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Feasibility Evaluation of Chemical Waste Classification

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Chemical waste classification is an important part for realizing effective decrement and reclamation, as one of the effective ways to improve the safety control of chemical waste. From analyzing the harm consequences of chemical wastes, we build a chemical waste classification evaluation indicator system that integrates four elements: the types of chemical waste, the identity and the gender of classification bodies, the requirements of competent authorities. The Analytic Hierarchy Process (AHP) is used to determine the weight of each indicator, and based on the scores marked by experts, a fuzzy evaluation is performed on determining whether chemical waste classification is feasible. The results show that it is feasible to implement chemical waste classification. There are some factors affecting the classification efficiency such as mandatory requirements of the competent authorities, the identities of classification bodies and the types of chemical waste.

1. Introduction

In China's reform and opening process, the chemical industry has produced an enormous economic benefit, so that it plays a non-negligible role in the process. However, a lot of chemical waste generated in chemical production process often contains a given mass of harmful components, and if we leave them alone, they will cause serious or even irreversible damage to the ecological environment (Wang, 2018).

Chemical waste is just the leftover materials left in the production and utilization processes of chemical raw materials, or those that have been contaminated during the production process and cannot be used in situ. In the light of the harm consequences, chemical waste can be classified into three types: 1) solid leftover from chemical raw materials, which derive from natural world or agricultural production, and are not fully utilized and contaminated in chemical production process, such as minerals, crops, and animal products, etc. This type of chemical waste are less contaminated, generally does not produce radioactive, infectious, genetic and other environmental pollution, but they will occupy the lands and drift away everywhere if improperly disposed;2) solid leftover from chemical raw materials, which also derive from natural world or agricultural production, and are contaminated chemically or by harmful chemicals in chemical production processes, such as chemical fertilizer stained by organic solvents and oils, and adhered with heavy metals on the surface. It has a low environmental pollution, but the deposit on its surface does high due to great concentration, causing serious consequences; 3) dangerous chemicals, whether it is a raw material or a product, if improperly disposed, it will severely ruin the environment.

Chemical waste of different nature must be disposed safely for the sake of environmental safety, while effective classification is the premise and basis for safe disposal of chemical waste (Zhu, 2018). However, compared with the burgeoning chemical industry, many companies have not attached enough importance to the classification and harmless disposal of chemical waste, and even some units have never known about these. They always make a random disposal of chemical waste, which not only brings a low degree of reclamation, but also helps harm consequences and other problems progressively appear. In particular, the toxic and harmful chemicals directly discarded without safe disposal will be more prone to jeopardize human health. For this purpose,

A scientific evaluation is performed on the feasibility of chemical waste classification. Some key factors are chosen for developing specific control measures, which have a positive effect on the safe disposal and

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resource utilization of chemical waste, social and ecological environment safety, as well as the healthy development of the chemical industry.

2. Basic principles of AHP and membership determination

Analytic Hierarchy Process (AHP) is a system approach by which complex target is decomposed into multiple objects with several levels and the fuzzy quantification method for qualitative indicators is used to calculate the single sort (weight) and total sort at each level as the multi-objective (multi-indicator), multi-conceptual optimization strategy. It features simplicity, flexibility and universal practicability. The AHP includes four procedures: 1) build a hierarchical structure model; 2) construct the comparative judgment matrix; 3) calculate the maximum eigenvalue of the comparative judgment matrix and the corresponding eigenvector; 4) sort the hierarchies and perform consistency test (Suresh and Mujumdar, 2004).

2.1 Building a hierarchical structure model

After the statistics and analysis of the chemical waste classification, the chemical waste classification is divided into three levels for feasibility evaluation: 1) objective layer (A), that is, chemical waste classification feasibility evaluation; 2) criteria layer (B), including the types of chemical waste, the requirements of the competent authorities, the identities and the genders of the classification bodies. This layer determines how difficult the chemical waste classification is. Its effect also needs to be reflected by the specific factors relevant to it, as the intermediate chain to solve the problem; 3) strategy layer(C), the criteria layer is refined down to each specific control factor. The feasibility evaluation of chemical waste classification can be completed by analyzing and solving the hierarchical problem.

