Distribution Characteristics of Water Pollution on Hainan Island of China

Zhong-yuan Yu, Bo Li, Te-sheng Sun, and Hua Bi

Abstract The article uses multiple-factor method, Lorenz curve, comprehensive pollution index and Borda law analyzing the spatial and industrial distribution traits, studying the reasons, discussing strategic ways to further building of eco-province in Hainan. All study is based on the data form 2004 water environmental report of Hainan province and sticks to the national standard of water quality. By calculation and analysis, the article divides the province into three water pollution areas: low pollution area, middle pollution area and high pollution area. And colludes that (1) water pollution distribution on Hainan Island is uneven spatially; (2) waste water is the main source of water pollution; (3) economical development, population distribution, natural environments and the way of land usage have great impact on the format of water pollution distribution on the island. At the end, the article puts forward some strategies of building eco-province in Hainan.

Keywords Distributional traits · Hainan Island · Hazard · Water pollution

1 Introduction

Most of the researches on surface water pollution focus on the processes and reasons of pollution or on quality analysis. Jizhen studied Kuznets traits of surface water of Xuzhou city in Jiangsu province, analyzing the relationship of surface

Z.-y. Yu (✉)
China Research Center for Assessment of Ecological Assets, College of resources, Beijing Normal University, Beijing 100875, China
and
Institute of Geography and Tourism, Hainan Normal University, Haikou 571158, China
e-mail: yzy123456789@126.com

B. Li and T.-s. Sun
China Research Center for Assessment of Ecological Assets, College of resources, Beijing Normal University, Beijing 100875, China

H. Bi
Institute of Geography and Tourism, Hainan Normal University, Haikou 571158, China

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water quality with economic growth factors (Jizhen 2006). Dong-yajie analyzed spatial and temporal distribution of water system pollution and its change by using a model of pollution barycenter, taking some main pollution characterization factors of a river as examples (Dong-yanjie 2008); Liu yan and Liu-jiaxiang analyzed the dynamic change and its reasons of surface water bodies (Liuyan 2007). More scholars studied the status quo of water pollution in some river basins. In all, few scholars have been studying distribution traits of surface water in a whole geographical region like Hainan Island and put forward its counter measures.

Hainan province is located in the southernmost of China with total area 35,400 km^2, for which Hainan Island (34,100 km^2) is the main body. It governs 19 affiliated administrative regions of county level with a population of 8,263,100 (China Statistic Bureau 2005). As early as 1999, Hainan put forward the strategy of eco-province construction, being the first experimental eco-province in China. Since then on, Hainan has gone a long way in developing economy, at the same time keeping the environment first-class in the country. However, in some area, there still exist contradiction and discord between development and environmental protection, with some areas more or less polluted.

The research studies the area of Hainan Island of the province (including 18 county-level areas) based on the data of Hainan Provincial sewage outfall census in 2004. According to the nature of water pollution and the reality of water resources of Hainan Province, the research selects flow rate, water temperature, PH, sewage amount entering the rivers, CODcr, BOD_5, NH_3-N, TP and volatile phenol as factors, uses multiple-factor evaluation method, Board Law, Lorenz curve, comprehensive water pollution index to analyze the spatial and industrial distribution traits as well as their reasons. The research has theoretical value in that it bridges the gap of studying traits of surface water in provincial unit and providing advice and theoretical reference for decision making in building eco-province in Hainan.

2 Method of Monitoring Water Pollution

Monitoring water quality: use method of swage analyzing and sampling in comprehensive swage discharge standard (GB8978-1996). Methods of analyzing water quality factors are listed as followed (Table 1). Monitoring flow rate: use current meter method, float method; overflow weir method and volumetric methods.

Table 1 Method of analyze of water quality

	Items	No. of used standard
1	Temperature	GB13195-1991
2	PH	GB6420-986
3	CODcr	GB11914-1989
4	BOD_5	GB7488-1987
5	NH_3-N	GB7479-1987
6	TP	GB11893-1989
7	Volatile phenol	GB7490-1987

3 Method of Research

3.1 Calculate the Comprehensive Pollution Index of each county and industry

$$S_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(X_{ij} - \overline{X}_j\right)^2} \tag{1}$$

$$K_{ij} = \left(X_{ij} - \overline{X}_j\right)/S_j \tag{2}$$

$$K_i = \sum_{j=1}^{6} a_j K_{ij} \tag{3}$$

1. Use formula (1) to get standard deviation of the distribution of each pollutants among different counties or different industries. In the formula, X_{ij} is the value of j pollutant in i county (or industry); $\overline{X}_j$ is average quantity of j pollutant in the province (or all industries); S_j is the standard difference (SD) of j pollutant among counties (or industries). "n" is the number of i (18 counties or 20 industries).
2. Use the formula (2) for standardization of pollutant distribution data to get distribution index. In this formula, K_{ij} is the pollution index of j pollutant in i county (or industry).
3. And follow the formula (3) to get the comprehensive pollution index of each county and industry. In the formula, K_i is the composite pollution index of i county (or industry). a_j is the weighting coefficient of pollutant j. In this research, the weighting coefficients of pollutant factors of yearly swage charge entering the rivers, are set as 0.1, 0.25, 025, 0.15, 0.1 and 0.15 respectively.

