Desalination and Water Treatment
www.deswater.com

doi:10.5004/dwt.2021.27330

228 (2021) 72–83
July

Public participation in rural domestic sewage treatment: a study from Inner Mongolia of China

Chao Ding[a,b,*], Chen Li[a], Ju Zhu[a], Zhenhua Wang[a,b], Wenxiu Dong[a,b]

[a]*School of Civil Engineering, Inner Mongolia University of Science and Technology, Baotou 014010, China, Tel. +86-133-470-83460; emails: dckinger@imust.edu.cn (C. Ding), 2019022336@stu.imust.edu.cn (C. Li), 2019023210@stu.imust.edu.cn (J. Zhu), lanseman@imust.edu.cn (Z. Wang), 2018941@imust.edu.cn (W. Dong)*
[b]*Research Center of Intelligent Construction and Operation Engineering Technology, Inner Mongolia University of Science and Technology, Baotou 014010, China*

Received 31 December 2020; Accepted 17 April 2021

ABSTRACT

Rural domestic sewage is the primary source of rural non-point source pollution in China. In rural domestic sewage treatment, it is faced with the risk of insufficient public participation of rural residents, which leads to the unfavorable promotion of sewage treatment projects or idle after completion. Therefore, improving the effective participation of rural residents in sewage treatment is the key to the success of rural sewage treatment projects. Based on an investigation into Inner Mongolia's rural and pastoral areas, this study selected 48 villages from 12 cities as the research object. Fourteen influencing factors were identified and evaluated based on Gt-Dematel-Ism integrated analysis model constructed and the hierarchical relationship among the influencing factors was characterized. The results show that: (1) to fundamentally improve the level of public participation of farmers at this stage is to enhance their awareness of environmental protection, with an emphasis on carrying out environmental protection education. (2) "participation mechanism", "technology choice", and "economic factors" are all necessary means of enhancing the willingness to participate in sewage treatment. (3) the "participation mechanism" can improve farmers' sense of identity with rural sewage treatment projects. "Technology selection" enables farmers to better understand the projects they are involved in. The focus of "economic factors" is to lighten the burden on farmers.

Keywords: Public participation; Rural; Sewage treatment; Inner Mongolia

1. Introduction

With the development of the world economy, human demand for water and sewage discharge are increasing. [1]. Water pollution has become one of the significant problems in the ecological environment [2]. Water pollution in China originated in industrialization in the 1950s and became severe after the 1970s. At present, rural environmental pollution has exceeded the industrial and urban ecological destruction in the first place and shows a trend of continuous deterioration. China proposes to "speed up the reform of the ecological civilization system and build a beautiful China." The only way to build a beautiful China is to create beautiful countryside. To make a beautiful countryside, we must manage the rural environment well, and the excellent rural water environment is the foundation and the core symbol of the beautiful village [3]. Currently, the current sewage treatment situation in rural areas is difficult to be satisfactory [4–6]. The supporting facilities and treatment capacity of rural sewage treatment are backward [7,8], and a large amount of domestic sewage is discharged without treatment [9]. It has led to a series of environmental pollution problems, such as the eutrophication of rural lakes and rivers [10]. The main reason is that there are significant limitations

* Corresponding author.

in the current rural environmental management model [11]. As an essential participant in the pastoral environmental treatment work, farmers do not effectively participate in the rural water environmental treatment work [12]. As a result, the rural sewage treatment project is easy to fail. This is also the key reason why sewage treatment facilities in some rural areas are only built [13], and some sewage treatment projects are "basking in the sun" [14]. Therefore, to promote rural sewage treatment quickly, it is essential to effectively improve rural residents' public participation [3].

Many factors are affecting rural residents' participation in rural sewage treatment, which are finally reflected in farmers' willingness to participate and participation behavior. Studies have shown that people in arid and water-scarce areas are more likely to have positive attitudes toward wastewater treatment and recycling [15,16]. The more positive the attitude and sense of responsibility toward environmental protection, the more agreeable they are to wastewater treatment [17,18]; farmers' perceptions of ecology and responsibility also influence their participation willingness [19]. Information disclosure will have an important impact on the willingness of public participation [20]. At present, further research shows that in the process of sewage treatment and reuse, the public has a stereotype on the use of reclaimed water contacted by different human beings, which also impacts the willingness of public participation [21]. However, in the actual wastewater treatment process, it was found that environmental awareness and environmental behavior are not consistent [19,22]; that is to say, there is a divergence between the farmers' participation willingness and their actual action [23]. There are many reasons for this situation. For example, from the economic aspect, farmers believe that the government is the main provider of public infrastructure in rural areas. The proportion and responsibility of government investment should be more important than that of farmers. [24]. However, farmers are willing but not willing to bear the burden [25]. The "top-down" decision-making [26] in rural environmental governance in China involves multi-level principal-agent relationships and lacks a scientific, rational, and practical public participation mechanism [27]. Simultaneously, due to the nature of the rural water environment as a public good, wastewater discharge has obvious negative externalities, while wastewater treatment has obvious positive externalities. The "tragedy of the commons" and the inevitable "free-rider" phenomenon most likely leads to "Prisoner's Dilemma" [28].

Thus, rural wastewater management is a technical issue and a management issue [29–32]. As the ultimate beneficiaries and rural wastewater management participants, farmers' behavior is influenced by various factors, which are directly related to the success or failure of rural sewage treatment. Many factors influence farmer participation, and many studies have analyzed and classified the influencing factors from different perspectives. Still, in general, there is a lack of systematic organization, and the relationship between various influencing factors is not effectively revealed, making it difficult to grasp the full picture. Therefore, this paper hopes to integrate the identification, classification, and hierarchy of influencing factors into a system using a variety of technical means (Grounded theory, Decision-making trial and evaluation laboratory method, and Interpretative structure model). Build a network of influencing factors that can be expressed hierarchically to express the relationship between influencing factors. In this way, it can help decision-makers clarify the internal relationship among the influencing factors, thus reveal the mechanism of rural household participation in rural sewage treatment, and provide a reference for the formulation of corresponding countermeasures.

2. Materials and methods

2.1. Methods

The more commonly used methods in current research are Grounded Theory (GT), Decision-making Trial, and Evaluation Laboratory (DEMATEL) [33], and Interpretative Structural Model (ISM) [34]. GT is better suited for making empirical generalizations from primary data to construct a theoretical framework, but it cannot discern each influencing factor's importance. DEMATEL can identify causal relationships between elements and distinguish the importance of factors, but it is not good at extracting characteristics and stratifying influences. ISM has the advantage of visually presenting the findings in a hierarchical topological diagram. Therefore, in this study, the GT-DEMATEL-ISM integrated evaluation method (Fig. 1) was constructed by combining the three methods' characteristics and linking them.

