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Risk Level Prediction of Fine Chemical Hazard based on Improved Wavelet Transform

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Abstract: Due to the complexity of the risk level prediction index of fine chemical hazard, its prediction results are easily affected by subjective factors, and the improved wavelet transform technology can effectively reduce the event impact threshold, so the risk level prediction of fine chemical hazard based on the improved wavelet transform is proposed. According to the hazard identification standard, the hazard risk level index was established, and the risk level prediction threshold was modified by combining with the improved wavelet transform technology, so as to complete the hazard level prediction after denoising. The simulation experiment is designed, and the prediction results of the improved wavelet transform prediction method and the conventional neural network model prediction method are compared, which proves the effectiveness of the design.

Keywords: Improvement; Wavelet transform; Fine chemical industry; Risk level

1. Introduction

As one of the important industries in the chemical industry, fine chemical industry not only provides raw materials for other industrial production, but also is a necessity for production and life [1]. With the continuous increase of China's industrialization process and the increase of fine chemical production scale, its production, raw materials, intermediate products equipment and equipment are also moving towards large-scale and large-scale development. The production conditions and processes of fine chemical industry are relatively harsh. During the production process, the reaction medium is usually in special processes such as high temperature and high pressure, accompanied by a variety of chemical reactions such as synthesis and cracking [2]. In the reaction process, the intermediate materials are prone to explosion, combustion, leakage, volatilization and strong toxicity, etc. In the production process, if equipment failure, electrostatic accumulation, operating errors may cause fire, explosion and major environmental pollution accidents, resulting in casualties and property losses. The particularity of fine chemical production determines the complexity of its risk level prediction to a certain extent. In the risk level prediction of fine chemical hazard sources, it is not only necessary to identify such routine accidents as poisoning, explosion, leakage and fire, but also to predict major environmental pollution accidents that may be caused by environmental accidents or improper handling [3]. However, the existing risk level prediction methods of fine chemical hazard sources are easily affected by objective factors, resulting in the deviation of the prediction results. Therefore, the risk level prediction of fine chemical hazard sources based on improved wavelet transform is proposed.

2. Risk Level Prediction of Fine Chemical Hazard Sources based on Improved Wavelet Transform

2.1. Indicators of risk level of hazard source

According to the "identification of major hazard sources of hazardous chemicals" (GB 18218-2018), the hazard classification index R is:

$$R = a\left(b_1\frac{q_1}{Q_1} + b_2\frac{q_2}{Q_2} + \ldots + b_n\frac{q_n}{Q_n}\right) \quad (1)$$

Where, q_1, q_2,…, q_n is the actual amount of each hazard source; Q_1, Q_2,…, Q_n is the corresponding critical quantity of each hazard source; b_1, b_2,…, b_n is the relative correction coefficient of each hazard source; a is the correction coefficient of persons exposed in the hazard area. When the value is set to more than 100 persons, the value is set to 2.0, 50~99 persons, 1.5, 30~49 persons, 1.2, 2~29 persons, 1.0, 0 persons and 0.5 [4].
The value of b is 2 for explosives, 1.5 for flammable gases and 1 for other hazardous chemicals according to the types of hazard sources. Values of some common fine chemical toxic gases are shown in table 1:

Table 1. Values of calibration coefficient β of common toxic gases

Name of toxic gas	β value
Hydrogen sulfide	5
Chlorine	4
Methyl bromide	3
Hydrogen chloride	3
Epoxy ethane	2
Ammonia	2
Carbon dioxide	2
Carbon monoxide	2
Methyl isocyanate	20
Phosphine	20
Carbonyl chloride	20
Hydrogen cyanide	10
Nitrogen dioxide	10
Hydrogen fluoride	5

According to the calculation results, the risk level index of hazard source is put forward to reflect the inherent danger of hazard source [5].