2.2 Constructing the indicator system

The indicator system for chemical waste classification is constructed on four fronts, i.e. the types of chemical waste, the requirements of competent authorities, the identities and the genders of classification bodies: 1) given that most of chemical industries integrates processing, painting and decoration, and the consequences caused by different types and processes vary widely, it is determined that the type of chemical waste is a feasible indicator for the chemical waste classification. If the hazardous type of chemical waste cannot be classified and disposed in time, it is likely to cause ecological environment pollution. 2) the requirements of competent authorities demonstrate to some extent whether the chemical waste classification is mandatory. The executive powers of enterprises on the rules and regulations are often higher than its own constraints. To the end, it is determined as the indicator for evaluate whether the chemical waste classification is feasible; 3) the staff in chemical waste area in the industrial enterprises hold at different levels, play different roles, etc. which has a great impact on whether chemical waste is classified, so that the identity of the chemical waste classification body can be determined as the indicator for evaluating whether chemical waste classification is feasible; 4) the impact of gender factors on social activities will be self-evident, especially in the classification work, its role has a significant difference. For this purpose, the genders of chemical waste classification bodies can be determined as one of indicators for evaluating whether chemical waste classification is feasible.
The above four factors belong to the second layer, and the feasibility evaluation indicator system for chemical waste classification is built, as shown in Figure 1.

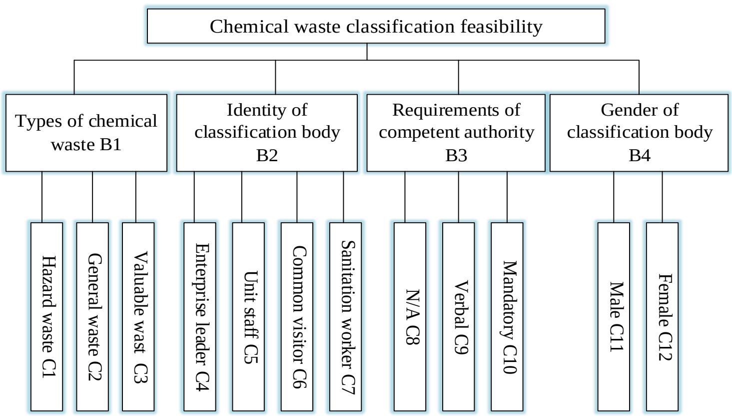

Figure 1: Evaluation indicator system for chemical waste classification

2.3 Fuzzy comprehensive evaluation path

The basic path for the fuzzy comprehensive evaluation on chemical waste classification feasibility is to comprehensively consider the impact degree of all factors and adopt the AHP to determine the weight for each factor; construct the mathematical model to calculate the possibility of the impact of each factor, among which the factor with higher possibility is the final definite value (Xu et al., 2013).
The procedure of multi-level fuzzy comprehensive evaluation:
(1) Determine the evaluation indicators and appropriate weight.
(2) Establish the set V of evaluation results, with same meaning as established in the single-level fuzzy comprehensive evaluation, V={v1, v2, ⋯⋯, vn}.
(3) Conduct a comprehensive evaluation on the primary indicators, that is, perform this operation based on various factors of a certain type. It is assumed that the elements of I (i=1, 2, ⋯, n) are comprehensively evaluated, and the evaluation object membership matrix of the elements k (k=1, 2, ⋯, m) in the set of evaluation results is:

$$R_i = \begin{bmatrix} r_{i11} & r_{i12} & \dots r_{i1m} \\ r_{i21} & r_{i22} & \dots r_{i2m} \\ \dots & \dots & \dots & \dots \\ r_{in1} & r_{in2} & \dots r_{inm} \end{bmatrix}$$