1) Identifying factors influencing farmer participation [35]

After collecting the data, the data were first to open coded, disassembled, and reorganized to redefine the conceptual findings' scope (influencing factors). This is followed by principal axis coding, which involves clustering the category found after open coding to find correlations among the genera. Finally, selective coding is performed to analyze and process the correlations between the main types and construct the theoretical model. The next step is to select a portion of the reserved data for academic saturation testing to ensure that no new categories emerge. The final class (influencing factor) x_i (i = 1, 2, ..., n) constitutes the system influencing factors X, $x_i \in X$.

2) Constructing the direct influence matrix N

Assume that scales 0, 1, 2, 3, and 4 represent a range from "not relevant" to "strongly relevant" [36]. After extracting the influences, the respondents were re-invited to rate the degree of correlation between the influences (Table 1 for the semantic scale).

Constructing an $n \times n$ matrix $B^k = [\beta_{ij}^k]$, (k = 1, 2, ..., m; i = 1, 2, ..., n; j = 1, 2, ..., n), β_{ij}^k based on the semantic descriptions between the k respondents of the influences $B^k = [\beta_{ij}^k]$, (k = 1, 2, …, m; i = 1, 2, …, n; j = 1, 2, …, n), β_{ij}^k is the value given by the kth respondent of the degree of association of influences x_i on influences x_j, where when $i = j$ (i, j = 1, 2, …, n), $\beta_{ij}^k = 0$. Take the average of the opinions of the k respondents to further construct the initial matrix:

$$\beta_{ij} = \frac{1}{m}\sum_{k=1}^{m}\beta_{ij}^k \left(k = 1,2,\ldots,m\right) \quad (1)$$

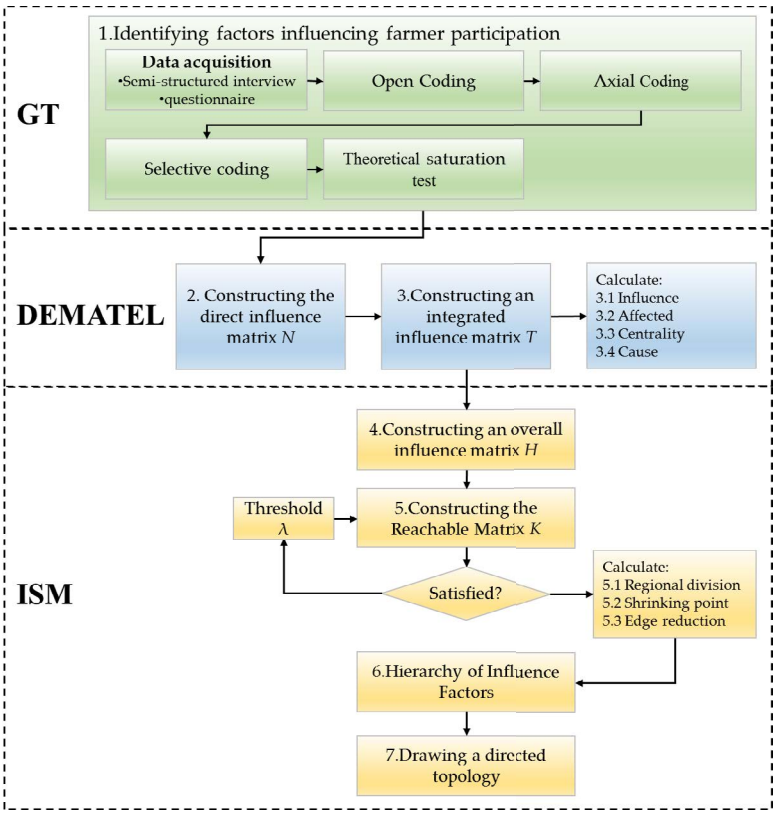


Fig. 1. GT-DEMATEL-ISM integrated analysis model.

Table 1
Semantic scales [36]

Semantics	Degree to which influence factor x_i is related to influence factor x_j				
Description	Not relevant	Weak relevant	General relevant	Stronger relevant	Strongly relevant
Score β_{ij}	0	1	2	3	4

From this, the initial matrix is constructed N':

$$N' = \begin{bmatrix} 0 & \beta_{12} & \cdots & \beta_{1n} \\ \beta_{21} & 0 & \cdots & \beta_{2n} \\ \vdots & \vdots & 0 & \vdots \\ \beta_{n1} & \beta_{n2} & \cdots & 0 \end{bmatrix} \tag{2}$$

The direct influence matrix N is normalized to the initial matrix using the row and maximum method. N', Thus:

$$N = \frac{1}{\mathrm{Max}(a)} \begin{bmatrix} 0 & \beta_{12} & \cdots & \beta_{1n} \\ \beta_{21} & 0 & \cdots & \beta_{2n} \\ \vdots & \vdots & 0 & \vdots \\ \beta_{n1} & \beta_{n2} & \cdots & 0 \end{bmatrix} \tag{3}$$

where a is the set of sums of each row of the matrix N' prime.

3) Constructing an integrated influence matrix T

The integrated influence matrix T reflects the interaction of factors including direct and indirect relationships [37]. $T = N + N^1 + N^2 + \cdots + N^k = \sum_{k=1}^{\infty} N^k$, so:

$$T = N(I - N)^{-1} = [t_{ij}](i = 1,2,\ldots,n; j = 1,2,\ldots,n) \tag{4}$$

where I is the unit matrix. From the integrated influence matrix T, we can further calculate the measure of influence in the system for the four elements: influence, affected, centrality, and cause.

$$D_i = \sum_{j=1}^{n} t_{ij} (i = 1,2,\ldots,n) \tag{5}$$

$$C_j = \sum_{i=1}^{n} t_{ij} (j = 1,2,\ldots,n) \tag{6}$$

$$M_i = D_i + C_j \tag{7}$$

$$R_i = D_i - C_j \tag{8}$$

where D_i is the degree of influence, that is, the combined effect of the factor on other factors; C_j is the degree of being affected, that is, the combined influence of the factor on other factors; M_i is the degree of centrality, that is, the importance of the factor; R_i is the degree of cause, if it is positive, it is the causal factor, indicating that the factor is coupled with other factors; if it is negative, it is the resulting factor, indicating that the factor is coupled with other factors.

4) Constructing an overall influence matrix H

T only reflects the relationship and degree of influence between the different influencing factors but does not consider its own influence on itself. Hence, the overall influence matrix is essentially a modification of the comprehensive influence matrix that considers the influence of the factors themselves [38].

$$H = \left[h_{ij}\right] = T + I \tag{9}$$

where $h_{ij} = 0$ means that there is no influencing relationship between factors x_i and x_j, otherwise there is an influence relationship.

