Risk Evaluation of Food Poisoned Sites Based on Information Diffusion Theory

Yuan Feng

School of Humanities and Economic Management
China University of Geosciences,
Beijing, CUGB, China
e-mail:514067057@qq.com

Long Zhang,

School of Humanities and Economic Management
China University of Geosciences,
Beijing, CUGB, China.
Corresponding Author
e-mail:Zhanglongdragon@hotmail.com

Juan Yang

School of Economics and Management,
Dezhou University
Dezhou, China
e-mail:729375550@qq.com

Abstract **— In this paper, risk prediction and evaluation model was constructed by information diffusion theory. Risk evaluation in domestic food poisoning was made according to data from Health Development Planning Commission between 2000 and 2014. The risk spread features of domestic food poisoning sites were then analysed: Families and food providing units were in moderate risk in the spatial distribution of death resulting from food poisoning, while collective canteens and other food courts were in low risk. For food poisoning risk, there were lower risks in food provided by units and other food courts compared with families and canteens. The study on risk evaluation on food poisoning provides support for risk prevention and decision-making.**

Keywords - information diffusion; food poisoning; risk evaluation

I. INTRODUCTION

All Food poisoning is an acute or sub-acute non-communicable disease caused by eating or drinking food or water containing biological, chemical or other poisonous and harmful substances [1]. Food poisoning, as a common public health emergency, includes many uncertain factors, such as different pathogenic factors in different months or different seasons, different places to eat, and different groups of people, which leads to limited research on a credible regularity. This paper intends to establish a set of risk analysis method and technical means by information diffusion theory based on China's food poisoning accidents understand and grasp the regularity of food poisoning accidents, so as to lay scientific foundation of China's risk evaluation in food poisoning and food safety incidents, and to provide scientific evidences for developing food safety detection and protection smoothly.

The data of food poisoning accidents, belonging to short time series data, are mainly acquired from the statistics of the Health Ministry, and the topic is mostly researched by the risk possibility model based on law of large numbers. However, as the actual sample size is far smaller than the one needed by the model, the risk evaluation results are inconsistent or even far away from the practical situation. With the development of mathematical calculation method in recent years, the information diffusion theory that can accurately analyse small sample accidents, has been widely used in the risk evaluations on floods, droughts, fires, weather disasters, mining accidents and so on, and some good results has already been achieved[2-6]. However, due to the limitation of data resources and relative information, the information diffusion theory was rarely introduced into the study on food safety accidents analysis. In this paper, the classification on food poisoning sites was studied by the application of information diffusion theory, in order to give a comprehensive comparison evaluation on risks of domestic food poisoning accidents and potential distribution risks in different places.

II. CLASSIFICATION OF FOOD POISONING ACCIDENTS AND RELATED DATA

A. Introduction and Classification of Food Poisoning

By the analysis on basic situations of domestic food poisoning between 2000 and 2014, 2006 was a watershed for both the number of food poisoning accidents and the number of victims in recent 15 years. The trend showed a decrease first, following with an increase, then a decrease again, implying that China's food safety situation has obviously been improved, due to the government's increasing supervision, self-discipline of food making companies and units, together with consumer's improving awareness of food safety. However, although the number of deaths of food poisoning shows a decline in recent 15 years, the mortality rate is still high, maintaining at about 1.95%, showing that the problem of food safety in China is still serious [7].

According to the requirement of the National Standards of People's Republic of China on General Principles of Diagnostic Criteria and Technical Management of Food Poisoning (GB 14938-94), the circulars on domestic food poisoning accidents are classified in terms of food poisoning places, like canteens, families, food providing units and other food courts, or classified in terms of the poisoning reasons like microbial, chemical, toxic plants and animals, unknown reasons or reasons to be found [8]. Both classifications above mentioned laid research foundation for this paper.

