



Environmental Pollution of Livestock and Poultry Raising in Rural Areas and Control Measures: Taking Hebei Province in China as an Example

Yue Wang[†], Jinxu Sun and Hongjun Lin

Hengshui University, Hengshui, Hebei 053000, China

[†]Corresponding author: Yue Wang

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 17-04-2017

Accepted: 19-07-2017

Key Words:

Livestock
Poultry
Rural areas
Raising pollution
Control measures

ABSTRACT

The development of China's rural area construction, the continuous adjustment of rural industrial structure and the increasing growth of the demand for livestock and poultry products have caused the livestock and poultry raising scale to extend constantly. Large amounts of livestock and poultry excrement produced have not been addressed promptly and effectively and have also caused serious water, soil and air pollution. This study takes Hebei province in China as an example to analyse the environmental pollution caused by livestock and poultry raising in rural areas, and propose related treatment measures. The study also analyses the pollution hazard caused by livestock and poultry raising in rural areas, discusses why livestock and poultry raising in rural areas causes pollution, and provides measures to manage livestock and poultry raising pollution in rural areas. Results indicate that pollution caused by livestock and poultry raising in rural areas can be reflected through the soil, water, and air directly or indirectly. The main reasons for the pollution are the low degree of utilization of livestock and poultry waste, lack of awareness of environmental protection, and imperfect treatment mechanism of livestock and poultry raising. This pollution can be addressed by formulating and improving legal rules and regulations of livestock and poultry raising pollution management, establishing a strict environment supervision system, improving the public's awareness in managing livestock and poultry pollution, and actively prompting the ecological livestock and poultry raising mode. The research results have significant reference value for systematically analysing the environmental pollution condition of livestock and poultry raising, analysing the reasons for this type of pollution, proposing countermeasures to address the issue, and government's formulating prevention measures for livestock and poultry raising pollution.

INTRODUCTION

The continuous development of China's economy and improvement in living standard has resulted in an evident change in the residents' food consumption structure and a rapid increase in the demand for livestock and poultry products, such as meat, milk and eggs. This scenario has prompted the rapid growth of the livestock and poultry raising industry. The development of this industry will produce chemical elements, such as nitrogen and phosphorus, pesticide, and other organic or heavy metal pollutants through irrigation or rainfall. These pollutants will be washed into the surrounding rivers and ditches, thereby causing environmental pollution through farmland surfaces, underground water flow, or farmland leakage. Livestock and poultry pollution is currently the main pollution source in rural areas. Given that the pollution from livestock and poultry excrement do not match with the requirements for environmental protection, livestock and poultry pollution not only restrains the development of the social economy, but also constrains the sustainable development of the industry itself.

Hebei Province in China is a province with large livestock and poultry business. With the development of the

livestock and poultry industry, pollution from the industry has become the main source of environmental pollution in rural areas. The livestock and poultry excrement has also increased considerably in recent years. The rapid development of large-scale and centralized raising has led to excessive excrement and urine concentrations and increased washing of wastage water, which imposes huge pressure on the environment. Most livestock farms cannot treat and utilize livestock and poultry excrement effectively, causing the problem of pollution to become more evident. Clearly, the industry has become a new heavy pollution source. Livestock and poultry raising pollution can have a direct or indirect effect on water, soil, air and human health. Therefore, the study provides a valuable reference for the government in formulating livestock and poultry pollution prevention measures by exploring the reasons for Hebei livestock and poultry raising pollution, analysing the current livestock and poultry environmental pollution conditions in the area, appealing to the government, encouraging households and the public to pay attention to livestock and poultry raising pollution prevention, and proposing measures to address livestock and poultry raising pollution in Hebei Province.