5) Constructing the reachable matrix K

The range of values for the reachable matrix elements is generally [0,1], where 0 means no relationship and 1 means a relationship, and the type of values is similar to a Boolean variable. Therefore, a threshold value of λ can be set to Booleanize H to obtain K. λ is used to filter the small effects represented by H's element. The goal of the filtering is to highlight the main factors that influence farmer participation. The filtering goal is to highlight the main factors influencing farmer participation to avoid oversimplification. Thus, the reachable matrix is represented by $K = [k_{ij}]$, and the value of k_{ij} is determined by the following equation:

$$k_{ij} = \begin{cases} 1, & h_{ij} \geq \lambda\left(i, j = 1,2,\ldots,n\right) \\ 0, & h_{ij} < \lambda\left(i, j = 1,2,\ldots,n\right) \end{cases} \tag{10}$$

The main principle that should be followed to determine λ [39] is that each influencing factor's nodal degree should be moderate and the influencing factor with a large nodal degree should be included in the third step of the DEMATEL method. In this study, the nodal degree is expressed in terms of n_i by the following equation. A suitable value of λ can be obtained through several trials:

$$n_i = \sum_{i \neq j} h_{ij}\left(i, j = 1,2,\ldots,n\right) \tag{11}$$

5) Hierarchy of influence factors x_i

The set of influences x_i in K with a row value of 1 is the result set $R(x_i)$, and the set of columns with a column value of 1 is the set of antecedents $Q(x_j)$:

$$R\left(x_i\right) = \left\{x_i \middle| x_i \in X, k_{ij} \neq 0\right\}, \left(i = 1,2,\ldots,n\right) \tag{12}$$

$$Q\left(x_j\right) = \left\{x_j \middle| x_j \in X, k_{ij} \neq 0\right\}, \left(j = 1,2,\ldots,n\right) \tag{13}$$

The hierarchical approach prioritizes causes:

$$R\left(x_i\right) \cap Q\left(x_j\right) = Q\left(x_j\right) \tag{14}$$

6) Drawing a directed topology

Based on the above results, draw the most streamlined hierarchical directed topology diagram.

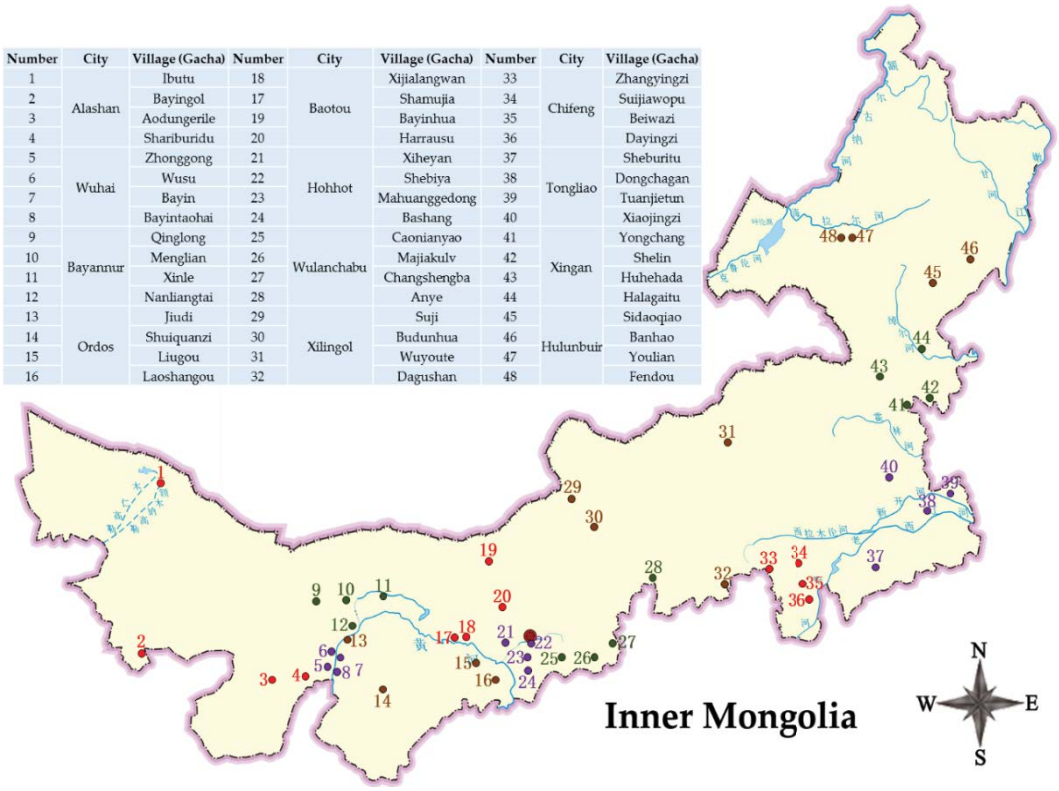
2.2. Data sources and testing

2.2.1. Research program design

According to the characteristics of the research methodology, data acquisition was carried out in two steps. The first step is to use school students who live in rural pastoral areas of Inner Mongolia to conduct in-depth interviews with target audiences during the summer vacation after training, from July 1 to August 31, 2019. According to the principle of population coverage, coverage, and type balance, the research team selected 48 farm households from 48 villages (Gacha) in 12 cities of Inner Mongolia (Fig. 2). Members of the investigation team conducted in-depth interviews on a one-on-one basis, with an average interview time of 30 min. Interviews were conducted with heads of household, and concepts related to rural wastewater management were introduced to the interviewees before the research began to ensure that they understood the issues correctly. The interviews were conducted without a fixed answer and it is mainly expressed and organized by farmers themselves after the consultations. In the second step, after extracting the influencing factors, a questionnaire was administered to the original respondents to evaluate the influencing factors' correlation.

2.2.2. Sample characteristics

The majority of the sample was 85.42% male, mainly because the head of the household was asked to come and be surveyed. Most of the households recommended the male as leaders. 87.5% of the respondents were over the age of 40, and 64.58% of the respondents had junior high school education or less. In terms of family characteristics, 81.25% of the families were 5 or fewer people, 64.58% were mainly farmers, and 56.25% had an annual income of more than 50,000 CNY. The proportion of respondents' households in village committees is low. In general, the sample selected



Number	City	Village (Gacha)	Number	City	Village (Gacha)	Number	City	Village (Gacha)
1	Alashan	Ibutu	18	Baotou	Xijialangwan	33	Chifeng	Zhangyingzi
2		Bayingol	17		Shamujia	34		Suijiawopu
3		Aodungerile	19		Bayinhua	35		Beiwazi
4		Shariburidu	20		Harrausu	36		Dayingzi
5	Wuhai	Zhonggong	21	Hohhot	Xiheyan	37	Tongliao	Sheburitu
6		Wusu	22		Shebiya	38		Dongchagan
7		Bayin	23		Mahuanggedong	39		Tuanjietun
8		Bayintaohai	24		Bashang	40		Xiaojingzi
9	Bayannur	Qinglong	25	Wulanchabu	Caonianyao	41	Xingan	Yongchang
10		Menglian	26		Majiakulv	42		Shelin
11		Xinle	27		Changshengba	43		Huhehada
12		Nanliangtai	28		Anye	44		Halagaitu
13	Ordos	Jiudi	29	Xilingol	Suji	45	Hulunbuir	Sidaoqiao
14		Shuiquanzi	30		Budunhua	46		Banhao
15		Liugou	31		Wuyoute	47		Youlian
16		Laoshangou	32		Dagushan	48		Fendou

Fig. 2. Study areas.