Therefore, the fuzzy comprehensive evaluation set of the factors of type *i* is:

$$B_i = W_i \cdot R_i = (W_{i1} + W_{i2} \cdots W_{in}) \cdot \begin{pmatrix} r_{i11} & \cdots & r_{i1m} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{inm} \end{pmatrix} = b_{i1}, b_{i2}, \dots, b_{im}$$

Where, i=1, 2...n, B_i is the operation result of parent factors responding to each level factors included in the indicator *i* of the layer B; b_i is the weight responding to each child factor under indicator *i* in the layer B; R_i is the fuzzy evaluation matrix.
Make comprehensive evaluation on secondary factors
The evaluation matrix should be the lowest level fuzzy comprehensive evaluation matrix:

$B=W \cdot (B1B2 \cdots Bn)^T=(w1w2 \cdots wn) \cdot (B1B2 \cdots Bn)^T$

3. Chemical waste classification indicator weight and consistency test

3.1 Constructing the judgment matrix

After the chemical waste classification indicator system is determined, the judgment matrix is constructed by using 1 ~ 9 comparation scales. In the judgment matrix A, b_{ij} is the relative importance of b_i for b_j, and generally takes 1, 2, ⋯, 9 and its reciprocal; $b_{ij}=1$ indicates the factor *i* and *j* have equal importance; $b_{ij}=3$ indicates the factor *i* is slightly more important than factor *j*, and so on; $b_{ij}=9$ indicates the factor *i* is extremely important than factor *j*. The judgment matrix satisfies: $b_{ii}=1$, $b_{ij}=1/b_{ji}$.
When the judgment matrix is constructed using 1 ~ 9 comparison scales, the ratio of importance degrees of the chemical waste type in the constructed judgment matrix and the gender of classification body is 3/2, that is, the element a_{14} in the matrix A is 3/2; the type of chemical waste is a factor that cannot be ignored in the classification process, but the classification body is still human being. Therefore, the identity of the classification body is more important than the factor the type of chemical waste. The ratio of importance degrees of the factor the type of chemical waste and the identity of classification body in the structure judgment matrix is 3/7, that is, a_{12} is 3/7. Similarly, the importance degrees of other elements are compared, and the following judgment matrix is constructed:

$$A=\begin{bmatrix} 1 & \frac{3}{7} & \frac{3}{5} & \frac{3}{2} \\ \frac{7}{3} & 1 & \frac{7}{5} & \frac{7}{2} \\ \frac{5}{3} & \frac{5}{7} & 1 & \frac{5}{2} \\ \frac{2}{3} & \frac{2}{7} & \frac{2}{5} & 1 \end{bmatrix}; B_1=\begin{bmatrix} 1 & \frac{9}{5} & 9 \\ \frac{5}{9} & 1 & 5 \\ \frac{1}{9} & \frac{1}{5} & 1 \end{bmatrix}; B_2=\begin{bmatrix} 1 & \frac{7}{5} & \frac{7}{2} & \frac{7}{8} \\ \frac{5}{7} & 1 & \frac{5}{2} & \frac{5}{8} \\ \frac{2}{7} & \frac{2}{5} & 1 & \frac{2}{8} \\ \frac{8}{7} & \frac{8}{5} & \frac{8}{2} & 1 \end{bmatrix}; B_3=\begin{bmatrix} 1 & \frac{2}{3} & \frac{2}{7} \\ \frac{3}{2} & 1 & \frac{3}{7} \\ \frac{7}{2} & \frac{7}{3} & 1 \end{bmatrix}; B_4=\begin{bmatrix} 1 & \frac{1}{2} \\ 2 & 1 \end{bmatrix}$$

3.2 Single sort consistency test for hierarchies

a_{ij} of element A in the judgment matrix can be estimated using the knowledge and experience of the evaluator. Since the evaluator's estimation is subjective, a consistency test must be performed before making decision using the estimated judgment matrix.
Since it is estimated judgment, not any element of the comparative judgment matrix satisfies:

$a_{ij} = a_{ij} \cdot a_{ij}$, CI=(λmax-n)/(n-1)

Hence, a consistency test must be performed by calculating the consistency indicators and the consistency rate. The consistency rate is:

CR=CI/RI

Where, RI is a random indicator, an element in a comparison matrix of different *n*, assigned value by random numbers 1/9, 1/7, ..., 1, ..., 7, 9, and 100-500 are used for different *n*. The consistency is calculated, and the average is obtained, as a random indicator, recorded as RI, as shown in Table 1.