Developed countries began to implement large-scale intensive raising and establish intensive livestock and poultry raising farms in suburbs and towns since the 1950s. The generation of a large amount of excrement and polluted water was difficult to process and utilize, resulting in serious environmental pollution. Foreign countries began to conduct research on livestock and poultry pollution at the beginning of the 1960s and focused mainly on explaining the mechanism and consequence of livestock waste damage, excrement and urine treatment and utilization, and pollution removal technologies, policies and laws. For livestock and poultry raising pollution in rural areas, Dzikiewicz believed that the main reason for water pollution in Poland was the improper nutrient storage and process system in animal management, which caused significant loss of organic matter and nitrogen (Dzikiewicz 2000). Erisman stated that the fermentation of livestock excrement would generate a large amount of harmful malodorous gas that can have a serious effect on air quality of livestock and poultry farms and their surrounding environment, as well as the physical and psychological health of livestock and poultry keepers and nearby residences (Erisman et al. 2008). After analysing the livestock and poultry production and nitrogen pollution load in China for the past 30 years, Yang regarded the rapid development of the Chinese livestock and poultry industry and their wastage as the main source of agricultural pollution (Yang et al. 2013). Wang analysed the time and space change trends of livestock and poultry pollutants in Sichuan Province in China and estimated the pollution load caused by livestock and poultry raising (Wang et al. 2015). Tongquan analysed the influence of agricultural non-point source pollution at Hongfeng Lake in Guiyang City and summarized that farmland cultivation, livestock, poultry, and aquaculture have become the most important sources of water environment pollution (Tongquan et al. 2016). Li and co-workers found that livestock raising had the most contribution to water system pollution, which resulted in the eutrophication of surface water and nitrate concentration of underground water (Li et al. 2016). Gan analysed the geographical distribution of livestock and poultry raising pollutants in China and regarded livestock and poultry raising as the main source of agricultural pollution (Gan et al. 2016). Qingbo published a forecast on large-size livestock and poultry raising excrement pollutant output (QingBo et al. 2016). In terms of treatment measures for livestock and poultry raising pollution, Shortle reported that the agricultural non-point source pollution control policy includes tax and subsidies, as well as standard, market, contract, bond, and responsibility rules (Shortle et al. 2001). Romstad stated that charging different taxes for agricultural water pollution, encouraging farmer households to actively report pol-

lution discharge conditions, and take self-discipline measures to decrease the pollution discharge are better mechanisms (Romstad 2003). Chin investigated dairy farming pollution in Hanoi, Vietnam and determined that the government should provide technical and financial support to adopt methane technology in families and communities (Chin 2005). Geng stated that the total amount of animal excrement should be controlled (Geng et al. 2013). Pan selected a choice experiment method to analyse the effects of farmer preference on the Chinese livestock and poultry pollution control policy (Pan et al. 2016). The aforementioned literature review highlights the significant convergence in the livestock and poultry raising pollution research conducted by local and international scholars, such as convergence data source, convergence explanation factors, convergence analysis methods, and convergence strategies and suggestions. Many studies have been conducted on point source pollution caused by livestock and poultry raising, but few have focused on the supervision, environment, hygiene, and actual processing of livestock and poultry excrement at different sizes of livestock and poultry raising farms in rural areas. Therefore, the current study combines related statistical material and livestock and poultry excrement processing conditions, analyses the current environmental pollution of livestock and poultry raising in Hebei Province, explores why livestock and poultry raising causes pollution, and proposes treatment measures based on the literature. These mechanisms can significantly strengthen Hebei livestock and poultry raising pollution prevention.