Table 2
Household characteristics of interviewed farm households

Category	Options	Persons
Gender	Male	41 (85.42%)
	Female	7 (14.58%)
Age	20–30	2 (4.17%)
	31–40	4 (8.33%)
	41–50	31 (64.58%)
	51–60	8 (16.67%)
	Over 60	3 (6.25%)
Education level	Primary school	10 (20.83%)
	Secondary school	21 (43.75%)
	High school	15 (31.25%)
	University and above	2 (4.17%)
Number of family members	≤3	3 (6.25%)
	4–5	36 (75%)
	≥6	9 (18.75%)
Family main Revenue sources	Farming	31 (64.58%)
	Non-farm	17 (35.42%)
Gross annual household income	<3 million CNY	4 (8.33%)
	3–5 million CNY	17 (35.42%)
	5–10 million CNY	23 (47.92%)
	>10 million CNY	4 (8.33%)
Whether a family member serves on the village council	Yes	4 (8.33%)
	No	44 (91.67%)

for this study is basically in line with the farm households' current situation in Inner Mongolia (Table 2).

3. Results

3.1. Extraction and mechanism of influence factors (GT)

Forty-three were randomly selected for open coding from the 48 interview data obtained [38]. In this study, initial concepts that were repeated more than three times were chosen for categorization. Finally, 14 initial categories (influencing factors) were extracted, and five main types were formed. In conjunction with the study's theme, the core category was dominated by "influencing factors of farmers' participation in rural wastewater management" (Table 3). The saturation test on the five reserved records showed that no new influences and relationships exist. Therefore, the model of influencing factors on farmer participation in rural wastewater management is theoretically saturated.

A preliminary framework model for the action mechanism of influencing factors is constructed (Fig. 3). The motivation of environmental protection is the dynamic mechanism for forming farmers' willingness to participate, which comes from farmers' awareness of the importance of environmental protection and the degree of surrounding pollution. Simultaneously, the motivation of ecological protection also comes from social pressure: the influence of surrounding people or the sense of honor brought by environmental protection behavior. The willingness to participate is affected by the regulation mechanism, and

Table 3
Example of the coding process for factors influencing farmers' participation in rural wastewater management

Factors	Name	Initial category content	Representative original statements
x_1	Education	x_1 includes education on environmental protection knowledge, environmental protection laws and regulations, and whether there are channels around to influence and change the level of ecological awareness to enhance residents' understanding of environmental protection.	No one talks specifically about environmental protection. All I know is from the news, sometimes on Wechat.
x_2	Form of education	x_2 indicates the channels for environmental education, including brochures, bulletins, television, promotional videos, Wechat, online videos, etc.	It is mainly TV. It is often said in the news that there are also some short videos on Douyin.
x_3	Awareness of the importance of environmental protection	Rural residents' awareness of environmental protection and their awareness of environmental protection, the more they recognize the importance of environmental protection, the more likely they are to participate in environmental governance.	In the past 2 y, the country has been promoting the idea that "green water and green mountains are golden mountains".
x_4	Perception of the degree of pollution	The more rural residents feel about environmental pollution, the more they understand and feel about the pollution, the more likely they are to participate in environmental governance.	Sandstorms have actually improved a lot in recent years, but the air is not good, and so is the river.
x_5	Social pressure	The psychological pressure brought by the behavior of the surrounding families. The sense of honor brought by the environmental protection behavior of rural residents. The stronger the sense of honor of residents, the more they can actively participate in environmental governance.	If everyone does it, my family will certainly not be behind. It's a good thing to do for future generations, and we want to do it.
x_6	Household income	The income level of the family.	Our family income is not high, the children are still in school, isn't it to spend a lot of money?
x_7	Apportionment of construction funds	Whether and how much the residents bear the construction funds will affect the residents' enthusiasm to participate in the sewage treatment project.	If the money is not much, we can still afford some, we think it should be done in the village or town.
x_8	Bear the operating cost	After completion, the operation of the project, whether it is convenient, whether it needs personnel, land security, the burden of operating costs, or whether it can bring benefits. These conditions will affect the enthusiasm of residents to participate in sewage treatment projects.	How much do you charge for this? If you collect it with tap water, you can't collect too much.
x_9	Information acquisition	x_9 represents the timeliness and accuracy of information release. Residents' ignorance will also lead to reduced participation.	I don't seem to have heard of any sewage treatment projects. I don't know much about it.
x_{10}	The form of participation	x_{10} indicates the specific form of residents' participation in environmental protection projects. Specifically, it includes public participation in environmental protection assessment, environmental protection hearings, or specific participation in environmental protection demonstration projects. The lack of forms of participation will lead to the inability of residents to participate effectively.	My family has not participated in it, but if there is a project, I think it would be nice for us to listen to the introduction.
x_{11}	Degree of participation	x_{11} indicates the specific level of participation in environmental protection projects. It includes rural planning, terminal location, pipeline direction determination, or construction supervision.	If the sewage treatment project is to occupy an area, I hope to be able to participate in this site selection. This is very important.
x_{12}	Sewage treatment technology	x_{12} indicates sewage treatment technology's specific choice, including centralized sewage treatment technology and decentralized sewage treatment technology.	I don't know anything about technology. I hope the smaller the better and the easier the better.

Table 3 *continued*

Factors	Name	Initial category content	Representative original statements
x_{13}	Technical knowledge	x_{13} means to ensure the regular operation of sewage treatment equipment, daily management, and other knowledge.	I don't understand how the equipment is operated. If I really want to do this, I must hope to teach it as simple as possible.
x_{14}	Willingness of public participation	x_{14} indicates the willingness of rural households to participate in sewage treatment.	My family is willing to participate in the village sewage treatment, which is also good for everyone.