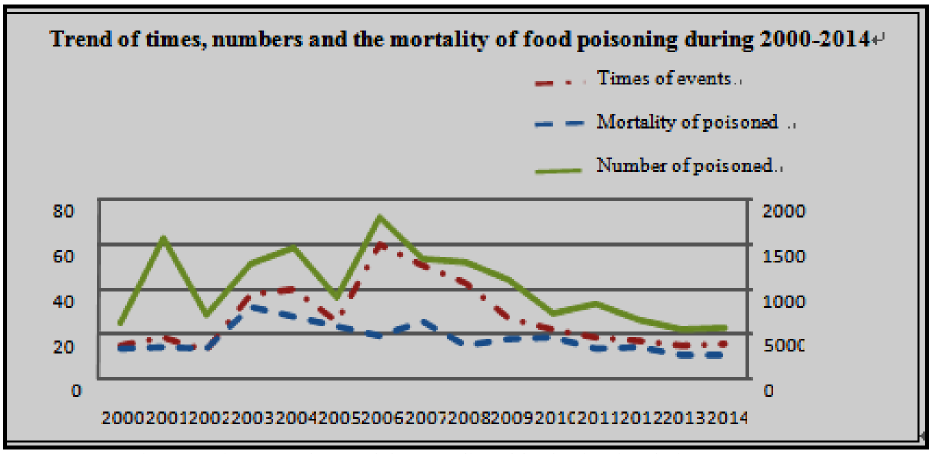

Figure 1. Times, numbers and the mortality of food poisoning during 2000-2014.

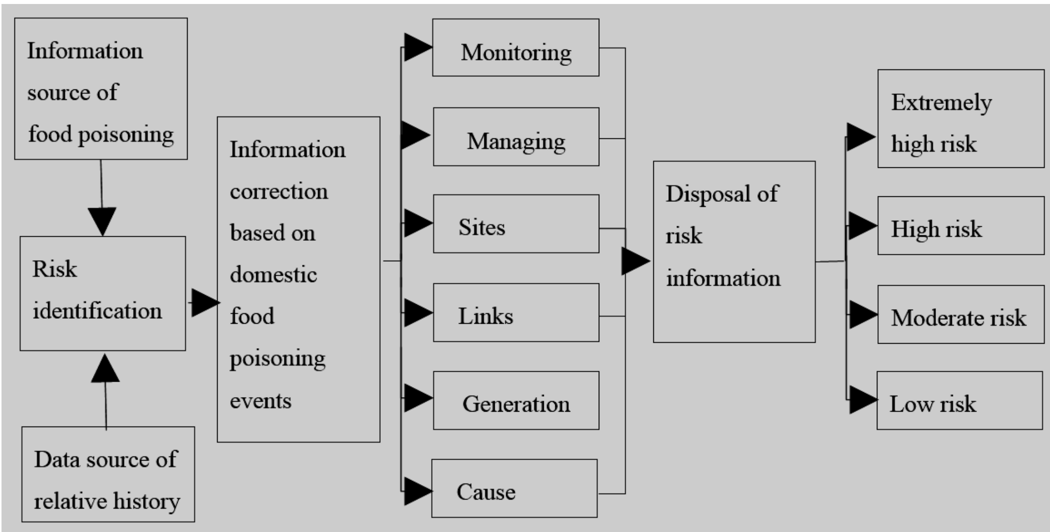

Figure 2. Risk analysis model of food poisoning accidents.

B. Research methodology and model construction

The evaluation on domestic food safety risk status and site distribution, and the comprehensive comparison evaluation on risks in different scenarios of food poisoning are made with the application of information diffusion theory on the basis of the Statistic Annuals by Health Ministry from 2000 to 2014 Information diffusion theory belongs to one of the fuzzy mathematical methods. Its original form is information distribution, developed from molecular diffusion theory. The theory preferentially makes normal diffusion on samples to get abundant sample size, and then makes set valued processing on fewer samples, which thereby makes up the insufficiency of sample data [9-11].