3.2 Calculate the Borda Index and Rank Water Pollution of Each County

$$N_i = \sum_{j=1}^{6} N_{ij} \tag{4}$$

(Wang-jiaotuan et al. 2008; ShinjiOhseto 2007; Nitzan and Rubinstein 2002; Xiong-yang and Xu-xiaodong 2005; Yue-chaoyuan 2003)

In formula (4), N_i is the Borda Index; N_{ij} is the number of county which follow i county in the ranking list of j pollutant. For a county, the bigger the Borda index, the more forward it stands in ranking list of water quality and the smaller, the pollution index. Vice versa.

3.3 Divide the Distribution Types of Water Pollution of Each County

Using the comprehensive water pollution index K_i and Borda index N_i to divide the distribution types. Considering the reality of Hainan Province, the research decides (1) if comprehensive water pollution index $K_i > 1$ and Borda index ≤ 10, this county is belong to high pollution area; (2) If $0 \leq K_i \leq 1$, and $10 \leq$ Borda ≤ 30, we call this county middle pollution area; (3) if $K < 0$, Borda ≥ 30 we call the county low pollution area (Liuyan 2007).

3.4 Calculate Pollutant Spatial Concentration Index and Draw Lorenz Curve

$$I_j = \frac{C_j - R_j}{M_j - R_j} \tag{5}$$

(Lu-dadao 1991)

In the formula, $\mathbf{I_j}$ is the spatial concentration index of pollutant, C_j is the sum of cumulative percentage of j pollutant of each county. R_j is the concentration index when pollutant distributes evenly (minimum), M_j is the concentration index under extreme situation that all j pollutant of the province concentrates in one county (max). The bigger the I_j, the more j pollutant concentrates.

3.5 Check the Feasibility of the Factors Selected and the dependability of Division of Water Pollution Type of Each County by Judgment Index

Use the difference value between 1 and the ratio value of number of unmoral samples against number of total samples to calculate the Judgment Index.

$$J = 1 - \frac{B + G - |B_m - G_m|}{T} \tag{6}$$

(Yuan-jianping Liu-fuke et al. 2008)

In the formula, J is the Judgment index, B is the total number of factors which present bad in ranking list in low pollution counties, G is the total number of factors which present well in ranking list in high pollution counties. $|B_m - G_m|$ is the absolute value of the difference between the numbers of factors presenting well and factors presenting bad respectively in medium class counties. T is the amount of

the samples. If R ≧ 85%, it means that the factors are correctly selected and we can use them to make a judgment. If R < 85%, it means that we have not selected enough factors or what we select are not suitable for making a judgment, need to adjust or add some other factors. In this research, $R = 1 - \{0 + 0 + |6 - 14|\}/90 = 91.11\%$, it indicates that the factors selected have high dependability, can be used to make a judgment.

4 The Distribution Traits of Water Pollutants on Hainan Island

4.1 Spatial Distribution Traits

Water pollutants are relatively concentrated. Water pollutants of Hainan province are unevenly distributed, as demonstrated by the deviation of accumulative curve of pollutants from even-distribution curve in the picture (Fig. 1). Most of the pollutants are concentrated in Haikou, Lin'gao, Tunchang, Baisha, Danzhou and Sanya city, especially Haikou has more than 30–50% of all water pollutants of the province, being the most seriously polluted area. All spatial concentration index of water pollution factors on Hainan island are bigger than 50%, especially the sewage amount entering the rivers, CODcr, NH_3-N, and volatile phenol (see Table 2).

Water quality of inland rivers is better than that of coastal rivers; southeastern is better than northern western part of the island. The average index of the western (Lin'gao, Dongfang, Ledong, Cheng'mai, Changjiang, Baisha, Danzhou) of the island is −0.0614; the middle (Haikou, Sanya, Baoting, Qiongzhong, Ding'an, Wuzhishan, Tunchang) 0.29 and the eastern (Wenchang, Linshui, Qionghai, Wanling) −0.41. If we divide the province into north and south parts, the northern has an average comprehensive water pollutant index of 0.332, whereas the

