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Study on the Non-point Source Pollution in the Mountainous Area of West Sichuan — A Case Study of Livestock and Poultry breeding in Baoxing County

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Abstract. In this paper, the impact of non-point source pollution of livestock and poultry farming in mountainous areas on the water environment in mountainous areas is studied, which is in order to provide a scientific basis for the migration control of non-point source pollution and managing the water environment. Concluded as follows: (1) The main pollutants are *TN* and *COD*. What's more, *TN*, *COD*, *TP* and NH_4^+-N in the East River are insensitive. *TN* and *COD* sensitivity of the West River and Baoxing River are mildly sensitive and *TP* and NH_4^+-N is insensitive. (2) The risk sources of East River, West River and Baoxing River are explored. According to 4R control technology of non-point source pollution, source reduction, process interruption, recycling and ecological restoration should be strengthened. Therefore, this study diagnoses the main pollutants and identifies the sources of risk and provides a scientific basis for effective control measures.

1. Introduction

Water pollution is one of the serious problems of environmental pollution in the twenty-first century. The effective evaluation of non-point source pollution is the basis for the development, utilization and protection of water resources. In the early 1970s, the North American region first proposed a model of the output coefficient to estimate the non-point source pollution load. It is popularized because of its precision and the ability to use the land use condition^[1]. And it is a method of centralized accounting of non-point source pollution. China is a large country of livestock and poultry breeding. There are about 800 thousand large-scale and intensive farms. Most of them are scattered near the rural areas and towns in China. The pollution is amazing. There are also local livestock and poultry pollution problems in Tibet. At present, the research on non-point source pollution mostly concentrated in the large basin or in the provinces and cities as the research unit, and China has proposed the "precise poverty" of the new requirements. At the same time, grass-roots administrative agencies often have strong executive capacity for non-point source pollution control in their jurisdiction. Therefore, it is very necessary to study the non-point source pollution load in the township as a unit.

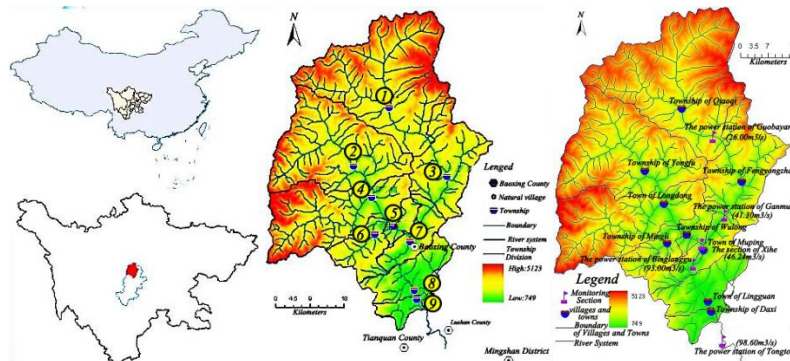
2. Materials and methods

2.1. Overview of the study area

Baoxing County that is the most northern mountain area of Ya'an City is located in the western edge of the Sichuan Basin. It is situated in longitude 102° 28'E~103° 02'E and latitude 30° 09'N~30°



56°N. The entire county covers 3,114 square kilometers in size. At the same time, Baoxing County is a subproject area jointly researched by the State Environmental Protection Administration (SEPA) and the United Nations Environment Program (UNEP) on Nature Protection and Flood Control in the Yangtze Basin. Baoxing River is the main source of Qingyi River, which is the key area for ecological barrier construction in the upper reaches of the Yangtze River and an important source of water for the newly liberated area of Chengdu. Due to the rapid growth of livestock farms, consuming cattle and sheep-based traditional breeding industry in the county, the use of excrement is seldom reused, and livestock are often fixed in natural grassland stocking points, resulting in different degrees of grassland degradation. At the same time, the centralized treatment of pollutants is not perfect, which also increases the risk of water environment.