In the model, it is assumed that the sample set of the actual values of the risk evaluation index of the food safety accidents in the past m years in a certain type of places is $X=\{x_1,x_2,\cdots,x_m\}$, where x_i stands for the sample point, and m stands for the total observations. Assuming U, the domain of food poisoning accident frequency, is the information diffusion set for each actual observed sample within X, and $U=\{u_1,u_2,\cdots,u_n\}$, where u_i are the discrete real values discretized by fixed intervals within the domain, namely control points, and n stands for the number of discrete points.

In sample set X, any observed sample point x_i diffuses the information it carries by following formula (1) to all points within domain U :

$$f_j(u_i) = \frac{1}{h\sqrt{2\pi}} \exp\left[-\frac{(x_i - u_i)}{2h^2} \right] \tag{1}$$

$$i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, m$$

In formula (1), h is diffusion coefficient, whose value is closely related to its sample size, representing the controlled area of information diffusion? To calculate h with average distance hypothesis or the principle of selecting near points between two[12], the formula is established as follows:

$$h = \begin{cases} 0.8146 \times (b-a) & m = 5 \\ 0.5690 \times (b-a) & m = 6 \\ 0.4560 \times (b-a) & m = 7 \\ 0.3860 \times (b-a) & m = 8 \\ 0.3362 \times (b-a) & m = 9 \\ 0.2986 \times (b-a) & m = 10 \\ 2.6851 \times (b-a)/(m-1) & m \geq 11 \end{cases}$$

$$a = \min_{1\le i\le m} \{x_i\},\ b = \max_{1\le i\le m} \{x_i\}$$

If $C_i = \sum_{j=1}^{n} f_i(u_j)$ is noted, the membership function $f_i(u_j)$ will be normalized so as to make each set valued equal. Then, the normalized information distribution of any sample x_i can be recorded as $u_{x_i}(u_j) = \frac{f(u_j)}{C_i}$. Assuming $q(u_j) = \sum_{i=1}^{m} u_{x_i}(u_j)$ and $Q = \sum_{j=1}^{n} q(u_j)$, the ratio of the two variables is the frequency value of samples at u_j $p(u_j) = \frac{q(u_j)}{Q}$, where $q(u_j)$ shows the information diffusion treatment on $u_{x_i}(u_j)$: if the observed value is one value taken from U, then x_i is the number of samples of the correspondent observed value u_j, when x_i is regarded as representative samples.

Q- Sum of the total number of samples at the point observed.

$p(u_j)$- The frequency value when all samples fall at $U = \{u_1, u_2, \ldots, u_n\}$, which can be used as an estimated probability value, and then the expression of its transcendental frequency is $P(u \geq u_j) = \sum_{j=1}^{n} p(u_j)$, in which P stands for the risk prediction value in different food poisoning accidents.

III. RISK PREDICTION AND EVALUATION BY SITE CLASSIFICATION ON FOOD POISONING

A. Determination of evaluation model parameters

A1. Selecting evaluation index

Many indicators can describe the risk of food poisoning. Limited by data resources, this paper takes the indexes of the number of victims by food poisoned and the mortality by food poisoning to describe the risk of food poisoning [13]. The first index is defined as the number of victims in each food poisoning accident in a certain year, and specifically it refers to the ratio of the number of victims and the times of food poisoning accidents. The data collected in the paper came from the Ministry of Health Statistics Yearbook. The mortality by food poisoning refers to the ratio of the death number of food poisoning to the times of food poisoning accidents. The higher, the index is, the more dangerous of the food poisoning is, and the more deaths, and vice versa.

The calculation formula is as follows:

$$X_p = \frac{N_p}{Q}; \qquad X_d = \frac{N_d}{Q}$$

In which X_p is the food poisoning index; X_d is the mortality index of food poisoning; N_p is the number of poisoned people per year, N_d is the mortality by food poisoning per year, and Q is the times of food poisoning accidents happened per year.