HARM CAUSED BY LIVESTOCK AND POULTRY RAISING POLLUTION IN THE HEBEI RURAL AREA

Soil pollution: Soil, which forms on the surface of the Earth, is natural matter that contains water and fertility and nutrient elements that facilitate plant growth. Soil quality has a direct effect on plant growth because of the soil surface. Livestock and poultry raising in the rural areas of Hebei province displayed generally increasing trend from 2013 to 2015. The number of houses, donkeys and mules exhibited a decreasing trend after being affected by the market, whereas the number of cows, pigs, sheep and poultry increased continuously because of the large market demand. A large amount of poultry excrement was stocked on the farmland and the wastage water permeated into soil surface. These conditions could result in loose soil gap being blocked and hardened, decreasing gas and water permeability of the soil, and negative effects on providing nutrition and water for plants. The decrease in soil quality translates into a decrease in crop quality and output. With the large usage of concentrated feeds that contain additives for poultry raising (Fig. 1) in recent years, heavy metals in the feed (e.g., lead, cop-

per, and zinc), are discharged from animal bodies along with excrement, which permeate the soil. The heavy metal concentration prevents the soil from absorbing or digesting them, which can lead to changes in the soil structure and functions. It then further blocks the normal growth of animals and plants to some extent. For example, when the copper element from poultry excrement permeates the soil, the copper concentration stops it from being absorbed by plants, which affects the growth speed of plants, resulting in a largely lowered output. When the excrement containing a copper element is applied on the grassland, it causes an intoxicating phenomenon among sheep, which are sensitive to copper. If livestock and poultry excrement wastewater is used to irrigate farmlands for a long time, it will break the natural growth law of plants, affect output and quality, pollute farmlands, lower soil quality, and harm the growth environment of crops.

Water pollution: Nitrogen, phosphorus and kaliumare concentrations in wastewater will increase and result in water eutrophication if livestock and poultry farmers do not process livestock and poultry excrement, as well as the wastewater caused by washing breeding houses and pour them into nearby rivers or lakes (i.e., the feeds contain large amounts of nitrogen, phosphorus, and kaliumare used) (Fig. 2). Under such circumstances, the rapid growth of algae plants will cause a large decrease in dissolved oxygen in water, causing aquatic animals and plants to suffocate. The continuous discharge of large amounts of livestock and poultry raising wastewater will cause the body of water to become black and smelly. The livestock and poultry excrement and washing wastewater that flows with overland run-

off will cause serious water pollution. Statistics from China's State Environmental Protection Administration show that the runoff rate of pollutants from solid excrement in water is between 2% and 8%, whereas the run-off rate of pollutants from solid discharge in water reaches 50% (Table 1). However, these pollutants can form dead water, which transforms into bog and lowers water quality. It cannot be utilized directly when it exceeds the self-cleaning capacity of water, which will further result in the death of aquatic animals. When livestock and poultry wastewater permeates the water cycle system through overland runoff, poisonous and harmful substances will hide in the soil and tiny gaps in the rock, which extends the cycle. This condition is difficult to notice, treat, and recover from, once the water body is polluted. Although the water body is equipped with a self-cleaning system, it will take several decades or even hundreds of years to remove these poisonous and harmful substances. If pollutants from livestock and poultry wastewater, such as germs and parasites, are absorbed by the human body through drinking water or the food chain, it will cause several types of infectious diseases that can harm human health and safety.

Air pollution: Malodorous gas generated by livestock and poultry raising farms will seriously damage air quality when accumulated to a certain degree of concentration. The main contents of malodorous gas are gases with strong pungent odours, such as ammonia, sulphurated hydrogen, skatole, and methane. Normal air contains gases, such as oxygen, nitrogen, a small amount of carbon dioxide, and other gases suitable for animal and plant growth as well as human survival. After the stocking and fermentation, livestock and