Note: ① stands for township of Qiaoqi. ② stands for township of Yongfu. ③ stands for township of Fengtongzhai. ④ stands for town of Longdong ⑤ stands for township of Wulong. ⑥ stands for township of Mingli. ⑦ stands for town of Muping. ⑧ stands for township of Linguan. ⑨ stands for township of Daxi.

Fig.1 Baoxing County water system, townships, section position and flow

2.2. The Model of Generation

$$L_b = \sum N_b \times I_{bc} \times D \quad (1)$$

Formula (1), L_b is the pollution load of livestock and poultry breeding (t/a). N_b is the livestock raising amount ($\times 10^4 \text{ capita}$). I_{bc} is the coefficient of production of TN , TP , COD and NH_4^+-N in livestock and poultry breeding ($g \cdot \text{capita}^{-1} \cdot d^{-1}$) [2-6]. D represents the breeding period of pigs, sheep, rabbits, poultry and cattle, and takes 150d, 365d, 90d, 60d and 365d respectively [2]. The coefficient of generation phase is shown in Table 1.

Table 1 The coefficient of generation phase

Contaminants	$I_{bc}/g \cdot \text{capita}^{-1} \cdot d^{-1}$				
	Pig	Sheep	Rabbit	Poultry	Cattle
TN	15.36	6.25	0.99	0.71	104.10
TP	3.39	1.23	0.33	0.06	10.17
COD	403.67	52.11	1.10	13.05	2235.21
NH_4^+-N	3.29	0.16	0.10	0.34	12.00

2.3. The Model of Loss

$$O_b = \sum N_b \times O_{bc} \times D \times C_{ci} \quad (2)$$

Formula (2), O_b is the loss load of livestock and poultry breeding (t/a). O_{bc} is loss coefficient of TN , TP , COD and NH_4^+-N in livestock and poultry breeding ($g \cdot \text{capita}^{-1} \cdot d^{-1}$) [2-6]. C_{ci} is a factor of seismic intensity correction. According to Chinese seismic intensity scale (GB/T17742-2008), *Intensity*

distribution map of Wenchuan's 8.0 magnitude earthquakes and Intensity map of Lushan's 7.0 magnitude strong earthquakes in April 20th, coefficient of *I* to *V*, *VI* to *IX* and *X* to *XII* takes 1.0, 1.1 and 1.2 respectively. Seismic intensity correction factor of all townships in Baoxing Country takes 1.1 during Wenchuan Earthquake(in 2008) and Lushan Earthquake(in 2012)^[8].

Table 2 The coefficient of loss stage

Contaminants	$O_{bc}/g.capita^{-1}.d^{-1}$				
	Pig	Sheep	Rabbit	Poultry	Cattle
<i>TN</i>	13.79	2.186	0.347	0.22	43.48
<i>TP</i>	1.28	0.432	0.116	0.04	3.82
<i>COD</i>	259.09	13.030	0.330	1.21	912.17
NH_4^+-N	0.68	0.050	0.010	0.02	3.80

2.4. The Model of Coming into the River

$$R_b = \sum O_b \times R_{bc} \times C_{ct} \times C_{cr}, \quad C_{ct} = \frac{L(\theta_j)}{L(\bar{\theta})} = \frac{c(\theta^d)}{c(\bar{\theta}^d)} = \frac{\theta^d}{\bar{\theta}^d} \quad (3)$$

Formula (3), R_b is load of into the river of livestock and poultry (t/a). R_{bc} is the base River coefficient of livestock and poultry breeding^[2], taking 0.25. C_{ct} is the river modification coefficient affected by the terrain^[2], and C_{cr} is correction coefficient which consider the effect of rainfall during the pollutants into the river. Seeing Table 3 and Table 4 for details.

Formula (3), L is the load quantity(kg). c and d are constant. θ is the slope of spatial units in the study area. $\bar{\theta}$ is the average slope of the entire study area. d takes 0.6104 in this formula. Using ArcGIS to calculate the DEM map of the study area, and average slope of township in Baoxing County is shown in Table 3.