2.2. Revision of risk level prediction threshold

As an important step of risk level prediction, the probability of risk occurrence is mostly affected by subjectivity in the previous analysis methods, resulting in the omission of basic event selection. Therefore, the probability of risk occurrence is denoised and the probability threshold is corrected by the improved wavelet transform technology [6]. Since the probability of risk occurrence is not fixed, the selection of wavelet threshold will reduce the noise amplitude and improve the prediction authenticity with the increase of the event decomposition process scale.

Considering the accuracy of hazard risk assessment of fine chemical industry, the risk grade structure is firstly determined, the fault factor is converted into the risk grade to predict the intermediate event and the basic event, and the corresponding fault interpretation is specified by functional structure mapping, so the failure probability of risk grade prediction is calculated as follows:

$$Q_0(\mathrm{j}) = 1 - \prod_{a=1}^{n} (1 - Q_a(\mathrm{i})) \quad (2)$$

Where, $Q_0(\mathrm{j})$ is the occurrence probability of dangerous events j, and $Q_a(\mathrm{i})$ is the occurrence probability of basic events i.

Considering the accident as a repairable factor, the failure probability of the basic event is:

$$Q_a(\mathrm{i}) \approx l_{\mathrm{i}} M_{\mathrm{i}} \quad (3)$$

Where, l_{i} is the failure probability of each basic event, and M_{i} is the average repair time of each basic event.

In view of the shortage of general threshold in prediction, the threshold in basic events is improved by using wavelet transform technology:

$$Q_a^T = s\sqrt{2\ln N} \Big/ \frac{\mathrm{i}-1}{2} \quad (4)$$

Where, s is the standard variance of event prediction noise, N is the impact scale of event occurrence, and j is the decomposition scale. With the increase of j, the event improvement threshold Q_a^T decreases relatively, which is more in line with the actual development trend of event prediction [7].

After revising the prediction threshold, calculate the risk after the occurrence of hazard source accident:

$$QR_{\mathrm{x,\ y}} = \sum_{\mathrm{i}=1}^{T} (\mathrm{f_i} P_{\mathrm{f,\ i}}) \quad (5)$$

Where, $QR_{\mathrm{x,\ y}}$ represents the risk of accident (x, y), $\mathrm{f_i}$ is the probability of the occurrence of the event i, and $P_{\mathrm{f,\ i}}$ represents the loss caused by the event i.

The probability of accident risk is obtained from the accident risk function, and through the correction of the probability of the initial event, the modified risk calculation formula of hazard source is obtained as follows:

$$QR_{\mathrm{x,\ y}} = \sum_{\mathrm{i}=1}^{T} \left((1 - \prod_{a=1}^{n} 1 - Q_a(\mathrm{i})) \ P_{\mathrm{f,\ i}} \right) \quad (6)$$

According to the accident consequences of different hazard sources, the author mainly calculates the risk of storage, production, explosion accident and poisoning accident of hazardous chemicals in fine chemical industry, and calculates the overpressure value of a point of hazard source by using the formula, and then puts it into the hazard risk function to get the hazard source area. The smaller the distance from the hazard source, the greater the risk.

2.3. Hazard level assessment

After the revised risk function of hazard source is calculated, the risk source grade evaluation factor $U = \{U_1, U_2, \ldots, U_{\mathrm{i}}, \ldots U_{\mathrm{n}}\}$ is established, and its sub-factor set is $U_{\mathrm{i}} = \{\mathrm{u_1}, \mathrm{u_2}, \ldots, \mathrm{u_n}\}$, $U_{\mathrm{i}}(\mathrm{i} = 1, 2, \ldots, \mathrm{n})$. The evaluation factor will be assigned U_{i} weight coefficient, and the corresponding weight vector is $A_{\mathrm{i}} = (\mathrm{a_{i1}}, \mathrm{a_{i2}} \ldots, \mathrm{a_{ij}})$, the corresponding weight vector of U is $A = (\mathrm{a_1}, \mathrm{a_2} \ldots, \mathrm{a_i})$.