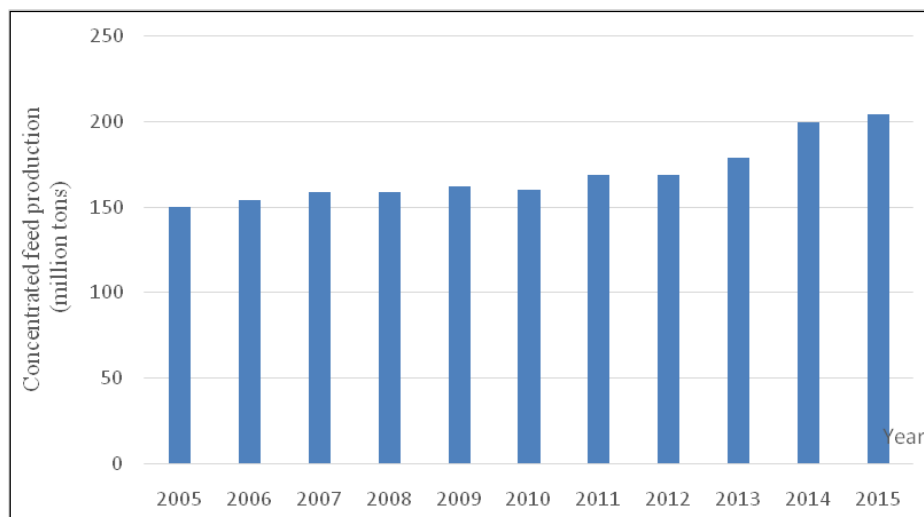


Fig. 1: Concentrated feed output in Hebei Province from 2005 to 2015. (Data from the "Hebei Rural Area Statistical Yearbook" 2006-2016).

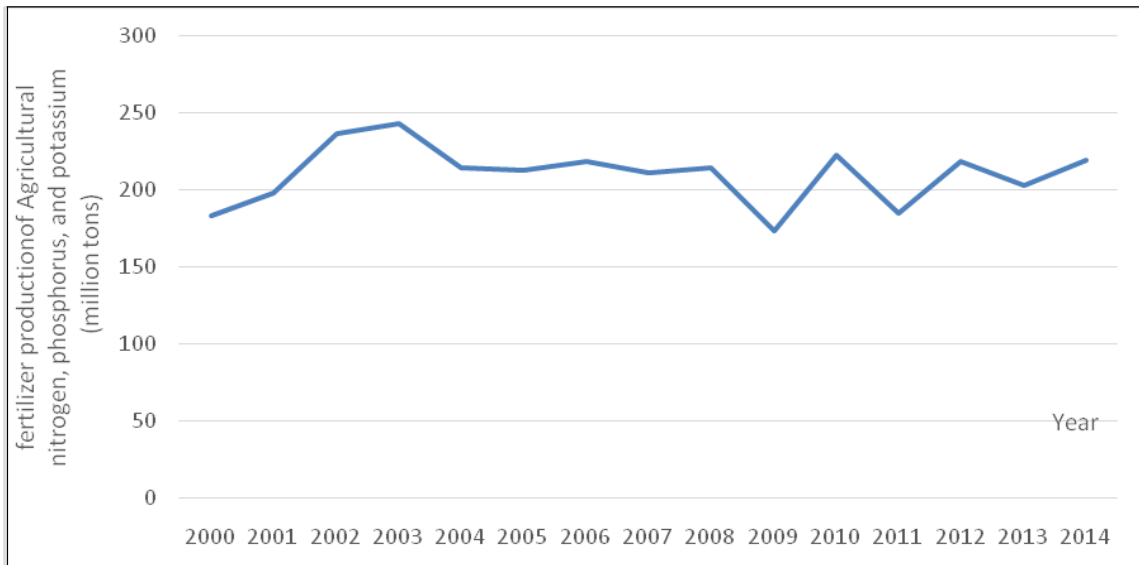


Fig. 2: Output of agricultural nitrogen, phosphorus and Kaliumare in Hebei Province from 2000 to 2015 (10,000 tons). (Data from "Hebei Rural Area Statistical Yearbook" 2006-2016).

Table 1: Run-off rate of livestock and poultry excrement and urine in water (%).