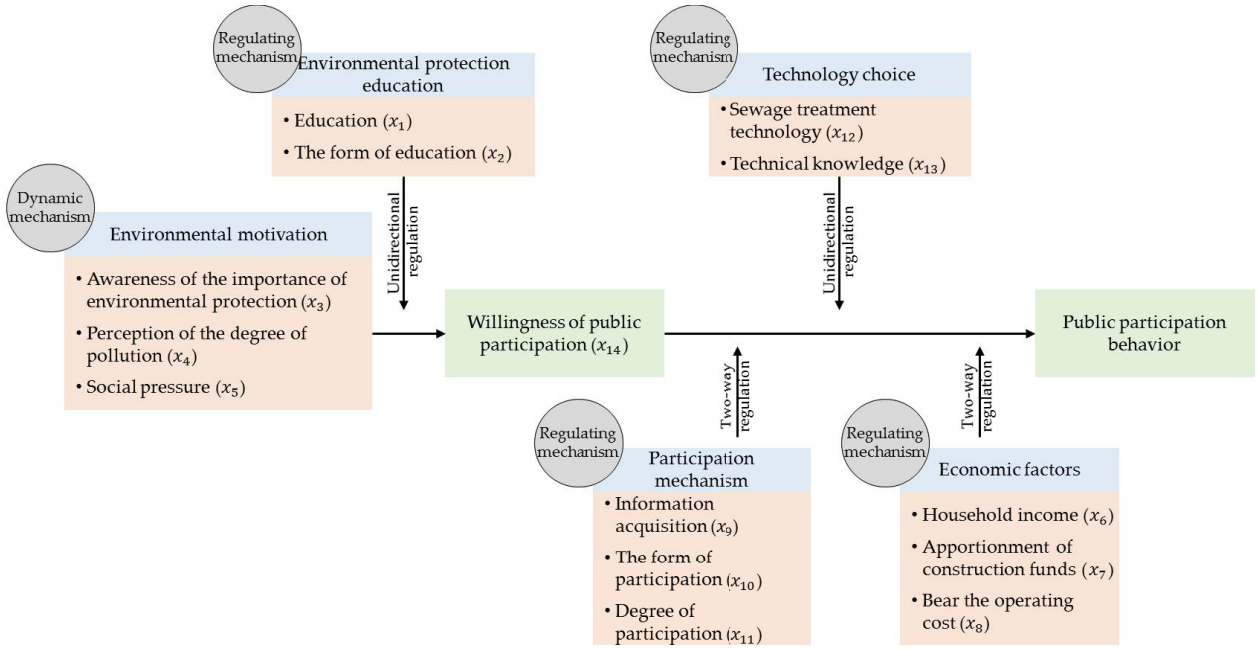


Fig. 3. Theoretical framework model for influencing factor mechanisms.

ecological protection education is the antecedent factor of the desire to participate, which plays a one-way regulatory role. Environmental education affects environmental protection motivation and then affects the willingness to participate, but the desire to join will not affect ecological education. Willingness to participate directly affects participation behavior but does not directly lead to participation behavior, which is affected by regulatory mechanisms such as technological choice, participation mechanism, and economic influence, leading to a deviation between participation intention and behavior. The technology selection factor is one-way regulation, and the participation mechanism and economic influencing factors are two-way regulation. That is, they will interact with each other. In the end, the willingness to participate plays an approximate intermediary role. The dynamic mechanism and regulation mechanism indirectly affect the desire to participate, and finally, involve the public participation of rural residents.

3.2. Identifying relationships between factors (DEMATEL)

Cause-and-effect diagrams can visually show the importance and cause-and-effect relationship of each factor, providing useful information to support the decision-making process. This study follows the generalized matrix format in which regions are divided by the degree of cause and degree of centrality.

The red area in the upper right corner indicates the range of important factors and most likely to influence other factors. The blue area in the lower right corner indicates the range of factors that are both important and most likely to be influenced by other factors. the lighter the color, the less important they are. Fig. 4 shows that x_1, x_2, x_3, x_4, x_6, x_9, x_{12}, and x_{14} are causal factors that are important in influencing the changes in other factors. x_5, x_7, x_8, x_{10}, x_{11}, and x_{13} are outcome factors, which are most likely to be changed by other factors.

Among them, x_1, x_3, x_4 are critical causal factors influencing other factors, x_3, x_4 are influential factors of motivational mechanisms, x_1 is a moderator of participation willingness,

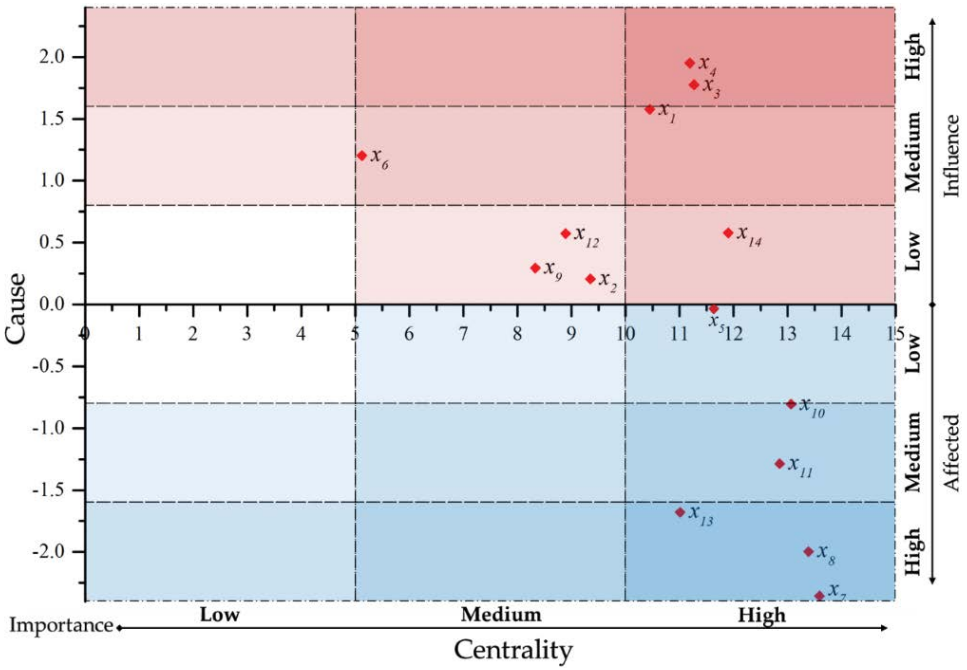


Fig. 4. Cause-and-effect diagram of influencing factors.

