Population Health Vulnerability of Heavy Metal Exposure and Environmental Risk Management in Daye city, China

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Abstract

The research on risk assessment has focused on protecting human health mostly from chemical exposure. However, the vulnerability has received little specific attention in the risk assessment literature. A tentative comprehensive index for environmental health vulnerability which is the product of physical vulnerability index and social vulnerability index was proposed. Based on the collected data of heavy metal pollution in soil and vegetables and the questionnaire data of population parameter, the physical vulnerability, social vulnerability and comprehensive environmental health vulnerability were analyzed in Daye city, China. For physical vulnerability, the average physical vulnerability value of the population in the polluted area and the reference area were 3.99 and 1.00, respectively. Weiwang village has the highest physical vulnerability, reaching 8.55. Vegetable intake is the exposure that should be paid more attention, which contributes more than 90% to physical vulnerability among four exposure pathways. Arsenic and cadmium should be the priority pollutants with the average physical vulnerability value contribution of 63.9% and 17.0%, respectively. According to social vulnerability assessment, Luoqiao village has the highest social vulnerability, with a value of 0.77. For comprehensive environmental health vulnerability, 5 villages nearby mining areas and 2 villages far from the mine-affected area have a high physical vulnerability and high social vulnerability, which are the urgent areas in environmental risk management. In order to improve environmental risk management, it is necessary to give priority to identifying and controlling pollution areas and pollutants and effectively identify vulnerable population.

Objectives

The purpose of the research is to identify priority protection objectives with high health vulnerability among 16 villages in Daye through environmental health vulnerability assessment, and provide important information for environmental risk management.

Data

(1) Heavy Metal Pollution Data

A total of 32 surface soil samples (1 kg each) were collected from the top 0 to 20 cm layer at the sampling sites with reference to HJ/166-2004 (China, 2004). A total of 204 vegetable samples were collected directly from the land from which the soil samples were collected, including 7 kinds of vegetables.

(2) A questionnaire of population parameters in Daye area

The questionnaire mainly includes basic information, exposure parameters and personal habits and health information. Questionnaires on basic information of the respondents included age, height, weight, occupation, education level and income, etc. Dietary exposure parameters include the types of vegetables grown at home, the types of vegetables consumed daily, the consumption of fresh vegetables and other dietary behavior parameters. Habits and health information is about smoking, illness, sleeping time, working hours, work intensity, etc. Four hundred questionnaires were issued, and 389 valid responses were obtained.

calculation method of physical vulnerability index

$$HI = HQ_v + HQ_o + HQ_d + HQ_i = \frac{ADD_v}{RfD_v} + \frac{ADD_o}{RfD_o} + \frac{ADD_d}{RfD_d} + \frac{ADD_i}{RfD_i} \quad (1)$$

$$ADD_v = \frac{(C_v \times IR_v \times EF_v \times ED)}{(BW \times AT)} \quad (2)$$

$$ADD_o = \frac{(C_s \times IR_o \times CF \times EF \times ED)}{(BW \times AT)} \quad (3)$$

$$ADD_d = \frac{(C_s \times ABS \times SA \times AF \times EF \times ED)}{(BW \times AT)} \quad (4)$$

$$ADD_i = \frac{(C_s \times IR_b \times EF \times ED)}{(PEF \times BW \times AT)} \quad (5)$$

The hazard index (HI) for the health risk of a variety of heavy metals was calculated using Equation (1), and corresponding dose received through each of the four pathways was evaluated by Equations (2)–(5).

The pollution hazard index is the quantitative value of physical vulnerability

calculation method of social vulnerability index

Three Aspects	Indicators	Indicators Explanation	Quantization Method	Weight
Socio-Economic Conditions (SEC) 0.267	Education	Divided into 6 categories: undergraduate or above, junior college, secondary school or high school, junior high school, primary school and below, and others	Ratio of whose qualifications below senior high school	0.109
	Occupation Structure	Divided into 7 categories: agriculture, industry and mining, construction, housewives, self-employed, students, and others	Ratio of whose occupations with more exposure to pollution	0.117
	Income	Per capita disposable income	Ratio of whose households below average income	0.117
Receptor Characteristics (EB) 0.28	Working conditions	Divided into 3 categories: good, medium and poor	Ratio of people in poor working conditions	0.128
	Labor intensity	Divided into 3 categories: high, medium and low	Ratio of people with high labor intensity	0.086
	Working time	-----	Ratio of people working more than 8 hours	0.078
	Sleeping time	-----	Ratio of people with unreasonable sleeping time	0.065
Self-sensitivity SS（0.234）	Gender	Males and females	Female ratio	0.086
	Age	-----	Percentage of people younger than 14 or older than 65	0.105
	Disease Situation	divided into people who have suffered from disease and have not suffered from disease	Percentage of people who have suffered from chronic or major diseases	0.109