A2. Model and parameter analysis

By formula $h = 2.6851 \times (b-a)/(m-1)$, taking the total number of observation samples m=15, the classified number of persons by food poisoning h_p, and the mortality information diffusion coefficient h_d can be calculated with the data from 2000 to 2014 (See Table 1). Considering the accuracy of calculation, points are selected from consecutive domain [0,210], [0, 2], so as to make it into a discrete domain. This paper takes 16 control points (n=15), and the information diffusion range is $U_p = (0, 15, 30, 45, \ldots, 210)$ and $U_d = (0, 1, 2, 3, \ldots, 14)$ respectively.

TABLE I. RESULTS OF FOOD POISONING INFORMATION DIFFUSION COEFFICIENT

Analysis of Factors		ap	bp	hp	ad	bd	hd
Dining sites	Collective Canteen	33	185	29.2293	0	0.14	0.0268
	Home	8	30	4.1176	0.895	1.6563	0.146
	Food Providing Units	27	111	16.1106	0	4.3	0.8247
	Other food courts	22	69	9.0516	0.2759	1.4828	0.2315
Causes of Poisoning	microbial	42	155	21.7988	0.0204	0.5	0.092
	chemical	14	68	10.3993	0.7215	1.9	0.226
	toxic plants and animals	9	34	4.8115	0.5629	1.6452	0.2076
	unknown cause or to be found	22	66	8.4331	0.1176	0.9091	0.1518

B. Classification of food poisoning risks

According to the National Food Safety Emergency Plan, the classification on VaR (value-at-risk) of food poisoning was made, which has been evaluated by information diffusion model based on risk classification standards, which is helpful for the food management and monitoring department to realize the risk level[4].

Based on principles of comparability and applicability, the risk levels of food poisoning are divided into 3 types: low risk, moderate risk and high risk. Low risk refers to the least probability of food poisoning reoccurrence. Risk probability (R=1/P) is used to make the concept of risk classification much clearer. As shown in table 2, R = 1 means one harm resulted from every food poisoning event; 1 < R < 5 means one harm resulted from 1 to 5 food poisoning accidents, and R > 5 means one harm resulted from more than 5 food poisoning accidents.

TABLE II. CLASSIFICATION OF RISK UNDER THE INDEXES OF FOOD POISONING AND MORTALITY

X_p , X_d	High Risk	Moderate Risk	Low Risk
$X_p \geq 30, X_d \geq 1$	$R = 1$	$1 < R \leq 5$	$R > 5$
$X_p \geq 60, X_d \geq 2$	$1 < R \leq 5$	$5 < R \leq 10$	$R > 10$
$X_p \geq 120, X_d \geq 3$	$5 < R \leq 10$	$10 < R \leq 20$	$R > 20$
$X_p \geq 180, X_d \geq 5$	$10 < R \leq 20$	$20 < R \leq 50$	$R > 50$

C. Analysis and evaluation on food poisoning risk

Based on the risk analysis model of food poisoning and risk classification standards by information diffusion theory, Figure 3 shows the evaluation result of domestic food poisoning accidents by the indexes of X_d, food poisoning death,, and X_p, the food poisoning .

C1. Analysis and evaluation on food poisoning death risk

As shown from figure 3-a, when $X_d \geq 1$, death of food poisoning shows a moderate to high risk, and one poisoning case takes place probably from 1-5 accidents. Risk spread features of food poisoning sites takes on a high risk in families, where one case takes place per accidents, while in the other food courts, one case takes place in 1-1.3 accidents, the risk of which is relatively high though it belongs to moderate risk. Furthermore, food providing units and collective canteens are in lower risk, where one case takes place from 8 food poisoning accidents.

As shown in figure 3-B, different from the case of $X_d \geq 1$,, when $X_d \geq 2$, the death risk of food poisoning decreases, but generally the risk is lower at other food courts and collective canteens compared with in families. The risk in families belongs to moderate risk, and one such case takes place from 5 food poisoning accidents; while the risk in food providing units, food courts and collective canteens are safer with one such case from more than 10 accidents.

