Safety evaluation of Chinese nickel resources based on analytic hierarchy process and fuzzy comprehensive evaluation

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Abstract. China is now the world's largest producer and consumer of nickel. As an important strategic mineral, nickel is widely used in various industries of national economy. Whether the supply of nickel ore resources is sufficient or not directly restricts the development of downstream industries. It is becoming more and more important to evaluate the safety of nickel resources in our country, and to formulate the corresponding safety strategy. This paper uses fuzzy analytic hierarchy process to evaluate the safety of nickel resources in China, and overcomes the subjectivity and singleness of traditional evaluation methods. On the basis of the analytic hierarchy process to determine the weight, the fuzzy comprehensive evaluation is introduced. At present, the safety situation of nickel resources in our country is in a more dangerous level, and we need to take positive measures to improve it.

1. Introduction
As an important strategic mineral resource, nickel resource plays an important role in the development of China's national economy. With the rapid development of Chinese economy, Chinese stainless steel industry has also developed rapidly. As an important raw material of stainless steel, nickel demand is also rapidly increasing. China is now the world's largest nickel consumer. In 2015, Chinese primary nickel consumption of 980 thousand and 100 tons, accounting for the world's primary nickel consumption of 51.8%. At the same time, China is also the world's largest producer of nickel. In 2015, Chinese primary nickel production was 597 thousand and 700 tons, accounting for about 30.3% of the world's primary nickel production. However, the relative shortage of nickel resources in Chinese, the production of its own nickel mine is less than 100 thousand tons a year. In 2015, Chinese nickel ore production was 93 thousand tons, accounting for only about 4.3% of the world's nickel production. From the above data, Chinese nickel resource gap and the gap between supply and demand are great. The problem of the supply and demand of nickel resources is becoming more and more serious. How to obtain sustainable, stable and economical nickel resources has become a major strategic issue related to Chinese economic development and social stability. Therefore, it is of great significance to determine the safety status of nickel resources in China by evaluating the safety of nickel resources in China[1].
2. Safety Evaluation Index System of Nickel Resources
Nickel resource security is a complex system involving many factors, such as resources, economy, politics and so on. It can be divided into the following four aspects.

2.1. Domestic Resource Endowment Factor
It is the most basic indicator of the safety of a country's mineral resources, including nickel reserves, resource quality, storage and production ratio, per capita resources. In general, reserves account for a large proportion of the world's total reserves, good quality of resources, high storage and production ratio, large per capita resources, mineral resources, high security; the other hand, low safety of mineral resources[2].

Domestic resource endowment factor is divided into three secondary indicators. Accounting for the proportion of reserves of nickel reserves in the world (C1): it is an indicator of the natural abundance of nickel resources in China, the greater the proportion, the higher the security of resources. Nickel storage ratio (C2): a year of nickel resources, the ratio of domestic reserves and production, is the characterization of China's nickel resources development potential indicators, the higher the proportion, the higher the security of resources. Nickel per capita resources (C3): the ratio of Chinese nickel reserves and the total population of China, is an indicator of the abundance of nickel resources in China, the greater the proportion, the higher the security of resources.

2.2. Nickel Resource Market Factor
Nickel resources market factors are mainly reflected in the nickel resources can be safely obtained in order to meet the needs of the country. It includes the consumption gap of nickel resources, foreign dependence on nickel resources, import concentration and international transportation safety. Generally speaking, the nickel resource consumption gap is small, the degree of dependence on foreign countries is low, the import concentration is low, and the transportation safety is good, so the safety of mineral resources is high[3].

Nickel resources market factor is divided into five secondary indicators. Nickel resources external dependence (C4): the ratio of imports of nickel resources in China and the year of annual consumption, is characterized in China nickel resources dependence index of imports, external dependence is high, China's nickel resources safety is low. Nickel resources import source concentration (C5): the ratio of imports of nickel nickel resources in China a year ago three of the country of origin of imports and imports of nickel resources in China, China's imports of nickel is the characterization of risk index, the higher the concentration of import sources, China nickel resources safety is low.

International nickel ore price (C6): is to characterize the cost of nickel resources utilization indicators, the higher the price, the higher the cost of use, the lower the safety of China's nickel resources. The nickel resource consumption gap (C7): the indicators including the production and consumption of resources, its connotation is that in a certain period of time or period, the total production of mineral resources a country can meet the national or the local resource consumption, the gap is bigger, said the security degree of the mineral is low. International transportation safety (C8): it is also an indication of the overseas utilization cost of nickel resources in our country. The better transportation safety, the safety of nickel resources is higher.

