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Analysis on the factors that influence the nuclear energy acceptability of the residents with higher culture levels around Ningbo Zone of Sanmen Nuclear Power Station

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Abstract. Understand the factors that influence the nuclear energy acceptability of the residents with higher culture levels around Ningbo Zone of Sanmen Nuclear Power Station. Method: Conduct a questionnaire survey to learn the nuclear energy acceptability of the residents with higher culture levels within the range of 30km of Ningbo Zone of Sanmen Nuclear Power Station by adopting the snowball sampling method. **Result:** Being close to the nuclear power station (<10km), benefit distribution (discrepancy in the compensation mechanism caused by the management of administrative division), risk perception and high score in neuroticism scale are the main factors that influence the nuclear energy acceptability of the residents with higher culture levels around Ningbo Zone of Sanmen Bay. **Conclusion:** To establish a fair economic compensation mechanism not restricted by the administrative division of the nuclear power station, carry out the risk perception publicity and education and formulate specific communication and intervening measures for the people with different personalities is the effective measure to enhance the nuclear energy acceptability of the residents with higher culture levels around Ningbo Zone of Sanmen Bay.

Key words. nuclear energy acceptability, influence factor, higher culture level, ordinal regression.

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1. Introduction

Nuclear power is a kind of technology-intensive and fund-intensive clean energy. As the world resources are becoming scarcer and scarcer with each passing day, it provides an option for the energy development and more and more countries have started to develop nuclear power. According to the data of the International Atomic Energy Agency, at the end of 2015, there were 449 working nuclear reactors in 31 countries with a total installed capacity of over 390 billion watts, which were mainly distributed in the developed countries in Europe and North America. China started to develop nuclear power later than them, but its nuclear power development momentum is strong. However, the Chernobyl Nuclear Accident that happened in Ukraine in 1986 and the Fukushima Nuclear Accident that happened in Japan in 2011 have greatly influenced the public's perception of nuclear power safety and several countries have suspended their nuclear power plants under construction or even have shut down the working nuclear power plants. The researches of some scholars have shown the public's perception has directly influenced the nuclear power development [1-4]. The Massachusetts Institute of Technology and Harvard University have listed the public's attitude, nuclear safety, nuclear proliferation, etc. as the main factors that influence the nuclear power future [5].

The 13th Five-year Plan of China has pointed out that the energy structure adjustment is the strategic choice of the national energy development and nuclear power as a kind of clean energy will develop at a high speed in China. According to the *Medium-term and Long-term Nuclear Power Development Plan* [6] and the 13th Five-year Plan for Energy Development[7] issued by the State Council, the installed capacity of the working nuclear power plants of China will be 58 million watts and the installed capacity of the nuclear power plants under construction will be over 30 million watts by 2020. The coastal regions in the east of China will be the main areas of the nuclear power development in China. However, the nuclear energy development acceptability of the residents around the nuclear power plants is quite different and the nuclear energy acceptability of the residents may become the potential factors that restrict the nuclear energy development of China.

Located in Maotoushan Peninsula, Jiantiao Town, Sanmen County, Taizhou City, Zhejiang Province, Sanmen Nuclear Power Station is only 7.5 kilometers away from the closest adjacent area of Ningbo. A survey of the attitudes of the residents around Ningbo Zone of Sanmen Bay towards the nuclear energy development carried out in the early stage has shown[8] that only 20.1% of the respondents support nuclear energy development in their residence or working areas. The residents with associate degrees or above understand nuclear energy knowledge better than the other people and they dislike the nuclear energy development very much in the local area. It seems that the more nuclear energy knowledge they have, the more opposed to nuclear energy construction they are, which is consistent with the results of the surveys on China's nuclear power sustainable development acceptability of the public conducted by Zeng Zhiwei, etc. after the Fukushima nuclear accident. The survey results have shown that the most trustworthy information sources of the ordinary people are the knowledgeable people around them. The survey results have suggested that the

wrong nuclear energy perception information of the most respondents is mainly from the knowledgeable people around them. To understand the factors that influence the nuclear energy construction perception attitudes of the groups with higher culture levels around the nuclear power station, taking the groups as the study objects, the study conducted an analysis on the factors and channels that influence the nuclear energy development acceptability of the residents with higher culture levels from July 2016 to September 2016 to provide reference for the formulation of the specific intervening measures or communication strategies in the late stage.