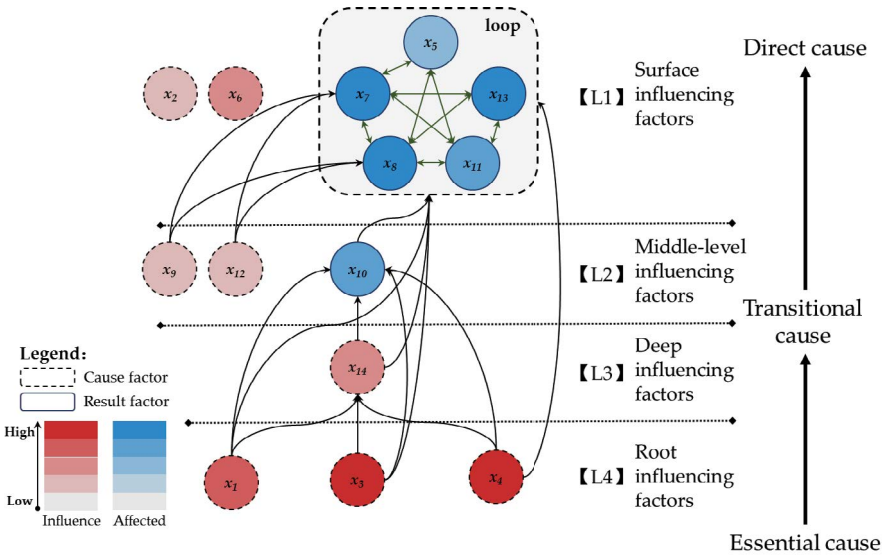


Fig. 5. Hierarchy of influencing factors.

and changing them will significantly impact other elements. Although x_{14} is very important, it does not substantially affect other factors. Instead, it acts as a mediator between influences and specific behaviors, which is more consistent with the mechanistic model of action developed earlier. The lower half of the horizontal axis in Fig. 4 shows that x_7, x_8, and x_{13} are very important and susceptible outcome factors, while x_{10} and x_{11} are somewhat less susceptible. This means that economic burden and technical knowledge are essential and sensitive factors in minimizing the divergence between participation willingness and behavior, and therefore it is a breakthrough and focus of our work.

3.3. Identify the hierarchy between factors (ISM)

In constructing the reachable matrix, we selected the thresholds by multiple tests, where λ is 0.45, 0.48, 0.51, and 0.57. According to the principle described above, a threshold value of $\lambda = 0.46$ is chosen here. According to Eqs. (12)–(14), the hierarchy of influencing factors is carried out using the "cause first" method, and due to a large number of influencing factors and complex relationships, there are loops in the system. Combined with the analysis of the influencing factors in DEMATEL, the resulting comprehensive directed topology is shown in Fig. 5, which ultimately shows the

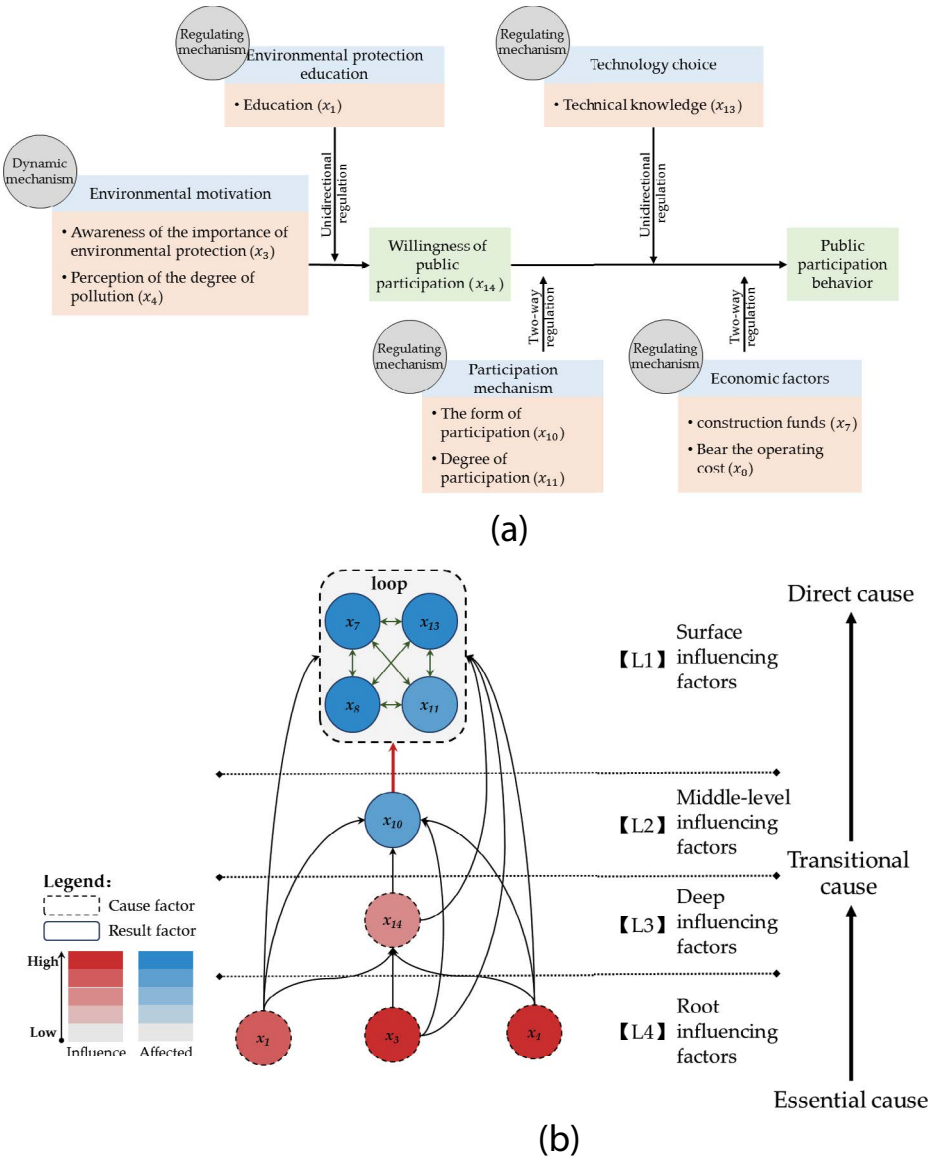


Fig. 6. Results of the GT-DEMATEL-ISM integrated analysis model: (a) simplified theoretical framework of action mechanism and (b) simplified hierarchy.

relationship between the elements. As shown in Fig. 5, the factors influencing rural households' participation in rural wastewater management can be divided into four levels.

4. Discussion

By constructing a GT-DEMATEL-ISM integrated analysis model, this study extracts the influencing factors of farmers' participation in rural wastewater management. By dividing the importance and hierarchy of the influencing factors, it forms an action mechanism framework, and the action characteristics of each element are separated. So, it is necessary to discuss the influencing factors further:

- The cognition of environmental protection and pollution (x_3, x_4) is the fundamental factor affecting farmers' public participation. The sense of honor and disgrace caused by social pressure (x_5) is not as important as we think, which is related to the fact that the whole society has not yet fully formed a unified understanding of the role of environmental protection and social atmosphere. Therefore, x_5 is a surface factor, whose importance is not enough, and its driving effect as a dynamic mechanism is not apparent.
- The role of environment protection education as a moderating mechanism to influence participation willingness is consistent with expectations, and x_1 is shown to be a vital root cause in the hierarchy. However, unlike the current intuitive understanding that different forms of diverse environment protection education can increase participation willingness, x_2 is only a superficial and less critical factor. Does this mean that it is not essential

to consider the form of education in environment protection education? We speculate that the reason for this result is the severe shortage of environmental education in rural areas. Therefore, the first thing to be addressed is whether there is environmental protection education for rural residents. So, at this stage, the format is not so important. Whether it is a micro-classroom, a micro-interactive, or any other form of education, the key is just to carry it out [40,41].