Table 3 Slope and correction factor of terrain and coming into the river

Index	Muping	Lingguan	Longdong	Daxi	Wulong	Mingli	Yongfu	Fengtongzhai	Qiaoqi	Average
Slope	25.38	14.80	19.73	17.96	24.57	15.74	26.76	20.30	15.83	20.42
C_{ct}	1.14	0.82	0.98	0.92	1.12	0.85	1.18	0.99	0.86	/
C_{cd}	1.2	1.2	1.2	0.8	1.2	0.8	1.2	1.2	1.2	/

Table 4 The average annual rainfall

Year(<i>a</i>)	2007	2008	2009	2010	2011	2012	2013
Rainfall(<i>mm</i>)	907.5	856.6	765.3	1013.7	851.4	912.2	1054.9
Rainfall correction(C_{cr})	1.4	1.3	1.2	1.5	1.3	1.4	1.5

2.5. The Model of Equal Standard Pollution Load

$$P_{ijk} = q_{ijk} / (C_{0ij} \times 10^{-6}) \quad (4)$$

P_{ijk} is the equivalent pollution load (m^3/a) of contaminant i discharged from the pollution path j in the stage k . q_{ijk} is the total amount(t) of contaminant i discharged from the pollution path j in the stage k . C_{0ij} is the evaluation criteria (mg/L), according to the class standard value of *Surface Water Environmental Quality Standard* (GB3838-2002)^[2].

2.6. The Load Ratio of the Equal Standard

According to the tree structure, P_{ijk} is the equivalent pollution load (m^3/a) of contaminant i discharged from the pollution path j in the stage k . What's more, there are m kind of pollution paths and q kind of contaminants. Then, the proportion of individual pollutants to all pollutants is expressed as follow:

$$P_{ik} = \sum_{j=1}^m P_{ijk}, \quad K_{ik} = \frac{P_{ik}}{\sum_{i=1}^q P_{ik}} \quad (5)$$

The pollutants whose cumulative percentage is greater than 80% are classified as the main pollutant load in this area.

2.7. Water Quality Index and Sensitivity Analysis of Coming into the River

$$I = C/C_s, \quad C = M/Q \quad (6)$$

I is the river water quality index, and C is the pollutant discharge concentration. C_s is the standard concentration of class *III* in *surface water environmental quality standard*(GB3838-2002). M is the load of coming into the river. Q is the water resources of river node upstream. If water quality index is less than or equal to 1, the risk of non-point source pollution is low. While water quality index exceeds 1, the risk of non-point source pollution is severe. The sensitivity of this study is shown in Table 5 [2].

Table 5 Sensitivity level

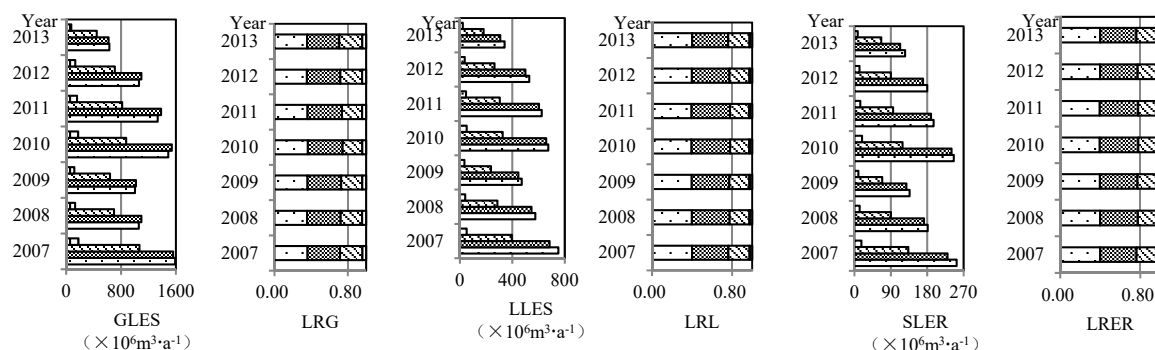
level	$\rho(TN)/mg \cdot L^{-1}$	$\rho(TP)/mg \cdot L^{-1}$	$\rho(COD)/mg \cdot L^{-1}$	$\rho(NH_4^+-N)/mg \cdot L^{-1}$
Insensitivity	[0,1]	[0,0.2]	[0,20]	[0,1]
Mildly sensitive	(1,15]	(0.2,0.5]	(20,50]	(1,15]
Moderately sensitive	(15,20]	(0.5,1]	(50,60]	(15,20]
Highly sensitive	(20,30]	(1,3]	(60,100]	(20,30]
Extremely sensitive	(30, +∞)	(3, +∞)	(100, +∞)	(30, +∞)