Item	Cow Excrement	Pig Excrement	Sheep Excrement	Poultry Excrement	Cow and Pig Urine
BOD	4.87	6.14	6.7	6.78	50
COD	6.16	5.58	5.5	8.59	50
TP	5.5	5.25	5.2	8.42	50
TN	5.68	5.34	5.3	8.47	50

poultry excrement will generate a large amount of poisonous and harmful gases, which will expand continuously after entering the atmosphere causing serious damage to the air quality. It can threaten human beings and other living things in a larger area with windy conditions and during frequent air cross-ventilation. When concentrated pollutants fall onto the surface of the Earth along with rain and snow, it will pollute the water and the soil, causing further harm to animal and plant growth, resulting in a vicious cycle of livestock and poultry excrement, wastewater, and malodorous gases. This condition causes difficulties with pollution treatment. If these harmful gases enter the human body through the respiratory system, it can cause different respiratory diseases, harm the health of farmland workers and surrounding villagers, and seriously pollute the living environment of the surrounding villages.

REASONS FOR LIVESTOCK AND POULTRY RAISING POLLUTION IN THE HEBEI RURAL AREA

Low degree of livestock and poultry waste recycling: The significant increase in the degree of livestock and poultry

raising pollution can be attributed mainly to livestock and poultry waste not being fully recycled. Given the rapid development of intensive and large-scale raising industry, the breeding stock of livestock and poultry has increased (Table 2), and the livestock and poultry feeding and management methods have changed considerably. The stocking rate in a certain land area has also increased, thereby resulting in more livestock and poultry waste. However, farming households do not have sufficient land to consume increasing livestock and poultry excrement and urine. The layouts of several large-scale livestock and poultry raising farms are unreasonable. Several farmlands are built at the rural-urban continuum, where convenient transportation is present, to lower the cost. Along with the increase in urban development and population, several farms have become unified with nearby cities, towns, and residences, which have accelerated the worsening of the urban ecological environment. The transfer of livestock and poultry raising industries from pasture and rural areas to town areas and their surroundings, as well as from rural areas with small populations to town areas with dense populations has caused a disjoint between agriculture and pastures. Excrement cannot be transported and applied in farms and large stocks of excrement and urine in the rural-urban continuum have worsened the environment. Excrement has the disadvantages of large size and volume. The cost of transporting livestock and poultry excrement back to the farmlands is also high. On the contrary, fertilizers have the advantages of suitable effect and convenience for transportation and storage. Hence, farmers select commercial fertilizers instead of organic fertilizers from livestock and poultry excrement.

Table 2: Livestock and poultry inventory in the Hebei rural area from 2010 to 2014 (10,000 tons).

0	Cow	Horse	Donkey	Mule	Pig	Sheep	Live Poultry
2000	516.73	45.04	149.14	63.33	1959.6	1676.6	45515.9
2001	487.72	43.31	138.92	60.22	1904.2	1639.5	44432.9
2002	476.64	40.64	130.04	55.6	1909.9	1572.5	47707.8
2003	477.87	36.83	121.05	49.31	1926.2	1594.3	42212.7
2004	528.39	35.53	112.56	45.33	1964.3	1664.5	51602.9
2005	584.92	33.13	104.11	40.47	1977.5	1679.1	41070.5
2006	458.93	28.99	90.16	34.92	1812.8	1552.6	37495.5
2007	474.99	24.92	80.72	29.86	1907.1	1583.7	39106.9
2008	449.01	22.7	70.65	27.39	2015.2	1617	37996.3
2009	429.11	20.3	62.89	24.36	1968	1565.1	34922.4
2010	404.2	18.85	57.73	23.09	1846	1408.6	33106.4
2011	400.31	18.2	55.8	21.41	1885.2	1457.2	35668.3
2012	403.1	18.44	55.49	21.12	1847.5	1413.5	38528.8
2013	390.66	18.07	53.64	20.16	1932.9	1455.1	37206.4
2014	402.42	17.06	49.92	18.79	1915.5	1526.4	38694.7

(Data from "Hebei Rural Area Statistical Yearbook" 2001-2015)

Livestock and poultry excrement and urine are stocked and disposed casually, which can cause serious environmental pollution.