- In the transformation from public participation willingness to participation behavior, participation mechanism factors are more critical, especially x_{10} plays a bridging role in the hierarchical structure. This shows that participating in the stages of site selection, project establishment, design, construction, and operation of the project in different forms and degrees, is vital to promote farmers' public participation in the rural sewage treatment project. Simultaneously, through the hierarchical structure, we can also find that x_9 does not seem to be very useful, but this does not mean that sunny disclosure of the information is not essential, mainly because the village (Gacha) is generally tiny. It is relatively easy to obtain information about some important events in the town.
- In the rural sewage treatment work, we have been developing and promoting some technologies that adopt local conditions, which is very important from the technical level. However, from the perspective of fostering rural residents' public participation, it is necessary to distinguish between "selected technology" and "what technology to choose." Because for rural sewage treatment technology, whether it is constructed wetlands or biological filters and other technologies, it is difficult for non-professionals to master. Therefore, in the hierarchical structure, we can also see that x_{12} is a less critical factor close to the surface, and farmers are not very concerned about the specific technology. Therefore, "x_{13} technical knowledge" is the focus of our work. We should not talk about "what is technology" and popularize "what to do with technology." We should let farmers understand the land, manpower, energy, and other needs involved in technology operation.
- "x_6 household income" has little impact on public participation, while economic impact (x_7, x_8) is still the most critical surface factor affecting public involvement. Therefore, to promote farmers' effective participation in the initial stage of rural sewage treatment, the government should subsidize the construction of the project and the operation after completion, and the larger the initial subsidy level, the better [42]. With the improvement of rural residents' awareness and the project's continuous process, the subsidy level will be adjusted.
- In summary, the hierarchy is shown in Fig. 5 basically confirms the mechanism of the influencing factors initially constructed in Fig. 3. The "x_{14} Willingness of public participation" is a crucial mediator of farmer participation in rural wastewater management, which is driven by the driving mechanism (x_3, x_4) and regulated by the regulating agency (x_1), and is in turn related to the "participation mechanism", "willingness to participate", and "willingness to be involved". "Economic impact" and "technology choice" are some of the regulating mechanisms that make the farmers' willingness to participate in rural wastewater management deviate from the behavioral outcomes. Based on the above analysis, this study further strips away some superficial and unimportant factors, and the final simplified mechanism and hierarchy are shown in Fig. 6.

5. Conclusions

From this analysis, the following conclusions can be drawn:

- The GT-DEMATEL-ISM integrated analysis model is constructed in this paper. The model can identify the influencing factors, determine the vital controlling factors, and effectively characterize the hierarchical relationship between different influencing factors, which is conducive to the systematic analysis of the mechanism of farmers' participation in rural sewage treatment. The results also proved to be effective.
- At the present stage, the key to improve farmers' participation effectively in rural sewage treatment still fundamentally lies in raising their awareness of environmental protection, and the practical means to promote it is "environmental protection education", with emphasis on whether or not to carry out education. The specific forms of education need not be considered too much at this stage.
- "Participation mechanism", "technology choice", and "economic factors" are all necessary means to realize the willingness to participate in sewage treatment.
- The "participation mechanism" can improve farmers' sense of identity with rural sewage treatment projects. "Technology selection" enables farmers to understand their projects; the key is not to master the implementation details of sewage treatment technology but to understand the land, workforce, and energy needs involved in the operation of technology. The "economic factors" are mainly to reduce the burden on farmers, which still needs to be led by government input at the present stage. The rural sewage treatment work can be carried out quickly and play an exemplary and propaganda role.
- The implication of public in rural domestic sewage treatment management become a must for successful and sustainable projects. The GT-DEMATEL-ISM integrated analysis model constructed in this paper can express the relationship between different influencing factors in the form of hierarchical network structure and identify the key control factors simultaneously. The model is a handy research tool. However, at present, identifying various influencing factors is still in the form of a questionnaire survey. The quality of the questionnaire survey data is closely related to the subjects, and the quality is not easy to control. In future research, we can further consider using the physiological index measurement method to identify the influencing factors to obtain more accurate influencing factors.

Acknowledgments

This research was funded by the Natural Science Foundation of Inner Mongolia (2019LH07002) and the Research Program of Science and Technology at Universities of Inner Mongolia Autonomous Region (NJSY18131).

