of agricultural film, mulching film and mulching film

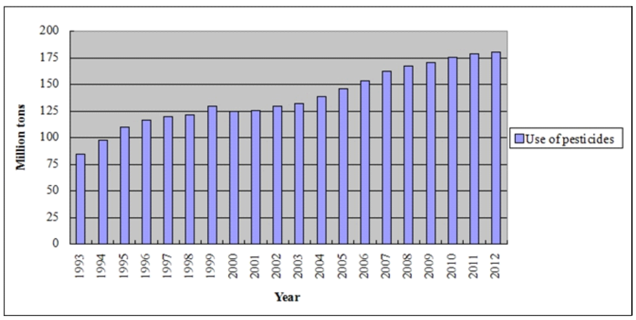

Fig. 5: Use of pesticides in China between 1993 and 2012.

Briefly, the above mentioned pollutions do not only flow along surface and groundwater through moisture infiltration and overland runoff but also enter the atmosphere through dust or volatilization, thereby increasing the range of ecological damages, such as mutations, cancers, deformities and human illnesses (Wen 2007). Pollutants then form the compound, intersectional, and circular three-dimensional pollution involving soil, water and organisms, which is extremely difficult to be controlled.

INSTITUTIONAL CAUSES OF CHINA'S AGRICULTURAL CHEMICAL POLLUTION

Causes of the complex agricultural chemical pollution in China can be analysed in terms of institution, organization, concept and technique. The present study mainly analysed the institutional causes listed below.

Urban-rural Dualism as Underlying Cause of the Increasingly Serious Agricultural Chemical Pollution in China

China's unique urban-rural dualism led to all kinds of unequal distribution of resources between urban and rural areas. In a sense, the intensification of rural environment pollution reinforces the existing dual system, which weakens the rural areas' ability to reduce the urban-rural gap and further widens the difference between the two areas. First, population increase intensifies China's agricultural chemical pollution. The growth trend of China's population is inevitable, indicating that the demand for agricultural products will continue to increase. For some time in the future, reliance on chemicals in agriculture will exist persistently to ensure the supply of agricultural products. Compared with cities, the population size in rural areas increases much rapidly, posing great pressure on environmental resources. Second, the urban-rural dualism in environmental protection enables the control of agricultural chemical pollution to be situated in a disadvantageous situation. China's environmental protection causes, legal regulation, institutional construction, capital input, and scientific research are based on cities and industries rather than rural areas. Although this situation is gradually changing, the influence of urban-rural dualism cannot be eliminated within a short period, causing the rural environmental management to face long-term threat because rural areas demonstrate the following: relatively low environmental need and poor environmental governance, insufficient input for rural environment, difficulty in starting infrastructure projects for pollution control in rural areas, and failure in the maintenance of post-management and operation. Third, in terms of the choice of economic development path, rural areas prefer extensive economic growth mode, which is not conducive to the orderly evolution of a complex ecological system and also increases the difficulty of controlling nonpoint source pollution.

Institutional Offside Stimulates China's Agricultural Chemical Pollution to a Certain Extent

The government-implemented policy interventions in both production and consumption of pesticides, chemical fertilizers, and other products can disable the function of market discipline. In terms of production, tax preference policies encouraged the increase of agricultural chemical pollution. In considering VAT rates, China implements tax reduction to newly produced pesticides, fertilizers and other products, regardless of the negative effects and serious pollution these may cause to the rural environment when used excessively. For example, in fertilizer production enterprises in the 1960s and 1970s, the Chinese government resorted to subsidies and other forms to encourage the development of fertilizers, without considering that these products are harmful to the environment (Si 2010). In terms of consumption, China is driven by demands, encouraging farmers to use large amounts of fertilizers, pesticides, and plastic films in production behaviour of farmers (Jin et al., 2009).

Institutional failure aggravates the extent of China's agricultural chemical pollution

Failure of some agricultural policies: With the acceleration of urbanization, China's arable land will certainly decrease as the population increases, providing tremendous pressure to China's grain production. To ease the pressure on food production, China's government considers food security as the focus of its agricultural policy. With the goal of increasing the food production and farmers' income, the extensive use of rural fertilizers, pesticides and plastic film will not reduce in a short period but will gradually increase. Therefore, pollution problems associated with agricultural inputs will become more serious in the future.