Table 1: Values of random indicator RI

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.51	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

If the consistency rate CR < 0.10, it is considered that the consistency in the comparative judgment matrix is acceptable, so does the weight vector W.
The maximum eigenvalue λmax of each judgment matrix and its corresponding eigenvector $\mathbf{W_i}$ (i=1, 2, ⋯, 5) are calculated by the Maple, and the feature matrix vector is normalized to W_i. For matrix A, λmax=4.001, W_1=(0.1760.4120.2940.118); for the matrix B_1,λmax=3.004, W_2=(0.600 0.3330.067); for the matrix B_2,λmax=4.001, W_3=(0.3180.2270.0910.364); for the matrix B_3,λmax=3.005, W_4=(0.1670.2500.582); for the matrix B_4,λmax=2.001, W_5=(0.333 0.667); then the consistency test can be performed using the CR method. After the matrix A is tested, it follows that: λmax=4.001, CI=0.0003, CR=0.00037<0.10.
Thus, the matrix A has a satisfactory consistency. Similarly, the matrices B1, B2, B3, and B4 also have a satisfactory consistency.

3.3 Total sort for hierarchies

The total sort for the hierarchies refers to the order of the relative importance degrees of the indicator layer to the target layer, that is, the weights of indicators that have impact on the chemical waste classification, calculated by the probability multiplication. The weight of the hierarchical total sort indicator is the product of the weight of the layer C indicator and the weight of the corresponding upper layer B indicator, and the sum of the total sort weights is 1.
After calculation, the absolute weights of the 12 indicators in the layer C are shown in Table 2.

Table 2: Weight of factors affecting the chemical classification feasibility

Target layer A	Criteria layer B	Indicator layer C	Synthesis weight A(B×C)
Chemical waste classification feasible	Types of chemical wasteB_1(0.176)	Hazard wasteC_1(0.600)	0.106
		General wasteC_2(0.333)	0.059
		Valuable wasteC_3(0.067)	0.012
	Identity of classification bodyB_2(0.412)	Enterprise leaderC_4(0.318)	0.131
		Unit staffC_5(0.227)	0.094
		Common visitorC_6(0.091)	0.038
		CleanerC_7(0.364)	0.150
	Requirements of competent authoritiesB_3(0.294)	N/AC_8(0.167)	0.049
		Verbal requestC_9(0.250)	0.074
		MandatoryC_{10}(0.583)	0.171
	Gender of classification bodyB_4(0.118)	MaleC_{11}(0.333)	0.039
		FemaleC_{12}(0.667)	0.079

4. Establishment and inspection of fuzzy relationship

4.1 Determine the membership

Qualitative indicators refer to those indicators that cannot be judged by quantitative figures and can only be explained by the degree. Here, the feasibility can be described as the degrees very infeasible, infeasible, general and feasible. The percentile statistics method is used to directly count up the evaluation results of the objects to be evaluated and regard them as the membership degrees of the indicators (Yuan, 1991; Barbara and Antonio, 2006). When performing the feasibility evaluation on chemical waste classification, 20 experts were invited to conduct rating, of whom, eight consider it "very infeasible", at the membership degree of 0.4; 4 considered it "infeasible", at the membership degree of 0.2; 6 considered it "general", at the membership degree of 0.3; the remaining "feasible" membership degree is 0.1. In summary, the fuzzy evaluation matrix of the chemical waste classification is [0.4 0.2 0.3 0.1].

4.2 Establish the fuzzy relations matrix

According to the above method of determining the membership degree, after the statistics of scores rated by experts, the membership degrees are aggregated to obtain the fuzzy comprehensive evaluation matrix, as shown in Table 3.