References

[1] T. Veldkamp, Y. Wada, J. Aerts, P. Doll, S.N. Gosling, J. Liu, Y. Masaki, T. Oki, S. Ostberg, Y. Pokhrel, Y. Satoh, H. Kim, P.J. Ward, Water scarcity hotspots travel downstream due to human interventions in the 20th and 21st century, Nat. Commun., 8 (2017) 1–12, doi: 10.1038/ncomms15697.
[2] S. Lu, X. Zhang, H. Bao, M. Skitmore, Review of social water cycle research in a changing environment, Renewable Sustainable Energy Rev., 63 (2016) 132–140.
[3] R. Zhang, H. Zheng, H. Zhang, F. Hu, Study on the influence of social capital on farmers' participation in rural domestic sewage treatment in Nanjing, China, Int. J. Environ. Res Public Health, 17 (2020) 1–11, doi: 10.3390/ijerph17072479.
[4] H. Zhao, B. You, X. Duan, S. Becky, X. Jiang, Industrial and agricultural effects on water environment and its optimization in heavily polluted area in Taihu Lake Basin, China, Chin. Geogr. Sci., 23 (2013) 203–215.
[5] M. Wang, H. Gong, Imbalanced development and economic burden for urban and rural wastewater treatment in China—discharge limit legislation, Sustainability, 10 (2018), doi: 10.3390/su10082597.
[6] L. Jin, G. Zhang, H. Tian, Current state of sewage treatment in China, Water Res., 66 (2014) 85–98.
[7] M.A. Massoud, M.A. Massoud, J. Tareen, J. Tareen, A. Tarhini, J. Nasr, M. Jurdi, Effectiveness of wastewater management in rural areas of developing countries: a case of Al-Chouf Caza in Lebanon, Environ. Monit. Assess., 161 (2010) 61–69.
[8] X. Guo, Z. Liu, M. Chen, J. Liu, M. Yang, Decentralized wastewater treatment technologies and management in Chinese villages, Front. Environ. Sci. Eng., 8 (2014) 929–936.
[9] Z. Bi, Research on typical model of classified management of rural domestic waste in the Yangtze River Delta, Environ. Sanit. Eng., 26 (2018) 8–11.
[10] L. Wu, T. Qi, D. Li, H. Yang, G. Liu, X. Ma, J. Gao, Current status, problems and control strategies of water resources pollution in China, Water Policy, 17 (2015) 423–440.
[11] Z. Li, Chinese rural comprehensive reform: theoretical innovation, key contradictions and countermeasures, J. Northeast Agric. Univ., 03 (2016) 81–91.
[12] K. He, J. Zhang, Y. Zeng, Rural households' willingness to accept compensation for energy utilization of crop straw in China, Energy, 165 (2018) 562–571.
[13] Y. Li, Y. Song, Study on the current situation and countermeasures of rural domestic sewage treatment in Beijing City, Meteorol. Environ. Res., 11 (2020) 89–92.
[14] X. Song, R. Liu, Q. Yu, X. Sheng, L. Chen, Management mode construction for operation and supervision of rural sewage treatment facilities: towards the information-to-intelligence strategy, Bioresour. Technol. Rep., 11 (2020) 1–9, doi: 10.1016/j.biteb.2020.100481.
[15] L. Ching, A quantitative investigation of narratives: recycled drinking water, Water Policy, 17 (2015) 831–847.
[16] L. Garcia-Cuerva, E.Z. Berglund, A.R. Binder, Public perceptions of water shortages, conservation behaviors, and support for water reuse in the U.S., Resour. Conserv. Recycl., 113 (2016) 106–115.
[17] A. Hurlimann, S. Dolnicar, Public acceptance and perceptions of alternative water sources: a comparative study in nine locations, Int. J. Water Resour. Dev., 32 (2016) 650–673.
[18] S. Wu, H. Fu, H. Li, C. Ding, M. Wang, Residents' willingness to invest in sanitation: evidence from rural China, Desal. Water Treat., 182 (2020) 405–413.
[19] S. Shipeng, L. Xin, H. Ansheng, S. Xiaoxia, Public participation in rural environmental governance around the water source of Xiqin Water Works in Fujian, J. Resour. Ecol., 9 (2018) 66–77.
[20] C. Hou, H. Fu, X. Liu, Y. Wen, The effect of recycled water information disclosure on public acceptance of recycled water-Evidence from residents of Xi'an, China, Sustainable Cities Soc., 61 (2020) 1–29, doi: 10.1016/j.scs.2020.102351.
[21] C. Hou, Y. Wen, Y. He, X. Liu, M. Wang, Z. Zhang, H. Fu, Public stereotypes of recycled water end uses with different human contact: evidence from event-related potential (ERP), Resour. Conserv. Recycl., 168 (2021) 1–8, doi: 10.1016/j.resconrec.2021.105464.
[22] Q. Bi, H. Wang, Y. Zuo, Farmers' willingness to pay (WTP) for reducing agricultural non-point source pollution: based on the empirical analysis of 453 farmers, Asian Agric. Res., 6 (2014) 60–68.
[23] M. Chen, M. Chen, Y. Lu, L. Wang, Y. Huang, The farmers' perceptions of ANPS pollution and its influencing factors in Poyang Lake Region, China, Water Sci. Technol., 73 (2016) 1591–1598.
[24] A. Padilla-Rivera, J.M. Morgan-Sagastume, A. Noyola, L.P. Güereca, Addressing social aspects associated with wastewater treatment facilities, Environ. Impact Assess., 57 (2016) 101–113.
[25] Q.Z. Liu, G.H. Gao, Problems and countermeasures for the development of rural area in central China, Asian Agric. Res., 2 (2010) 17–21+26.
[26] P. Wenying, X. Feng, Demand and Satisfaction of Rural Residents for Infrastructure in China: A Case Study of Household Survey in Beijing, Demand and Satisfaction of Rural Residents for Infrastructure in China: A Case Study of Household Survey in Beijing, Chengdu, China, 2011, p. 11.
[27] W. Li, Failure by design – National mandates and agent control of local land use in China, Land Use Policy, 52 (2016) 518–526.
[28] J. Alonso, A. Fernandez, H. Fort, Prisoner's Dilemma cellular automata revisited: evolution of cooperation under environmental pressure, J. Stat. Mech. Theory Exp., 2006 (2005) 1–10, doi: 10.1088/1742-5468/2006/06/P06013.
[29] M. Rashid, D. Pandit, Determining the provision of wastewater management infrastructure in rural India from the local communities' perspectives, Water Sci. Technol., 79 (2019) 489–500.
[30] J. Boguniewicz-Zablocka, I. Klosok-Bazan, A.G. Capodaglio, J. Ploskonka, D. Beben, A. Rak, Z. Perkowski, Planning the optimal solution for wastewater management in rural areas - case study, MATEC web Conf., 174 (2018) 1–10, doi: 10.1051/matecconf/201817401035.
[31] M. Rashid, D. Pandit, Rural communities' perception of and willingness to pay for wastewater and storm-water management infrastructure in Bihar, India, J. Water, Sanit. Hyg. Dev., 10 (2019) 36–47.
[32] A. Piasecki, Water and sewage management issues in rural Poland, Water, 11 (2019) 1–16, doi: 10.3390/w11030625.
[33] E. Akyuz, E. Celik, A fuzzy DEMATEL method to evaluate critical operational hazards during gas freeing process in crude oil tankers, J. Loss Prevent. Proc., 38 (2015) 243–253.
[34] L. Wang, Q. Cao, L. Zhou, Research on the influencing factors in coal mine production safety based on the combination of DEMATEL and ISM, Saf. Sci., 103 (2018) 51–61.
[35] Y. Tang, X. Xie, The psychological barrier attribution and policy intervention of urban integration of landless farmers in suburbs:an analysis based on Grounded Theory, Comp. Econ. Soc. Syst., 6 (2018) 148–161.
[36] G.X. Shen, S.G. Sun, Y.Z. Zhang, Z.Q. Wang, C. Ma, System failure analysis based on DEMATEL-ISM and FMECA, J. Cent. South Univ., 21 (2014) 4518–4525.
[37] C. Vincenzo, B. David, Introduction to Stochastic Models, Benjamin/Cummings Publishing Company Inc., Menlo Park, 1988.
[38] Y.W. Du, X.X. Li, Hierarchical DEMATEL method for complex systems, Expert Syst. Appl., 167 (2020) 1–22, doi: 10.1016/j.eswa.2020.113871.

[39] Y. Wang, S. Wang, Risk Transmission and Control in Complex Systems, National Defense Industry Press, Beijing, 2015.
[40] K. Black, E. McBean, Analysis of challenges and opportunities to meaningful Indigenous engagement in sustainable water and wastewater management, Water Policy, 19 (2017) 709–723.
[41] C.L.S.L. Zhang, Current situation and countermeasures of water body pollution in rural areas of China, Meteorol. Environ. Res., 6 (2015) 42–47.
[42] Y. Chen, Improvement of rural human settlements and rural planning strategies from the perspective of public goods, J. Landscape Res., 11 (2019) 51–56.