Note: The higher the quantified value of the 10 indicators in the table, the higher the social vulnerability will be.

calculation method of Environmental health vulnerability

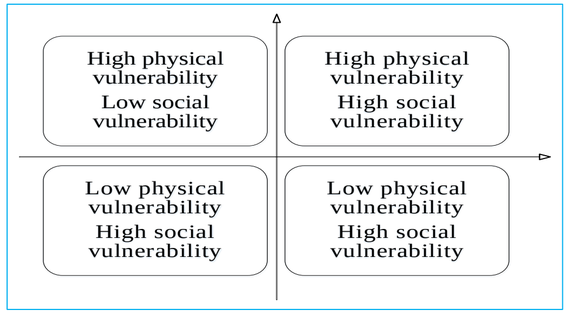
The environmental health vulnerability index is obtained by multiplying the physical vulnerability quantitative value with the social vulnerability index, which can directly reflect the vulnerability of villages.

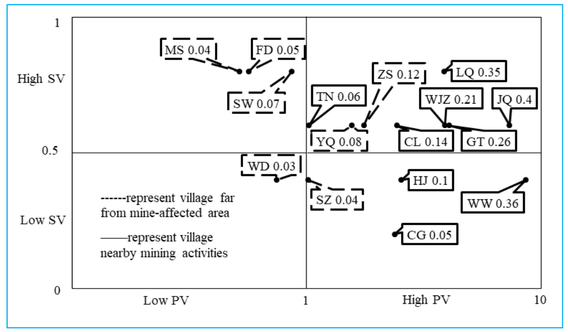
Results

Village	HI	Pollution Hazard Index for different Exposure Pathways				Pollution Hazard Index for different heavy metals				
		HQ_o	$HQ_d(10^{-4})$	$HQ_i(10^{-6})$	HQ_v	HI_{Cu}	HI_{Zn}	HI_{As}	HI_{Cd}	HI_{Pb}
SW	0.86	0.05	4.48	1.28	0.81	0.19	0.07	0.42	0.09	0.09
ZS	1.75	0.04	3.69	1.04	1.71	0.17	0.07	1.27	0.14	0.11
MS	0.52	0.07	4.66	1.72	0.45	0.16	0.05	0.16	0.05	0.10
FD	0.57	0.06	4.42	1.45	0.51	0.12	0.09	0.13	0.16	0.07
WD	0.74	0.06	4.89	1.67	0.68	0.20	0.08	0.34	0.09	0.04
YQ	1.55	0.04	3.29	8.79	1.51	0.12	0.07	1.07	0.14	0.15
SZ	1.01	0.07	5.32	1.76	0.94	0.16	0.07	0.58	0.11	0.09
GT	4.05	0.29	17.9	7.86	3.76	0.19	0.07	3.54	0.10	0.14
CL	2.41	0.12	15.6	2.65	2.29	0.23	0.08	1.22	0.84	0.03
CG	2.37	0.19	19.5	4.55	2.18	0.26	0.07	1.32	0.55	0.16
HJ	2.52	0.17	17.9	4.34	2.34	0.27	0.09	1.38	0.62	0.16
WJZ	3.87	0.10	8.25	2.41	3.78	0.35	0.09	2.76	0.40	0.27
WW	8.55	0.14	18.2	3.14	8.41	0.36	0.13	6.40	1.32	0.34
JQ	7.30	0.12	12.4	2.88	7.18	0.35	0.17	3.91	2.30	0.58
LQ	3.86	0.09	7.26	2.29	3.77	0.37	0.15	2.46	0.31	0.57
TN	1.02	0.07	5.24	1.92	0.94	0.26	0.05	0.58	0.10	0.03

Village	Social Vulnerability			Total
	Socio-Economic Conditions(SEC) Composite score	Behavior Characteristics(BE) Composite score	Self-sensitivity(SS) Composite score	SV score
SW	0.29	0.28	0.12	0.69
ZS	0.25	0.23	0.11	0.59
MS	0.31	0.2	0.13	0.64
FD	0.19	0.25	0.25	0.69
WD	0.04	0.24	0.07	0.35
YQ	0.15	0.19	0.11	0.45
SZ	0.14	0.09	0.11	0.34
GT	0.2	0.19	0.15	0.54
CL	0.23	0.14	0.11	0.49
CG	0.02	0.07	0.1	0.19
HJ	0.11	0.08	0.15	0.33
WJZ	0.2	0.12	0.13	0.46
WW	0.14	0.02	0.19	0.36
JQ	0.17	0.22	0.07	0.46
LQ	0.3	0.18	0.29	0.77
TN	0.2	0.15	0.15	0.5

Results of Environmental health vulnerability





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