As shown in Figure 3-c and Fig. 3-d, the risk probability shows a declining trend when $X_d \geq 3$ or $X_d \geq 5$, and the overall risk level is low. Collective canteens, families and other food courts take on a low risk, where one such case takes place every 20 accidents, while the risk level in food providing units is moderate with one such case every 10-20 accidents.

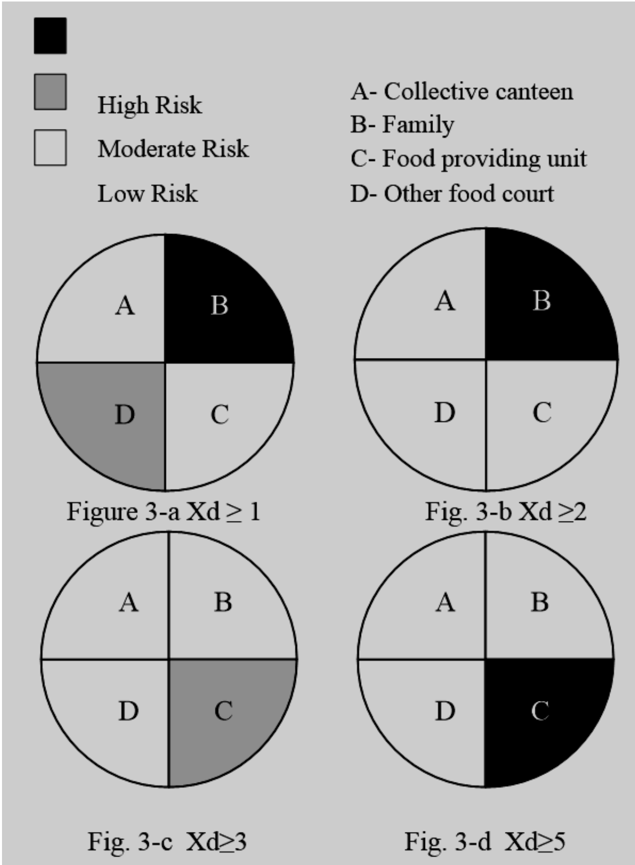

Figure 3-a Xd ≥ 1
Fig. 3-b Xd ≥2
Fig. 3-c Xd≥3
Fig. 3-d Xd≥5

TABLE III. RISK ANALYSIS AND EVALUATION ON FOOD POISONING MORTALITY

X_d	**High Risk**	**Moderate Risk**	**Low Risk**
$X_d \geq 1$	Family	Other food court	Collective canteen and Food providing unit
$X_d \geq 2$	Family		Collective canteen, Food providing unit and Other food courts
$X_d \geq 3$		Food providing unit	Family, Collective canteen and Other food courts
$X_d \geq 5$	Food providing unit		Family, Collective canteen and Other food courts

To sum up, with the increase of damage degree of domestic food poisoning, the probability of food poisoning death shows a decreasing trend, and the site spread feature takes on a moderate to high risk in families, low to moderate risk in food providing units, and low risk in collective canteens and other food courts. As shown in Table 3, in different scenarios of food poisoning mortality, the risk resulting in death in families and food providing units are both high. However, with the increase of food poisoning mortality index, the risk at food providing units significantly increases.

The main causes of poisoning is eating poisonous mushrooms or misusing toxic chemicals. In these conditions, rural areas are the main places having high food poisoning mortality. Family feasts leading to food poisoning accident takes the highest proportion of the number of poisoned people in family poisoning accidents. In rural areas in China (especially remote mountainous areas), the lacking of knowledge of food safety, poor eating habits and limited medical conditions caused by inconvenient traffics, make it difficult for severe poisoned patients to obtain timely and effective treatment, which increases the trend of death from food poisoning.

C2. Analysis and evaluation on food poisoning risk

As shown in Figure 4-a and Fig. 4-b, when $X_p \geq 30$, the risk probability is high in each site, and one such case takes place in each accident. When $X_p \geq 60$, although the risk level decreases significantly, the overall risk is still relatively high, showing high risks in all public places other than families. To compare those dinning places, family is at low risk, where one such case takes place in at least 10 accidents, while it is risky in food providing units, collective canteens and other food courts, with one such case in 1-5 accidents.