Market failure: Neo-institutional economics believe that the market is also a system (Chen 2011). Economics suggests that in the absence of externalities, free competition in the market will produce effective results; but with externalities, the results of market competition may not be efficient. China's traditional agriculture pursues the harmony between production process and the natural process and demonstrates natural positive externalities for rural environment. However, China's modern agriculture is market-oriented and pursues individual profit maximization, resulting in the negative externalities for rural environmental pollution. At present, China is situated at the important stage of market economy transfer; given that the market is not mature enough, it does not have the basic functions such as supply and demand regulation and factor allocation.

In such a market economy environment, neither the negative externalities of modern agriculture nor the positive externalities of traditional agriculture can be reflected through the prices of agricultural products. Therefore, various production factors, out of their nature to pursuit interest, flow into sectors that gain more benefits. Extensive use of chemicals helps crops achieve high yield and obtain more market benefits, which attract a variety of production factors to flow into sectors producing chemical fertilizers, pesticides and agricultural films, as well as into production methods that require the use of various chemicals in large quantities.

Institutional Absence Increases the Difficulty in Preventing and Controlling China's Agricultural Chemical Pollution

Legal absence increases the difficulty of preventing and controlling China's agricultural chemical pollution: China established a relatively complete environment legal system. Currently, China has over 100 laws, rules and regulations involving environmental protection, including the Environmental Protection Law, Air Pollution Prevention Law, Marine Environmental Protection Law, Environmental Noise Pollution Prevention Law, Energy Conservation Law, Mineral Resources Law, Water and Soil Conservation Law, Water Pollution Prevention Law, and Wild Animal Protection Law, etc.

Nevertheless, legislation pertaining to rural environmental protection is relatively weak. First, laws, rules and regulations specifically designed for rural environmental protection are basically blank. Legislations that show relatively more concern for rural environmental protection include Basic Farmland Protection Regulations, Fertilizer Registration Management Approach, Pesticide Management Regulations, Measures for Implementing Land Reclamation Regulations and Regulations of Returning Farmland to Forestry. However, they are of lower rank relative to other laws, and as principle-based regulations, they do not have strong operability. Second, sections devoted to rural environmental protection in the existing legal system are relatively fragmented and not systematic. For example, in the Environmental Protection Law (revised in 2014), only Article 33 of Chapter III is specifically devoted to the environmental protection in rural areas, stipulating that governments at all levels should strengthen the agricultural environment protection, promote the use of new technology in agricultural environmental protection, strengthen the monitoring and early warning for agricultural pollution sources, co-ordinate relevant departments to take measures to prevent soil pollution and phenomenon of ecological imbalance, and promote the integrated control of plant pests; and that county and township governments should raise the level of public services in rural environmental protection and promote the comprehensive improvement of rural environment. Besides, in Agriculture Law (amended in 2012), Chapter VIII of agricultural resources and agricultural environmental protection, contains a total of only ten articles; in Water Pollution Prevention Law (revised in 2008), the fourth section of Chapter IV of agriculture and rural water pollution prevention law contains a total of merely five articles.

The blank that exists in environmental policies leads to the undesirable effect of controlling China's agricultural chemical pollution: To date, China's existing environmental policies show very inadequate concern for rural environmental protection. An example is the policy charges on pollution. In China's Sewage Charges Imposition Regulation (2003), Article II stipulates that units and individual businesses (hereinafter referred to as polluters) which directly discharge pollutants into the environment shall pay sewage charges in accordance with the provisions of this Regulation. This provision indicates that the existing pollution charge policy is only targeted at those units and individual businesses which directly discharge pollutants into the environment, while excluding a variety of nonpoint source pollution in rural areas from the taxation subject catalogue. With regard to environmental influence assessment, concerns are only shown for pollution prevention in new, renovated, or expanded projects. As for controlling pollution within a prescribed time, concerns are mainly shown for industrial pollution sources that exceed standards to a large degree.

COUNTERMEASURES FOR INSTITUTIONAL CAUSES OF CHINA'S AGRICULTURAL CHEMICAL POLLUTION

Among the numerous causes of agricultural chemical pollution, the present study mainly focuses on the institutional cause; a broader perspective is needed to resolve this issue when countermeasures are being considered. Therefore, China should grasp the following points on the whole. First, rural-urban division is a major cause of environmental problems in rural areas; therefore, China should coordinate urban and rural environmental protection. Given that China is focusing on the protection of urban environment, the government should shift the focus of environmental protection to rural areas. Second, China should coordinate the relationship between agricultural development and environmental protection. The government should not only value food security for the contemporary society, but it should also consider the sustainable development of agriculture in the future. Thus, it should handle well the relationship between agricultural development and environmental protection, and pursue the harmony between the two when formulating relevant policies. The government should also develop specific measures to prevent and control agricultural chemical pollution by paying attention to the combination of technological progress and institutional innovation; on the one hand, research and promotion of agricultural technology in the future should be based on the environmentally friendly principle; on the other hand, in terms of institution building, China should create an institutional environment favourable for the sustainable development of agriculture from the perspectives of market guide and sound system of social trust. Specific countermeasures for the institutional causes are listed as follows.