2. Respondents and methods

2.1. Respondents

The survey location is A County of Ningbo City — an area 30 kilometers away from Sanmen Nuclear Power Station. The respondents were the inhabitants (the people who had lived in the local area for more than 3 years) with associate degrees or above at the age of 18 – 60. A questionnaire survey was conducted by using the snowball sampling method and 689 questionnaires were distributed among the residents with associate degrees or above in the monitoring area. After the questionnaires underwent data examination and logic checkout, 637 questionnaires proved to be valid. The valid questionnaire recovery rate was 92.5%.

2.2. Methods

According to the survey results on the attitudes of the residents towards nuclear energy development in the early stage[8], the study took the subjective nuclear energy development acceptability of the residents in the range of 30 kilometers of the survey area as the subject, selected all the possible problems that may influence the nuclear energy acceptability of the residents with higher culture levels by referring to literature and the early-stage interview data and formulated a *Questionnaire on Factors that Influence the Nuclear Energy Acceptability of the Residents with Higher Culture Levels around Ningbo Zone of Sanmen Bay.* The first section of the questionnaire consists of the personal feature and behavior data, including the basic data such as age, sex, identity registration location, occupation, household income, residence place and the distance from the nuclear power station, information acquisition channel and information acquisition preference. The second section is the local nuclear energy development recognition degree of the public, which has been defined as follows: 1=welcome, 2=indifferent, 3=somewhat opposed, 4=very opposed. The third section is about the general influence factors, including 19 questions such as nuclear knowledge, nuclear incidents, government subsidies, intention to visit a nuclear power station and policy trust degree (There are four options for each question). After the Kaiser-Meyer-Olkin (KMO) measure was used to check the partial correlation among the 19 questions, the value was 0.861, close to 0.9, which indicated that there was connection among the questions and the factor analysis method should be used. The varimax orthogonal rotation was used to find the common fac-

tors from the 19 questions. The five common factors — benefit distribution, risk perception, public participation, project trust degree and professional knowledge — were selected through the scree plot. The characteristic root of each common factor was greater than 1 and the sum of the five common factors explained 98.869% of the total variance. The fourth section was a survey on the influence of psychological factors on the acceptability. The questionnaire also includes the Satisfaction With Life Scale (SWLS) and the Eysenck Personality Scales. As for all the variable assignments, see Table 1. After a pre-survey of the residents in the survey area was conducted, the analyzed data has shown that the internal consistency coefficient of the a *Questionnaire on Factors that Influence the Nuclear Energy Acceptability of the Residents with Higher Culture Levels around Ningbo Zone of Sanmen Bay* is 0.846. All the investigators were trained before the formal survey was conducted. The training contents include the questionnaire instructions, questionnaire contents, requirements for filling out the questionnaire and precautions. When the survey was conducted, the respondent was informed of its contents. After the respondent gave his or her informed consent, the respondent started to fill out the questionnaire. The investigator explained all the problems occurred during the survey. All the questionnaires were taken back at the survey site.

Table 1.The influence factor variable assignment checklist of the nuclear energy acceptability of the residents in Ningbo Zone of Sanmen Bay

Variable name		Variable assignment
General characteristic data	Age	1=21-30a, 2=31-40a, 3=41-50a, 4=51-60a
	Sex	1=male, 2=female
	Marriage	1=unmarried, 2=married, 3=divorced or spouse-bereft
	Household income	1= 100,000, 2=110,000-200,000, 3=210,000-300,000, 4=>300,000
	ID registration location	1=local ID registration 2=nonlocal ID registration
	Occupation	1=civil servant 2=public institution 3=enterprise 4=student 5=other
	Distance between residence and nuclear power station	1= 10km, 2=11-20km, 3=21-30km
Behavior data	Nuclear energy information acquisition channel	1=smart phone, 2=computer, 3=TV, 4=broadcast, 5=newspaper, 6=family member or friend

*Note: The common influence factor variable is the common factor got after the factor is analyzed. After the scores are assigned according to the relevant question answers, the common factor variable is assigned according to the four categories.