2.8. Analysis of Risk Sources

The average load of TN , TP , COD and NH_4^+-N in land use, livestock breeding and human life at each stage of each township is the weighted average of non-seismic years. We use ArcGIS's Inverse Distance Weight Platform to draw risk distribution map of non-point source pollution load. At the same time, using equal load ratio to sort the townships and townships whose cumulative load ratio is more than 80% can be regarded as risk sources[2].

3. Result

3.1. Major contaminants : Load ratio of equal standard



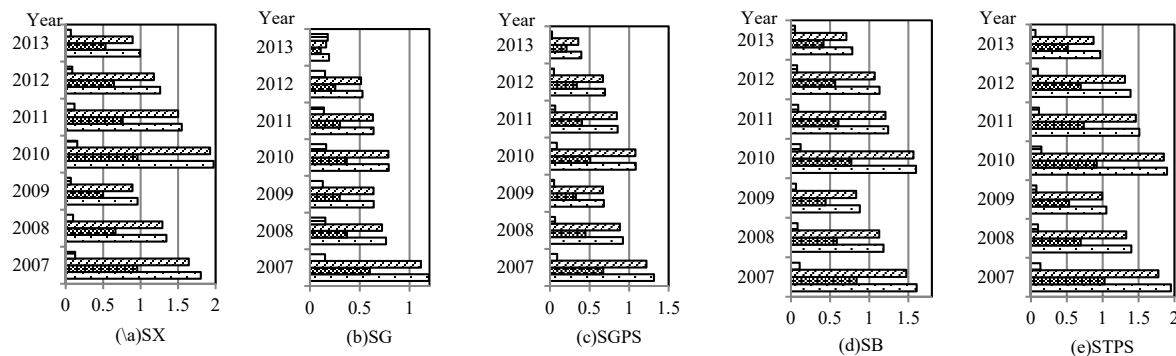
Note: The legend is $\square NH_4^+-N$ $\square TP$ $\square COD$ $\square TN$. GLES(Generating load of equal standard, GLES).

LRG(Load ratio of generating, LRG). LLES(Lossing load of equal standard, LLES).LRL(Load ratio of losing, LRL). SLER(Standard load of entering river, SLER). LRER(Load ratio of entering river, LRER).

Fig.2 The interannual variation of equal load and load ratio at three stages($\times 10^6 m^3 \cdot a^{-1}$)

According to Fig.2, the order of four kinds of pollutants is TN , COD , TP and NH_4^+-N in turn from 2007 to 2013. And the standard load emissions of TN and COD , which are accounted for the total discharge of the four kinds of pollutants by about 80% at three stages. Therefore, TN and COD are relatively larger than other pollutants in the stage of production, runoff and river entry.