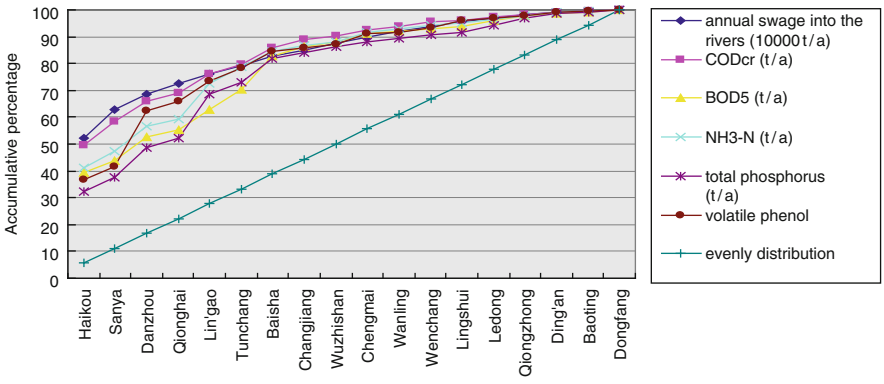

Fig. 1 Lorenz curve of spatial water pollution in Hainan province

Table 2 Spatial difference of water pollution of counties in Hainan Province

Type of water pollution	Counties	Main pollutants	Ki	Ni
High pollution area	Haikou, Lin'gao	CODcr, BOD5	≥1	<10
Middle pollution area	Sanya, Danzhou, Baisha, Tunchang	CODcr, TP, NH_3-N BOD_5,	0–1	10–30
Low pollution area	Dongfang, Qionghai, Ledong, Baoting, Qiongzhong, WanglingWenchang, Lingshui Chengmai Wuzhishan Changjiang Ding'an		≤0	>30

southern −0.386. Also, if we divide the province into inland area and coastal area, the inland has an index of −0.033, while the coastal 0.109.

The water quality of big river is better than that of small river, Trunk Stream better than tributary, suburban river better than urban one, lake better than river.82.5% of the stream segments reach or surpass the national water quality standard III, trunk streams of the three main rivers, Nandujiang, Wanquan river, Changhua river reach or surpass the national water quality standard III. Stream segments with standard IV, V are mainly in medium or small rivers and some branch river of Nandujiang. Thirty-three percent of urban rivers are inferior to standard III water quality. Most of lakes surpass national water quality standard III, better than river. Only 6.2% of lakes in the province are inferior to standard III. Big reservoirs have greater anti-staining ability than small ones. In recent years, part of the reservoirs are experiencing eutrophication due to increase of nutritive salts of nitrogen and phosphor in the waters (Hainan Provincial Water Business Bureau 2006).

4.2 Analyze the Industrial Distribution Traits

Sanitary sewage is the main sources of water pollution. Sewage quantity entering rivers is up to 257 270 000 t/a, of which sanitary swage accounts for 78.92%, most of which are produced by civilian life; industrial swage is about 15.84%, mainly from farm product processing and food processing industries. The main water pollutants entering rivers are CODcr, BOD_5 ammonia nitrogen and TP. Especially, CODcr, BOD_5 are the main pollutants in rivers inferior to standard III.

Cynicism, sugar processing, glue manufacturing, aquaculture industry starch processing are the main polluting industries. These industries produce large number of swage with huge amount of pollutants. Farming irrigation produces high concentration of CODcr, BOD_5 and TP. Sugar Processing, glue manufacturing, Aquaculture industry, weaving, and paper making produce relatively high concentration of volatile phenol. Rubber processing plant is one of the main pollution sources, most of them in southern part of the island, Nandu river and the northwest region of the island. Most of the rubber processing plants scattering on the island use inefficient anaerobic method and oxidation pond process to deal with swage,

being the main reasons of pollution of some stream segments (Hainan Provincial Water Business Bureau 2006).

Cultivation, rubber processing, aquaculture, butchery and sugar processing are industries with high comprehensive pollutant index and highest concentration of pollutants. Irrigation swage, produces high concentration of CODcr, BOD_5, TP and NH_3-N. Sugar processing industries give out volatile phenol, and starch processing and sugar processing industries bring relatively high concentration of BOD_5, while rubber processing plants volatile phenol, NH3-N and TP and aquaculture, butchery volatile phenol and NH_3-N.

Aquaculture industry and livestock and poultry breeding industry are the main areal source of water pollution. In recent year, tropic agriculture and aquaculture develop rapidly, the resulting areal pollution problems are getting more and more serious. This mainly exits in urban area and suburban village, where the pollutants are organic matter, fertilizer, and pesticide. The unscientific fertilizing and drainage and irrigation system, the improper ways of fresh water aquiculture stocking, urban waste, and sanitary swage in the area resulted in serious pollution of the surface water.

5 Conclusion and Countermeasures

Water pollution distribution on Hainan Island is uneven spatially and industrially; waste water is the main source of water pollution; economical development, population distribution, natural environments and land usage have great impact on the format of water pollution distribution. Hainan province is the biggest tropic oceanic province and the biggest special economical zone in China, also the first to put forward the strategy of building eco-province. Furthermore, recently, Hainan set up to build international tourist island. Water pollution is an important factor threatening construction of eco-province and international tourist island. Ecological environment, efficient agriculture, ocean industry, vacation tour are the strengths of Hainan province. We should foster the strengths and circumvent the weaknesses, promote developing recycling economic, strengthen industrial adjustment, further develop eco-agriculture, eco-industry and eco-tourism, improve technology of production and swage prevention and treatment; rely on the masses, depend on the support and the concerted consecutive effort of all sides of society to build Hainan a harmonious, ecological civilized, prosperous and beautiful eco-province, paradise for living, production, investing and vocation.

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