Lack of environmental protection awareness in livestock and poultry raising: Several farm households commonly engaged in the livestock and poultry raising industry for the long term, lack environmental protection awareness. In most raising farms, only production is considered, but related excrement process facilities are ignored. Few raising farms have multi-stage settling and filter ponds. Few large-scale and standardized raising farms have matched biogas digesters, whereas other farms discharge excrement waste into rivers and ditches directly; several farms even stock them outdoor. Most common farm households and small-scale farms have capital shortage, and they only consider basic production facilities in their construction and disregard matched excrement and wastewater treatment facilities. Several middle or large-sized farms have constructed settling and filter ponds, introduced "zero-discharge" raising technology, and process livestock and poultry excrement. Operation cost is only shown as a demonstration or applied when an audit is being conducted, but it does not play an important role in actual practice.

Imperfect livestock and poultry treatment and safeguard mechanisms: Livestock and poultry pollution treatment in Hebei Province lacks strong and powerful safeguard mechanisms, which can largely affect the overall advancement of livestock and poultry raising pollution treatment. Given the legal rule "whoever causes pollution is responsible for its treatment," the treatment of livestock and poultry raising industry should depend on the investment of households and farm owners. However, large investment is required for environmental protection facilities and small-

and middle-sized livestock and poultry raising households do not have extra capital for environment treatment facilities. Many raising farms were built at the later period of the last century, when the raising pollution treatment had insufficient investment. Several pollution treatment facilities established by raising farms cannot implement pollution treatment for small volume and imperfect technology. Other facilities cannot operate normally because of high operation cost, which has resulted in a large number of environmental protection facilities that exist in name only. Thus, the pollution problem cannot be prevented. Small and large-sized enterprises are unwilling to invest in biogas energy engineering, which has high processing cost and can meet the livestock and poultry pollutant discharge standards of a country and land is insufficient to fully consume biogas liquid in most pig farms.

COUNTERMEASURES FOR LIVESTOCK AND POULTRY RAISING POLLUTION IN RURAL AREA

Formulate and improve livestock and poultry raising pollution management rules: The formulation and implementation of environment pollution prevention regulations should provide further details on the livestock and poultry pollutant discharge standards, as well as issue more detailed raising pollution prevention rules. These rules should include specific requirements for livestock and poultry raising scale, raise the wastewater discharge standards, excrement utilization standards, and location and layout of raising farms. Practical and effective measures should be taken to supervise and audit the effects of livestock and poultry production, as well as the processing on the environment and actually implement different management laws. The environment pollution treatment policy should also be

strengthened, and wastewater discharge should be included in the total amount of wastewater discharge in Hebei Province. Environmental indicators in rural areas should be included in the assessment system at different levels of local governments by utilizing awarding instead of treatment and remediation, as well as providing related preferential and supportive policies. Some experience and measures from other countries can be introduced, and scientific awards for livestock and poultry raising can be increased. Because research on livestock and poultry excrement resource utilization projects are encouraged and supported, an incentive mechanism can be established to provide more favourable subsidies, such as tax, credit load, electricity, land, and similar subsidies, for raising owners who treat pollution in their own initiative. Farm owners who contribute to serious pollution but refuse to take countermeasures to ensure the better realization of the treatment target should be addressed.