As shown in Figure 4-c and Fig. 4-d, when $X_p \geq 120$, the risk probability shows from low to moderate in every place, where one such case takes place in every 10 to 20 accidents. However, when $X_p \geq 180$, the risk level of canteens shows a high, where one such case takes place in at least 10-20 accidents; while the risk in food providing units decreases to low just like that in home and other food courts, with one such case in every 20-50 accidents.

With the damage increase of domestic food poisoning, , the overall risk probability shows a decreasing trend, with high to moderate risk in collective canteens, and moderate to low risk in other places. As shown in Table 4, in different scenarios of food poisoning, the risk of poisoning in canteens and food providing units are relatively high. But with the increase of poisoning index, the risk in canteens shows a U-shape, while and a decreasing trend in families, food providing units and other food courts, among which the risk in families significantly drops.

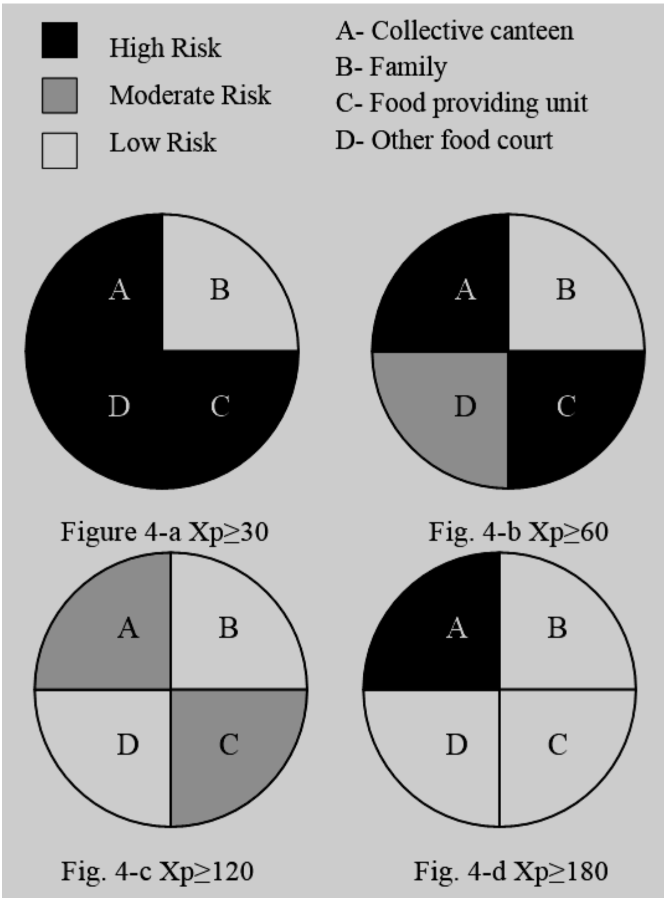

TABLE IV. ANALYSIS AND EVALUATION ON FOOD POISONING RISK

X_p	High Risk	Moderate Risk	Low Risk
$X_p \geq 30$	Family, Collective canteen, Food providing unit and other food courts		
$X_p \geq 60$	Collective canteen, Food providing unit	Other food courts	Family
$X_p \geq 120$		Collective canteen, Food providing unit	Family and other food courts
$X_p \geq 180$	Collective canteen		Family, Food providing unit and other food courts

It is the incorrect ways of food processing and storage resulting in cross pollution or spoilage of food that lead to canteens the easiest place to get food poisoned, and therefore, the biggest number of people poisoned. According to the statistics, school canteens is the major site where food poisoning takes place, which is the main reason of a high-low-high risk trend in canteens with the increase of food poisoning index in collective canteens.