2.3. Quality control and statistical analysis

Bidirectional and directional test questions were added to the questionnaire during the questionnaire design. If the answers to bidirectional test questions do not follow the logic or directional test questions are not selected according to the design requirements in a questionnaire, the questionnaire is regarded as invalid. Epi Data 3.1 was used in the double entry data check and logic checkout. The data were processed and analyzed by using the software SPSS 16.0. Wilcoxon Rank-Sum Test and the linear trend test were used to analyze the difference of the respondents' answers to different research factors in a single factor condition. The statistic difference variables were included in the ordinal regression model to carry out the analysis and the inspection level α=0.05. In the ordinal regression model, the accumulated probability of the ordinal evaluation level was the response variable and the number of the response variables to be fitted minus a Logit regression model. The subjective nuclear energy development risk perception acceptability was a quantized code of an ordinal response variable in the study. The factors that may influence the nuclear energy acceptability of the residents with higher culture levels were used as the explanatory variables to carry out the fitting and create the ordinal regression model.

3. Results

3.1. General conditions

In the survey, the male respondents accounted for 49.45% (315/637), the female respondents accounted for 50.55% (322/637), the average age was 37.6±10.6. The married accounted for 92.46% (589/637) and the unmarried accounted for 7.54% (48/637). The respondents with an annual household income of RMB 100,000 or below accounted for 15.54% (99/637), the respondents with an annual household income of RMB 110,000 – 200,000 accounted for 29.36% (187/637), the respondents with an annual household income of RMB 210,000 – 300,000 accounted for 36.89% (235/637) and the respondents with an annual household income of RMB over 300,000 accounted for 18.21% (116/637). The respondents with local ID registration accounted for 76.77% (489/637) and the respondents with nonlocal ID registration accounted for 23.23% (148/637). The occupation distribution was as follows: civil servants 11.30% (72/637), public institution workers 29.20% (186/637), enterprise employees 35.32% (225/637), students 7.06% (45/637) and other 17.11% (109/637). The respondents less than 10 kilometers away from the nuclear power station accounted for 31.24% (199/637), the respondents with a distance of 11-20 kilometers away from the nuclear power station accounted for 30.46% (194/637) and the respondents with a distance of 21-30 kilometers away from the nuclear power station accounted for 38.30% (244/637). Among all the respondents, the respondents who welcomed nuclear power station construction in the local area or nearby accounted for 27.79% (177/637), the respondents who were indifferent to nuclear power accounted for 9.26% (59/637), the respondents who disliked nuclear power

station construction in the local area or nearby accounted for 31.55% (201/637) and the respondents who disliked nuclear power station construction very much in the local area or nearby accounted for 31.40% (200/637).

3.2. Single factor analysis of nuclear energy acceptability influence factors

In the single factor analysis, the variables of statistical significance related to the nuclear energy acceptability are sex (X^2=7.798, P =0.050), distance from the nuclear power station (X^2=27.552, P =0.002), benefit distribution (X^2=43.279, P =0.000), risk perception (X^2=20.724, P =0.014), project trust degree (X^2=9.676, P =0.026), nervousness (X^2=37.069, P =0.001) and life satisfaction (X^2=8.973, P =0.031). See Table 2 for the detailed information.

Note: The Wilcoxon rank-sum test was used to carry out the sex difference analysis. The linear tendency test was used to carry out the other. As for the variables corresponding to the codes, see Table 1.

Table 2. Results of single factor analysis on the factors that influence the nuclear energy acceptability of the residents in Ningbo Zone of Sanmen Bay