2.3. Nickel Resources Comprehensive Utilization Factor
It is mainly reflected in the technical progress can reduce the cost of mining, enhance the exploration capacity of nickel resources and efficient use of renewable resources, etc.. The comprehensive utilization of nickel resources is high, which can greatly improve the efficiency of resource utilization, and to some extent alleviate the safety problems caused by the shortage of resources.

Nickel resources comprehensive utilization factor is divided into three secondary indicators. Nickel resources comprehensive utilization efficiency (C9): it is the index that indicates the utilization efficiency of nickel resources in our country. The higher the comprehensive utilization efficiency is, the lower the cost of using. The impact of nickel resources development and utilization on the
2.4. National Security Factor
It mainly includes the state's possession of nickel resources and the policy support and economic support for nickel resources. Generally speaking, the country has abundant foreign nickel resources, the policy and the economic support are large, the mineral resources security is high.

National security factor is divided into three secondary indicators. National overseas resource control (C12): the more nickel resources in our country, the higher the safety of nickel resources in china. Policy support and completeness (C13): Chinese policy support for nickel resources, the greater the intensity, the more complete, the safety of nickel resources is higher in china. Strategic reserve (C14): a certain number of nickel reserves that are planned to be established in peacetime, in order to cope with the war and other unforeseen circumstances, to ensure the normal operation of the national economy and national defense needs. The more abundant nickel resources, the safety of nickel resources is higher.

2.5 Establishment of Index System
Based on the investigation and analysis of the influencing factors of nickel resources, the author established the nickel resource safety evaluation system by using the analytic hierarchy process (AHP), based on the previous study on the research on the safety evaluation system of nickel resources and other related mineral resources, as shown in Fig1.

3. Fuzzy Evaluation of Nickel Resource Security in China
Fuzzy mathematics can be used to analyze the uncertainty and fuzziness. There are many factors affecting the safety of nickel resources, and the influence is also uncertain and fuzzy, so the fuzzy comprehensive evaluation method can be used for quantitative analysis.
3.1 Weight Calculation

Using the analytic hierarchy process to calculate the weight of China's nickel resources security factors[7], the weight of the first factor set is

\[ A = [0.597 \ 0.214 \ 0.068 \ 0.121] \] (1)

For the second level factor set, the weights are respectively

\[ A_1 = [0.308 \ 0.079 \ 0.618] \] (2)

\[ A_2 = [0.263 \ 0.045 \ 0.072 \ 0.516 \ 0.104] \] (3)

\[ A_3 = [0.648 \ 0.122 \ 0.229] \] (4)

\[ A_4 = [0.109 \ 0.582 \ 0.309] \] (5)

Among them, \( A \) represents the weight of the four categories of nickel resources in China. \( A_1 \) represents the weight of the 3 indicators in the domestic resource endowment factor. \( A_2 \) represents the weight of the 5 indicators in the nickel resource market factor. \( A_3 \) represents the weight of the 3 indicators in the comprehensive utilization of nickel resources factor. \( A_4 \) represents the weight of the 3 indicators in the national security factor.

It can be seen from the above weight that the weight of domestic resource endowments is the highest among the four major influencing factors of nickel resource safety in China, followed by nickel resource market factors, national safeguard factors and comprehensive utilization of nickel resources. Among the 14 indicators which affect the safety of nickel resources in China, the five secondary factors, which are most important to the safety of nickel resources in China, are the amount of nickel per capita, the proportion of nickel reserves in the world's reserves, the consumption gap of nickel resources, and the dependence of nickel resources Degree, nickel storage ratio. As China's current environmental requirements for the development of nickel resources is still low, so the smallest impact is the impact of nickel resources development on the environment[8].

3.2 Establishment of Single Factor Evaluation Matrix

According to the current situation of China's nickel resources and access to the relevant information, combined with expert opinion, we grade the secondary indicators[9], the results are shown in table 1.