Countermeasures for filling institutional blank: First, a comprehensive environmental protection law specifically devoted to rural areas should be established. For example, government can develop a specific Rural Environmental Protection Law and strengthen the laws and regulations on the use of fertilizers, pesticides and plastic films. Second, the rural environment protection in China's existing environmental policies should be strengthened and environmental pollution and ecological destruction should be prevented right from the source. For example, the government should broaden the range of taxation subject in the sewage charge system to levy charge on the polluters who cause nonpoint source pollution in rural areas. China should also implement the environmental target responsibility system at township level and establish a system of rural public participation in environmental protection. The third is to implement policy support and offer economic subsidy for the ecological-agricultural development in rural areas. The government should offer policy support to promote circular agriculture and construct a model of ecological-agricultural development based on the requirements of "pollution reduction, reuse, and resource utilization", to achieve recycling use of material and energy in planting and breeding sectors and reduce environmental pollution. The government should also offer considerable economic subsidies to support various rural areas to achieve success in ecological agriculture practices.

Countermeasures for improving institutional shortage: The first is to further promote the system of contiguous remediation in rural environment. For example, government should take effective measures to ensure safety of drinking water for rural residents, pay attention to water pollution treatment, take effective measures to deal with the rural production and living garbage, and prevent soil water pollution and soil erosion. The second is to improve the financial security system for China's agricultural chemical pollution control. Government can adopt a diversified fund-raising mode "government-leading + town and village self-raising + market activation." The third is to reduce policy intervention for production and consumption of agricultural products that cause pollution to the environment, including fertilizers, pesticides and agricultural films. For example, government can terminate offers of favourable tax policy to fertilizer-producing enterprises. The fourth is to further implement the system of promoting agricultural science and technology. Government should actively promote mature techniques of using chemicals, adopt modified fertilizing method and time, and other measures that reduce the amount of fertilizers and pesticides used in agricultural practice (Cai 2010). The government should learn from successful foreign experiences and introduce such pollution control methods and measures at constructed wetlands, river relief area and underground water control.

CONCLUSIONS

Along with rapid economic and social development, pressure on agricultural intensification continues to increase, as well as the number of agricultural chemical fertilizers, agricultural films and pesticides. These chemicals directly resulted in a serious situation of chemical pollution, which may continue to worsen in the future. Therefore, diversified and integrated rural environmental governance is a long-term and complex process that requires the government, enterprises, rural residents, and social parties to actively participate in. They should all collaborate to establish and improve a sound prevention and control system from multiple dimensions and perspectives. Through perseverance in study and practice to eliminate agricultural chemical pollution, the common goal of a green rural environment can and will be achieved.

REFERENCES

Cai, R. 2010. Agri-chemicals inputs and its impact on environment. China Population, Resources and Environment, 20(3): 107-110.

Chen, M.Y. 2011. Conception of the market in new institutional economics. Journal of Hebei University of Economics and Business, 32(1): 31-36.

Frasineanu, C., Chiurciu, I.A. and Stamate V. 2013. Management of polluting systems in the agricultural crops. NMATEH - Agricultural Engineering, 40(2): 87-96.

Hanson, J. C., Lichtenberg, E., Decker, A. M. and Clark, A. J. 1993. Profitability of no-tillage corn following a hairy vetch cover crop. Journal of Production Agriculture, 6(3): 432-436.

He, H.R., Zhang, L.X. and Li, Q. 2006. Rational fertilization and reduction of large-scale farmland pollution by rationalized fertilizer usage. Journal of Agrotechnical Economics, (6): 2-10.

He, W.Q., Yan, C.R. and Zhao, C.X. et al. 2009. Study on the Pollution by Plastic Mulch Film and Its Countermeasures in China. Journal of Agro-environment Science, 28(3): 533-538.