3.2. Major contaminants : Load ratio of equal standard



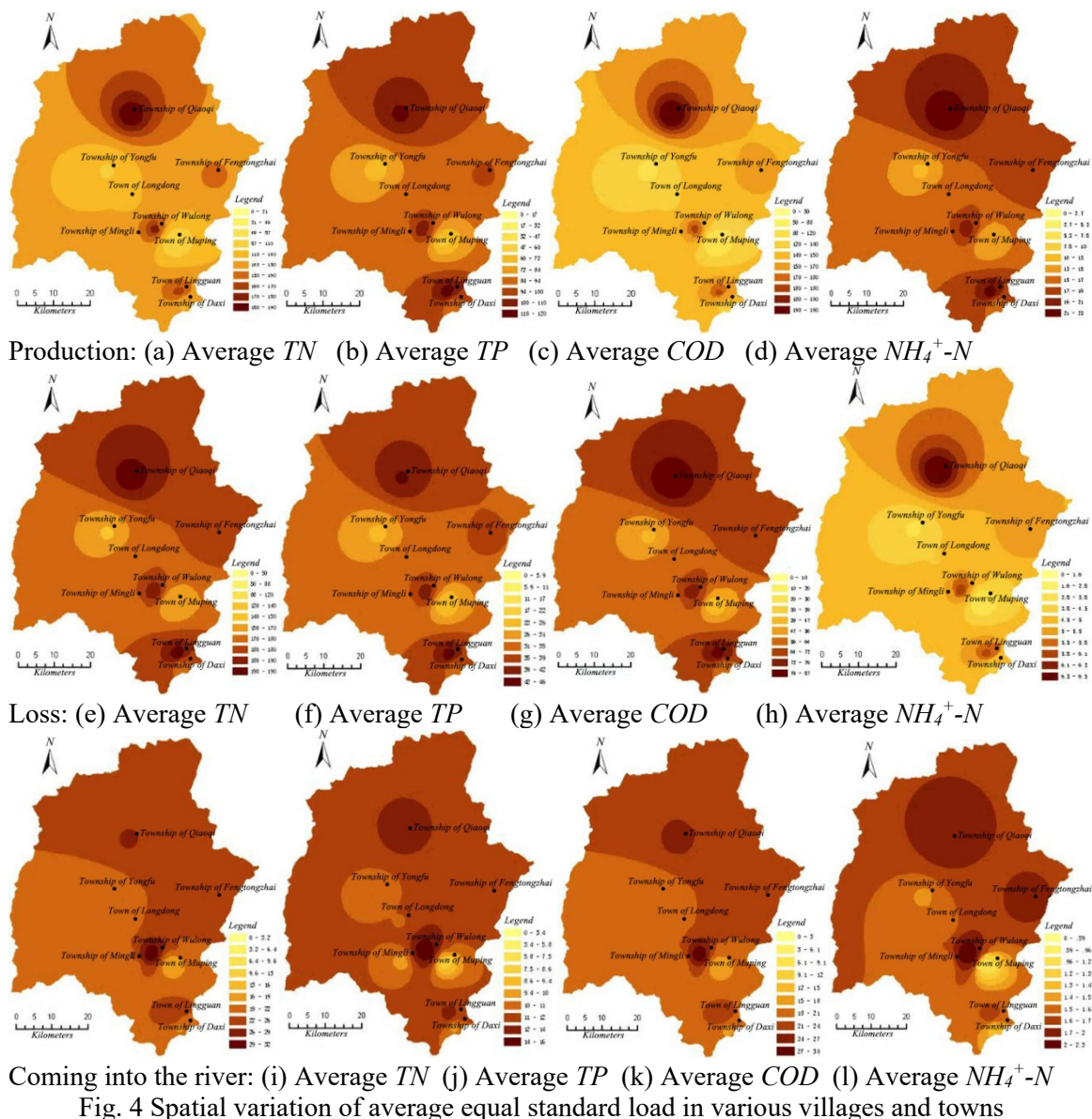
Note: The legend is $\square NH_4^+-N$ $\square COD$ $\square TP$ $\square TN$. SX(Section of West River, SX). SG(Section of Guobayan, SG). SGPS(Section of Ganmuhe power station, SGPS). SB(Section of Binlanggu, SB). STPS(Section of Tongtouchang power station, STPS).