Table 3: Fuzzy evaluation matrix in layer I

Evaluation indicator layer	Evaluation factor layer	Very infeasible	Infeasible	General	Feasible
Types of chemical waste	Hazard waste	0.7	0.3	0	0
	General waste	0	0.1	0.4	0.5
	Valuable waste	0.3	0.6	0.1	0
Identity of classification body	Enterprise leader	0	0	0.2	0.8
	Unit staff	0	0	0	1
	Common visitor	0.8	0.2	0	0
	Cleaner	0	0.1	0.2	0.7
Requirements of competent authorities	N/A	1	0	0	0
	Verbal	0.8	0.2	0	0
	Mandatory	0	0.2	0.1	0.7
Gender of classification body	Male	0	0	0.6	0.4
	Female	0	0	0.4	0.6

As described above, the fuzzy comprehensive evaluation matrix R of the other child indicators of the B layer is calculated, respectively, the results are listed in the following table. The first-level evaluation results are generated by operation results for individual indicators, as shown in Table 4 and Table 5.

Table 4: Fuzzy comprehensive evaluation matrix in layer II

W	R	B
W_1=[0.6000.3330.067]	$R_1=\begin{bmatrix}0.7 & 0.3 & 0 & 0\\ 0.7 & 0.1 & 0.4 & 0.5\\ 0.3 & 0.6 & 0.1 & 0\end{bmatrix}$	B_1=[0.44010.25350.13990.1665]
W_2=[0.3180.2270.0900.364]	$R_2=\begin{bmatrix}0 & 0 & 0.2 & 0.8\\ 0 & 0 & 0 & 1\\ 0.8 & 0.2 & 0 & 0\\ 0 & 0.1 & 0.2 & 0.7\end{bmatrix}$	B_2=[0.07200.05440.13640.7362]
W_3=[0.1670.2500.583]	$R_3=\begin{bmatrix}1 & 0 & 0 & 0\\ 0.8 & 0.2 & 0 & 0\\ 0 & 0.2 & 0.1 & 0.7\end{bmatrix}$	B_3=[0.36700.1666 0.05830.4081]
W_4=[0.3330.667]	$R_4=\begin{bmatrix}0 & 0 & 0.6 & 0.4\\ 0 & 0 & 0.4 & 0.6\end{bmatrix}$	B_4=[000.46660.5334]

Table 5: Level I evaluation results

Set of Layer B factors	Very infeasible	Infeasible	General	Feasible
Types of chemical waste	0.4401	0.2535	0.1399	0.1665
Identity of classification body	0.0720	0.0544	0.1364	0.7362
Requirements of competent authorities	0.3670	0.1666	0.0583	0.4081
Gender of classification body	0	0	0.4666	0.5334

The relationship of the factors of under the target layer A with the evaluation result can be available from calculation, that is, the fuzzy evaluation matrix R. The weight of each factor under layer A is $W=[0.1760.4120.2940.118]^T$.

From the formula: B=W·R= [0.2150.1160.1530518]^T.

Table 6: Level II evaluation results

Chemical waste classification feasibility level	Very infeasible	Infeasible	General	Feasible
Evaluation results	0.215	0.116	0.153	0.516

5. Conclusion

The chemical waste classification as an effective way aims to build a resource-saving society and improve the living environment and natural world. The fuzzy AHP can evaluate whether the chemical waste classification is feasible. The results show that it is true. Among 12 evaluation factors, the mandatory requirements of the competent authorities, cleaning personnel, business leaders, and chemical waste hazard degree have the impacts ranking the top four.

Based on the above evaluation results, first, it is suggested that relevant divisions should urge chemical industries to carry out chemical waste classification in accordance with legislation or mandatory measures. Second, special attention should be paid to the popularization of relevant knowledge about chemical waste and its classification to improve the knowledge level of employees in the chemical industry and help them gradually establish the awareness of chemical waste classification; in the end, special measures or channels should be taken for classification and special disposal of hazardous chemical waste.

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