Hong, C.C., Liu, M.C. and Li, W.H. 2015. Evaluation on the policies of non-point pollution control of chemical fertilizer in China. Journal of Arid Land Resources and Environment, 29(4): 1-6.

Huang, W.F. 2011. Analysis of the policy causes of pollution from agriculture fertilizers and its countermeasures. Ecology and Environmental Sciences, 20(1): 193-198.

Jin, S.Q., Wei, X. and Wang, J.X. 2009. Learning from advanced countries' experiences in controlling agricultural non-point source pollution. Environmental Protection, (10): 74-75.

Line, D. E., Osmond, D. L., Coffey, S. W., McLaughlin, R. A., Jennings, G. D., Gale, J. A. and Spooner, J. 1997. Nonpoint sources. Water Environment Research, 69(4): 844-860.

Oenema, O., Boers, P. C. M., Van Eerdt, M. M., Fraters, B., Van der Meer, H. G., Roest, C. W. J., Schröder, J. J. and Willems, W. J. 1998. Leaching of nitrate from agriculture to groundwater: the effect of policies and measures in the Netherlands. Environmental Pollution, 102(1): 471-478.

Peng, K. and Zhu B. 2006. Discussion on non-point pollution and management of agricultural nutrients. Environmental Protection, (1): 15-17.

Reilly, W.K. 1985. Protecting groundwater. Journal of Soil and Water Conservation, 40(3): 260-260.

Si, Y.W. 2010. Second-best tax policies to reduce agricultural nonpoint source water pollution. Journal of Central University of Finance & Economics, 9: 6-9.

Thomas, L.M. 1985. Management of nonpoint-source pollution: What priority? Journal of Soil and Water Conservation, 40(1): 8-8.

Tian, Y.H. 2003. Agricultural chemical pollution and preventive ways. Sci/tech Information Development & Economy, 13(10): 152-153.

Wang, X. Y., Wang, X. F., Wang, Q. P., Zhen-Gang, W. and Cai, X. G. 2004. Loss of nonpoint source pollutants from shixia small watershed, Miyun reservoir, Beijing. Scientia Geographica Sinica, 24(2): 227-231.

Wang, Y., Ye, S.H. and Ding, D.W. 2005. Game's analysis on trans-boundary environmental pollution problems. Journal of Dalian Maritime University, 31(3): 53-56.

Wen, T.J., Cheng, C.W. and Shi, Y. 2013. China agricultural pollution causes and steering choices. Environmental Protection, 41(14): 47-50.

Wu, J. and Babcock, B.A. 1998. The choice of tillage, rotation, and soil testing practices: Economic and environmental implications. American Journal of Agricultural Economics, 80(3): 494-511.

Xu, P., Feng, Y.P. and Fan, J. et al. 2014. Organochlorine pesticides pollution in soils of typical areas in China: Recent advances and future prospects. Agrochemicals, 53(3): 164-166.

Yan, S. 2012. The impact of white pollution on the security of agricultural ecological environment. Agro-Environment & Development, (5): 40-42.

Yang, J.M., Cheng, C.W. and Su, Qingqing 2004. Investigation of organochlorine pesticides residue in the suspended solid of Wuhan section of the Yangtze river. Research of Environmental Sciences, 17(6): 27-29.

Yiridoe, E. K. and Weersink, A. 1998. Marginal abatement costs of reducing groundwater-N pollution with intensive and extensive farm management choices. Agricultural and Resource Economics Review, 27(2): 169-185.

Zeng, Z.C., Sun, Z.Z. and Hong, B. 2007. Distribution of Organochlorine Pesticides (OCPS) in the Water and Sediment of Jiuduansha Wetland in Changjiang Estuary. *Resources and Environment in the Yangtze Basin*, 16(Z2): 85-89.

Zhao, C., Liu, X.Z. and Zhou, L.F. et al. 2010. Pollution Characteristics of Organochlorinated Pesticides in Sediments from the Middle and Lower Reaches of Ganjiang River. *Ecology and Environment*, 19(10): 2419-2424.

Zhang, Q.J., Cheng, X.H. and W. Z.R. et al. 2001. Investigation of Agricultural Chemical Pollution Level in Xinjiang Underground Water. *Arid Environmental Monitoring*, 15(3):159-161.

Zhiyong Zou, Lijia Xu and Zhiliang, Kang, et al. 2015. Design of an intelligent monitoring system for a pesticide spraying machine based on zigbee technology. *NMATEH - Agricultural Engineering,* 45(1): 15-24.