Fig. 3 Water quality index of coming into the river

According to Fig.3, the water quality index of TN and COD in the section of West River, the section of Binlanggu and the section of Tongtouchang power station were all exceed the standard. The sensitivity level of TN and COD was mildly sensitive, while TP and NH_4^+-N was insensitive. At the same time, the water quality index of section of Guobayan Hydropower Station is basically not exceeded, and TN , TP , COD and NH_4^+-N in water are insensitive, mainly due to the large cross-section flow (up to $26m^3/s$), desalting the pollutant concentration. The water quality index of the section of Ganmuhe Hydropower Station basically did not exceed the standard, and TN , TP , COD and NH_4^+-N in water are insensitive, mainly due to the larger discharge flow ($41.3m^3 / s$) in the Donghe River. Based on the analysis of load ratio and sensitivity, and the cumulative load ratio of TN and COD is more than 80%. Meanwhile, both TN and COD pose a slight risk to West River and Baoxing River, while water quality index of TN and COD in Donghe both is more than 0.5. Therefore, TN and COD are the main pollutants.

3.3. Risk sources

According to Fig.4, and the equivalent load order from big to small is Wulong township, Mingli township, Longdong town and Yongfu township in turn, and the cumulative load ratio of Wulong township, Mingli township and Longdong town is greater than 80%, and the risk sources are Wulong township, Mingli township and Longdong town in West River. In East River, the equivalent load order from big to small is Qiaoqi township and Fengtongzhai township in turn, and the cumulative load ratio of Qiaoqi township is close to 80%, and the risk source is Qiaoqi township in East River. In Baoxing River, the equivalent load order from big to small is Qiaoqi township, Lingguan town, Wulong township, Fengtongzhai township, Mingli township, Longdong town, Daxi township, Yongfu township and Muping town in turn, and the cumulative load ratio of the first seven townships is more than 80%, and the risk sources are the first seven townships in Baoxing River.



4. Discussion

The studies of Wang^[6] and others showed that the pollution of non-point sources on water environment needs to undergo several stages, which are consistent with the idea of this research. Li et al. ^[7] showed that there was a positive correlation between the livestock and poultry breeding and the emission intensity of pollutants TP , TN and COD , which was in good agreement with the main pollutants studied in this study. Research of Yan et al^[8] showed that after the earthquake, the pollution load of relocation diffusion had breeziness, seasonal sensitivity and hysteresis, which showed that the rationality of the earthquake increasingly the loss ratio and the ratio of coming into the river. Risk sources identified are basically coupled with the distribution of administrative districts, the characteristics of industrial distribution and the characteristics of waste resources.

5. Conclusion

(1) By equal standard load ratio and sensitivity analysis, the main pollutants for livestock and poultry breeding are TN and COD . What's more, TN , COD , TP and NH_4^+-N in the East River are insensitive.

TN and *COD* sensitivity of the West River and Baoxing River are mildly sensitive and *TP* and NH_4^+-N is insensitive.

(2) Based on ArcGIS spatial analysis, the risk source of East River is Qiaoqi Township, and the risk sources of West River are Wulong township, Mingli township and Longdong town, and the risk sources of Baoxing River are Qiaoqi township, Lingguan town, Wulong township, Fengtongzhai township, Mingli township, Longdong town and Daxi township. Therefore, the distribution of the administrative regions of risk sources, the characteristics of industrial distribution and the characteristics of waste resources are basically coupled.

(3) According to the 4R control technology of non-point source pollution, it should be reduced in source. In the loss stage, the pollution water should be intercepted and recycled. It needs the ecological restoration in the stage of coming into the river.

In time, this paper identified the main pollutants of Baoxing from 2007 to 2013, and it also diagnosed the risk sources of water body in space. Therefore, this research based on temporal and spatial change provides a scientific basis for water environmental risk assessment, especially in rural water safety and water source protection..

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