Factor	No.	Number of people (n/%)	Nuclear energy acceptability (n/%)				X^2 value
			Welcome	Indifferent	Some dislike	Strong dislike	
Sex	1	315/49.45	49/15.56	111/35.24	105/33.33	50/15.87	7.798
	2	322/50.55	35/10.87	102/31.68	110/34.16	75/23.29	
Distance from nuclear power station	1	149/23.39	9/6.04	44/29.53	61/40.94	35/23.49	27.552
	2	208/32.65	45/15.63	98/34.03	97/33.68	48/16.67	
	3	280/43.96	50/17.86	91/32.50	77/27.50	62/22.14	
Benefit distribution	1	59/9.26	7/11.86	24/40.68	27/45.76	1/1.69	43.279
	2	164/25.75	31/18.90	75/45.73	40/24.39	18/10.98	
	3	234/36.73	33/14.10	75/32.05	81/34.62	45/19.23	
	4	180/28.26	13/7.22	39/21.67	67/37.22	61/33.89	
Risk perception	1	107/16.80	14/13.08	45/42.06	35/32.71	13/12.15	20.724
	2	187/29.36	28/14.97	60/32.09	64/34.22	35/18.72	
	3	219/34.38	30/13.70	74/33.79	79/36.07	36/16.44	
	4	124/19.47	12/9.68	34/27.42	37/29.84	41/33.06	
Project trust degree	1	99/15.54	14/14.14	32/32.32	44/44.44	9/9.09	9.676
	2	187/29.36	34/18.18	67/35.83	50/26.74	36/19.25	
	3	242/37.99	27/11.16	80/33.06	91/37.60	44/18.18	
	4	109/17.11	9/8.26	34/31.19	30/27.52	36/33.03	
Nervousness	1	60/9.42	17/28.33	20/33.33	19/31.67	4/6.67	37.069
	2	160/25.12	31/19.38	70/43.75	46/28.75	13/8.13	
	3	181/28.41	18/9.94	50/27.62	80/44.20	33/18.23	
	4	159/24.96	13/8.18	53/33.33	45/28.30	48/30.19	
	5	77/12.09	5/6.49	20/25.97	25/32.47	27/35.06	

3.3. Multiple factor ordinal regression analysis of nuclear energy acceptability influence factors

Take the nuclear energy acceptability as the response variable, gradually include the factors of statistic difference in an ordinal regression equation in a single factor analysis and carry out multivariate regression analysis. The results have shown that the respondents who were less than 10 kilometers away from the nuclear power station were more opposed to the nuclear energy development in the local area than those with a distance of 21-30 kilometers away from the nuclear power station and there was no statistic difference between the nuclear energy acceptability of the respondents with a distance of 11-20 kilometers away from the nuclear power station and the nuclear energy acceptability of the respondents with a distance of 21-30 kilometers away from the nuclear power station. The nuclear energy acceptability of the respondents who believed the benefit distribution was or might be beneficial to them was higher than the nuclear energy acceptability of the respondents who believed that the benefit distribution was not beneficial to them. The nuclear energy acceptability of the respondents who believed that there were no risks or did not know any risks was higher than the nuclear energy acceptability of the respondents who believed that there were risks. The nuclear energy acceptability of the respondents whose scores in the N scales for personality test belonged to low score model and low score tendency was higher than the nuclear energy acceptability of the respondents whose scores in the N scales for personality test belonged to high score model. See Table 2 for the detailed information.

Table 3. Results of ordinal regression analysis on the factors that influence the nuclear energy acceptability of the residents in Ningbo Zone of Sanmen Bay

Variable type	Variable name	Code	β	SE	Wald	P	OR
Response variable Y	Nuclear energy acceptability	1	-2.192	0.382	28.743	0.000	-
		2	-1.794	0.358	17.193	0.001	-
		3	-0.660	0.316	3.645	0.031	-
Explanatory variable X	Distance from nuclear power station	1	0.547	0.205	7.108	0.008	2.022
		2	-0.009	0.173	0.003	0.959	1.206
		3	0.000	.	.	.	
	Benefit distribution	1	-1.217	0.284	26.348	0.001	0.304
		2	-1.123	0.211	6.354	0.043	0.494
		3	-0.624	0.331	1.960	0.108	0.709
		4	0.000	.	.	.	
	Risk perception	1	-0.826	0.254	9.003	0.011	0.379
		2	-0.449	0.221	4.028	0.047	0.503
		3	-0.377	0.269	2.193	0.101	0.674
		4	0.000	.	.	.	
	Nervousness	1	-1.041	0.270	9.345	0.009	0.308
		2	-0.909	0.317	5.651	0.048	0.518
		3	-0.353	0.259	1.104	0.126	1.212
		4	-0.129	0.165	1.582	0.216	1.971
		5	0.0000	.	.	.	

Note: [a]The variable reference group was set to 0 in the model.