Establish a strict livestock and poultry pollution environment supervision system: Related governmental departments should implement related livestock and poultry raising legal rules and regulations, as well as establish related systems and strict conduct evaluation for environmental influence. Any livestock and poultry raising behaviour should be forbidden in key protection areas, drinking water protection areas, places of interest, natural conservation areas, and population centres. The established livestock and poultry raising farms in a forbidden area should be moved in a certain period, closed, or banned. The raising farms that cannot implement treatment in a regulated period should be moved or closed. Having pollution treatment according to the law should fully utilize comprehensive means, such as administrative, legal, and economical methods, to establish and improve the raising industry environment treatment system. The raising industry should utilize the produced waste and implement environmental treatment comprehensively. The development of the raising industry should be led back to the agricultural ecological system, and the virtuous circle of the agricultural circle economy system should be realized. Different levels of the environmental protection department should strengthen the unified supervision and guidance for livestock and poultry raising pollution prevention, as well as organize the calculation and assessment of livestock and poultry raising pollution emission reduction. The animal husbandry department should be responsible for organizing livestock and poultry pollution prevention, as well as main pollutant emission reduction. A plan for the development of the livestock and poultry raising industry and pollution treatment should be crafted using scientific methods. Large-scale livestock and poultry raising statistics should also be reported regularly to environmental protection departments at the same level.

Improve the public's awareness of livestock and poultry pollution treatment: Several farm households engaged in the industry for the long term commonly have limited education background and lack environmental protection awareness. The design of most raising farms only considers productivity and related excrement process facilities are ignored. Few raising farms have multi-stage settling and filter ponds. Several large-scale and standardized raising farms have matched biogas digesters. The dissemination of information through the media, distribution of publicity materials, or organizing of training programs for raising workers regularly by the agricultural department can strengthen farm owners' awareness of raising pollution, environmental protection, and resource protection policy and laws. The continuous publicity of the harmful effects and serious consequences of livestock and poultry raising pollution on the surrounding environment can prompt people to realize the serious potential environmental problem caused by raising industry and its harmful effects on people's lives, as well as the importance, necessity, and urgency of livestock and poultry pollution treatment. Through these efforts, the environmental protection awareness of livestock and poultry raising owners as well as the level of pollution treatment can be raised, thereby improving their initiative on pollution treatment, change their attitudes toward environmental protection from passive receiving to positive joining, and advancing their sense of responsibility and capacity for pollution treatment.

Actively prompt ecological livestock and poultry raising mode: A comprehensive plan and matched design should largely develop green ecological animal husbandry facilities. Livestock and poultry excrement can be processed into fertilizers and methane resources for re-utilization, which can realize production without waste and pollution, reach "zero discharge," and address the problem of large investment and high operation cost of pollution treatment facilities. Actively prompting different standardized ecological raising modes can decrease the number of farm households and small-scale poultry and livestock raising in rural areas, support professional large-scale raising, and establish middle- and large-sized scale ecological raising farms. Given the different raising species and crops, different geographical conditions and climates in distinct areas, as well as the different planting technologies, different stereo ecological agricultural modes are necessary. The ecological raising modes selected by different areas are also different. These areas should design an appropriate raising mode according to their own conditions, instead of simply utilizing a certain mode. Combining the encouraging national policy and the supportive intensive raising industry plan can allow the government to formulate several "awarding instead of sub-

sidizing” policies for the livestock and poultry raising pollution treatment and provide capital support. This approach is also more favourable for policies, as well as livestock and poultry raising projects with clear pollution treatment effects and excellent demonstration effects.

CONCLUSIONS

The evident change in residents’ food consumption structure has resulted in the rapid increase in the demand for livestock and poultry products, such as meat, milk, and eggs. This scenario has prompted the rapid growth of the livestock and poultry raising industry. Pollution from this industry has become an important source of environmental pollution in different areas and has a direct or indirect effect on water, soil, air, human health, and environmental safety. Taking Hebei Province in China as an example, this study analyzes the harmful effects and reasons behind livestock and poultry pollution in rural areas. It then proposes measures to address the said problem. Research results show that livestock and poultry raising pollution in rural areas can cause soil, water, and gas pollution. The main reasons for livestock and poultry raising pollution are as follows: low degree of reutilization of livestock and poultry waste, lack of environmental protection awareness in livestock and poultry raising, and imperfect livestock and poultry raising treatment safeguard mechanism. Several countermeasures are proposed, including the regulation and improvement of the livestock and poultry pollution management laws, establishment of a strict livestock and poultry environmental supervision system, improvement of the public’s awareness of livestock and poultry pollution treatment, and active prompting of the ecological livestock and poultry raising mode. This study can significantly strengthen livestock and poultry raising pollution prevention, non-point pollution treatment, energy conservation, and emission reduction in rural areas. Prompting the upgrade and improvement of agricultural structures, improving the living environment in rural areas, and promoting the continuous development of animal husbandry are also important. Further research can focus on environmental pollution caused by specific animal raising, pollution prevention technology mode of different raising species and scales, estimation of the environmental economy losses caused by livestock and poultry raising, and the determination of the relevance of livestock and poultry raising pollution.