| First grade indicators | weight | Secondary indicators | weight | Security level |
|------------------------|--------|----------------------|--------|---------------|
|                        |        |                      |        | very safe     | Basic security | critical | More dangerous | very dangerous |
| \( B_1 \)              | 0.597  | C1                   | 0.308  | 0.1          | 0.3           | 0.5     | 0.7           | 0.5           |
|                        |        | C2                   | 0.879  | 0.4          | 0.1           | 0.5     | 0.3           | 0.1           |
|                        |        | C3                   | 0.818  | 0.3          | 0.4           | 0.7     | 0.6           | 0.8           |
| \( B_2 \)              | 0.214  | C4                   | 0.263  | 0.0          | 0.1           | 0.3     | 0.7           | 0.8           |
|                        |        | C5                   | 0.045  | 0.0          | 0.2           | 0.4     | 0.8           | 0.8           |
|                        |        | C6                   | 0.072  | 0.0          | 0.7           | 0.4     | 0.2           | 0.1           |
|                        |        | C7                   | 0.510  | 0.1          | 0.2           | 0.4     | 0.8           | 0.8           |
|                        |        | C8                   | 0.104  | 0.2          | 0.5           | 0.7     | 0.4           | 0.2           |
| \( B_3 \)              | 0.068  | C9                   | 0.648  | 0.2          | 0.4           | 0.6     | 0.6           | 0.4           |
|                        |        | C10                  | 0.122  | 0.3          | 0.5           | 0.3     | 0.2           | 0.1           |
|                        |        | C11                  | 0.429  | 0.2          | 0.3           | 0.1     | 0.3           | 0.3           |
| \( B_4 \)              | 0.121  | C12                  | 0.169  | 0.4          | 0.4           | 0.5     | 0.4           | 0.4           |
|                        |        | C13                  | 0.581  | 0.4          | 0.3           | 0.4     | 0.2           | 0.2           |
|                        |        | C14                  | 0.309  | 0.2          | 0.4           | 0.5     | 0.4           | 0.2           |

3.3 Fuzzy Comprehensive Evaluation

According to the weight of each secondary indexes and the corresponding single factor matrix, the fuzzy comprehensive evaluation of each index is carried out.

\[
B_1=W_1 \cdot R_1 = (0.308, 0.079, 0.618) \times \begin{bmatrix} 0.1 & 0.3 & 0.5 & 0.7 & 0.5 \\ 0.4 & 0.7 & 0.5 & 0.3 & 0.1 \\ 0.2 & 0.3 & 0.4 & 0.7 & 0.6 \end{bmatrix} \]

\[
= (0.186, 0.3331, 0.4407, 0.6719, 0.5327) \] (6)
Similarly, the four first-level indicators correspond to the membership degree of each evaluation grade, and then the results of the first-order fuzzy evaluation are used to carry out the second-level fuzzy comprehensive evaluation. The concrete results are shown in Table 2.

Table 2. The calculation results of membership degree of each index.

| Evaluating Indicator | very safe | Basic security | critical | More dangerous | very dangerous |
|----------------------|-----------|----------------|----------|----------------|----------------|
| B<sub>1</sub>         | 0.186     | 0.333          | 0.441    | 0.672          | 0.533          |
| B<sub>2</sub>         | 0.116     | 0.241          | 0.405    | 0.689          | 0.687          |
| B<sub>3</sub>         | 0.212     | 0.389          | 0.517    | 0.328          | 0.340          |
| B<sub>4</sub>         | 0.338     | 0.458          | 0.441    | 0.342          | 0.222          |
| A                     | 0.191     | 0.332          | 0.438    | 0.626          | 0.515          |

Among them, the secondary fuzzy evaluation is

\[
B = W \cdot R = (0.597, 0.214, 0.068, 0.121) \cdot \begin{bmatrix}
0.186 & 0.333 & 0.441 & 0.672 & 0.533 \\
0.116 & 0.241 & 0.405 & 0.689 & 0.687 \\
0.212 & 0.389 & 0.517 & 0.328 & 0.340 \\
0.338 & 0.458 & 0.441 & 0.342 & 0.222 \\
0.191 & 0.332 & 0.438 & 0.626 & 0.515
\end{bmatrix}
\]

\[
= (0.191, 0.332, 0.438, 0.626, 0.515)
\]  (7)

According to the calculation results, the safety of nickel resources in China is in a dangerous situation. Among the 4 factors, the domestic resource endowments and market factors have a higher degree of membership in the "dangerous" level, which indicates that these two factors are the main factors affecting the safety of nickel resources in China. However, it is difficult to change the domestic resource endowment in the short term, so we should take measures to improve the supply and demand of nickel resources.

4. Conclusion

To evaluate the safety of nickel resources in China using fuzzy AHP method, overcomes the defects of the traditional evaluation method of subjectivity and uniqueness, and can consider various factors affecting the safety of nickel resources comprehensively, more practical results, the traditional evaluation method is an effective supplement.

There are many factors affecting the safety of nickel resources in our country, and the selection of indicators will overlap to some extent, which needs to be studied and perfected in order to achieve better prediction results.

Through the fuzzy comprehensive evaluation of Chinese current situation of nickel resources security, we can see from the evaluation results that Chinese current situation of nickel resources security is more dangerous, the need for the state to take certain measures to protect Chinese nickel resources security. Suggested to take the safeguard measures are: to increase domestic nickel resources exploration and investment efforts to find new nickel resources, increase the domestic reserves of nickel resources; adhere to the "going out" strategy, increase investment in overseas nickel resources development efforts; Comprehensive utilization of resources to improve the comprehensive utilization of nickel resources[10].

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