3.4. Further analysis on problems related to influence factors

The ordinal regression analysis has shown that there was statistical relevance between the benefit distribution and the nuclear energy acceptability of the residents and between the risk perception and the nuclear energy acceptability of the residents. The problems related to the two common factors were proposed according to the two problems with the maximum coefficients of the factor score coefficient matrix. After they were sorted and analyzed, the results have shown that in the common factor of benefit distribution, 599 people (94.03%) thought that the government must

or should subsidize the residents in the areas adjoining the nuclear power station zone and 377 people (59.18%) very much worried about/worried about the decrease of enterprises and employment opportunities due to the nuclear power station. In the risk perception factor, 509 people (81.16%) very much worried about/worried about the influence of the nuclear power station operation on the people's health. 401 people (62.95%) very much worried about/worried about the occurrence of an accident similar to the Fukushima Nuclear Accident. The analysis on the spearman correlation between the personality (scores in the N Scales of the Eysenck Personality Scales) and the nuclear energy acceptability has shown that the two variables were negatively (r_s=0.639, P??0.05). Only 20.10% (40/199) of the residents 10 kilometers or less than 10 kilometers away from the nuclear power station supported the nuclear energy development. 27.32% (53/194) of the residents 11 - 20 kilometers away from the nuclear power station supported the nuclear energy development and 34.42% (84/244) of the residents 21 - 30 kilometers away from the nuclear power station supported the nuclear energy development.

4. Discussions

The public acceptability refers to the public's acceptance level or acceptance willingness of something and it refers to the nuclear energy development acceptance level of the residents around Ningbo Zone of Sanmen Bay in the study. The acceptability of the public is an important link in the establishment and good operation of important economic projects related to environmental impact. No matter how good the management system is, poor acceptability of the public will increase the resistance to the implementation and execution. The survey has shown that the local nuclear energy development acceptability of the residents around Ningbo Zone of Sanmen Bay was not high and the main influence factors were the distance from the nuclear power station, the benefit distribution, the risk perception and the personality feature. The survey has also shown that the acceptability of the residents 10 kilometers or less than 10 kilometers away from the nuclear power station was the lowest and the acceptability of the residents farther away from the station was higher. The survey results of the residents near the Tianwan Nuclear Power Station has shown that the relation between the distance from the nuclear power station and the acceptability was like an inverted letter U. The acceptability of the residents closest to the station and farther away from the station was higher. The difference between the above two groups shown in the survey results is likely to be related to the difference in benefit distribution. The residents 8 kilometers or less than 8 kilometers away from the Tianwan Nuclear Power Station were benefited due to the land transfer and the road and environment improvement. However, the residents in Ningbo Zone of Sanmen Bay adjoining the area of the station were given no compensation because the station belonged to a different prefecture-level city. 94.03% of the respondents thought that the government must or should subsidize the residents in the areas adjoining the station area though the areas did not belong to the city in which the station was. It can be found that the fairness of benefit distribution was one of the key factors that influenced the acceptability of the residents. The findings

of the survey have shown that risk perception was one of the factors that influenced the acceptability of the residents and the Fukushima Nuclear Accident had negative influences on the nuclear energy development risk perception of the residents, which was consistent with the survey results of Quan Shiwen, etc. on the nuclear power perception and acceptance willingness of Beijing residents in the background of the Japanese nuclear leak accident. The personality feature was also one of the factors that influenced the nuclear energy acceptability of the residents. The people with higher scores in the N Scales of the Eysenck Personality Scales usually were anxious and had a depression inclination and their emotional reaction to risky things was intense. Therefore, their acceptability was lower. Nuclear energy is a sensitive topic. Though the existing researches have shown that the increment to the original radiation quantity around a nuclear power station caused by the nuclear power station is very little when the station is operating normally, the nuclear power generation can effectively relieve the pressure of the thermal power generation on the environment and the safety of the nuclear power station will be further guaranteed with the fourth generation of nuclear power technology being gradually promoted, the public often relate nuclear energy development to the Fukushima Nuclear Accident, the Chernobyl Nuclear Accident, etc. and they feel doubtful about the publicity of the government. The nuclear energy development of China is at the primary stage. Whether it will greatly develop depends on the acceptability of the public. The public, especially the residents around the nuclear facilities, have great influences and their nuclear energy and nuclear radiation perception levels will play more and more important roles in the nuclear facility construction. The findings in the survey have shown that the following several specific intervening measures can be carried out. Firstly, remove the economic compensation difference among the residents around the nuclear power station caused by the administrative division and establish a fair compensation mechanism. Secondly, analyze nuclear energy risks, popularize nuclear energy knowledge, improve the nuclear energy operation transparency and establish a public informed participation mechanism. Finally, take some psychological intervening measures to improve the acceptability of the residents whose nuclear energy acceptability was low partly due to their personalities and temperaments.

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