ACKNOWLEDGEMENTS

This research has been financed by Project of Hebei provincial Science and Technology Department in 2016 “Study on agricultural non-point source pollution assessment and corresponding control measures in Hengshui Lake Basin” (project code 16223614), and Project of Hengshui Science and Technology Bureau in 2016 “Effects of different proportions of pig manure and corn straw on anaerobic methane production characteristics and process optimization” (item code 2016011002Z).

REFERENCES

- Chin, N.Q. 2005. Dairy cattle development: environmental consequences and pollution control options in Hanoi Province, North Vietnam. *Eepsea Research Report*, 1(1): 1-39.
- Dzikiewicz, M. 2000. Activities in nonpoint pollution control in rural areas of Poland. *Ecological Engineering*, 14(4): 429-434.
- Erisman, J.W., Bleeker, A. and Hensen, A. et al. 2008. Agricultural air quality in Europe and the future perspectives. *Atmospheric Environment*, 42(14): 3209-3217.
- Gan, L. and Hu, X. 2016. The pollutants from livestock and poultry farming in China-geographic distribution and drivers. *Environmental Science and Pollution Research*, 23(9): 8470-8483.
- Geng, W., Hu, L. and Cui, J. et al. 2013. Biogas energy potential for livestock manure and gross control of animal feeding in region level of China. *Transactions of the Chinese Society of Agricultural Engineering*, 29(1): 171-179.
- Li, F., Cheng, S. and Yu, H. et al. 2016. Waste from livestock and poultry breeding and its potential assessment of biogas energy in rural China. *Journal of Cleaner Production*, 126(126): 451-460.
- Pan, D., Zhou, G. and Zhang, N. et al. 2016. Farmers’ preferences for livestock pollution control policy in China: a choice experiment method. *Journal of Cleaner Production*, 131(5): 572-582.
- QingBo, Q., Peng, Y. and ZhongWei, Z. et al. 2016. Prediction methods of major pollutants production in manure from large-scale livestock and poultry farms: a review. *Journal of Agricultural Resources and Environment*, 33(5): 397-406.
- Romstad, E. 2003. Team approaches in reducing nonpoint source pollution. *Ecological Economics*, 47(1): 71-78.
- Shortle, J.S. and Horan, R.D. 2001. The economics of nonpoint pollution control. *Journal of Economic Surveys*, 15(3): 255-289.
- Tongquan, Y., Hongyan, L.I.U. and Yanghua, Y.U. et al. 2016. Agricultural non-point source pollution in drinking water conservation area of the Hongfeng lake in Guiyang City. *Journal of Landscape Research*, 8(5): 26-28.
- Wang, F., Zou, L. and Gui, P. et al. 2015. Estimation of non-point source pollution load of the livestock and poultry breeding in Sichuan Province, China. *Asia-Pacific Energy Equipment Engineering Research Conference*, 1(1): 535-538.
- Yang, F., Yang, S. and Zhu, Y. et al. 2013. Analysis on livestock and poultry production and nitrogen pollution load of cultivated land during last 30 years in China. *Transactions of the Chinese Society of Agricultural Engineering*, 29(5): 1-11.