IV. CONCLUSIONS

1) For the comparison of food poisoning sites, the mortality risk in families is the highest, while the overall risk in collective canteens is usually high. There may be more than 30 people poisoned in every 1 to 5 accidents when the food poisoning index is over 30, and it is common that food poisoning mortality index is no less than 1 in less than 5 accidents. When food poisoning index is bigger than 60, 120 or 180, it shows a severe poisoning damage, and a high frequency of moderate risk.

2) Distribution differences of food poisoning and poisoning mortality: As for mortality risk, families and food providing units are at moderate risk, while others are at low risk. For poisoning risk, families and collective canteens are mainly at high or moderate risk, while the risk in food providing units and other food courts are lower.

According to the analysis result, family is the worst place of both food poisoning and poisoning to death, solidified by the analysis model, parameters and prediction results, which successfully verifies the feasibility of the model. The analysis results can provide convincing technical support and decision-making advices for food safety supervision departments and health and family planning departments on carrying out corresponding propaganda on food poisoning prevention knowledge and emergency rescue measures.

3) To ensure that the risk analysis result is close enough to the actual value, the information diffusion coefficient should be corrected as soon as the number of actual observation samples of food poisoning accidents increases with time.

ACKNOWLEDGEMENT

The paper is supported by “the Fundamental Research Funds for the Central Universities”(No. 2652015014) and the Basic Research Program of Dezhou University (No. 2015skrc03)

REFERENCES

[1] Health Ministry of People’s Republic of China. The National Standards of People's Republic of China on General Principles of Diagnostic Criteria and Technical Management of Food Poisoning (GB 14938-94)[M]. Beijing: Standard Press of China, 1994.

[2] Yang, X. Li C, C. Research and Application of Fire Risk Assessment Model Based on Information Diffusion Theory[J]. Industrial Safety and Environmental Protection, 2010, 36(1): 42-43.

[3] Zhang L, J. Li W, L. Zhang D, Y. Meteorological Disaster Risk Assessment Method Based on Information Diffusion Theory[J]. Scientia Geographica Sinica, 2009(2): 250-254.

[4] Liu Y, B. Liu L, M. Xu, D. Zhang S, H. Risk Assessment of Flood and Drought in Major Grain-producing Areas based on Information Diffusion Theory[J]. Transactions of the CSAE, 2010, 26(8): 1-7.

[5] Wang, G. Guo D, Y. Risk Analysis of Mine Accidents in High-altitude, Cold and Drought Areas Based on the Information Diffusion Theory[J]. Journal of University of Science and Technology Beijing, 2012, 34(5): 495-499.

[6] Chu C, C. Risk Prediction on regional Forest Fire Based on the Information Diffusion Theory[D]. Central South University of Forestry & Technology, 2014.

[7] Luo H, B. He L, Y. Ye W, J. Analysis of the Food Poisoning in China from 2004 to 2013[J]. Chinese Journal of Food Hygiene, 2015, 27(1): 45-49.

[8] National Health and Family Planning Commission.Annual Bulletin of National Food Poisoning Cases by Health and Family Planning Commission(2000-2014) www. moh. gov. cn

[9] C. F. Huang Claudio Moraga. Extracting fuzzy if-then rules by using the information matrix technique[J]. Journal of Computer and System Sciences, 2005, 70(1): 26－52.

[10] Feng L, H. Huang C, F. A risk evaluation model of water shortage based on information diffusion technology and its application in analyzing carrying capacity of water resources[J]. Water Resour Manage, 2008, 22: 621－633.

[11] Xu L,Y. Liu G, Y. The study of a method of regional environmental risk evaluation[J]. J Environ Manage, 2009, 90: 3290－3296.

[12] Wang, G. Guo D, Y. Risk Analysis of Mine Accidents in High-altitude, Cold and Drought Areas Based on the Information Diffusion Theory[J]. Journal of University of Science and Technology Beijing, 2012, 34(5): 495-499.

[13] National Health and Family Planning Commission. Chinese health Statistics Yearbook (2000-2014) [M]. Beijing: Peking Union Medical College Press.