In the evaluation process, the index weight value and the normalized value are taken. Therefore, combining with the evaluation weight coefficient, the risk prediction formula of hazard source is obtained as follows:

$$D = \sum_{\mathrm{i}=1}^{A} QR_{\mathrm{i}} \times U_{\mathrm{i}} \quad (7)$$

Where, D is the risk coefficient of hazard source; QR_i is the weight coefficient of the underlying index; U_i is the normalized value of the underlying index.
After the risk coefficient of hazard is calculated, the risk classification standard is compared, as shown in table 2:

Table 2. Classification standards of hazard sources

Risk rating factor	Risk rating	Risk description
D<0.4	Third major source of danger	Low
0.4<D<0.8	Major secondary hazard	High
D>0.8	A major hazard	High

According to the hazard classification standard, the risk level of hazard was analyzed, and the risk level of hazard was predicted [8].

3. Simulation Experiment

3.1. Experimental preparation

In order to analyze the characteristics and defects of the risk level prediction method of fine chemical hazard based on improved wavelet transform, a simulation experiment was designed. It is compared with the prediction method of risk level of fine chemical hazard based on neural network model, and the prediction results of the two methods are analyzed under the same experimental condition. The experimental environment is set as a fine chemical industrial park, where the environmental climate is relatively cold, rainfall is less, and the overall perennial environmental temperature of the park is low. There are service facilities in the chemical industrial park with a population density of 34,000 /km2. There are many kinds of designed raw materials, intermediate products and products in the chemical industrial park, most of which are inflammable and explosive substances, including a small amount of toxic substances. The production probability of the park is shown in table 3:

Table 3. Production overview of fine chemical industrial park

Project	Scale
500,000 tons QTA project	500 thousand tons of terephthalic acid per year
450,000 tons/year aromatic engineering	P-xylene 400,000 tons/year, benzene 259,100 tons/year, o-xylene 12,500 tons/year
Polycarbonate	Ethylene glycol 16,800 tons/year, polycarbonate 60,000 tons/year
Epoxy	Epoxy
Benzoyl	1.5
Fine	15 million tons/year of pharmaceuticals, intermediates and fine chemicals

3.2. Analysis of experimental results

According to the "identification of major hazard sources" (GB 18218-2018), the two groups of methods predicted the hazard levels in the park respectively. The prediction results of the two groups are shown in table 4:

Table 4. Comparison of prediction results

Name of the material	A critical mass		Actual existence	The prediction error	
	Improved wavelet transform prediction	Neural network model prediction		Improved wavelet transform prediction	Neural network model prediction
Methanol	20	21	7900	0.76%	1.07%
Xylene	100	116	1950	0.49%	0.97%
Epoxy ethane	1	2.04	1.6	1.06%	1.43%
Hydrogen chloride	50	57	20	0.19%	0.49%
Toluene	20	16	40	0.86%	0.97%
Sulfur recovery - acid gas	2	1.76	19	0.73%	0.92%
Hydrogen sulfide	2	3	563	0.12%	0.76%
Methane	1	1.04	8	0.89%	1.06%
Hydrogen	1	0.76	54	0.48%	0.76%

Analysis chart can be seen, the two set of methods respectively according to the evaluation standard to make a prediction for the contents of the park there is a danger threshold, according to the predicted results can be seen that the neural network model to predict forecast method compared with improved wavelet transform method, the prediction error is bigger, and affected by different material properties the prediction accuracy will also produce certain fluctuation. However, the improved wavelet transform prediction method is relatively stable, and its prediction error is smaller, which is more suitable for the practical prediction of risk level of fine chemical hazard sources.

4. Conclusion

Based on the improved wavelet transform, the risk level prediction of fine chemical hazard sources is mainly aimed at the shortcomings in the current risk level prediction of hazard sources, and the corresponding solutions are proposed. Compared with the previous methods of death number and property loss, sum of correction ratio and neural network, etc., the indicators were quantified

and normalized by denoising, which reduced the fuzziness and subjectivity of grade prediction, and to some extent overcame the complex and difficult quantization problem of hazard risk grade prediction indicators.

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